BETTER CROPS
WITH PLANT FOOD

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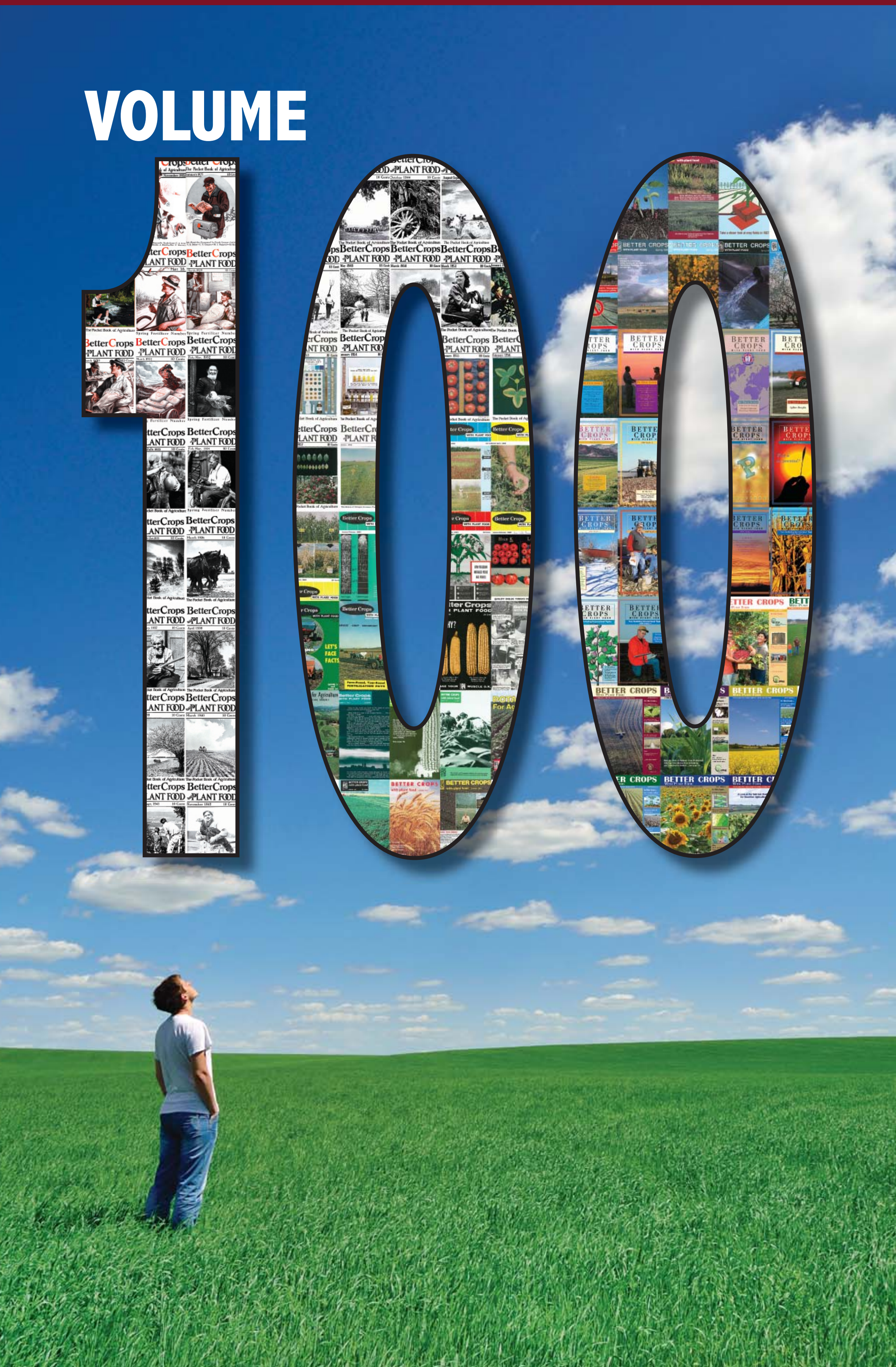

In This Issue...

Nutrient Considerations for Low Corn Prices

Purple: Its Link to Phosphorus Deficiency

Cropping System's Impact of Soil K Status in China

Also:

Interview with IPNI Science Award Winner

Our Photo Contest Winners

...and much more

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CONTENTS

Note to Readers: Articles which appear in this issue of *Better Crops with Plant Food* can be found at: >**www.ipni.net/bettercrops**<

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An Interview with 2015 IPNI Science Award Winner - Dr. Cynthia Grant

Dr. Cynthia A. Grant
2015 IPNI Science Award Recipient

The International Plant Nutrition Institute (IPNI) named Dr. Cynthia A. Grant as the winner of the 2015 IPNI Science Award.

Dr. Grant received her B.S.A. from the University of Manitoba in 1980; her M.Sc. from the University of Manitoba in 1982; and her Ph.D. from the University of Manitoba in 1986. Since 1986, Grant has worked as a research scientist at the Agriculture Canada Research Station in Brandon, Manitoba, Canada.

Q. What influenced your path into agronomy? *I grew up on a mixed farm and was actively involved in 4-H. I wanted to become a scientist, and agronomy seemed the logical choice.*

Throughout her decades long career, Grant has earned respect and recognition from her colleagues and the industry for her valuable research on soil fertility, crop nutrition, as well as the trace element contaminant cadmium.

Q. What was the best advice you were given and what advice would you give to young scientists in the field? *A good team can do far more to understand an issue than a person working alone. Good agronomic studies can be very expensive to run. Work with a team to get as much information out of every trial as you can.*

Since the 1990s, Grant has worked to assess the usefulness of enhanced efficiency fertilizers (EEFs) in cropping systems and in Canada. She has published 17 scientific papers, two review articles, a chapter on EEFs, and has prepared dozens of technology transfer articles and presentations on the topic in North America, Europe, and Asia.

Dr. Grant also worked to develop and assess beneficial management practices for nitrogen, phosphorus, potassium, sulfur, and chloride to improve nutrient use efficiency, becoming one of the first Canadian researchers supported by the international Fluid Fertilizer Foundation.

Q. What in your research career has given you the most satisfaction? *My career in agronomy has allowed me to work cooperatively with some of the most interesting, dedicated and collaborative people on the planet. This has been intensely satisfying. Also, this is a career where your job description is to go out and learn new things. What could be better?*

Grant has published 165 journal articles on nutrient management, co-authored chapters on soil fertility management in dryland agriculture and sulfur management, and co-edited a book on Integrated Nutrient Management. Her research has been recognized with several awards including, the International Fertilizer Industry Association Award, The Robert E. Wagner Award, the Fluid Fertilizer Foundation Researcher of the Year Award, and the Manitoba-North Dakota No-Till Non-Farmer of the Year Award. She also served on the editorial board of several scientific journals and as Associate Editor of the Journal of Environmental Quality, Canadian Journal of Soil Science, and Canadian Journal of Plant Science.

Q. What are your thoughts on the future challenges for agronomy? *Future challenges to agronomy will center around the need to produce enough food for our growing population without destroying our natural resources. We need to be able to effectively use the scientific tools that become available to us. At times, good technology may be left unused because of philosophical concerns or fears, rather than on real risks. Science literacy is becoming more and more important, both for agriculture and for the general public. It is also a challenge to communicate the importance of agriculture to a population that is increasingly isolated from the farm.*

The IPNI Science Award is intended to recognize outstanding achievements in research, extension, or education; with focus on efficient management of plant nutrients and their positive interaction in fully integrated cropping systems that enhance yield potential. Dr. Grant receives a special plaque along with a monetary award of US$5,000. A committee of noted international authorities selects the recipient.

Private or public sector agronomists, soil scientists, and crop scientists from all countries are eligible for nomination. This is the eighth year the IPNI Science Award has been presented. More information about the IPNI Science Award can be obtained from http://www.ipni.net/awards. BC

Nutrient Considerations for Low Corn Prices

By T. Scott Murrell

Corn prices are low and many producers are asking tough questions about their nutrient management programs.

Maintaining grain yield and revenue with lower fertilizer bills is possible, but you need to consider all the science.

Account for Nutrient Supplies Already in the Soil

It is important to take advantage of the nutrient-supplying power that exists within individual fields. Soil test results provide the best guidance for deciding which nutrients should be applied and how much of them to use. If soil test levels of P and K are high, there is little chance that an economic response to these nutrients will occur in the year of application. In such cases, producers can take advantage of existing soil nutrient supplies. However, this approach must be done with the understanding that supplies will need to be replenished later to avoid future nutrient deficiencies and associated revenue losses.

Taking N credits for previous crops is an important part of buying only what is needed. Many people also forget that with some crops, such as alfalfa, lower N application rates may be justified for crops planted up to 2 years after termination of the stand (Yost et al., 2014a, b).

An often overlooked, but effective tool is the soil nitrate test. This test helps producers account for the nitrate already present in their soils. If levels are high enough, freshly applied N rates can be reduced, or in some cases, omitted. This test is particularly useful where manure applications have been made, previous crop yields were poor, or climatic conditions are dry.

Account for Nutrient Supplies on the Farm or Nearby

If there is access to manure, use it as effectively as possible. Also, be sure that you know the nutrient content of the manure and the rate at which manure is applied, so you can calculate how much of each nutrient is being put on. If you have previously felt that spreader calibration and manure testing were too time consuming or too expensive to deal with, this may be the year to reconsider. If manure application equipment is dated, it may be time to run the numbers and see if updated equipment capable of applying lower, agronomic rates can be justified. In some cases, manure application rates can be cut in half and still meet crop needs, allowing manure to be a nutrient source on more acres.

Time Nutrient Applications for Highest Efficiency

Spring fertilizer applications provide N at a time closer to crop need, reducing the chances for loss. However, spring applications can also carry higher logistical risks, since conditions are typically wetter than in the fall and time is more limited. In some areas, fall N applications can be effective if they are made when soil temperatures drop below 50°F (10°C) and remain there. Nitrification inhibitors can also reduce or eliminate N losses from fall to spring.

Splitting the total N application across various times in the season can sometimes increase N recovery by the crop. Several options exist. For example, a pre-plant application combined with a second application during early vegetative growth stages is an often-used split.

Whenever possible, manure applications should be made close to the time of crop need, such as the spring.

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

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Banded fertilizer applications placed near the seed provide critical early season access even in soils with moderate to high P fertility status.

Place Nutrients for Greatest Efficiency

Banded nutrient applications generally provide higher first-year recovery of applied P and K than do broadcast applications. Consequently, some universities suggest rate reductions when nutrients are applied in this manner. If short-term economic decisions dictate banding P and K at rates less than those of crop removal, producers and advisers may want to build in a plan for replenishing soil nutrient supplies in the future, when economic conditions improve. In fields with low soil P concentrations but longer-term management strategies, a combination of a banded application with a broadcast application may have the best chance for maximizing yields (Anghinoni and Barber, 1980). Fertilizer bands placed near the seed provide early season access to nutrients, while overall higher fertility levels in the bulk soil provide access to the larger root system later in the season.

Use the Most Effective Fertilizer Technologies Available

Fertilizer technologies have come a long way with nitri-

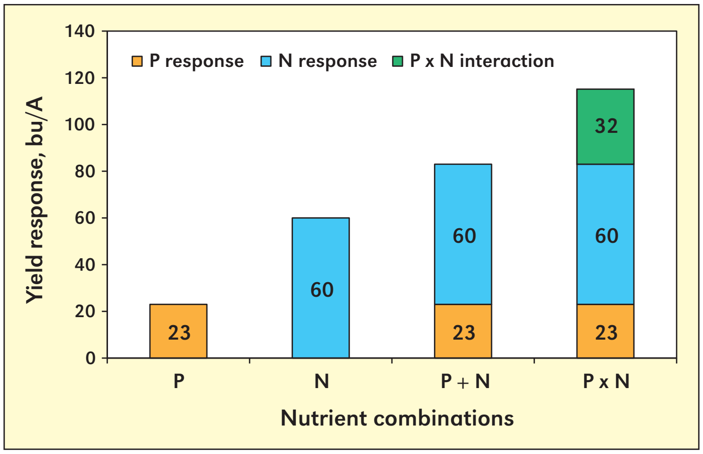

Figure 1. Corn response to N alone at 161 lb N/A (N), P alone at 40 lb P_2O_5/A (P), and both N and P applied (P x N). The sum of the responses to the N and P (P + N) was calculated by adding the individual effects (Schlegel et al., 1996).

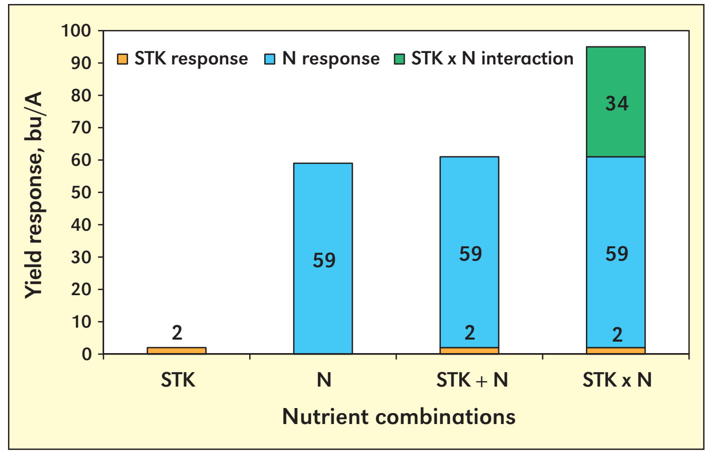

Figure 2. Corn response to increasing soil test K from 80 to 116 ppm (STK), applying 240 lb N/A (N) or increasing soil test K and applying N (STK x N). The sum of the responses to STK and N (STK + N) was calculated by adding the individual effects (Johnson et al., 1997).

fication inhibitors, urease inhibitors, and controlled-release fertilizers being just some of the options available. Be sure to understand these products thoroughly and examine university research that tests their efficacy. There are situations where these products provide an advantage. Know the conditions under which they have the best chances of making a difference.

Allocate Money to the Right Nutrients

In times like these, many emphasize that N needs must come first. Before jumping to this conclusion, soil test levels of a field or field area must be examined. In the worst case, it may be found that N, P and K are all in short supply. When this happens, crop response to any single nutrient will be limited if only that nutrient is applied. When P levels are low, the plant has a reduced supply of stored energy. Without enough energy, the plant is not effective in absorbing limited soil N, P or K supplies. In these cases, if recommended rates of each nutrient cannot be afforded, it is best to band at least low rates of P and K near the seed as part of the N fertilization program. This balanced approach will maximize the effectiveness of all applied nutrients.

Two examples of balanced nutrition are in **Figures 1** and **2**. The first example (**Figure 1**) comes from a 30-year study examining the interaction of P and N (Schlegel et al., 1996). Corn yield response to a combination of P and N (P x N) was greater than to applications of either P or N alone. The interactive effect was also larger than the sum of the individual effects (P + N). Similarly, increasing soil test K and fertilizing with N produced the greatest yield response (Johnson et al., 1997).

Prioritize Fields and Areas within Fields

Allocating nutrient funds across the farm should be based not only on soil tests, but also on economic evaluations of each field or field area. What is the break-even cost of production for each field in a farming operation? Which fields consistently make money, which ones are hit or miss, and which ones are just a drag on the business? Spending time looking at how fields have performed over time may help farmers and advisers focus resources on the moneymakers. The goal of such an analysis is to ensure that consistently profitable fields have the nutrients they need to maintain production and revenue levels. With precision agriculture, this evaluation can be brought to a higher level of resolution, extending the concepts to areas within a field, rather than the entire field.

Examine Yield Goals

Since many nutrient recommendations are based on yield expectations, setting realistic yield goals is important. One way to set realistic expectations is to look back at previous years' performance to get an idea of what typically happens, given specific levels of crop stress. Averages of several years of yields are often useful in setting goals.

Re-examine the Basis for Nutrient Recommendations

Are nutrient recommendations based on the best science available? University research and publications set the standard for science-based nutrient management decisions. How do currently used recommendations compare to these? If modifications or different approaches are being used, is there good information behind them? It may be time to look at the scientific guideposts, like university guidelines, to see how current management practices compare.

Summary

When funds are limited and crop prices are low, it is critical that nutrients be used as effectively as possible. Effective use is possible only when informed decisions are made. Keeping soil test information up-to-date, identifying profitable fields or field areas, using all nutrient sources available, and generally adopting 4R nutrient management practices founded on proven scientific principles ensure the greatest chances for success. BC

Dr. Murrell is a Director, IPNI North America Program, West Lafayette, IN, USA; E-mail: smurrell@ipni.net

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Potassium Changes in Soils Managed for Cash or Grain Crops

By Ping He, Fang Chen, Shutian Li, Shihua Tu, and Adrian M. Johnston

Analysis of soil test K from soil samples collected over 23 years, and yield responses from over 2,000 field experiments, indicate that any increase in average soil K in China were most attributable to high K fertilizer use on cash crops. Little change in grain crop field soil K was observed over the same period.

Urgent site-specific K nutrient management is needed in China to address the great variation in soil available K across its different regions and cropping systems.

Understanding soil K status is important when developing appropriate K nutrient management. Potassium deficiency is a serious problem for many regions in China; however, with the development of agricultural mechanization, implementation of policies by the Chinese central government promoting the return of crop straw to fields after harvest, and increased use of organic (compost) fertilizers, some soils are showing an increase in plant-available K. Contradictory reports on changes in soil available K have also raised concerns of scientists and the fertilizer industry. These contradictory results may be attributed to differences in soil sampling points, number of samples, time of sampling, and analytical methods. Up to now, the effects of K fertilizer use have not attracted concerns like those seen with N and P.

The historic national soil survey conducted in the early 1980s in China does not reflect current soil K status. The current soil K balance in China is influenced by the imbalance of K relative to N and P fertilizers, and crop K removal by new and high-yielding genotypes. The objectives of this study were to evaluate the temporal and spatial variation of soil available K and crop yield response to K fertilizer in China from 1990 to 2012.

Datasets for soil available K and crop yield were compiled from published and unpublished data sources between 1990 and 2012 from IPNI China Program. In total, 58,559 soil available K records and 2,055 yield records were collected (**Figure 1**). These experiments were conducted in farmers' fields, where yield data was obtained from first season harvests from N, P and K application plots. The rates of N, P and K fertilizers were recommended based on soil testing. The NP treatment rates were based upon those used in the NPK treatment.

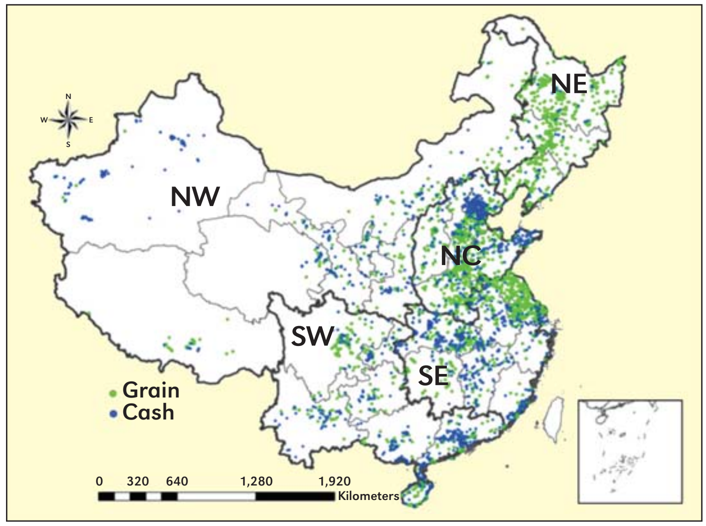

Figure 1. Distribution of experimental sites for five production regions of China from 1990 to 2012. The green and blue dots represent grain and cash crops, respectively.

To evaluate spatial variation of soil available K, five agricultural regions were grouped based on geographic location and China's administrative divisions (i.e., northeast, north central, northwest, southeast, and southwest). Each agricultural region was further divided into two sub-groups based on soil utilization pattern (i.e., grain or cash crop system). In the grain crop

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; IPNI = International Plant Nutrition Institute.

IPNI Photo/S. Tu

IPNI Photo/S. Li

Soils under grain or under cash crops show distinctly different K availability over the past two decades.

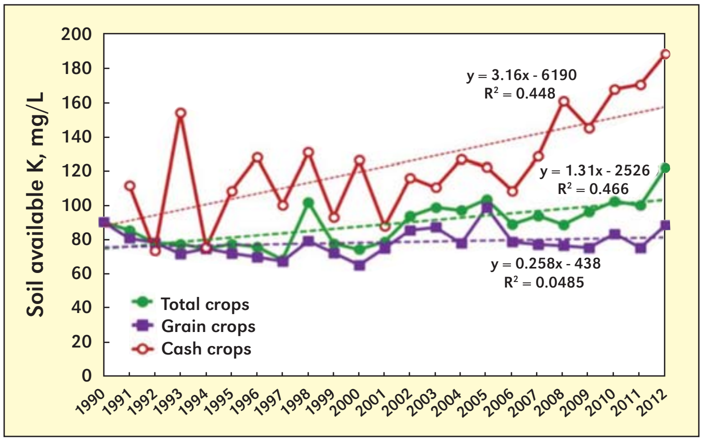

Figure 2. Trends in mean soil available K in China from 1990 to 2012.

systems, fields grew wheat, maize, rice, potato, and soybean. In the cash crop systems, vegetables, fruit trees, rapeseed, sunflower, cotton, and sugar crops, with higher fertilizer rates and higher economic returns, were planted. The geographical distribution of the data is shown in **Figure 1**.

Changes in Soil Available K

Soil available K from all experiments showed an increasing trend from 1990 to 2012 (**Figure 2**). Soil K under cash crops increased steadily from 1990 to 2012, while in grain crops, soil K fluctuated annually and did not show an obvious increase over this period of time. Fertilizer application for grains averaged 110 kg K_2O/ha (ranging from 30 to 360 kg K_2O/ha), while in cash crops the average was 255 kg K_2O/ha (ranging from 15 to 1,867 kg K_2O/ha) (data not shown). These results demonstrate the strong influence that high fertilizer K input in cash crops has on soil K concentrations, which is driving the increasing trend of soil available K in China.

Spatial and Temporal Variation of Soil Available K

Balanced fertilization was introduced to China in the 1980s, and there has been a major focus on the balanced use of K fertilizers in China since the 1990s. However, great variation in soil test K has existed across different regions, with mean values for ASI soil test K (Portch and Hunter, 2002) being 77, 100, 118, 84, and 81 mg/L for northeast, north central, northwest, southeast, and southwest China, respectively. A comparison of soil available K across the 1990s (1990 to 1999) and 2000s (2000 to 2012) shows that mean values increased from 80 mg/L in the 1990s to 93 mg/L in the 2000s. Soil available K showed no difference in the northeast between the 1990s and 2000s. However, soil available K increased by 35% (76 to 103 mg/L), 18% (72 to 84 mg/L) and 30% (69 to 83 mg/L) from the 1990s to 2000s for north central, southeast, and southwest China, respectively. Mean values decreased by 76% (154 to 116 mg/L) from the 1990s to 2000s for northwest China (**Figure 3A**).

Soil available K in grain crop fields followed the same trends as those shown for the average for all crops, but the results varied across regions (**Figure 3B**). For the north central, southeast and southwest regions, the soil K increased by 9%, 21% and 9%, respectively in the 2000s from baselines of 72, 65 and 66 mg/L in the 1990s. However, for the northwest, soil available K in the 2000s decreased by 74% compared with the 1990s (**Figure 3B**).

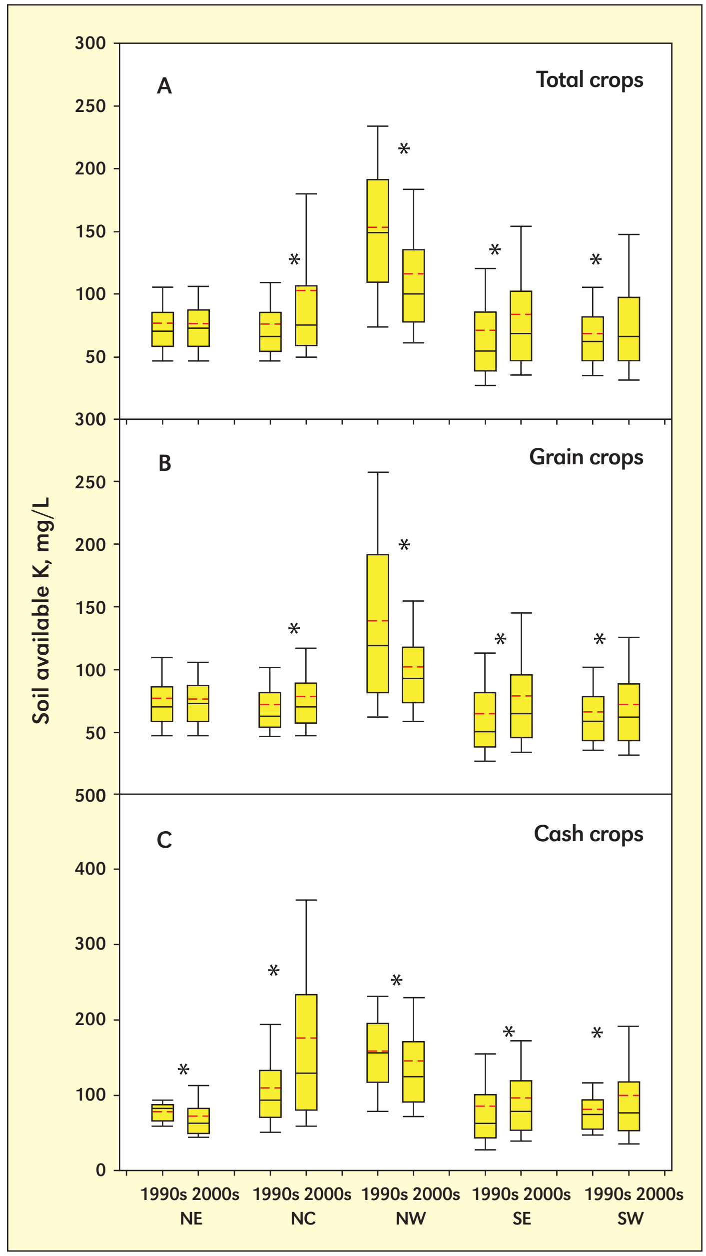

Figure 3. Comparison of soil available K between 1990s and 2000s. (A) Total crops; (B) Grain crops; (C) Cash crops. The star * between the two boxes indicates soil available K between 1990s (left box) and 2000s (right box) significant different at $p < 0.05$. The black and redlines, lower and upper edges, bars represent median and mean values, 25th and 75th, 5th and 95th percentiles of all data, respectively.

The soil available K in the 2000s for cash crops only increased by 60%, 12% and 22% for north central, southeast and southwest China, respectively, if compared to values in the 1990s, but declined to only 92% of 1990 values in the northeast and northwest. The increased soil available K in the north central and southwest regions were attributable to the large area of cash crops, while the increased mean values in the southeast was mainly attributed to larger increases in grain crops. The decrease in soil available K in the northwest was attributable to the large decline in soil available K in grain crop fields (**Figure 3C**).

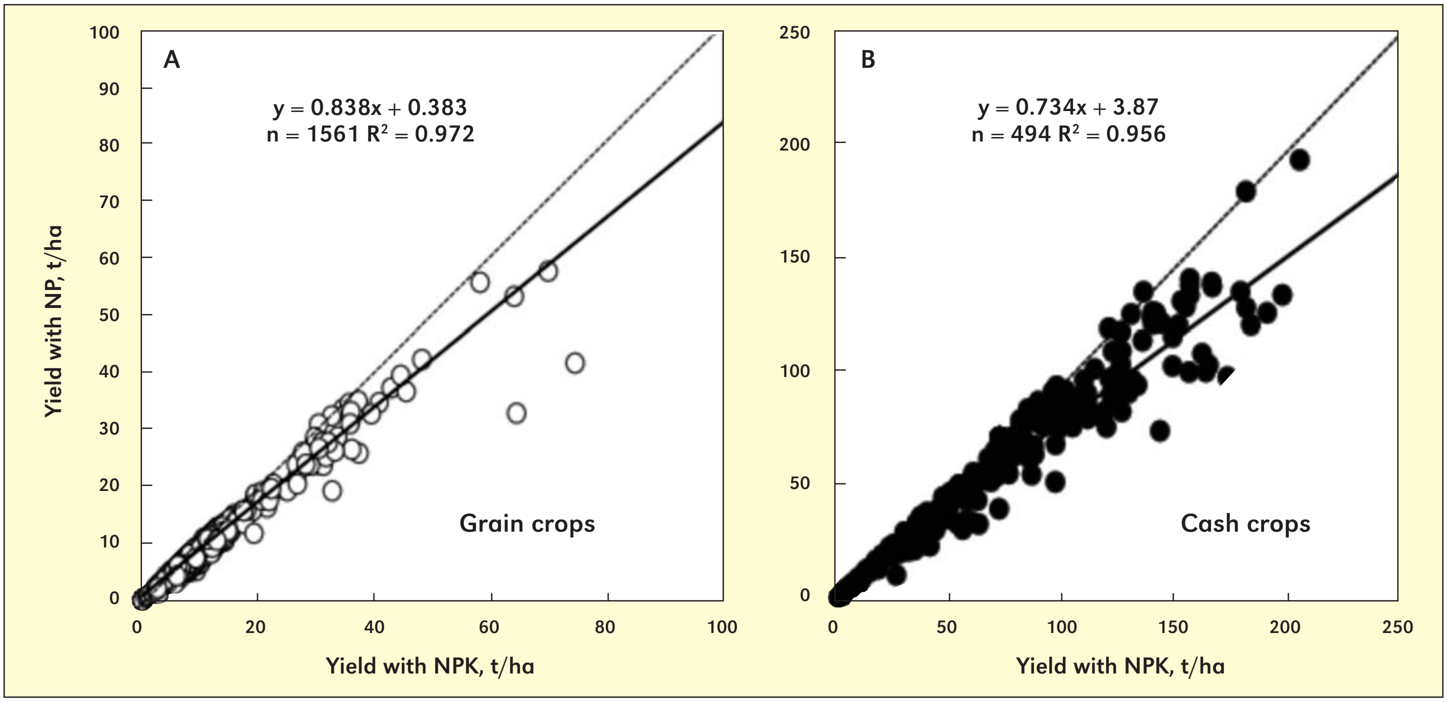

Figure 4. Yield with PK and yield with NPK for (A) Grain crops; (B) Cash crops. The dashed line is the1:1 line.

Results from this study indicate that soil available K showed a minor increase in soils planted to grain crops, but increased significantly in those soils planted to cash crops. The trends of increased soil K for cash crops is in accordance with the high fertilizer K application rates used by farmers. The K fertilizer application rates for cash crops averaged 164, 231, 205, 240, and 391 kg K_2O/ha, which were 1.7, 2.1, 1.7, 2.1, and 2.8 times those for grain crops for northeast, north central, northwest, southeast, and southwest China, respectively (data not shown). However, the soil available K for grain crops in 2000s were lower than 80 mg/L (the critical value for K deficiency) in all regions except the northwest. Therefore, more K fertilizer was needed for soils planted with grain crops and no increase in soil indigenous K supply has been measured. The results can be supported by relative yield and a great number of site-to-site reports as well. Although with the development of agricultural mechanization and more crop residues being returned back to soils, reports from grain crop fields indicated that the return of straw alone is not sufficient to maintain the soil K balance. Fertilizer K application is essential to maintain both high yield and soil K balance.

Although soil K values in cash crops were observed to be higher than those in grain crops, the relative yield of cash crops were lower than grain crops indicating that yield reduction with NP treatment, or without K application, was larger for cash crops than grain crops as compared with NPK treatment (data not shown). This observation was also supported by the larger response to K application for cash crops than that for grain crops (**Figure 4**). These results indicate that the contribution of soil indigenous K supply to yield was higher for grain crops than for cash crops. More K is needed to achieve the optimal yield of cash crops, with larger yield response to K, as compared with that for grain crops. In addition, the K nutrient removal by cash crops was larger than that for grain crops.

Summary

Soil available K in China has shown an increasing trend from 1990 to 2012 and these increases came from the increased soil K in cash crop fields due to higher K fertilizer application. Therefore, K fertilizer application is required not only for grain crops with lower soil K levels, but also for cash crops with large yield response to K application as well. The strategies used to address this challenge need to be regional and site specific. The information from the current study can also be used to guide future research activities, such as research on soil K critical values for individual cash crops, K nutrient cycling, and 4R nutrient management strategies under agricultural mechanization. BC

Acknowledgment

More detail on this research can be found in the original article published by He et al. in Field Crops Research (2015, 173: 49-56) http://dx.doi.org/10.1016/j.fcr.2015.01.003.

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Fertilization Practices in Tunisian High-Density Olive Planting Systems

By Ajmi Larbi, Monji Msallem, Sofiene Mestaoui, Mohamed Bechir Sai, Mohamed El Gharous, and Hakim Boulal

Fertilization within high-density olive plantations needs to be improved to help control tree vigor, reduce environmental impacts, lower cost of production, and increase productivity.

Tunisia is one of the largest olive producers in the world. Its olive production sector plays a strategic role in the national economy with its 1.8 million ha under olive representing 34% of the countries agricultural land. However, large portions of these olive orchards are old and poorly maintained. The government of Tunisia initiated in early 2000 a large program for the introduction and expansion of the hyper-intensive olive system in the irrigated area. In 2011, the intensive olive grove areas in Tunisia reached 50,000 ha, with 4,500 ha managed using a super high-density planting (SHD) system (Larbi et al., 2014). However, little information has been provided with regards to an improved technical production package for those wanting to transition to SHD plantations. Among the constraints that farmers are facing during this switch are the nutrient management practices required for SHD plantations. Little research has been conducted on fertilization management in high-density plantation systems and farmers are still using traditional fertilization practices based on the application of the same amount every year without taking into account the nutritional status of the trees. The development of a 4R Nutrient Stewardship strategy on right source, rate, time, and placement of fertilizer application in SHD olive production systems is key for improving both olive and oil production, as well as nutrient use efficiency.

For a better understanding of farmers' practices, a survey was conducted in 2011 to assess farmers' fertilization practices in new SHD systems. Farmers were selected in collaboration with the Ministry of Agriculture of Tunisia who compiled a list of 112 SHD olive farmers with plantations varying in density from 1,250 to 1,660 trees/ha (DGPA, 2010). A sample of 27 farmers, representing 12 regions of Tunisia (**Figure 1**), were selected to be interviewed. The survey showed that 67% of farmers were small farmers with an olive orchard area of less than 25 ha. Large farmers (more than 100 ha) represented 13% and medium (25 to 100 ha) represented 20% of surveyed farmers (**Figure 2**). The survey found that SHD farmers rely on three olive tree varieties. The variety Arbequina occupies 63% of SHD area, followed by Arbosana with 30%, and Koroneiki with 7%. All farmers in this study used drip irrigation.

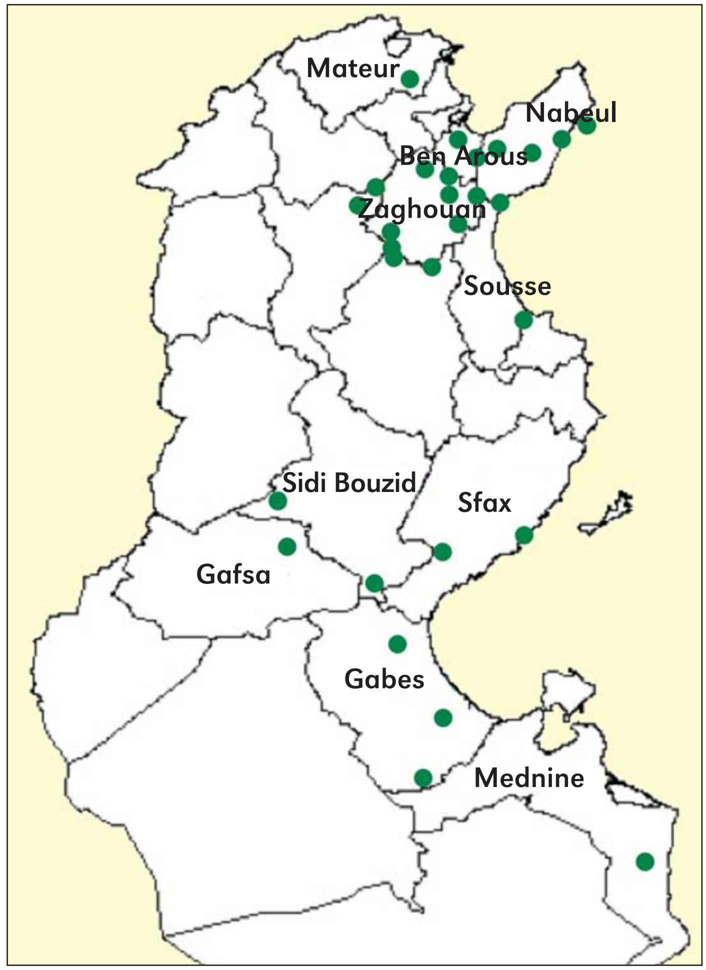

Figure 1. Location of the surveyed olive farmers in Tunisia.

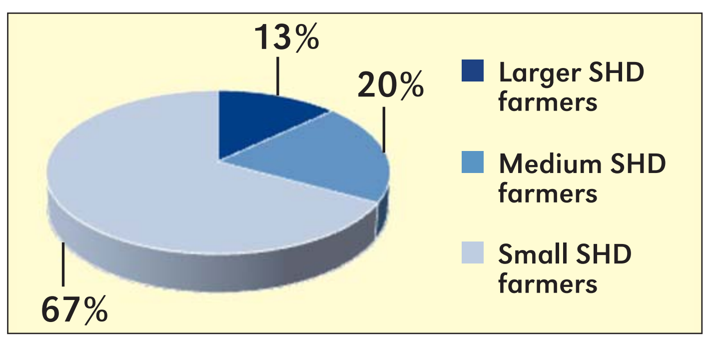

Figure 2. Distribution of surveyed super high-density (SHD) olive farm sizes.

Fertilization Practices

Results of the survey showed that 85% of interviewed farmers use mineral and organic fertilization, while the rest (15%) do not apply any mineral or organic fertilization due mainly to the lack of awareness of the importance of fertilization in olive oil quality and production. Farmers that do not apply any fertilizer to their orchards are mainly small farmers with an orchard area varying from 2 to 4 ha. All interviewed farmers who apply fertilizer reported the use of drip irrigation for mineral fertilizers application. The use of organic fertilization was confirmed only by three farmers who belong to the small

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; B = boron.

Super high-density olive plantation images from Tunisia.

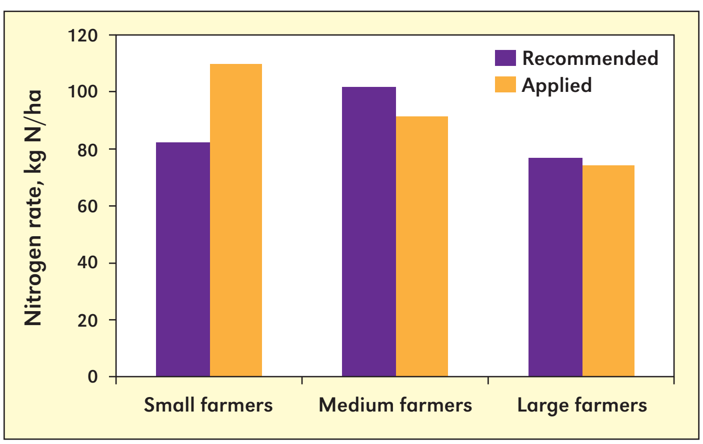

Figure 3. Nitrogen rates compared to the recommended rates for each category of super high-density olive plantation.

SHD group. The survey found that 56% of respondents have contact with regional agricultural extension centers. However this group of farmers indicated that technical staff of these centers did not provide any advice related to fertilization management.

Fertilizer Sources

Of the farmers who use nutrients, 100% of them use N and P, while 82% apply N, P and K. The main source of N and P are ammonium nitrate (91%) and urea (9%) for N and phosphoric acid (100%) for P. Farmers reported that the limited use of urea was a reflection on the high salt content of the irrigation water source. For K, the main sources are potassium sulfate (75%) and potassium nitrate combined with potassium sulfate (25%). It has also been reported that 30% of farmers who apply fertilizers use foliar application of B (mineral boron) and K (potassium sulfate and NPK products with high K content).

Fertilizer Rates

The survey showed that the amount of fertilizers applied varied significantly according to the olive orchard's age and yield. A high percentage of small farmers (95%) applied fertilizers without any structured plan. Indeed, N and P fertilizers are applied excessively as compared to recommended rates (**Figure 3** and **4**). Average N and P_2O_5 rates were about 109 and 33 kg/ha, respectively, while the recommended amounts based on fruits uptake are about 82 and 25 kg, for N and P_2O_5, respectively. However, for K, small farmers often applied

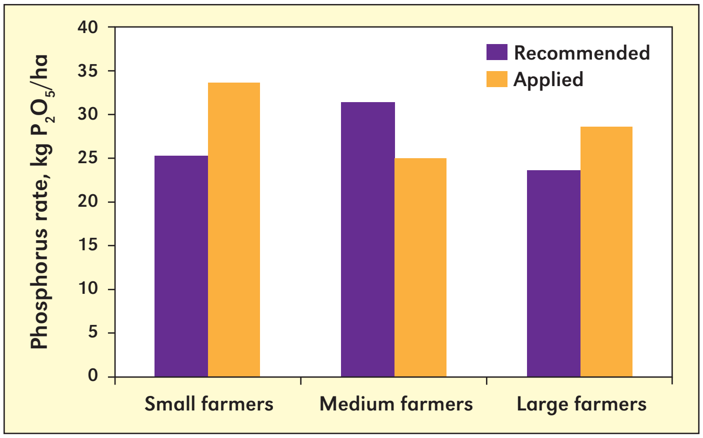

Figure 4. Phosphorus rates compared to the recommended rates for each category of super high-density olive plantation.

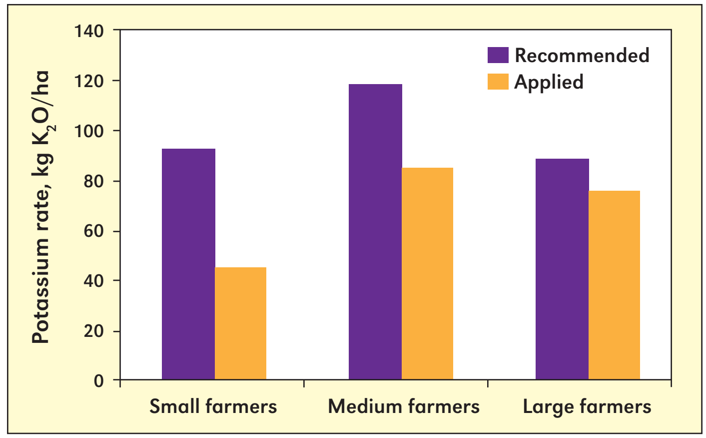

Figure 5. Potassium rates compared to the recommended rates for each category of super high-density olive plantation.

less K fertilizers as compared to recommended rates (**Figure 5**). Contrary to small farmers, most of the medium and large farmers are using foliar fertilizers and soil analysis for their fertilization management. Fertilizer rates applied by these medium and large farmers range from 74 to 91 kg N/ha, 25 to 28 kg P_2O_5/ha and 76 to 85 kg K_2O/ha (**Figure 3, 4** and **5**). These rates varied slightly as compared to the recommended rates that are about 77 to 102 kg N/ha, 23 to 31 kg P_2O_5/ha and 88 to 118 kg K_2O/ha (Pastor Muñoz-Cobo et al., 2015). From the survey, we noted that K rates applied by all three groups of farmers are often less than the tree requirements (**Figure 5**).

Fertilizers Application Time

About 70% of the respondents reported that the time of application of N, P and K is based on the tree requirements, which is related to the vegetative stage and reproductive cycle. Only 55% of small farmers take into account the time of application as an important factor in their fertilization management. However, all medium and large SHD farmers consider application timing as an important nutrient management factor. Farmers interviewed revealed that 80% of N needed is applied between March and July, and the rest is applied between September and October. Phosphorus is applied equally between March to July, and after that only small amounts are applied for the chemical maintenance (cleaning fertigation lines) of drip irrigation systems. With regard to K, farmers revealed that K fertilizers are applied mainly from June (after fruit set) until October.

Summary

In Tunisia's SHD olive plantation orchards, 85% of farmers use fertilizers. However a large number (about 66%) apply fertilizers without any plan. Rates of N and P are applied in excess of crop requirements, while K is applied at suboptimal rates. The main sources of N, P and K are ammonium nitrate, phosphoric acid and potassium sulfate. The role of regional agricultural extension centers should be improved to assist SHD farmers (mainly small farmers) in fertilization management. BC

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2015 Crop Nutrient Deficiency Photo Contest Winners

IPNI is once again pleased to announce the winners of the 2015 Crop Nutrient Deficiency Photo Contest.

Many excellent examples of crop nutrient deficiency were received across all four of our contest's categories. Preference was given to well-photographed entries that provided a good representation of the impact of the deficiency to the whole plant, adequate nutrient analyses information, and details concerning current or historical fertilization at the site.

IPNI thanks all participants for their submissions to this annual contest. By providing these excellent examples of documented nutrient deficiencies in crops, you are contributing to our mission to increase awareness on their diagnoses and treatment.

Many congratulations to all of this year's winners who, in addition to their cash award, will also be receiving a complimentary version of our most recent USB flash drive collection of crop nutrient deficiency images. For more details on this collection please see: http://ipni.info/nutrientimagecollection.

We encourage all participants to check back regularly with the contest's website maintained at www.ipni.net/photocontest for details on submitting your entries for 2016.

Featured Category (Root and Tuber Crops)

First Prize (US$300) – Phosphorus Deficiency in Turnip – Jaume Cots Ibiza, BC Fertilis, Valencia, Spain. This image from Spain captured a vivid example of P deficiency in turnip. Note the purple color of the leaves and slow growth of the entire plant, especially the youngest leaves. Turnips were grown in loamy soil (pH 7.4) with high K content (340 mg/kg - photometric method) and low P content (5 mg/kg – Olsen).

Second Prize (US$200) – Phosphorus Deficiency in Sweet Potato – S. Srinivasan, Tamil Nadu Agricultural University, Tamil Nadu, India. This is a noticeable example of P deficiency in a three-month-old sweet potato plant grown on black calcareous soil near Kovilpatti, Tamil Nadu. The plant received no P after planting. Under acute deficiency, the younger leaves can also develop interveinal purple pigmentation on the upper surface. The soil test (Olsen-P) revealed that P content was very low (less than 1.3 mg P/kg). Leaf tissue analysis also registered a lower value of 0.05% P.

Nitrogen Category

First Prize (US$150) – Nitrogen Deficiency in Potato – Daniel Geisseler and Patricia Lazicki, University of California, Davis, California, USA. Taken in a "no-fertilizer" plot of a cover crop experiment at the Intermountain Research and Extension Center in Tulelake, California. Average soil nitrate-N in the top 10 inches of soil prior to planting was 14 ppm. Adjacent plots, which had had a woolypod vetch cover crop tilled-in, had an initial soil nitrate-N of 28 ppm. Potatoes in these plots were markedly greener.

Second Prize (US$100) – Nitrogen Deficiency in Palm – N.D. Yogendra, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India. A close-up N deficiency in Areca palm leaves shows yellowing of older leaves, which is progressing to younger leaves. During the later stages of growth, drying of leaf tips was observed. The soil texture was sandy loamy and soil pH was 5.7. Tissue analysis of leaves conformed N deficiency, affected leaves N content was found to be low 1.58%. Available N (alkaline $KMnO_4$) was also low (190 kg/ha).

Abbreviations and Notes: N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; CEC = cation exchange capacity.

Phosphorus Category

First Prize (US$150) – Phosphorus Deficiency in Corn – Jason Kelley and Morteza Mozaffari, University of Arkansas, Arkansas USA. Soil samples (0 to 4 inches) taken from this P deficient field at Lon Mann Cotton Branch Research Station, in Marianna, Arkansas had a Mehlich-3 extractable P of 17 ppm (low). Weather conditions after corn planting and emergence had been cool and wet that likely reduced root growth and P uptake, increasing visual symptoms of P deficiency. As growing conditions improved and the plants root system became larger, deficiency symptoms disappeared without additional P fertilizer.

Second Prize (US$100) – Phosphorus Deficiency in Sugarcane – M. Dhasarathan, Tamil Nadu Agricultural University, Tamil Nadu, India. Profound P deficiency in a local cultivar of sugarcane growing in a farmer's field in near Salem, Tamil Nadu, India. A strong reddish-purple margin occurred in the older leaf. Soil and plant analysis both showed low soil (20 kg/ha) and leaf (0.09%) P contents–lower than normal levels near 75 kg/ha and 0.3%, respectively.

Potassium Category

First Prize (US$150) – Potassium Deficiency in Corn – Jason Kelley and Morteza Mozaffari, University of Arkansas, Arkansas USA. This field near Lon Mann Cotton Branch Research Station, in Marianna, Arkansas had not had any K fertilizer applied in several years. The corn plants were also hampered by shallow root systems due to soil compaction, which further reduced the amount of K available to the plant. Soil samples (0 to 4 inches) from the area showing K deficiency had a Mehlich-3 extractable K of 78 ppm (low). Potassium deficiency symptoms were present season long without any additional K fertilizer.

Second Prize (US$200) – Potassium Deficiency in Groundnut – Gopal Ramdas Mahajan, ICAR - Central Coastal Agricultural Research Institute, Goa, India. Taken at Tiruchirapalli, Tamil Nadu, typical yellowing of the older leaves, starting from the margins, has progressed towards the midribs in this flowering groundnut crop. The crop was grown on acid upland (14% slope, lateritic, pH 5.8) soil. The soils were deficient in the basic cations and had very low soil available K (61 kg/ha). Total leaf K content in the deficient leaves was only 0.6%, whereas it was 1.8% in the healthy crop grown in the level lowland at the base of the slope.

Other Category (Secondary and Micronutrients)

First Prize (US$150) – Magnesium Deficiency in Corn – Jason Kelley, University of Arkansas, Arkansas USA. Magnesium deficiency was found in a non-irrigated corner of a pivot-irrigated corn field near Augusta, Arkansas. The site's soil was sandy with a CEC of 7.9 cmol/kg. Soil analysis from a 4-inch sample at tasselling stage showed a pH of 4.1 (1:1 method) and a soil Mg level of 26 ppm. Tissue samples collected from ear leaves at tasselling indicated a Mg concentration of 0.07% and all other nutrients were considered sufficient.

Second Prize (US$100) – Magnesium Deficiency in Papaya – Mavinakoppa S. Nagaraja, University of Horticultural Sciences, Bagalkot, Karnataka, India. Papaya plants found at Bagalkot, Karnataka are showing the Mg deficiency symptom of interveinal chlorosis of older leaves. Younger leaves appear normal, which indicates mobilization of Mg within the plant system. The site's calcareous soils are known to produce Mg deficiency unless external sources are applied. Soil analysis found a wide ratio of Ca:Mg (13:1) with 0.68 cmol Mg/kg soil compared to 8.82 cmol Ca/kg soil. Petiole analysis of normal and deficient plants also suggested Mg deficiency (0.33% in healthy plants; 0.17% in deficient plant).

The Colors in Phosphorus Deficient Plants

By Tom Bruulsema

Purple or red coloring sometimes indicates P deficiency for some plant species; however, colored leaf margins seem to serve a wide variety of functions in plant acclimation to environmental stress.

Examining the physiology and biochemistry of pigment production explains some of the variable color responses. It also highlights the role of P in photosynthetic energy transfer, a role crucial to high-yield crop production systems.

"Not all purple plants are phosphorus deficient, and not all phosphorus deficient plants turn purple."

In some species, reddening or purpling of the leaf margin indicates that the plant is under some kind of stress, for example, P deficiency or freezing stress. But other species display these colors all the time, while some not at all. In most cases the pigment causing these colors is—or is presumed to be—anthocyanin. A recent review of potential ecological and physiological functions (Hughes and Lev-Yadun, 2015) brings out a lot of interesting points about these pigments and their relation to P deficiency.

Anthocyanins come in a wide range of colors. They are the same compounds that color flowers. The anthocyanins associated with P deficiency are usually red to purple. In some species, including corn, apples, pears, and strawberries, symptoms are most prominent on leaf margins (**Table 1**). Experiments with apples have shown that when a P deficiency is relieved, the red/purple color of the leaf margins subsides. In other species, for example tomatoes, the undersides between the veins turn purple. Other species—like sugar beet, rice, potato, and onions—don't change color at all, other than perhaps a deepening of greenness as the plant's growth is stunted. Chlorophyll contains no P, so in a deficient plant, chlorophyll may have higher abundance relative to P-containing compounds (Marschner, 1995).

Table 1. Crop species classed by P deficiency symptoms.

Red/purple on leaf margins	Red/purple in other places	None, or dark blue-green leaf
Apple	Cabbage	Onion
Canola	Eucalyptus	Potato
Corn	Sugar maple	Soybean
Lentil	Tomato	Sugar beet
Grape		Rice
Guava		
Pear		
Strawberry		
Sweet potato		

A question that intrigues plant scientists is why plants produce purple and red colors. Possibilities include undermining the camouflage of insect pests to make them more visible to their predators. Or "aposematism"—a warning signal to make the plant part look inedible or dangerous to pests that might be tempted to feed on the leaf. Insects see color, and red or purple could look to them as if the leaf is either well-defended or not very nutritious to eat. Red leaves are generally lower in N and P—and thus less nutritious. They are also higher in phenolics, and anthocyanins themselves may be antinutritional for insects and other herbivores. In one New Zealand shrub species, the width of the red portion of the leaf margin correlated to higher levels of the plant defense compound polygodial and was associated with less damage from herbivory.

Abbreviations and notes: N = nitrogen; P = phosphorus.

A P-deficient corn leaf is not photosynthesizing at its maximum rate.

Birds are the most common predators of plant-eating insects, and they too see color. Thus a non-green color on the leaf margin can help them find and consume the herbivore insects that have green camouflage. Birds are also smart enough to learn that a leaf margin with breaks from insect feeding is a sign of greater likelihood of finding a caterpillar. A plant that colors its margins will show these breaks more conspicuously.

Pigments can play a role in helping plants deal with excess uptake of certain trace elements. The trace elements can include excess amounts of nutrients like boron (B), cobalt (Co), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn), and other metals like aluminum (Al), cadmium

An extreme example of purpling on the underside of a tomato leaf.

The P-deficient soybeans (right) show no sign of red or purple color.

Even a severe P deficiency in a potato leaf shows no sign of red or purple margins – but the whole leaf may turn a deep bluish green.

(Cd), lead (Pb), and silver (Ag). Several kinds of anthocyanins can chelate metal ions with two or three positive charges. Trace elements are often found to accumulate more at the leaf margins than elsewhere.

Anthocyanin pigments can help plants defend themselves from environmental stresses. They do this by blocking visible and ultraviolet wavelengths of light. They also play an antioxidant role. Both roles are called "photoprotection" and are important in situations where a leaf is exposed to more light than it can use, or more light than it can process in photosynthesis.

Within plant cells, chloroplasts use what is called the Calvin-Benson cycle to harvest the energy of sunlight to make three-carbon sugar phosphates from atmospheric carbon dioxide. Part of the energy is stored in the bond of the phosphate to the sugar. But to move these sugar phosphates out of the chloroplast, the phosphate supply needs to be replenished. If the supply of phosphate in the chloroplasts is depleted, photosynthesis slows down for several reasons. One, not enough phosphate remains available to continue making new sugar phosphates. Two, the chloroplasts accumulate starch, and starch accumulation feeds back to inhibit photosynthesis. The amount of light energy entering the chloroplasts is still the same. That light energy, interacting with chlorophyll and other light-harvesting

Phosphorus deficiency in canola.

Phosphorus deficiency observed in guava.

IPNI2015GSU01-1061

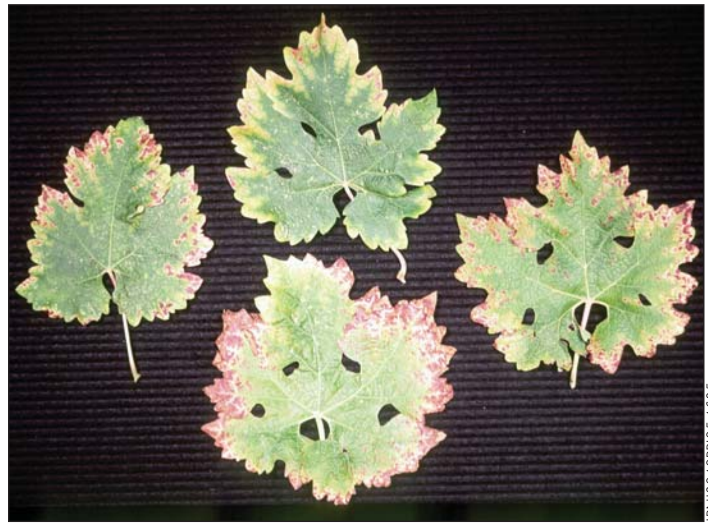
Phosphorus deficient lentil plants showing purple lower leaves.

molecules, can produce oxygen free radicals and other damaging oxidative chemicals. When plants respond by producing anthocyanins to protect the chloroplasts from oxidative damage, these non-green pigments also curb maximum photosynthetic capacity.

Environmental stress situations occur with low temperatures, water deficit, low leaf N and P, and light-sensitive stages of leaf development. Leaf margins can be particularly vulnerable to all of these stresses, and thus colors can show there first, rather than across the whole leaf (except N deficiency, which shows symptoms first in the center of most leaves). Leaf margins dry out and experience cold more quickly than the rest of the leaf. They are also further removed from nutrient transport in xylem and phloem tissue, making them last to receive nutrients. In at least some species, leaf tissue is more tightly packed, and the surface has fewer stomatal pores near the margins, and thus internal carbon dioxide levels may be lower owing to restricted diffusion. Lower carbon dioxide means more potential for oxidative damage.

IPNI2011GSU01-1356

Phosphorus deficiency in sweet potato.



IPNI2010PPI05-1685

Cabernet Sauvignon grape leaves showing purple margins.

Source/sink imbalance is also often associated with red/purple coloring. Within the cells of green plant tissue, P plays key roles in the source/sink balance, because of its involvement in the steps of conversion of carbon dioxide to the various forms of sugars and starches, and transport of sugars.

So what does it all mean for managing P? First, visual symptoms don't stand alone but need backup from soil testing, plant analysis, and growth comparisons. Second, it's clear from the biochemistry that P is involved in the photosynthetic core of any high-yield crop production system, the crucial point at which energy is transformed from light into sugar and then into the myriad of unique compounds that plants provide for us. So as we develop plant production systems for ever higher levels of productivity and sustainability, we need to continue refining assessment methods for assuring the right P nutrition for all crops in the system for every day of their growth cycle. BC

IPNI2012GSU01-3120

Whole lower leaves in P-deficient cabbage showing red/purple.

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Importance of Phosphorus Management in Maize-Wheat Cropping Systems

By Rakesh Kumar, S. Karmakar, A.K. Sarkar, Sudarshan Dutta, Kaushik Majumdar, T. Satyanarayana, and Adrian M. Johnston

Omission of phosphate fertilizer reduced cropping system productivity, showing the importance of balanced P application in the relatively low fertility red and lateritic soils of Jharkhand.

Yields within the state of Jharkhand's maize-wheat cropping system are under performing at 1.8 and 1.9 t/ha, respectively. These yields are much lower than the national averages of 2.6 t/ha (maize) and 3.1 t/ha (wheat) (FAI, 2014). This region of eastern India has large tracts of red and lateritic soils that have coarse texture, low organic matter content, low pH, and generally low availability of N, P, K, secondary, and micronutrients.

Increased cereal crop production can be addressed in these soils through the use of high-yielding varieties and improved nutrient management. It is realistic to expect two to three-fold increases in crop yields with the adoption of these practices. The approach of this research was to estimate inherent soil nutrient supply through the nutrient omission plot technique, which was followed by adequate and balanced application of all yield-limiting nutrients, based on attainable yield targets.

As part of the IPNI Global Maize Initiative >http://research.ipni.net/article/EXP-3006<, field experiments were conducted for three consecutive years (2010-11 to 2012-13) at the Birsa Agricultural University Farm in Ranchi, Jharkhand to assess the effect of nutrient use and phosphate omission on crop yields, nutrient uptake, soil health, and the economics of the maize-wheat cropping system. The experiments used hybrid maize (var. Pioneer 30V 92 planted within a 70 x 18 cm geometry), which was grown during the rainy season as a rain-fed crop (June to October). The following wheat crop (var. DBW 17, 25 cm row-to-row spacing) was grown in winter as an irrigated crop.

The experimental area falls within the sub-tropical Eastern Plateau and Hill region. The soil was sandy loam in texture with pH 5.2, 4.9 g O.C./kg, low available N, P and K (272 kg N/ha, 32 kg P_2O_5/ha, 139 kg K_2O/ha) determined by Subbiah and Asija (1956), Bray and Kurtz No. 1 (1956), and Jackson (1967) methods, respectively. The study's four treatments included: 1) ample NPK (250-120-110 kg N-P_2O_5-K_2O/ha for maize and 150-110-100 kg N-P_2O_5-K_2O/ha for wheat), 2) P omission from ample NPK, 3) SSNM (200-90-100 kg N-P_2O_5-K_2O/ha for maize and 120-70-60 kg N-P_2O_5-K_2O/ha for wheat), and 4) Farmers' Fertilization Practice (FFP – 2.5 t FYM/ha + 20 kg N/ha). All treatments were laid out in a randomized block design with four replications. Rates within the ample NPK treatment were chosen to avoid any nutrient limitation, while SSNM rates were based on published nutrient uptake values for maize, and nutrient use efficiencies for this soil type (Setiyono et al., 2010; IPNI personal communication). Nutrient application under FFP for maize and wheat were based on a farmers' participatory survey conducted with 10 maize-wheat growing farmers from the study region. The limiting secondary and micronutrients were applied to all treatments.

Abbreviations and notes: N = nitrogen, P = phosphorus; K = potassium; O.C. = organic carbon; SSNM = site-specific nutrient management. 1 US$ = 67 Indian Rupees (Rs.). IPNI Project IND-GM22.

IPNI Image/S. Dutta

IPNI Image/K. Majumdar

A visit to the maize-wheat experiment site at Birsa Agricultural University Farm in Ranchi, Jharkhand. Dr. Majumdar (L), Dr. Kumar (C), and Dr. Dutta (R) shown in top photo.

For calculation of the system yield, grain yield of wheat was converted to maize equivalent yield (MEqY) by using the following equation:

$$MEqY = \frac{[\text{wheat yield (kg/ha) x selling price of wheat (Rs/kg)}]}{\text{selling price of maize (Rs/kg)}} + \text{maize yield (kg/ha)}$$

Temporal variability of P response during 2009-13 was calculated as:

$$\text{P response (kg/ha)} = \text{grain yield in ample NPK (kg/ha)} - \text{grain yield in P omission (kg/ha)}$$

The economic benefit was calculated by the Return on Investment (ROI) for P fertilizer use calculated as:

$$ROI = \frac{\text{yield increase due to P fertilizer (kg/ha) x minimum support price of crop (Rs/kg)}}{\text{applied } P_2O_5 \text{ (kg/ha) x cost of } P_2O_5 \text{ (Rs/kg)}}$$

Composite surface soil samples (0 to 15 cm) were collected after two crop cycles for available N, P and K analysis. Agronomic efficiency (AE) of P was calculated as described by Cassman et al. (1998).

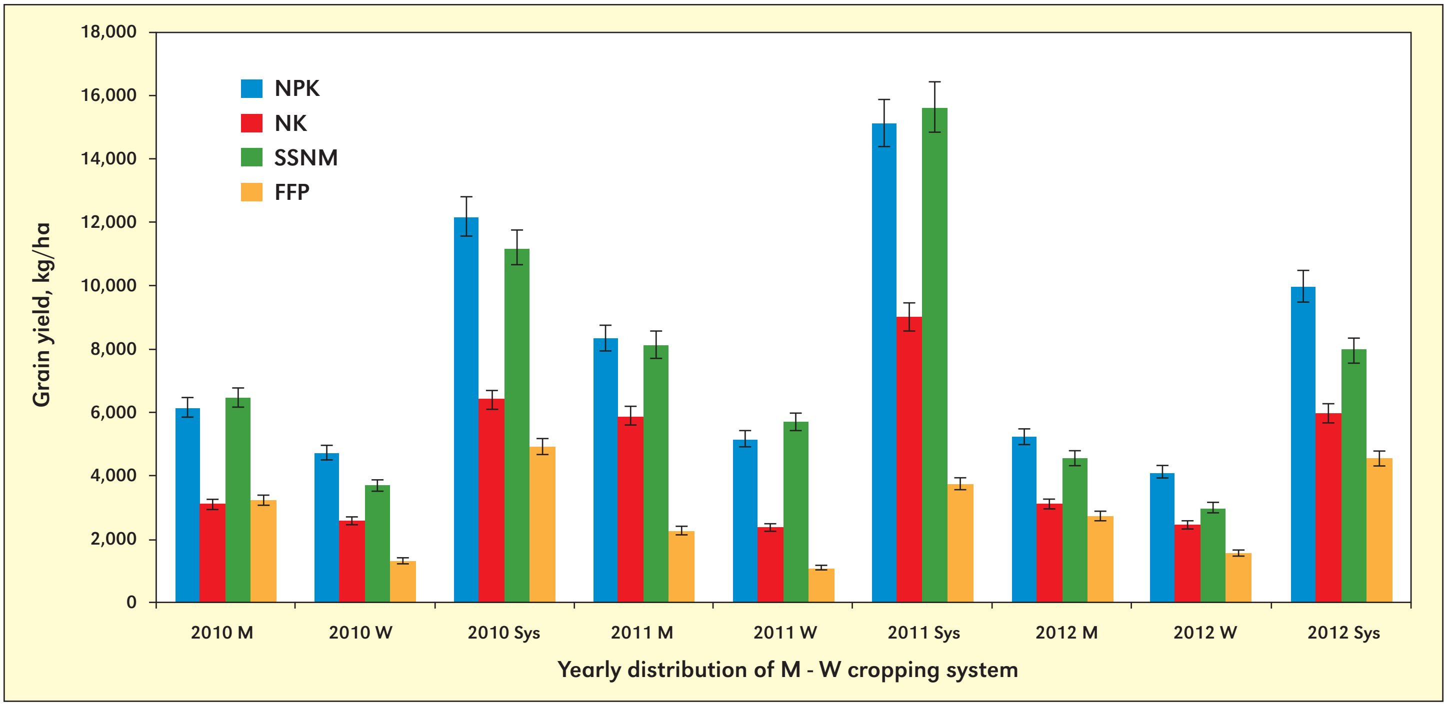

Figure 1. Grain yield of maize (M) and wheat (W) in maize-wheat sequence (Sys). SSNM and FFP = Site-Specific Nutrient Management and Farmers' Fertilization Practice, respectively. Error bars = Standard errors.

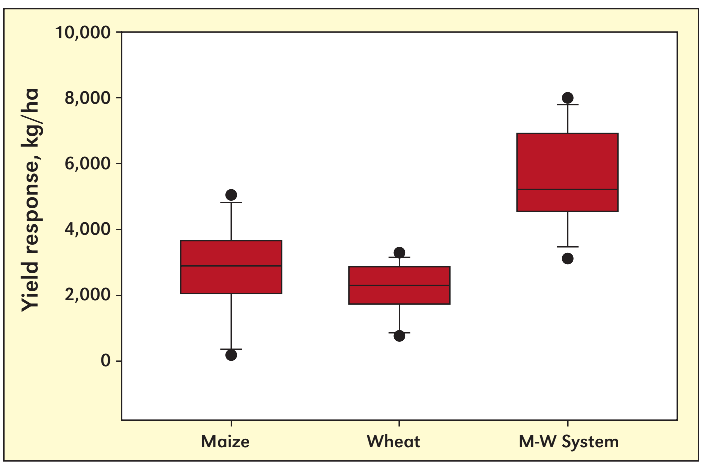

Figure 2. Average grain yield response of maize (M), wheat (W) and the system to applied phosphorus across three years of study (n = 36). Boxes represent data within the first and third quartiles (interquartile range). Lines extending beyond the interquartile range denote the 10th to 90th percentile of the data. Statistical outliers are plotted as individual points outside these lines.

Crop Yield and Nutrient Uptake

Application of P fertilizer enhanced both maize and wheat yields, and overall system productivity (MEqY). Maize grain yields were > 5 t/ha for both NPK and the SSNM treatments and were significantly ($p \leq 0.05$) higher compared to P omission as well as FFP plots (**Figure 1**). The same trend was observed for wheat yield where the NPK and SSNM plots averaged > 4 t/ha and were significantly ($p \leq 0.05$) higher than the 0 P and FFP treatments.

In 2010, the average grain yield in NPK maize and wheat plots was 6.2 t/ha and 4.7 t/ha, respectively; while the system productivity was 12.2 t/ha. In contrast, the P omission plot had a maize yield of only 3.1 t/ha and wheat productivity was 2.6 t/ha. In the SSNM plot, the maize productivity was 6.5 t/ha and wheat productivity was 3.7 t/ha with a system productivity of 11.2 t/ha. The FFP plot productivity for maize, wheat, and the system were 3.2, 1.3, and 4.9 t/ha, respectively.

In 2011, maize and wheat productivity under NPK increased up to 8.4 t/ha and 5.2 t/ha, respectively, while the system productivity went up to 15.1 t/ha. These productivities were significantly ($p \leq 0.05$) higher than P omission plots (6.6, 2.4 and 9.8 t/ha, respectively) and FFP (2.2, 2.1 and 5.0 t/ha, respectively) and were at par with the SSNM treatment (8.1, 5.7 and 15.6 t/ha, respectively). Higher maize production in 2011 could be attributed to the better rainfall pattern during the monsoon *kharif* 2011 and more favorable winter temperature during the following *rabi* season.

In 2012, grain yields were similar to those in 2010 where NPK yields for maize, wheat, and the system were 6.6, 4.1 and 11.4 t/ha and were significantly ($p \leq 0.05$) higher than P omission (3.1, 2.5 and 6.0 t/ha) and FFP (2.8, 1.6 and 4.6 t/ha) treatments. The SSNM yields (3.6, 3.8 and 8.0 t/ha) were also significantly ($p \leq 0.05$) higher than P omission and FFP plots. It was noted that the average maize and wheat yields of the 0 P treatment were significantly ($p \leq 0.05$) higher than the FFP from the 2010 wheat season onwards. Thus, although the P omission plot did not receive P fertilizer, its overall fertilization schedule appeared comparatively better than FFP as it did receive better N and K input (**Figure 1**).

The response study reported that the mean P response for maize was 2.8 t/ha, 2.2 t/ha for wheat and 5.5 t/ha for the MW system (**Figure 2**). In the case of maize, the response was highest in 2012 (3.5 t/ha) followed by that of 2010 (3.1 t/ha) and then 2011 (1.8 t/ha). Phosphorus deficiency is well reported on acidic soils because of the rapid reversion of soluble P into insoluble forms through reactions with iron and aluminum oxides. Therefore, P fertilizer has a very important role within the maize-wheat system, especially when compared with FFP.

Nutrient Use Efficiency

Nutrient use efficiency (NUE) provides an integrative index that quantifies total economic output relative to the utilization of all nutrient resources in the system. Agronomic Efficiency (AE) and Partial Factor productivity (PFP) are useful measures of NUE (Cassman et al., 1998). The AE values for maize and wheat varied (example equation for AE (P_2O_5) = (Yield in NPK plot – Yield in P omission plot) / P_2O_5 applied x 100) although there was no crop-wise pattern. Temporal variation also was observed in AE values in the present study; there was a decreasing trend in the AE value for maize from 2010 to 2012. On the other hand, AE of wheat increased in 2011 from 2010, but again decreased in 2012. Similarly the AE of the maize-wheat system increased in 2011 from 2010, but decreased in 2012 (**Table 1**). This could be attributed to the higher yield of both maize and wheat in the year of 2011. The PFP is being calculated by dividing the grain yield with the amount of nutrient applied; therefore, it is an indication of production per unit of nutrient applied. PFP can be increased with the increase in the amount, uptake and utilization of indigenous nutrients. PFP can also improve by increasing the efficiency with which applied nutrients are taken up by the crop and utilized to produce grain. The PFP value for P_2O_5 was significantly higher in the SSNM treatments compared to NPK (**Table 1**), and it is expected as SSNM yield was at par with NPK with lower rates of P_2O_5.

Table 1. Temporal variation of yield attributes across different treatments.

		----- 2010 -----		----- 2011 -----		----- 2012 -----	
		Maize	Wheat	Maize	Wheat	Maize	Wheat
Agronomic efficiency, kg grain/kg P	NPK	25.5	17.8	20.7	23.3	17.6	13.8
Partial factor productivity, kg grain yield/kg applied nutrient	NPK	51.4 a*	43.1 a	69.7 a	47.0 a	43.7 a	37.5 a
	SSNM	72.0 b	61.9 b	90.4 b	95.5 b	50.8 b	49.9 b

*Different letters within columns depict statistically significant ($p \leq 0.05$) differences.

Table 2. Prices of fertilizer, and minimum support prices for maize and wheat during the study.

Prices, Rs./kg	2010	2011	2012
Single superphosphate (50 kg bag)	197.00	197.00	360.00
P_2O_5	24.62	24.62	45.00
Maize	8.80	9.80	11.75
Wheat	11.70	12.85	13.50

Source: Primary Agriculture Cooperative Society, Government of Jharkhand; http://dfpd.nic.in/minimum-support-prices.htm

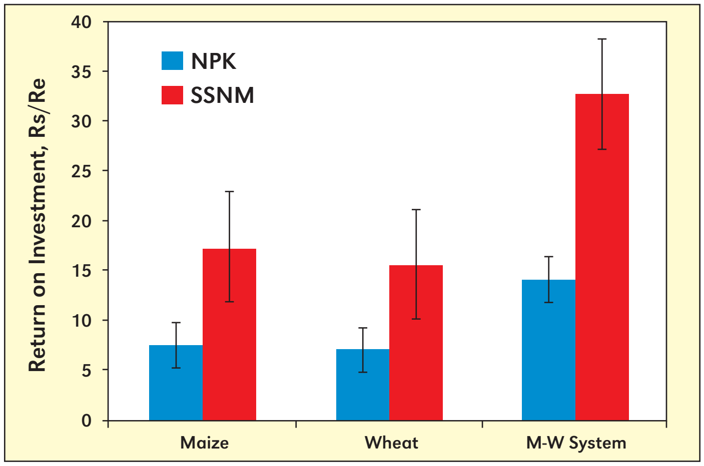

Figure 3. Return on investment values (Rupees invested/Rupees expended) for NPK and Site-Specific Nutrient Management treatments. The prices considered for calculations are given in Table 2. Error bars = Standard errors.

Economics

Return on investment (ROI) was calculated based on the varying minimum support price of maize and wheat and the unit price of P_2O_5 determined based on the unit price of single superphosphate (SSP) fertilizer (**Table 2**). Economic analysis of the nutrient management practices was determined through ROI that highlights the increase in profitability per unit investment in a particular nutrient. The study revealed that the ROI was higher with SSNM compared to NPK plots (**Figure 3**). A lower ROI value associated with the NPK treatment, ranged from 5 to 9 Rs/Re (Rupees invested/Rupees expended) for maize, 4 to 9 Rs/Re for wheat, and from 12 to 17 Rs/Re from the maize-wheat system. These results were significantly less than the SSNM treatments where ROI ranged from 12 to 24 Rs/Re for maize, 9 to 23 Rs/Re for wheat and 18 to 47 Rs/Re for system. Higher ROI in SSNM compared to NPK can be attributed to higher input cost associated with additional nutrients prescribed by the omission plot protocol (applications made to avoid any deficiency). The system ROI was also increased in the maize-wheat cropping system, indicating that production and profitability could be increased in maize-wheat systems in Jharkhand with balanced nutrient management practices, especially when special emphasize is given to P nutrient management.

Summary

This study shows that application of P fertilizer increases the maize, wheat, as well as maize–wheat system yield significantly over FFP and P omitted plots, accruing higher economic benefit in this process. BC

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Drought and Soil Salinity Influence Response of Cereals to Potassium and Sulfur Fertilization

By Qifu Ma, Richard Bell, Craig Scanlan, Gavin Sarre, and Ross Brennan

Wheat required more K under drought than non-drought conditions, and the effectiveness of K fertilization was improved by early application.

In moderately saline, low K soil, K input improved growth and yield of barley—a response partially attributed to the plant's ability to tolerate the substitution of Na for K.

In sandy soils or acid lateritic soils containing kaolinitic clay with low CEC, considerable amounts of K can be lost by leaching (Sittiphanit et al., 2009). In Western Australia (WA), greater removal of K in hay, grain and straw than fertilizer K input has steadily increased the incidence of K deficiency on uniform deep sands and sandy duplex soils (sand over loam, clay or lateritic ironstone gravel) (Wong et al., 2000). In low K soils (less than 40 mg Colwell-K/kg), the reduction of wheat and barley growth is relatively greater in roots than shoots (Ma et al., 2011, 2013). The favoring of shoot growth at the expense of roots under K deficiency may, in turn, have a negative feedback on plant uptake of soil water and nutrients and thus make low K plants more vulnerable to drought and/or salinity.

The climate in the south-west WA is a Mediterranean type with short, mild, wet winters and long, hot, dry summers. In this environment, crops often experience intermittent drought during early growth and terminal drought after anthesis. Plant nutrients in the drying topsoil become less available at the root surface, particularly when stratified in the topsoil under no-till farming. In south-west WA, soil salinity and/or sodicity severely affects about 1 million ha of agricultural lands and is expected to expand because of rising saline groundwater due to the landscape water imbalance under annual pastures or crops (Clarke et al., 2002). In this study, we conducted field experiments to investigate the role of K nutrition in alleviating drought and salinity stresses in wheat and barley and compare K-use efficiency between KCl and K_2SO_4 sources. The effect of time of K application was also examined.

2011 Experiment - Wheat

Wheat was grown near Bolgart, Dowerin and Borden, in WA. A pre-sowing soil analysis showed that soil K at 0 to 30 cm depth was low and potentially deficient at all sites (**Table 1**). The experiments were sown in mid June, and each plot had an area of 2 m by 22 m and seven rows at 0.25-m row spacing. At sowing, 100 kg/ha of NPS fertilizer enriched with Cu-Zn-Mo was banded 5 cm below the seed. The fertilizer had 12.6 N, 17.7 P, 5.5 S, 0.25 Cu, 0.35 Zn, and 0.025 Mo (w/w%). At five weeks after sowing (WAS), 200 kg/ha of urea (46% N) was broadcast.

All experiments included two K sources (KCl, K_2SO_4), four K rates (0, 20, 40, and 80 kg K/ha), and four application times (0, 5, 10, or 15 WAS) by broadcast method. In addition, 80 kg K/ha using KCl without gypsum was also applied at 5 WAS to compare with the response of plants treated at the same rate of KCl plus gypsum. At anthesis, shoot dry weight was obtained by quadrat cuts and shoot K concentrations were determined by inductively coupled plasma atomic emission spectroscopy. At maturity, individual plots were machine harvested for grain yield.

Abbreviations and notes: K = potassium; S = sulfur; Cu = copper; Mo = molybdenum; Na = sodium; Zn = zinc; KCl = potassium chloride; K_2SO_4 = potassium sulfate; CEC = cation exchange capacity. P and K are expressed as elemental forms. 1 mg of Colwell K/kg is equivalent to 0.1 cmol exchangeable K/kg

Table 1. Pre-sowing soil potassium (Colwell-K) and sulfur (KCl-40 S) at three sites in the central and southern regions of the grain belt in Western Australia.

Soil depth	Dowerin (central) K	Dowerin (central) S	Bolgart (central) K	Bolgart (central) S	Borden (southern) K	Borden (southern) S
			mg/kg			
0 – 10 cm	31	14.6	40	6.7	23	6.1
10 – 20 cm	29	1.8	30	4.6	23	3.5
20 – 30 cm	28	2.2	37	3.0	30	4.4
30 – 40 cm	37	3.0	45	4.0	–	–
40 – 60 cm	34	4.1	59	4.3	–	–
60 – 80 cm	33	7.2	59	3.3	–	–

2012 Experiment - Barley

Barley was grown at Beverley, WA. A pre-sowing soil analysis showed 20 mg Colwell-K/kg in the 0 to 40 cm profile, 10 mg S/kg in the top 10 cm soil and 6 mg S/kg at the lower depths. The soil was marginally saline. The experiment was sown in early June with similar rate of basal fertilizers to the 2011 experiments. At 2 WAS, KCl and K_2SO_4 were broadcast at 0, 20, 40, and 120 kg K/ha. At anthesis, photosynthetic gas exchange of the flag leaves was measured and concentrations of K and Na of the uppermost three leaves were determined. At maturity, grain yields were measured from quadrat cuts.

Results

In the 2011 season, there was a dry spell of <30 mm total rainfall from stem elongation to grain development at Dowerin, compared to regular rainfall at Bolgart and Borden with monthly averages of 54 and 41 mm over the growing period, respectively. The difference in rainfall among the sites affected crop response to soil K treatments. While little K response was observed at Bolgart and Borden, applying 20, 40 and 80 kg K/ha as either K_2SO_4 or KCl with gypsum at 0 or 5 WAS at Dowerin increased grain yield (**Figure 1**). Later broadcast application reduced the K effectiveness. The supply of 80 kg K/ha as KCl without gypsum at 5 WAS had lower shoot K and S contents, and decreased dry weight and grain yield than the same K rate using K_2SO_4 (**Table 2**).

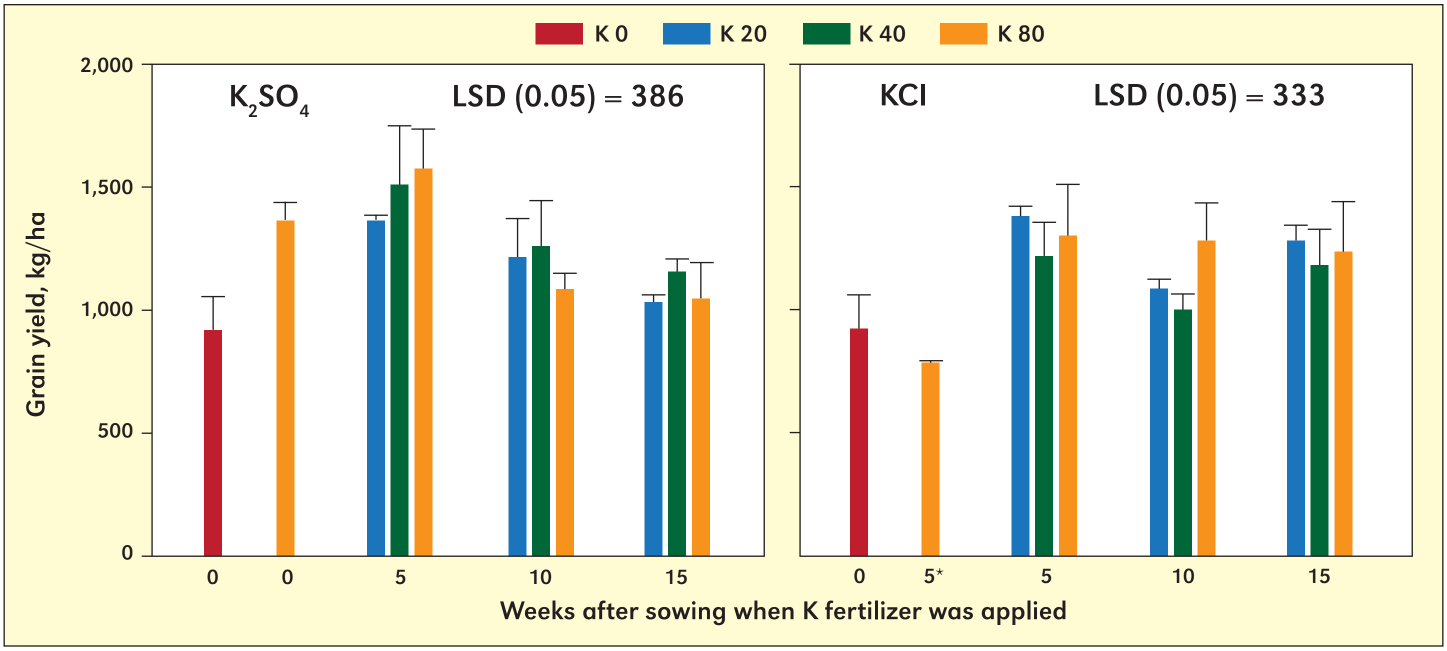

Figure 1. Grain yield of wheat in response to K source, rate and application time at Dowerin in 2011. Capped lines are standard errors. Except for 5* denoting 80 kg K/ha as KCl without gypsum at 5 weeks after sowing, all other K treatments received 100 kg of gypsum/ha.

At the saline site in 2012, 120 kg K/ha as KCl and both 40 and 120 kg K/ha as K_2SO4 increased K concentration, but decreased Na concentration of the uppermost three leaves at anthesis in barley (**Figure 2**). Applying K also improved leaf photosynthesis (**Figure 3**). At maturity, plants with 20 or 40 kg K/ha as K_2SO_4 generally had higher shoot K concentration and lower shoot Na concentration than plants from treatments with the same K rates as KCl. Grain yield was significantly increased by applying KCl and K_2SO_4 compared with zero K input, but the difference between the rates of 20, 40 and 120 kg K/ha was mostly not significant (**Figure 4**).

Table 2. Effects of 80 kg K/ha as K_2SO_4 or as KCl without gypsum on shoot growth, K and S contents at anthesis, and grain yield of wheat in the central and southern grain belts of Western Australia.

	--- Dowerin ---		--- Bolgart ---		--- Borden ---	
Response parameters	K_2SO_4	KCl	K_2SO_4	KCl	K_2SO_4	KCl
Shoot dry wt., kg/ha	2,295 a	1,054 b	4,284	4,249	6,816	6,153
Shoot K, kg/ha	19.5 a	7.8 b	66.4	65.0	77.2	54.7
Shoot S, kg/ha	4.9 a	2.4 b	7.1	6.7	13.3	11.4
Grain yield, kg/ha	1,365 a	792 b	1,776	1,848	2,673	2,684

Comparisons are within site. For each parameter, different letters indicate significant effect ($p \leq 0.05$) of K sources.

Conclusions

At three sites with similarly low soil K, fertilizer K application only increased shoot K, dry matter and grain yield at Dowerin where there was a long dry spell from the mid to late season, but had no effect at Bolgart and Bolden where there was regular rainfall through the season. Under drought, root growth and K uptake would be impaired, especially on low K soil where root growth is reduced at a greater extent than shoot growth (Ma et al., 2011, 2013). Increasing soil exchangeable K by fertilizer application would render more K available to plants for essential physiological functions (e.g., photosynthesis and turgor maintenance) and for better root growth. In this study, the positive response in wheat to soil K supply at the drought-affected site, but not at the non-stressed sites suggests more K is required for optimal growth and yield under limiting soil water supply.

Applying K fertilizers at sowing or 5 WAS was much more effective for dry matter and grain yield than later application. The majority of K uptake in wheat occurs in the vegetative phase and maximal K accumulation is reached at anthesis (Ma et al., 2013). Early K application would allow time for surface-applied K to move into the root zone and match the pattern of K uptake and growth demand, particularly during tillering which can be depressed by low K. Adequate plant K status would also promote translocation of photoassimilates to support root growth during the long dry spell and therefore enhance drought resistance.

On the K deficient and moderately saline soil, K fertilizer application improved leaf photosynthesis, plant growth and grain yield in barley, but the differences among the treatments of 20, 40 and 120 kg K/ha were relatively small and showed at least partial substitution of K by Na. The findings suggest that K fertilizer management needs to consider not only soil K status and crop requirement, but also soil Na status and genotypic variation in the uptake and use of K and Na. In this regard, since barley takes up Na into leaves, it may respond more to Na substitution of K than wheat, which excludes Na (Ma et al., 2011; Krishnasamy et al., 2014).

The fertilizer K_2SO_4 performed better than KCl at both the drought-affected and saline sites. Under drought, the treatment supplying 80 kg K/ha as KCl without gypsum lowered shoot S and K contents at anthesis, compared with the same rate of K using K_2SO_4 and other K treatments that received

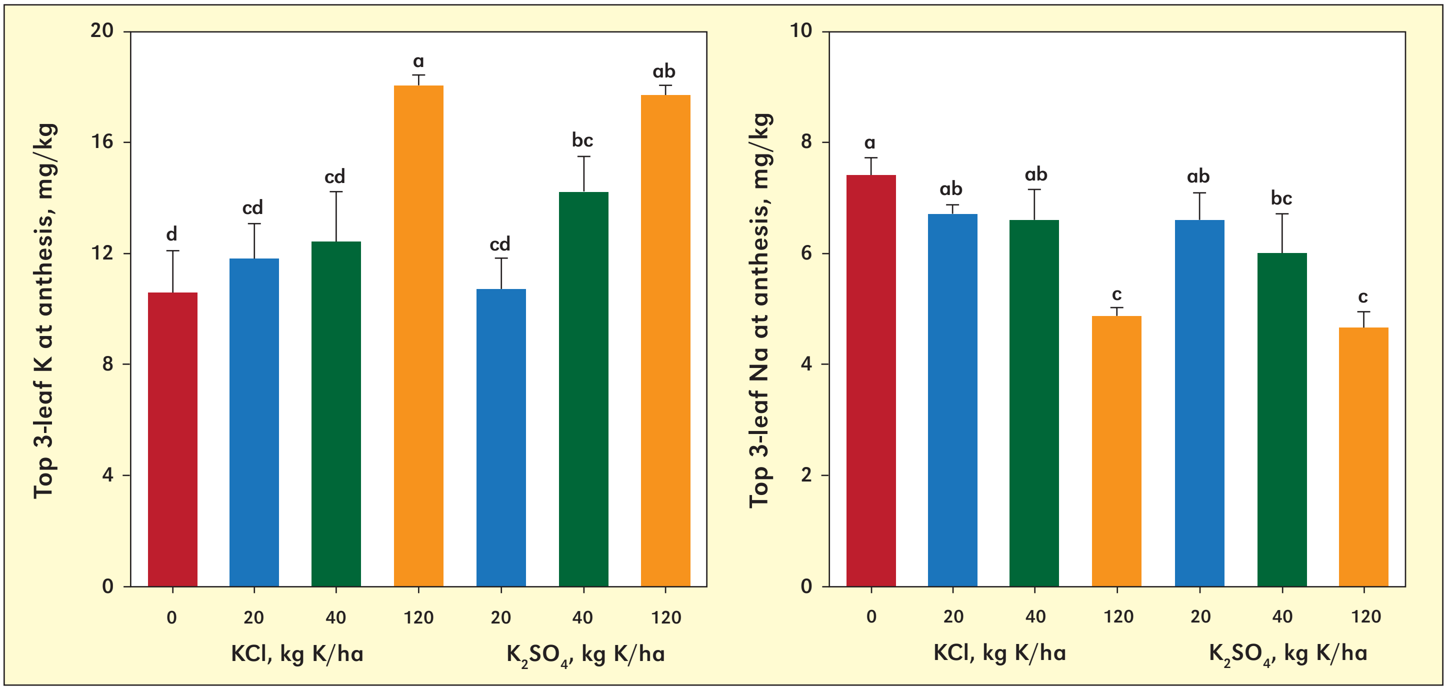

Figure 2. Effect of KCl and K_2SO_4 fertilization on K and Na concentrations in the uppermost three leaves at anthesis of barley grown in moderately-saline soil. Within a graph, means (+std. err.) with the same letter are not significantly different at $p = 0.05$.

supplementary S from gypsum. At the saline site, the soil had a moderate level of S (10 mg/kg) in the top 10 cm but was S deficient at the lower depths, and applying K_2SO_4 would have increased soil available S and K levels.

In the rainfed environment of WA, cereal crops responded to K fertilizer on low K soils, but the response varied with soil salinity and available S levels and soil water stress. BC

Acknowledgments

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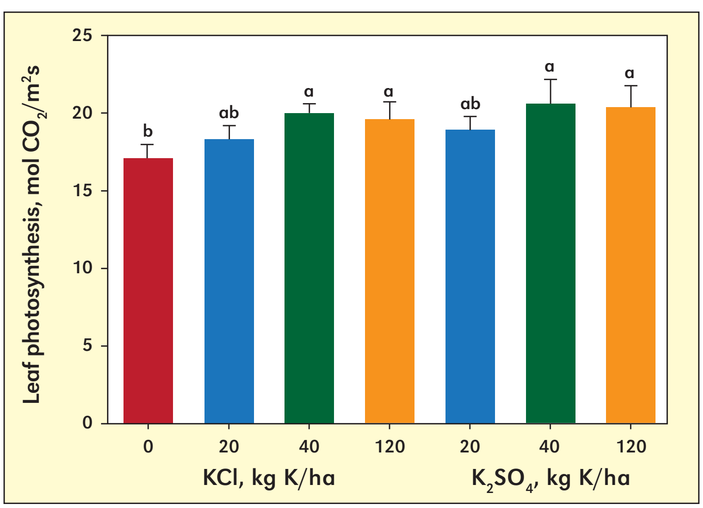


Figure 3. Effect of KCl and K_2SO_4 fertilization on leaf photosynthesis at anthesis of barley grown in moderately-saline soil. Means (+std. err., n=9) with the same letter are not significantly different at $p = 0.05$.

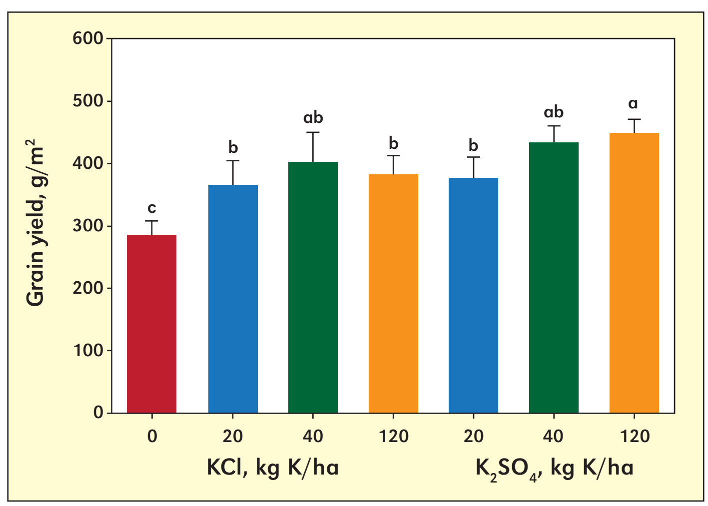


Figure 4. Effect of KCl and K_2SO_4 fertilization on grain yield of barley grown on a moderately-saline soil. Means (+std. err., n=3) with the same letter are not significantly different at $p = 0.05$.

Dr. Mirasol Pampolino Named Deputy Director For IPNI Southeast Asia Program

Dr. Mirasol Pampolino

The International Plant Nutrition Institute (IPNI) announced the appointment of Dr. Mirasol Pampolino as deputy director of the Southeast Asia Program (SEAP).

Ms. Pampolino joined IPNI as an agronomist in 2008. She has been instrumental in the development of Nutrient Expert®, a decision support tool that helps crop advisers to rapidly develop fertilizer recommendations for specific fields or growing environments. She will continue to manage global Nutrient Expert activities through 2017, before assuming full-time duties in the SE Asia region.

"Pampolino has very strong expertise in cereal crop production and management in tropical and sub-tropical regions," said Asia and Africa Group Vice President Dr. Adrian Johnston. "Her leadership will expand the level of engagement in SE Asia to cover a broader range of crops important to the region," Johnston said.

Prior to joining IPNI, Pampolino worked at the International Rice Research Institute for 15 years, where she served in different capacities conducting research studies related to soil science and plant nutrition. She obtained her B.Sc. in Agriculture and M.Sc. in Soil Science from the University of the Philippines Los Baños (UPLB) and her Ph.D. in Agricultural Chemistry (Soil Science) from Hokkaido University, Japan.

In her role as deputy director, Pampolino will lead field crop projects in SE Asia, including rice, maize, and cassava. Dr. Thomas Oberthur, SEAP regional director, will continue to lead tree crop projects, mainly oil palm and cocoa.

"The SE Asia region represents a great opportunity for IPNI to implement new programs while helping growers improve nutrient management of various crops," said IPNI President, Dr. Terry Roberts. "Mira's skills will help diversify and expand our reach," said Roberts. BC

Double Standards

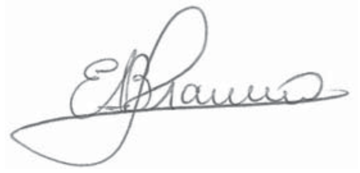
Our modern society, born out of the Industrial Revolution of the 19th century, enjoys the benefit of several technologies that can be used to save lives. Most think of airplanes, computers, automobiles, lab devices, among other crucial inventions. I've wondered why we do not add tractors, combines, precision ag. devices, and fertilizers to the list as well?

Without a doubt, the Green Revolution of the 20th century has allowed developed countries to modernize their cropping systems with new field techniques, which have made possible record achievements in crop yields, food supply, and hunger alleviation worldwide. Nevertheless, according to statistics from the United Nations World Food Programme (WFP), 795 million people in the world do not have enough food to lead a healthy active life. Furthermore, the number of people suffering from hunger is higher than the number of deaths caused by AIDS, malaria, and tuberculosis combined. Therefore, common sense tells us that fighting hunger through efficient production of accessible foods can save a huge number of lives.

On the other hand, the Cultural Revolution of the 20th century seems to have affected our ability to weigh the facts. The world's many, who are at risk of hunger-related disease and death, are relying on us to keep the focus on a healthy and affordable global food production system. Much like society's self-imposed need for the latest smart phone or high performance sneaker, by focusing only on premium health- or so-called "environmentally-friendly foods", agriculture risks creating a food system afforded only by the financially elite. Our conventional food production systems are not trendy, but are essential for food security, considering the present need to feed millions suffering of malnutrition.

To help us weigh the facts on the food quality debate, I suggest a scientific review published by the American Journal of Clinical Nutrition entitled *Nutritional Quality of Organic Foods: a systematic review*. You can access the article via this link >http://ajcn.nutrition.org/content/early/2009/07/29/ajcn.2009.28041.full.pdf+html<.

Enjoy the read!



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Deputy Director, IPNI Brazil Program

BETTER CROPS

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