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Editorial

Dear readers,

Fertilization with potash is still uncommon in many regions. "Potash" refers to all potassium fertilizers: the most commonly used is potassium chloride (KCl) or muriate of potash (MOP), followed by potassium sulfate (K_2SO_4 or SOP) and potassium nitrate (KNO_3 or NOP). With potassium discovered more than 200 years ago by English chemist, Sir Humphry Davy, in 1807; the theory of mineral nutrition in place since 1830 (Carl Sprengel, 1787-1859); and thousands of published research papers and a multitude of potassium products, why is it that, according to various indicators, K use is lagging in many areas?

There is no simple answer. Unlike nitrogen and phosphorous - at low crop yield levels, soil available K may be sufficient for the crop although it will not help to mitigate biotic and abiotic stresses. However, there is a great risk that soils become depleted of indigenous K and, in the long-term, yields decline further. Other on-farm inputs also contain potassium: K in irrigation water (e.g. in North India) and K in crop residues are the most common "sources" of these types of K fertilization. When preparing a fertilization program, these sources should be taken into account.

Having a quick, cost-effective, online and large-scale measurement for analyzing plant's K status would make recommendations easier and more applicable. Until such technology is made available, there is no alternative to the well-known and reliable soil and plant analysis, from which an accurate fertilizer recommendation can be derived. However, we have been pleased to learn of an exciting initiative developed by IRRI scientists to improve decision-making for N, P and K recommendations: The Nutrient Manager for rice is a decision support system (DSS), which assists farmers to define the fertilization required based on data from his own specific plot. With the DSS available for use on the web or on smart phones, the application has the potential to be used by large numbers of farmers who have yet to make site-specific adapted decisions. Developments, such as Nutrient Manager on mobile phones and other new initiatives should help to close the gap and promote more effective use of K (and other nutrients) application.

In this issue, we also feature research papers on potato production in the State of Bihar, India, K fertilization of sugarcane in Bangladesh, variable rate application of potash for soybean in Brazil as well as updates of events and new scientific publications.

Finally, we are pleased to report that IPI has completed the development of various social media tools. Our Twitter page is kept up to date with the latest news from the IPI website, other websites and sources. Our newly designed Facebook page has an application (app) to display IPI's projects in the regions, and the latest tweets and re-tweets from our Twitter page. These are designed to improve the visibility of our activities and to make them more easily available to Facebook and Twitter users.

I wish you all an enjoyable read. ■

Hillel Magen

Director

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The Potato Crop in Bihar: Status and Future Challenges

Singh, S.K.[1][2], *and R.P. Rai*[2].

Introduction

The state of Bihar is located on the fertile lands of the great Indo-Gangetic Plains (IGP). Agriculture is the backbone of the Bihar economy, employing about 80 percent of the workforce and generating nearly 42 percent of the state domestic product (Choudhary, 2011). Bihar's agricultural share of the state GDP is 39 percent, in comparison to 24.3 percent of national share of GDP, due to the fact that 89.5 percent of the state population have a rural and farming background. Bihar ranks 10th in area and 3rd in population with per capita income of about 25 percent of that of the nation. Bihar is the most highly populated state of India with 83 million inhabitants and a population growth of about 2.43 percent per annum. It has the highest population density of rural India with about 40 percent of the population below the poverty line.

According to estimates published by the International Food Policy Research Institute (IFPRI) and the International Potato Centre (CIP), India is likely to have the highest growth rates in potato production and productivity worldwide (Naik and Thakur, 2007). These growth rates indicate a total production in India by 2020 of around 43.3 million mt.

In Bihar, potato is the fourth major food crop after rice, wheat and maize. Although the crop occupies less than five percent of the net sown area across the State, due to its high nutritional value, it is an important source of food for millions of people across Bihar.

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Districts of Bihar

Potato has special significance since it gives exceptionally high yields per unit area in a relatively short period. The dry matter production in potato is about 47.6 kg ha^{-1} day^{-1} whereas wheat, rice and maize produce only 18.1, 12.4 and 9.1 kg ha^{-1} day^{-1} respectively (Ezekiel and Pandey, 2008). The task before the state of Bihar is to increase the production and quality of potato to meet domestic requirements and provide surplus for export.

Potato production situation

India is the world's third largest potato producing country. During the past 60 years the potato crop has shown spectacular growth in area, production and productivity in India with increases over this period of 6.6, 18.51 and 2.80 times respectively (Pandey and Naik, 2009). Potato productivity in India (18.4 mt ha^{-1}) is slightly higher than the world average (16.6 mt ha^{-1}) however, it is much lower than many countries in Europe and America, such as The Netherlands (42.4 mt ha^{-1}), mainly because in India it is grown as a short duration crop. The estimated total production in India for 2009-2010 was around 34 million mt from 1.55 million ha. At present, Bihar ranks third after Uttar Pradesh and West Bengal in potato area and production among the different states of India. In Bihar, potato is grown on 0.32 million ha with an annual production of 5.74 million mt and a productivity of 17.78 mt ha^{-1} (Anonymous, 2007). Potato is grown in all 38 districts of Bihar (Table 1 and map), but the major producers are Nalanda, Patna, Vaishali, Saran, Samastipur, Gopalganj, East and West Champaran, Muzaffarpur and Gaya, which account for 80 percent of the area. In terms of productivity, Nalanda, Patna and Vaishali are the foremost districts. Bihar has always been of concern for policy planners because of its low potato productivity despite the fact that it is blessed with highly fertile land and good quality water resources.

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Table 1. Area, production and productivity of potato in major districts of Bihar (2006-2007).

District	Area	Production	Yield
	ha	*mt*	*mt ha^{-1}*
Nalanda	27,000	653,320	24.19
Patna	16,050	409,400	25.50
Vaishali	13,500	255,040	18.89
Saran	13,500	249,970	18.51
Samastipur	12,300	250,910	20.39
Gopalganj	12,200	210,470	17.25
W. Champaran	12,200	201,300	16.50
Muzaffarpur	12,000	210,980	17.58
E. Champaran	11,750	202,750	17.25
Gaya	11,500	190,240	16.54
Rohtas	10,700	195,100	18.23
Madhubani	10,600	168,040	15.85
Siwan	10,300	113,460	11.01
Others	149,240	2,430,310	16.28
Total	322,840	5,741,290	17.78

Source: Directorate of Horticulture, Govt. of Bihar.

Crop cultivation scenario in Bihar

Soils

In Bihar, potato is grown under tropical and sub-tropical agro-climatic conditions during short and cool winter days from October-March, where crop duration is between 80-110 days only. Potato is grown in Bihar on a wide range of soils under varied climatic and environmental conditions. There are many types of soil in the state, which differ significantly between different regions as well as within the region itself. A brief description of important soil types in which potato is grown are given below:

1) Young alluvium calcareous soils: These soils occur in the large area of north Bihar associated with the river Gandak in the districts of Muzaffarpur, Samastipur, East Champaran, Southern part of West Champaran, Vaishali, Siwan, Gopalganj and Saran. Soils are light to heavy in texture having more than 10 percent free calcium carbonate ($CaCO_3$), with a maximum limit of up to 60 percent. The pH, EC and organic carbon in these soils vary from 7.7 to 9.8, 0.10 to 4.5 dS m^{-1} and 0.10 to 1.36 percent respectively. Soils are low to medium in available P_2O_5 and K_2O and about 73 percent soils are deficient in zinc.

2) Young alluvium non-calcareous soils: These soils occur in the districts of Madhubani, Darbhanga and Sithamarhi and are associated with the river Bagmati. The soils are neutral to alkaline in reaction and salt concentration can be low to high. Most of the soils are very low to medium in organic carbon, and available P_2O_5 and K_2O content. About 66 percent of the soils are deficient in zinc.

3) Recent alluvium non-calcareous non-saline soils: These soils cover the alluvial plains of Koshi and Mahananda rivers comprising the districts of Saharsha, Madhepura, Purnea and Katihar. Soils are yellowish white, flood-based and are medium to heavy in texture, acidic to neutral (5.6 to 7.3), low to medium in salinity (0.29 to 1.12 dS m^{-1}), and low to medium in available P_2O_5 and K_2O. Around 40-45 percent of these soils are deficient in zinc and boron.

4) Soils of South Bihar, known as old alluvium soils, are affected by the river Ganges. Soils are reddish-yellow to yellow-grey in color with distinct horizon differentiation; soils are slightly acidic to neutral in reaction varying from low to high in salinity, organic carbon, available P_2O_5 and K_2O. Soils of Patna Nalanda, Gaya, Nawada, Jahanabad, Rohtash and Bhojpur are medium to heavy in texture, varying from silty loam to clay loam, while soils of Munger, Sheikhpura, Bhagalpur are light in texture varying from silty loam to loam.

In some areas, two crops of potato can be grown in the same field i.e. early autumn and spring. In the Nalanda district of Bihar, for example, an early crop of potato can be harvested during October-December, and a spring crop during January-March. The produce of the early crop goes directly to the market for consumption whilst the harvest from the main crop is cold stored. In fact, the potato crop can grow and give economic returns under any climate, provided the night temperature during the tuberization phase remains around 20°C.

Crop season

The main potato crop begins with planting in late October to November and is harvested during February to

Spraying potato against disease. Photo by S.K. Singh.

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March. Throughout Bihar, the crop is grown during the main season. In some places, an early autumn crop is also grown, which is planted in September to October and often harvested prematurely in November to December to fetch a better market price. Important regions which grow early crops are Nalanda and the Sone river bed of Bhojpur, Patna and Aurangabad districts. As mentioned above, in some parts of Bihar a spring crop of potato is also grown. Thus, potato in Bihar is grown in different seasons i.e. autumn, winter and spring seasons (Table 2).

Table 2. Typical crop seasons of potato in Bihar.

Crop	Planting period	Harvesting period	Areas[(1)]
Autumn/Early	20/9–31/10	Mid November-December	Nalanda, Patna (15)
Winter/Main	11-mid 12	February-Early March	All Bihar Districts (80)
Spring/Late	Late 12–15/1	Late March	Tarai Region & Nalanda (5)

[(1)] in brackets is the area distribution between the crops (percent).

Agronomic practices

Seed is the most costly input and thus cut pieces of tubers are generally used as seed material in most parts of Bihar. In Patna and Nalanda, where early planting is done, small tubers of 15 to 20 g are preferable to cut pieces. Seed rate is maintained below 20 q ha^{-1}. Row to row space varies from 50 to 60 cm and tuber to tuber 15 to 20 cm. The spacing is closer when a pure crop of potato is taken but when intercrops such as maize, mustard etc. are to be grown, the row spacing should be wider. Planting and other intercultural operations are invariably done manually. Earthing up is done at 25-30 days after planting with top dressing of nitrogen. When intercropping is practiced, a higher ridge is made at planting to avoid the need for earthing up.

Table 3. Potato-based cropping systems prevalent in different districts of Bihar.

Cropping system	Districts
Paddy-potato	Bhojpur, Gaya
Paddy-potato-onion	Patna, Nalanda
Potato-potato-onion	Nalanda
Maize-potato-vegetables	Nalanda, Vaishali, Samastipur
Potato-wheat	Patna (Sone Diara)
Potato-mentha	Muzaffarpur, Begusarai
Rice-potato-jute	Katihar
Maize-potato-green gram	Muzaffarpur, Samastipur
Yam (elephant foot)-potato	Vaishali, Samastipur

Cropping Systems

Potato, being a short duration crop (80-90 days), fits very well as a "sandwich crop" in the most popular rice-wheat cropping system of the state. There is thus great opportunity for vertical increase in area and production of potato without affecting area and production of other crops. Due to prevailing agro-climatic conditions the rice-potato cropping system is at number one position in the State (Table 3). By utilizing residual fertility after potato, raising a third crop has become common practice in the potato growing regions of Bihar giving rise to a number of cropping systems such as rice-potato-onion, maize-potato-green gram, maize-potato-black gram, rice-potato-mentha, rice-potato-bottle-gourd/vegetable, potato-potato-onion and rice-potato-jute. The yam (elephant foot)-potato cycle is a newly emerging profitable cropping system and is being practiced in Vaishali and Samastipur districts (Table 3).

Potato field in Bihar. Photo by S.K. Singh.

Many intercropping systems are also practiced in Bihar. In north Bihar the most popular system is potato + maize. Other intercropping systems are sugarcane + potato, potato + mustard, potato + radish, potato + pumpkin/bottle gourd and potato + faba bean. East and West Champaran are two districts where potato + sugarcane intercropping is most common. Potato + radish is popular in Nalanda and Patna, whereas, inter-relay cropping of potato +

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pumpkin/bottle gourd is popular in Begusarai and Sone river beds.

More recently, potato is being grown in young orchards of mango and lychee and this is proving very remunerative. This practice can be observed in Vaishali and Muzaffarpur districts. In most intercropping except sugarcane + potato, the potato is considered as the main crop and is harvested early, while the intercrop continues to grow till maturity.

In the intercropping systems, the crops are grown in lines/rows. The fertilizer is applied in the rows of the respective crop at the time of planting as well as top dressing. The quantity of fertilizer applied is generally in proportion to the plant population.

Planting of an experimental potato field. Photo by S.K. Singh.

Harvesting

The early crop is generally harvested at 60 to 70 days. The main objective is to earn cash at the earliest opportunity and hence yield is secondary in importance. The yield varies between 120-160 q ha^{-1} depending upon crop maturity.

The main crop is harvested after 75 to 110 days depending upon the varietal maturity, and yield ranges between 175 to 300 q ha^{-1}. Average yield of the main crop is not less than 175 q ha^{-1} if not attacked by late blight. In Nalanda district, cultivation of Kufri Pukhraj has become very popular and the average productivity is 250-300 q ha^{-1}.

Fertilizer management in potato

Potato is a heavy feeder and responds well to the application of both mineral fertilizers and farmyard manure (FYM). Potato has a shallow root system compared to other crops limiting its foraging capacity in the soil. On the other hand, uptake of fertilizer nutrients (NPK) by potato per unit area and time is high due to faster rate during early growth and tuber bulking. The crop benefits from the FYM application, not only from the amount of the nitrogen, phosphorus, potash and other nutrients that it contains but also its improving effect on the tilth and moisture-holding (retaining) capacity of the soils. Application of FYM also meets the secondary and micronutrient needs of the crop. Therefore, well decomposed FYM at 15-20 mt ha^{-1} should be uniformly applied in furrows opened for potato planting.

The crop requires a balanced dose of NPK for optimum production. Nitrogen (N) contributes to the yield by enhancing the number of tubers, bulking rate, bulking period and delay in maturity. Phosphorus (P) is involved in a wide range of plant processes, including development of the root system and enhanced crop maturity. Its application increases the number of medium size tubers per plant. Application of potassium (K) increases plant height, crop vigor and imparts resistance against drought, frost and diseases. Response of potato to N is more pronounced when applied in conjunction with P and K. Combined application of an optimum dose of NPK maximizes the growth and yield of potato and increases efficiency of each nutrient. Application of P, K, and P + K with N increased the yield by 5.6, 6.2 and 26 percent compared to application of N alone. (Singh *et al.*, 2008).

The potato crop responds well to fertilizer depending on inherent soil fertility and the variety grown. The fertilizer needs of potato have been found to vary with the soil and climatic conditions. The optimum dose of inorganic fertilizer depends mainly on the soil type, soil fertility and crop rotation. The optimum rate of NPK fertilization based on tuber yield response under Bihar conditions has been found to be 120-150: 60-80: 80-100 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. The mean response to optimum dose of N, P and K fertilizer was 116, 46 and 51 q ha^{-1} respectively (Singh *et al.*, 2008). Therefore, in the absence of soil testing, the crop should be supplied with 60-75 kg N, 60-80 kg P_2O_5 and 80-100 kg K_2O per ha at the time of planting and 60-75 kg N per ha at the time of earthing up one month after planting. Processing varieties of potato like Kufri Chipsona-1, Kufri Chipsona-3 etc. grown specifically to produce large processing grade tubers,

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require 33-50 percent higher rate of fertilization than the recommended dose of potato for direct consumption.

Care needs to be exercised to select a proper source of fertilizer nutrients because of the highly beneficial response of potato to some sources but possible harmful effects of others. At planting, nitrogen can be applied in the form of ammonium sulfate (AS), calcium ammonium nitrate (CAN) or urea. AS is the best source but it is more costly. Urea is the cheapest and most available source of N in India, but is considered less efficient than AS and CAN. Urea is equally efficient when broadcast and ploughed under during land preparation at least 48 hours before planting potato. Topdressing of urea between rows at earthing up is equally efficient to other sources of N. Using CAN, Diammonium phosphate (DAP) or mixed NPK fertilizer combined with urea for basal application at planting and top dressing with urea at the time of earthing up of the remaining dose of N is economical, efficient and safe. Urea alone at planting in excess of 60 kg N ha^{-1} is harmful for emergence of potato. Similarly, ammonium chloride (ACl) is safe at a lower dose of N at 60 kg ha^{-1} at planting. Readily soluble sources of P such as single superphosphate (SSP), triple superphosphate (TSP) and DAP are most suitable for potato.

Sources of K like muriate of potash (MOP) and sulfate of potash (SOP) are equally efficient for potato. Split application of N (half at planting + half at earthing up) is essential for maximizing efficiency. Spraying two percent urea solution 40-50 days after planting corrects visual deficiency symptoms of N, if any. Split application of K is advantageous only in a light textured loamy sandy soil. No benefits from split doses of P are reported, because it is required mostly for early root and shoot growth. Foliar application of P and K was found to be of limited value. Band placement of P fertilizer is invariably better than broadcast, because of fixation of P in most soils. However, methods of placement of K fertilizer in bands at sides or above or below seed tubers or broadcast were equally efficient (Singh *et al.*, 2008). Therefore, combined basal application of a full dose of P and K along with half of N at planting is economically efficient and convenient. Moderation in the ratio of fertilization is possible based on soil test values, after calibration, depending upon the soil, climate, season and variety. The fertilizer recommendations should be based on soil and plant tests.

Potassium is an important nutritional factor in crop management, which contributes to production of high yields of quality potato. Potato requires substantial quantity of potassium to produce an optimum yield. However, potassium needs of the crop vary with the agro-climatic region, variety, crop sequence and soil type. A healthy crop of potato removes about 170-230 kg K_2O ha^{-1} from the soil (Trehan *et al.*, 2008). The varietal response to applied K is often related to its yield potential and the number of large sized tubers it can produce. In general, rapid bulking potato varieties producing large size tubers respond more to K than the varieties with small size tubers as application of K is known to increase the tubers size (Trehan and Grewal, 1990).

The ratio of uptake/removal of K from soil is often in excess of the applied K, resulting in negative balance of available K in the soil, particularly in potato-based cropping systems precluding build up of K in the soil. There is a need for revising K fertilizer recommendations in order to overcome the long term depletion of reserves of soil K. Fertilizer doses for potato grown in triple cropping intensity should be raised by 50 percent of the recommended dose in order to increase profit (Sharma *et al.,* 1999). Potato and other heavy feeder crops (rice, onion, maize etc.) in the rotation may induce a severe negative net balance of K in soil over a short time span of four years (Singh and Trehan, 1998). With high crop intensity and high K removal, the soils are likely to become deficient in K with time. Besides, K is highly mobile and the tendency of K leaching to lower soil horizons is high, particularly where the potato crop is irrigated.

Future line of work

The fertilizer recommendation for potato in Bihar is 150-180:60:100 kg ha^{-1} of N, P_2O_5 and K_2O, respectively, although in practice there is much variation within farmers' fields. In general, Bihar farmers are unaware of the benefit of the different fertilizers to be used. Fertilizers are also not available in the market in many of the regions. As such, farmers purchase whatever fertilizer is available in the market and broadcast it on their fields. There is a lack of awareness about correct dose and method of fertilizer application as fertilizers are broadcast rather than being placed in the furrows. Low use of fertilizers and severe imbalance in the N, P & K application ratio and imbalanced fertilization in favor of N and lack of potash application are the major reasons responsible for low production of potato in the State. So far, only blanket fertilizer recommendations have been in vogue and the current fertilizer rates are insufficient to sustain potato production and to replenish nutrient removal by the crop. Besides, most of the farmers in the region are also unable to purchase the required quantity of fertilizer, due to lack of cash as well as non availability of the fertilizer at certain times. In the absence of sufficient soil test support, imbalanced use of fertilizers is often observed. In some areas, higher doses of N and at other places higher doses of P application are common.

In major potato growing areas there is a need for nutrient indexing and development of a nutrient management schedule using diagnostic tools. Parameters relating to nutrient use efficient cultivars need to be established

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and characterized. There is urgent necessity to develop an integrated nutrient management technique for potato by the appropriate combined use of chemical fertilizer, biofertilizers, organics and micronutrients. There is also a need to develop farmer friendly site-specific nutrient management tools in potato production and the selection of suitable varieties to develop appropriate practices for organic potato production.

Opportunities, challenges and strategies for potato crop in Bihar

Land holding in Bihar consists predominately of small farms and holdings with a high degree of fragmentation. About 86 percent of farmers are small and marginal. The average size of holdings is declining, having fallen to around 0.6 ha, and the majority of farmers have less than 1 ha each. The land holding patterns of the state are summarized in Fig. 1.

Under conditions of increasing demand for food and diminishing per capita availability of land for agriculture due to the rising population in India, the importance of potato for ensuring sustainability in agriculture and the food production is immense. Potato is a high yielding crop. Due to a high protein - calorie ratio (17 gm protein: 1,000 kcal) and a short vegetative cycle, potato yields substantially more edible energy, protein and dry matter per unit area and cropping period than many other food crops. It produces 3 kg of protein ha^{-1} day^{-1} as compared to only 2.5 kg ha^{-1} day^{-1} in wheat, 1.2 kg ha^{-1} day^{-1} in maize and 1.0 kg ha^{-1} day^{-1} in rice. This is of considerable importance in India where energy supplies are more readily available than protein supplies.

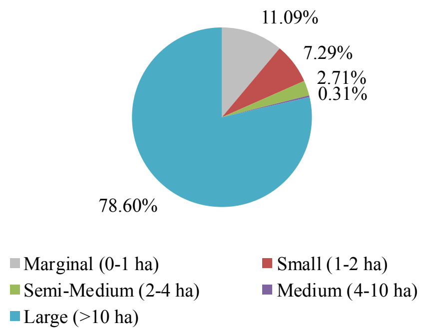

Fig. 1. Land holding pattern in Bihar (%).

Growing potato also provides excellent opportunities to raise farmers' incomes as it has the capacity to yield 5-10 times more than cereals, pulses or oilseeds. The high profitability of potato as a cash crop has made it an economically viable enterprise for small and marginal farmers and has contributed to increasing equity among farmers in the sub-tropics. Potato provides a high unit return and offers great scope for value addition. In this respect the crop generates high employment during production and harvesting. Potato requires an input of 250 man-days for cultivation of the crop per hectare. The cultivation of potato on 1.4 million ha area thus generates rural employment to the level of 350 million man-days annually. The same benefit of employment generation is also true for post-harvest handling including transportation, marketing and processing.

Low productivity is the most vital issue as it directly affects the profitability associated with crop production. Despite favorable soil and climatic conditions, it is a paradox that the productivity of potato crop in Bihar is lower, compared to that of other states and the national average. The factors contributing to low productivity of crops and inferiority of the products are inadequate supply of genuine good quality planting material, low seed replacement rate, poor crop management practices, i.e. lack of irrigation, proper fertilization and plant protection measures, high initial cost etc. Poor investment capabilities of the grower, fragmented small holdings, lack of mechanization and erratic market prices and low returns due to the absence of organized marketing are also important.

Late blight is the predominant disease and is widespread across the State. Adverse climatic conditions, particularly foggy weather in January and occasional rains, favor disease spread. Remedial measures are often difficult, although they can be cost effective but only if the disease is identified correctly in time.

In Bihar, potatoes are harvested in January-March, which is followed by hot summers. Potato cannot be stored under ordinary conditions where high temperature and dry weather prevails soon after its harvest. Therefore, to sustain increased potato production, proper cold storage facilities are essential.

The potato crop is produced seasonally but marketed throughout the year. Due to the lack of cold storage facilities, farmers are unable to keep their produce safely. This compels farmers to sell all their produce immediately after harvest. This causes a sudden price crash during the peak harvesting season and farmers are forced to sell their produce at a very nominal price, well below its value.

Awareness is increasing regarding the suitability of Bihar for producing potatoes fit for processing purposes. Currently potato processing companies are carrying out contract farming and, since there are no potato processing firms in Bihar, they are transporting the stocks to far off places for processing. There is thus an outflow of limited material from the State for processing and it is now highly likely that firms will soon be established within Bihar to make use of the best suited produce for processing.

Potato from Bihar is transported to other markets in the country for which cheap road transport and better marketing facilities are essential. Emphasis should be put on the establishment of new cold stores, processing industries in the

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production catchments to minimize transport cost and create employment opportunities in the rural sector.

Agricultural research institutes/Krishi Vignan Kendra (KVK) can be involved in training and demonstration of packages of practices for organic agriculture and capacity building of the farmers. An appropriate network of extension services needs to be created to stimulate and encourage both top-down and bottom-up flows of information between farmers, extension workers and research scientists.

In India about 73 percent of potatoes are consumed as fresh food in the form of vegetables, 10 percent are used as a seed. Of the remaining 17 percent, less than 4 percent is processed and less than 1 percent exported, with the rest, about 10-12 percent going to waste. In India, potatoes are not currently used for animal feed or as an industrial raw material for production of starch and alcohol.

Conclusions

Potato is one of the few foods capable of nourishing the population of the world. It is estimated that by 2020 India will have a population of 1.3 billion. This will require the country to produce about 49 million tonnes of potato. To achieve this production target, the productivity per unit area and time has to be increased. Adoption of improved technologies is imperative to achieve the desired productivity level. Moreover, there is a challenge to enhance productivity and quality under conditions of shrinking areas of arable land, reduced water availability, changing climatic conditions and expanding biotic and abiotic stresses. However, with an increase in production, recurring gluts are common across the country. The price crashes drastically during months of plenty, leading to distress selling by farmers who therefore incur substantial monetary loss. To absorb excess potato production and sustain growth, there is need for diversified and increased utilization and export of potatoes.

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Research Findings

The Effects of Soil Test Based Potassium Application and Manures on Yield and Quality of Sugarcane Grown on a Typical Calcareous Soil of Bangladesh

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Setup of the experiment in Bangladesh Sugarcane Research Institute (BSRI) at Ishurdi, Pabna farm. Photo by S.M. Bokhtiar.

Abstract

This field experimental study examines the potential to improve the yield and quality of sugarcane grown on a typical calcareous soil of Bangladesh through soil test-based (STB) application of potassium (K) combined with organic manure i.e. cowdung (CD) or poultry manure (PM). Five treatments were compared. In four treatments, K supply was varied with mineral fertilizer supply of N, P, S and Zn remaining the same across all treatments. Potassium was supplied as T_1 90 kg K ha^{-1}, T_2 127 kg K ha^{-1}, T_3 95 kg K ha^{-1} plus 10 mt ha^{-1} CD, and T_4 95 kg K ha^{-1} plus 5 mt ha^{-1} PM. In the fifth treatment no fertilizer was applied. The number of tillers and number of millable cane stalks did not differ significantly between the four K treatments, but the values were significantly greater than in treatment T_5 where no fertilizer was applied. Potassium application based on STB (T_2) increased cane yield by 25.4 percent in comparison to the present recommended K application (T_1) of 90 kg K ha^{-1}. However, applying only 75 percent K of STB along with CD (T_3) or with PM (T_4) increased cane yield by 16 percent and 17.7 percent respectively, when compared to the present recommended dose of K fertilizer (T_1). Maximum cane and sugar production in sugarcane monoculture requires an annual application of currently recommended doses of N, P, S and Zn fertilizer of 150 kg N, 50 kg P, 34 kg S, 3.5 kg Zn ha^{-1} with STB K fertilizer, i.e. 127 kg K to sustain high yields. Nevertheless, 75 percent of STB K fertilizer i.e. 95 kg K and 150 kg N, 50 kg P, 34 kg S, 3.5 kg Zn ha^{-1} supplied together with CD (10 mt ha^{-1}) or PM (5 mt ha^{-1}) is also suggested as a means to sustain both sugarcane yield and to maintain soil fertility. Further investigations are required to confirm these findings.

Keywords: Sugarcane, potassium, soil test base, organic manure, yield, calcareous soil.

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Introduction

The application of fertilizers plays a key role in increasing agricultural production by raising crop yields. STB fertilizer recommendations result in more efficient fertilizer use and maintenance of soil fertility. Among the various methods of fertilizer recommendations, the one based on yield targeting (Ramamoorthy *et al.,*1967) is unique as this recommendation not only indicates the STB fertilizer dose but also the level of yield that can be obtained if appropriate practices are followed in raising the crop. This targeted yield approach also takes into account balanced fertilization of the crop not only between the nutrients from the external sources but also from the soil available nutrients.

Sugarcane (*Saccharum officinarum* L.) is an important cash crop of Bangladesh covering 0.16 million ha and producing 7.8 mt cane in 2010-2011. Sugarcane is a high input demanding crop and capable of rapidly depleting soil nutrients, particularly potassium. Potassium, as an essential nutrient required for plant growth, plays a key role in many physiological processes, including photosynthesis, protein synthesis, water relations in plants, organic and inorganic nutrient mobility within the plant (Marschner, 1995; Thangavelue and Rao, 1997; and

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Subramanian, 1994). It has been found that 85 mt fresh weight of a sugarcane crop can remove 122, 24 and 142 kg N, P, K ha^{-1}, respectively from the soil (Bokhtiar *et al.,* 2001). If the depleted nutrients are not replaced, soil fertility and soil organic matter level decline creating a stressed soil environment that essentially requires optimal and balanced use of fertilizers (Ahmad, 2002). Under South African conditions, for instance, the aerial parts of an adequately fertilized 12 month old rainfed plant cane crop has been reported to contain 214 kg K ha^{-1} (Wood, 1990). Under irrigation, a cane crop of similar age and variety may remove as much as 790 kg K ha^{-1}. In the Histosols of Florida, an average of 343 kg K ha^{-1} was removed from the field at harvest of the sugarcane (Coale *et al.*, 1993). In Mauritius, more than 250 kg K ha^{-1} was recovered by sugarcane from soils high in available K, even when no K was applied (Cavalot *et al.,* 1990). In Australia the average kg K ha^{-1}, in the above-ground biomass of a crop of 84 tonnes cane ha^{-1}, was 198 kg K ha^{-1} (Chapman, 1996). It is thus clear that for the long-term and sustainable use of sugarcane lands, the removal of such large quantities of K needs to be balanced by an adequate re-application of K.

One of the main constraints for optimum sugarcane yield is its high nutritional requirements along with increased cost of fertilizers (Gholve *et al.,* 2001). Similarly, spiraling prices, coupled with a lack of availability of fertilizers on the market (Khandagave, 2003) and depletion of available nutrients and organic matter in the soil due to continuous cane cropping with inorganic fertilizers (Kumar & Verma, 2002; Ibrahim *et al.,* 2008; Sarwar *et al.,* 2008), necessitates the integrated use of organic and mineral fertilizer inputs. Cowdung (CD) and poultry manure (PM) can serve as good sources of organic manure. Therefore, an attempt was made to study the effect of the application of K supplied on a soil test basis in the form of mineral fertilizer, with or without organic manure, for the cultivation of sugarcane on a calcareous soil typical of many such soils across Bangladesh.

Materials and methods

An experiment was conducted at the Bangladesh Sugarcane Research Institute (BSRI) on the calcareous farm soil at Ishurdi, Pabna during the 2009-2010 season and on a soil typical of calcareous soils of Bangladesh. The soil samples (0-15 cm depth) were collected from experimental plots, air-dried, and passed through a 2 mm sieve. The pH of the calcareous soil was 7.64 and its organic carbon (OC) 0.78%. Total N was 0.07% and P, K, S and Zn contents were 12.0, 70.0, 17.0 and 0.86 mg kg^{-1} soil, respectively. The experiment comprised five treatment combinations.

- T_1: 150N-50P-90K-34S-3.5Zn kg ha^{-1} (current recommended dose).
- T_2: 150N-50P-127K-34S-3.5Zn kg ha^{-1} (K applied on a soil test basis (STB)).
- T_3: 150N-50P-95K-34S-3.5Zn kg ha^{-1} plus 10 mt ha^{-1} CD (K as 75% STB).
- T_4: 150N-50P-95K-34S-3.5Zn kg ha^{-1} plus 5 mt ha^{-1} PM (K as 75% STB).
- T_5: no fertilizer.

The treatments T_2, T_3 and T_4 were designed to supply STB K together with current recommended doses of N, P, S and Zn; animal manure (CD or PM) was also added to T_3 and T_4 respectively. Treatments were replicated three times in a randomized complete block design. Thirty-five day two-budded settlings raised in a soil bed were transplanted on January 13, 2010. Each plot had an area of 5 m × 6 m in which five rows of cane were planted at an inter-row spacing of 1 m. The sugarcane variety Isd 37 was used as the test crop. Urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum, and zinc sulfate were used as the sources of N, P, K, S, and Zn, respectively. The nutrient status of the organic manures used in the experiment, CD and PM (on oven dry

Dr. Gopal Chandra Paul, Head of Soils and Nutrition Division at the Bangladesh Sugarcane Research Institute with farmers at one of the project's experimental plots. Photo by B. Tirugnanasotkhi.

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basis) is shown in Table 1. The full amount of TSP, gypsum, zinc sulfate and all the CD, PM - together with one third of MOP - were applied in trenches and thoroughly mixed with the soil prior to settlings transplantation. Irrigation was applied just after planting of the settlings. N fertilizers were given in three equal splits: the first after establishment of the settlings, i.e. 20 days after planting (DAP); the second at tiller completion stage (90 DAP); and the third at grand growth phase (180 DAP). The remaining amounts of MOP were applied as top dressing at 90 DAP and 180 DAP like the N fertilizer. Cultural practices such as inter-row plowing, weeding, irrigation, earthing up, and tying were performed when required. The pesticide Curaterr 5G was applied at 40 kg ha^{-1} to control shoot borer during the early growth stage.

The number of tiller and millable cane stalks were counted at two different growth stages; peak tillering stage (150 DAP) and maturing stages (270 DAP). Soil pH was measured in a 1:2.5 soil water suspension by glass electrode pH meter. Total N was determined by micro Kjeldhal procedure and organic carbon by the Walkley and Black method. Available soil P was extracted with 0.5M sodium bicarbonate ($NaHCO_3$) and the amount was determined by spectrophotometry. Exchangeable K [1N ammonium acetate (NH_4OAc) extractable] was determined by flame photometry and available S by a turbidimetric method (Black, 1965) for soil and plant leaf. Leaf samples (3rd-4th) from the top of main cane stalks were collected from the sampled cane and separated into leaf blade and leaf sheath. Midribs were removed from leaf blade and samples were dried at 65°C and milled for nutrient analyses. The experimental plots were harvested on January 26, 2011. Data were statistically analyzed using analysis of variance (ANOVA) and the treatment differences were adjudged by least significant difference (LSD) test.

Results and discussion

Effects of K on sugarcane yields and growth parameters

In treatments T_1-T_4, the effect of potassium fertilizer was significantly higher in tiller number, number of millable cane stalks, and yield, in comparison to the no fertilizer plots in T_5. On the other hand, stalk height, stalk thickness and pol cane percent did not differ significantly from the no fertilizer treatment (Table 2). The highest cane yield of 126.3 mt ha^{-1} was recorded in treatment (T_2) where K (127 kg K ha^{-1}) fertilizer was applied on soil test basis (STB). This was followed by 75% STB K (95 kg K ha^{-1}) + PM (5 mt ha^{-1}) with 118.5 mt ha^{-1} and 75% STB K (95 kg K ha^{-1}) + CD (10 mt ha^{-1}) with 116.8 mt ha^{-1}. There was no significant difference between these two treatments. A significantly lower cane yield of 100.7 mt ha^{-1} was obtained in T1 where the current recommended dose of K (90 kg K ha^{-1}) fertilizer was applied. Results showed that K fertilizer application based on STB increased cane yield by 25.4 percent over current recommended doses of K fertilizer. This result agrees with Bokhtiar *et al.* (1995) who found in two locations of Tista Meander Flood Soils of Bangladesh that cane yield increased up to 37.7 percent at 166 kg K ha^{-1} but, beyond that dose, yield gradually decreased. Based on a field experiment of 11 locations in Sao Paulo State of Brazil, Korndorfer (1990) also found that raising application of K to 150 kg K ha^{-1} progressively increased cane yield. Table 2 shows that combined application of CD or PM with K fertilizers based on STB significantly enhanced the yield over the current recommended dose of K fertilizer. Application of CD or PM along with 75% STB K fertilizer increased yield by 16 percent and 17.7 percent respectively over present recommended dose of K fertilizer. Maximum stalk height and thickness were unaffected by different potassium treatments. Pol cane percent was similarly unaffected by potassium treatments. Possible beneficial long term effects of addition of organic manure together with mineral K fertilizer are worth studying from both the viewpoint of recycling K as well as the positive influence of additions of organic matter to improve soil structure.

Table 1. The nutrient status of the organic manures used in the experiment (on oven dry basis).

Characteristics	Manure	
	PM	CD
pH	7.88	8.60
Organic C (%)	20.53	15.76
Total N (%)	0.59	0.54
P (%)	0.13	0.16
K (%)	0.12	0.14
S (%)	0.21	0.12
Zn (%)	0.014	0.013

Table 2. Effect of potassium fertilizer on the yield and yield parameters of a sugarcane crop.

Potassium (kg ha^{-1}) and manure treatments	Yield	No. of tillers	No. millable cane stalks	Stalk height	Stalk thickness	Pol Cane
	mt ha^{-1}	--------×10^3 ha^{-1}--------		*m*	*cm*	*%*
T_1: 90$^{(1)}$	100.7 b	92.84 a	82.72 a	3.663	2.127	10.35
T_2: 127$^{(1)}$	126.3 a	93.22 a	84.92 a	3.740	2.277	9.947
T_3: 95$^{(1)}$ + 10 mt ha^{-1} CD	116.8 ab	92.51a	86.21 a	3.827	2.100	10.41
T_4: 95$^{(1)}$ + 5 mt ha^{-1} PM	118.5 ab	93.28 a	86.90 a	3.460	2.080	10.22
T_5: no fertilizer	60.1 c	73.48 b	70.51 b	3.713	2.270	10.71
LSD (.05)	18.9	13.02	11.75	NS	NS	NS

$^{(1)}$Received also the recommended dose of 150, 50, 34 and 3.5 kg ha^{-1} of N, P, S and Zn, respectively.

Figures with same letter do not differ significantly at 5% level as per DNMR test.

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Effects of K on leaf nutrient concentrations

Nutrient concentrations of N, P, K, S and Zn in leaves appear little affected by K fertilizer management (Table 3).

Effects of K treatments on soil properties

Levels of available soil nutrients at the beginning and end of the experiment are provided in Table 4. For the most part they show, as would be expected, little evidence of change over a period of only one cropping season. Lack of statistical data also means that only suspected trends can be reported. K availability appears to have increased by about 13 percent in the dung treated and current K recommendation treated plots. Interestingly, the K availability value was the same as the original soil status for the STB treatment. S and Zn appear to have increased in all treatments, but especially in the poultry manure treatment (59%) and (224%) respectively.

Table 3. Effect of K fertilizer on the nutrient contents in leaf tissues (Means of three replicates).

Potassium (kg ha^{-1}) and manure treatments	Total N	P	K	S	Zn
	-------------------%.-------------------				*ppm*
T_1: 90$^{(1)}$	2.11	0.20	1.23	0.17	26.6
T_2: 127$^{(1)}$	2.00	0.19	1.28	0.18	26.0
T_3: 95$^{(1)}$ + 10 mt ha^{-1} CD	1.85	0.20	1.23	0.17	24.5
T_4: 95$^{(1)}$ + 5 mt ha^{-1} PM	2.02	0.19	1.29	0.17	25.8
T_5: no fertilizer	1.96	0.19	1.22	0.16	22.0

$^{(1)}$Received also the recommended dose of 150, 50, 34 and 3.5 kg ha^{-1} of N, P, S and Zn, respectively.

Table 4. Effect of K fertilizer on pH, organic carbon (OC) and available nutrient contents in the 0-15 cm soil layer (Means of three replicates).

Potassium (kg ha^{-1}) and manure treatments	pH	OC	Total N	P	K	S	Zn
	Initial soil nutrient status						
		-----------%-----------		-------------*mg kg^{-1}*-------------			
	7.64	0.78	0.070	12.0	70.0	17.0	0.86
	Post harvest soil nutrient status						
T_1: 90$^{(1)}$	7.48	0.67	0.086	11.0	88.0	22.0	0.93
T_2: 127$^{(1)}$	7.40	0.78	0.085	13.0	70.0	22.5	0.95
T_3: 95$^{(1)}$ + 10 mt ha^{-1} CD	7.57	0.74	0.096	11.0	88.0	22.5	1.07
T_4: 95$^{(1)}$ + 5 mt ha^{-1} PM	7.56	0.71	0.081	12.0	88.0	27.0	1.93
T_5: no fertilizer	7.57	0.64	0.071	10.0	70.0	20.5	0.80

$^{(1)}$Received also the recommended dose of 150, 50, 34 and 3.5 kg ha^{-1} of N, P, S and Zn, respectively.

Conclusions

Potassium application of 127 kg K ha^{-1} made according to soil test basis (STB) significantly increased yield of sugarcane monoculture on a calcareous soil, by 25 percent over the current recommended dose of potassium for the region. The addition of animal manures (CD at 10 mt ha^{-1} or PM at 5 mt ha^{-1}) to the recommended fertilizer application in the region increased the cane yields by 16-18 percent. We suggest that adding manures is not only important in increasing yield but also in maintaining soil fertility. Further long-term investigations are required to evaluate the benefits of these organic manure treatments on soil fertility in relation to higher inputs of K.

Acknowledgement

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Variable-Rate Application (VRA) of Potassium Fertilization for Soybean in Brazil

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Introduction

Potassium (K) and phosphorus (P) are the two most common nutrient inputs in the cultivation of soybean crop on the highly weathered, low-fertile and acid soils of tropical Brazil. Supplying adequate K is essential to maintain high quality and profitable yields (Tanaka *et al.*, 1993). Not only does soybean have a high K requirement for growth but large amounts of K are also removed from the field when harvesting high-yielding soybean crops (Mascarenhas *et al.*, 1981).

Soybean yield variation within a given area is very common as agricultural fields are managed as uniform units. Previous results from Bernardi *et al.* (2002) in a no-till farm in southern Brazil illustrated this variation within a commercial soybean crop, where yields ranged from 1,800 to 5,300 kg ha^{-1} over the same area that had been managed uniformly (Fig. 1). This evidence of spatial variation of yield must be regarded as a function of textural differences of the soil, as reported in a study of the same plot by Machado *et al.* (2006). In this work the authors examined spatial variability of soil clay content at 0-20 cm depth. Average clay contents ranged from 612 to 667 g kg^{-1} in Zone A, and from 362 to 442 g kg^{-1} in Zone B which, according to Luchiari *et al.* (2000) and Machado *et al.* (2006), established the limits of the two management zones in this study (Fig. 2). The authors also related soil electric conductivity (EC) with soil clay content, and showed that an EC map adequately reflected the spatial variation in soil texture of the two management zones.

Study of the VRA of K

With the objective of detailing the spatial variability observed in this area, Machado *et al.* (2002) and Bernardi *et al.* (2002) studied how soil parameters and plant nutrient concentrations also varied within the commercial area. The average content of K determined by Machado *et al.* (2002) at the 0-5, 5-10, and 10-20 cm depth were considered medium to high (Fig. 3). Thus, the original existing exchangeable K levels in the soil were probably sufficient to meet the nutritional requirements of the crop.

Nevertheless, foliar diagnosis highlighted many regions with K levels below the adequate range for soybean (17 to 25 g kg^{-1}) under southern Brazilian growth conditions (Sfredo *et al.*, 1986; Fig. 4). These workers identified K as one of the main potential constraints to soybean yield. Their findings also indicated that soil fertility management has to take spatial variation within fields into account, not only because of a direct affect on crop yield but also for accurate protection of the environment. This is because the

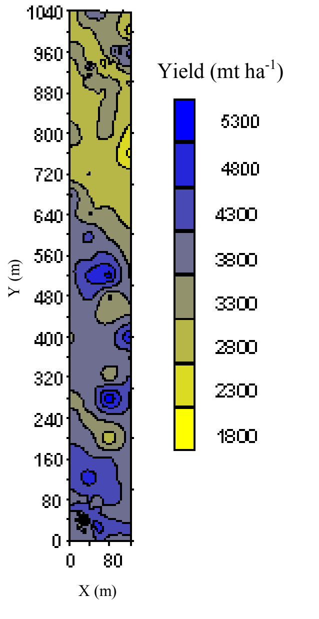

Fig. 1. Map of spatial variability of soybean yield in a no-till system in southern Brazil. *Source*: Bernardi *et al.*, 2002.

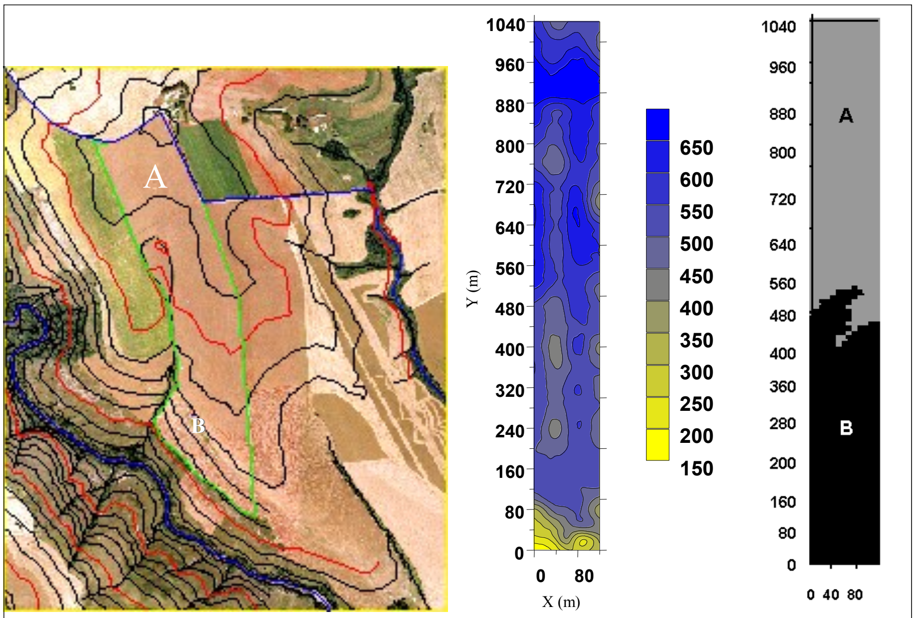

Fig. 2. Imaging of the study area and clay area spatial variability, kriged map of clay content (0-50 cm layer) and management zones. A = 612 to 667 g kg^{-1} of clay content; B = 362 to 442 g kg^{-1} of clay content. Adapted from Machado *et al.* (2006).

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uniform application of fertilizers and lime in areas with spatial variation in soil properties could result in points of fertilizer application above or below the required doses. The alternative, or control of the observed variability, could be a variable rate application (VRA) of nutrient supply.

Bongiovanni and Lowenberg-Deboer (2004), in an extensive literature review confirmed that VRA can contribute to maintaining agricultural sustainability by applying fertilizer only at locations where and when the need arises. The benefit of precision agriculture in this application is the usage of detailed data point (e.g. soil analysis) mapping which reduces losses caused by excessive application of fertilizers. A major weakness identified by the authors was that few studies actually measured levels of environmental impact or used sensors, and most of the estimated environmental benefits were indirect, i.e. measuring the reduced use of inputs.

Since VRA of fertilizer has the potential to improve nutrient use efficiency, improve economic returns, and reduce negative environmental impacts (in the case of N and P fertilizers), Bernardi *et al.* (2010) evaluated the VRA of K fertilizer to the soybean crop in a no-till system. The study was conducted on a 13 ha soybean grain field in Carambeí, State of Paraná, Brazil in a Typic Hapludox. The area has been under no-tillage for more than 10 years, growing grains (soybean, wheat and maize) in rotation with a cover crop (oats). Four treatments were used: control, 40, 80 and 120 kg ha^{-1} of K_2O applied as KCl at the V2 growth stage of soybean. Narrow strip plots of 18 x 1,000 m (Fig. 5 and 6) were assigned to three blocks within the field. In each strip, plot grain yield was continuously evaluated at harvest time with a combine equipped with yield monitoring and a real-time global positioning system (GPS) unit without differential correction. Data storage in a geographical information system (GIS) was used to fit the kriged yield map.

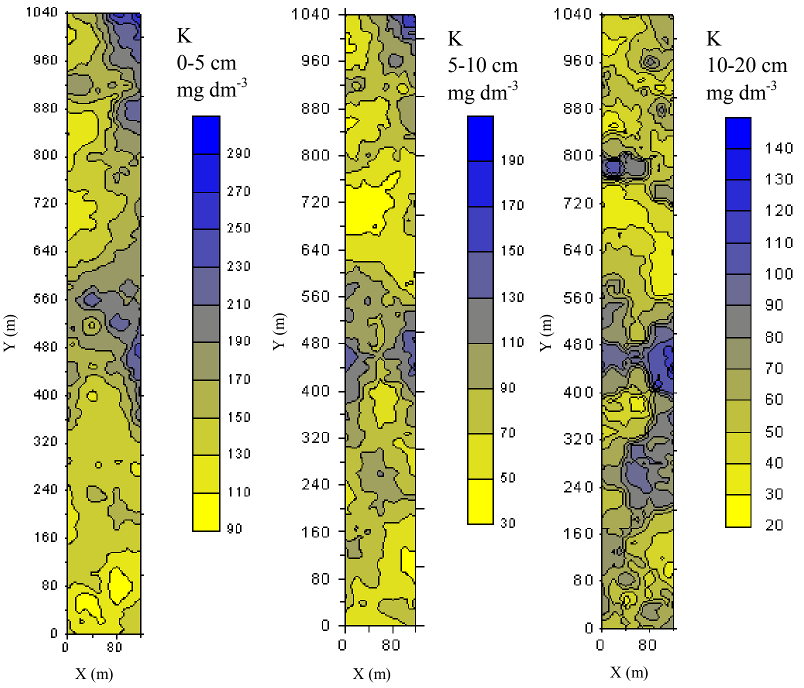

Fig. 3. Maps of spatial variability of soil exchangeable K in a soybean crop growth in a no-till system in southern Brazil. *Source*: Machado *et al.*, 2002.

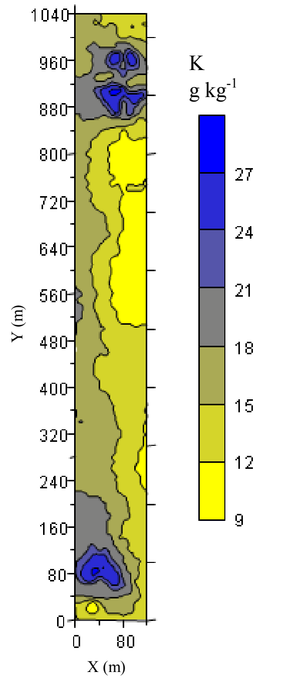

Fig. 4. Spatial variability of leaf K in a no-till soybean crop in southern Brazil. *Source*: Bernardi *et al.*, 2002.

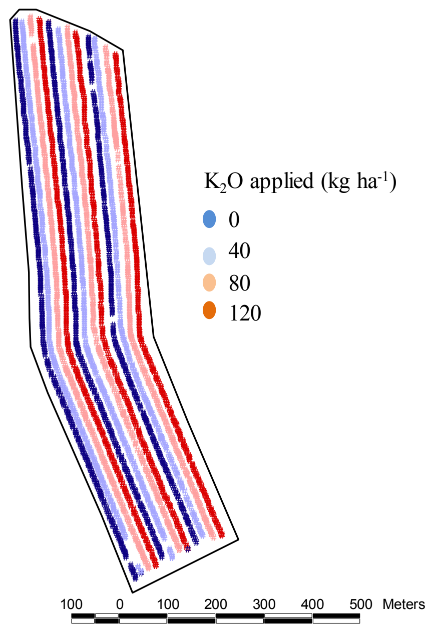

Fig. 5. K levels applied to soybean in a no-till soybean crop in southern Brazil.

Yield results (Bernardi *et al.*, 2010) are presented in Fig. 6, which illustrate the levels of K fertilizer as a function of distance from the plot and the kriged map of soybean yield. Soybean average yield was 3,838 kg ha^{-1}, and spatial differences in yield were observed with

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grain yields ranging from 2,100 to 6,583 kg ha^{-1}. These differences occurred where Machado *et al.* (2006) had shown soil texture variation. The results indicated no response to K fertilizer application at the tested doses.

These results confirm the findings of previous studies in which there were increases in soybean yield, even in soils with low levels of exchangeable K over successive crops (Mascarenhas *et al.* 1981; Palhano *et al.*, 1983; Rosolem *et al.*, 1988; Borkert *et al.*, 1997a; Borkert *et al.*, 1997b). From these findings, Rosolem *et al.* (1988) concluded that in addition to exchangeable K, there are other forms of K in the soil that can be released during the crop cycle, including non-exchangeable K.

According to Bernardi *et al.* (2010), an alternative for the producer would be to apply fertilizer in amounts to restore nutrients exported at harvest. In this respect, harvesting one tonne of soybean removes 18.7 kg K (Tanaka *et al.*, 1993), or 22.5 kg of K_2O from the soil. The results given in Fig. 7, showing exportation of K by soybean grains, have to be considered in relation to these values. If the amount of K removed at harvest was not properly restored, some K mining would be expected to occur. The balance of K fertilization (K_2O applied - K_2O exported) indicates that a positive balance can only be achieved by supplying 80 to 120 kg of K_2O ha^{-1}. The average fertilization (80 kg K_2O ha^{-1}) used by the producer in this area could still lead to a small deficit of K supply. These findings are also in agreement with those reported by Bongiovanni and Lowenberg-Deboer (2004), that VRA of K improved fertilizer distribution.

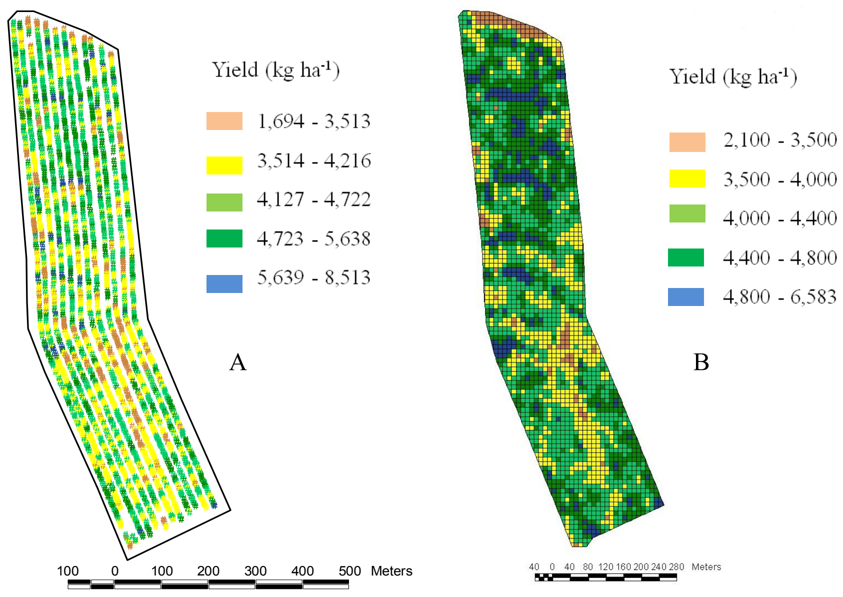

Fig. 6. Soybean yield in each narrow strip (A) and kriged yield of yield map (B). *Source*: Bernardi *et al.*, 2010.

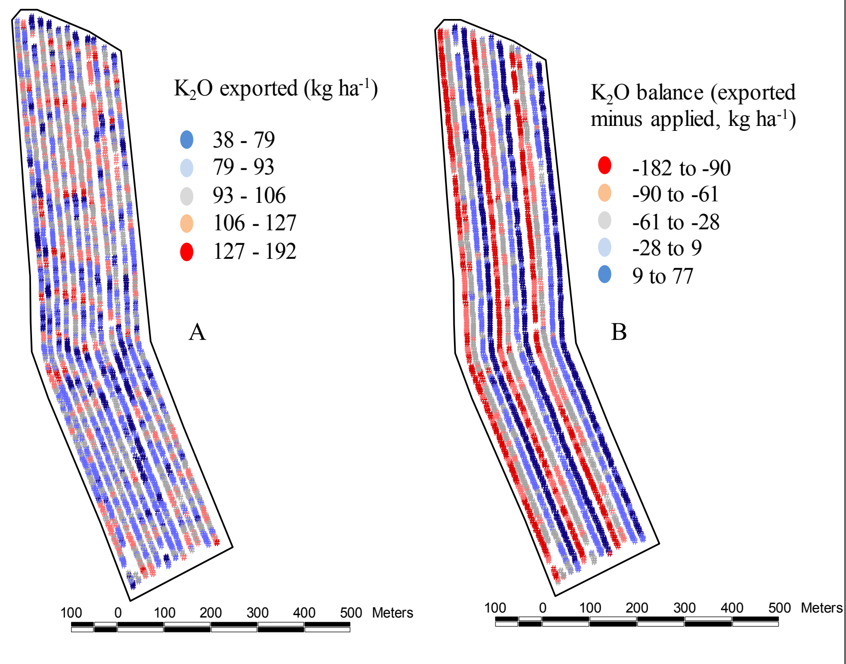

Fig 7. K exportation (A) and balance of K fertilization (B) (K_2O applied - K_2O exported). *Source*: Bernardi *et al.*, 2010.

Conclusions

These results showed that the recommended map for variable rate of K fertilization can be accomplished by using yield maps from previous years. With this information, VRA of K for this plot could be performed, and used to reduce yield variability and maintain profitability while optimizing K applications.

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Variable-Rate Application (VRA) of Potassium Fertilization for Soybean in Brazil" appears also at:

Regional Activities/Latin America

IPI Events

September 2011

State-Level symposium on potassium to summarize a project titled "Yield and Quality Studies of Rabi Onion as Influenced by Graded Levels of Potash in Inceptisols". Due on 15 September 2011, at the Department of Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. The symposium will deal with the importance of potassium application and more specifically on the results gathered during a 3 year experiment conducted by the department of soil science and IPI. For more details contact Mr. Eldad Sokolowski, IPI Coordinator China. ■

October 2011

International Symposium on "Role of Potassium in Sustaining the Yield and its Quality", Kandy, Sri Lanka, 27-29 October 2011. The symposium will be jointly organized by the International Potash Institute, University of Sri Jayewardenepura, Sri Lanka and Department of Agriculture, Sri Lanka. It is co-sponsored by the Bangladesh Fertilizer Association (BFA) and The Fertilizer Association of India (FAI). For more details see IPI website or contact Dr. Baladzhoti Tirugnanasotkhi, IPI Coordinator East India, Bangladesh and Sri Lanka. ■

July 2012

International Symposium on "Management of Potassium in Plant and Soil Systems in China", Chengdu, Sichuan, China, 24-27 July 2012. The symposium will be jointly organized by the International Potash Institute, Soil Science Institute, Nanjing, China, Chinese Academy of Sciences and the China Agriculture University. For more details see IPI website or contact Mr. Eldad Sokolowski, IPI Coordinator China. ■

Other Events

September 2011

International Conference on "Soil, Plant and Food Interactions", Mendel University, Faculty of Agronomy, Brno, Czech Republic, 6-8 September 2011. See conference website. ■

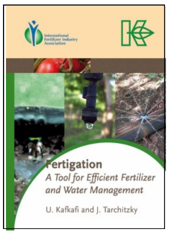
October 2011

10th African Crop Science Society Conference, Joaquim Chissano International Conference Centre Maputo, Mozambique, 10-13 October 2011. See conference website. ■

May 2012

Agritech Israel 2012. The 18th International Agricultural Exhibition, Tel Aviv, Israel, 15-17 May 2012. Agritech Israel 2012 is one of the world's most important exhibitions in the field of agricultural technologies. The exhibition program will include the conference of the International Committee for Plastics in Agriculture (CIPA). See Agritech website. ■

Publications



Fertigation. A Tool for Efficient Water and Nutrient Management. 2011. Kafkafi, U., and J. Tarchitzky. 140 p. ISBN 978-2-9523139-8-8 Published by IFA and IPI.

Sound water management has the potential to improve fertilizer/nutrient use efficiency. The introduction of well-tested, efficient fertilizer application through irrigation water or "fertigation" techniques could help turn vast areas of arid and semi-arid land in many parts of the world into farmland, as well as preventing water from being wasted in conventional irrigation systems. This book is a joint project of IFA and the International Potash Institute (IPI). It presents information relevant to soil-water-fertilizer interactions during fertigation. The authors have brought together various types of expertise on plant physiology, plant nutrition and irrigation, which are synthesized into practical knowledge related to fertigation in commercial field and greenhouse operations. Readers will find advice on selecting appropriate fertilizer products for fertigation of a number of field and horticultural crops. The suitability of some fertilizers for fertigation is explained from the point of view of the plant's physiological demand at different growth stages, the type of soil or growing medium, climatic conditions and irrigation water quality.

Download the full publication from IPI website. ■

Önemli Kültür Bitkilerinin Gübrelenmesi. (Fertilization of Selected Crops in Turkey). 2010. Edited by Dr. Dilek Anaç, Ege University, Bornova, Turkey. 111 p. Turkish. ISBN 978-605-87957.

A requirement for higher yielding crops due to population growth has led to a greater use of inputs, which are often used in excess, to increase agricultural production. Precautions to control the excess use of fertilizers are very important not only for agricultural production, but for the environment as well as for the economy. Therefore, optimization in the nutrition of crops is essential in producing high quality healthy crops in an effort to obtain higher yields per unit of agricultural land.

Optimal and efficient use of fertilizers can only be achieved by understanding factors such as climate, soil properties, cropping period and the timing, amount and type of fertilizers used. Otherwise,

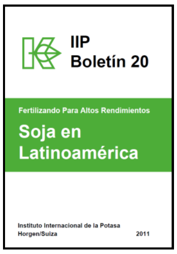
Publications

soil fertility and yield quality may decrease, and the environment may be negatively affected.

This publication includes eleven chapters, each focusing on the growth requirements of a different crop: apricots, cherries, citrus, cotton, figs, maize, olives, thyme, greenhouse tomato, vineyards, and wheat, with an emphasis on climate, soil properties, nutrition as well as fertilization practices and recommendations. The authors of the chapters are all leading researchers from Ege University, Bornova; Celal Bayar University, Manisa; and the West Mediterranean Agricultural Research Institute, Antalya.

The publication will be useful for researchers, extension and agri-business technicians working in Turkey.

Download from IPI website or order a copy from Prof. Dr. Dilek Anaç, Ege University, Faculty of Agriculture, Soil Sciences Dept., 35100 Bornova, Izmir, Turkey, dilek.anac@ege.edu.tr. ■

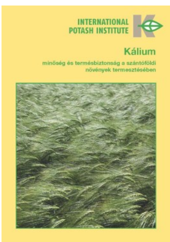


IIP Boletín No. 20: Fertilizando Para Altos Rendimientos: Soja en Latino-américa. (Fertilizing for High Yield and Quality: Soya in Latin America). 2011. 174 p. Spanish. ISBN 978-3-9523243-7-0. Authored by Dr. Ricardo Melgar, Estación Experimental de Pergamino, Buenos Aires, Instituto Nacional de Tecnología Agropecuaria (INTA), Argentina; Dr. Godofredo Vitti, Escuela Superior de Agricultura "Luiz Queiroz", Universidad de São Paulo, SP, Brasil; and Dr. Vinicius de Melo Benites, Centro Nacional de Investigación de Suelos, Río Verde, GO, Empresa Brasileira de Pesquisa Agropecuaria, EMBRAPA, Brasil.

The first edition of the IPI Crop Bulletin on Soya, written by Dr. Fauconnier, was published in 1986. Since this time, the area and productivity of soybean has dramatically increased, with Latin American producers playing a much more important role than before. The authors of this latest IPI publication in Spanish, Dr. R. Melgar (Argentina) and Drs. Vitti and de Melo Benites (Brazil), are well connected to this remarkable growth in their countries, and are well placed to outline soybean development in Latin America.

The publication includes four chapters, conclusions and color photos. In the opening chapter, the authors describe the economic importance of Soya in Latin America, including the development of the biofuel industry that uses soybean oil. The second chapter describes the general conditions required for the crop, climate, soils and potential across the Latin American region. In the third chapter, the role of each nutrient on the development and quality of the crop is outlined, and in the fourth chapter the various fertilization practices used in soybean production are discussed in detail, with a special focus on those applied in no-till systems.

Download from IPI website or order a copy from Dr. R. Melgar at rjrmelgar@gmail.com or rmelgar@pergamino.inta.gov.ar. ■



Kálium - minőség és termésbiztonság a szántóföldi növények termesztésében. (Potassium for Quality and Yield Security in the Cultivation of Arable Crops). 2011. István Terbe. 16 p. Hungarian.

The brochure deals with the potassium demand and management of cereals, root and tuber crops, oil crops, tobacco, fodder crops and meadows and pastures. It briefly touches the topic of potassium in soils and gives some recommendations for fertilization of these crops.

Download from IPI website or order a copy from Dr. Thomas Popp, IPI Coordinator Central Europe. ■

Publications by the PDA

The Potash Development Association (PDA) is an independent organisation formed in 1984 to provide technical information and advice in the UK on soil fertility, plant nutrition and fertilizer use with particular emphasis on potash. See also www.pda.org.uk/.

Note: Hardcopies of PDA's publications are available only in the UK and Ireland.

Disappointing First Cut Yields due to Drought are no Reason to Neglect Potash and Sulphur. June 2011. Yields of first cut grass have been lower than average in many parts of the UK. Pockets of the south west and N. Ireland aside, yields down by as much as 30% have been reported from Wales, Scotland and the midlands, north west and north east of England. Some grassland farmers may have delayed cutting to allow swards to bulk up, but with dry conditions encouraging early heading, this tends to exacerbate poor quality as stem elongation rushes on apace. See PDA website. ■

K in the Literature

Corn Responses to In-Furrow Phosphorus and Potassium Starter Fertilizer Applications. Mallarino, A.P., N. Bergmann, and D.E. Kaiser. Agron. J. 103(3):685-694, 2011.

Abstract:

Starter N-P or N-P-K fertilizers often are applied to corn (*Zea mays* L.), but questions arise concerning the

K in the Literature

usefulness of starter K. This study assessed responses of corn grain yield, early growth, and early P and K concentration and uptake to in-furrow fluid P-K and K starter fertilizers. Six replicated small-plot trials evaluated a control receiving no P or K, 3-8-15 (N-P-K) starter at 5 to 7 kg P ha^{-1} and 10 to 14 kg K ha^{-1}, 0-0-25 (N-P-K) starter at 10 to 14 kg K ha^{-1}; broadcast fertilizer at 49 to 66 kg P ha^{-1} and 112 to 140 kg K ha^{-1}; and broadcast-starter combinations. More N (191-224 kg ha^{-1}) was applied uniformly. Eight replicated field-length strip-trials evaluated 0-0-25 starter at 10 to 14 kg K ha^{-1}, broadcast fertilizer at 112 kg K ha^{-1}, and broadcast plus starter. More N (168-224 kg ha^{-1}) and P (49-66 kg ha^{-1}) were applied uniformly. The fields encompassed various tillage systems, hybrids, soils, and soil-test levels. Starter P-K applied in addition to broadcast P-K increased growth and P and K uptake compared with broadcast P-K at two trials, but did not increase yield. Starter K applied in addition to broadcast P-K at the small-plot trials or broadcast K at the strip-trials did not increase growth compared with broadcast fertilization, decreased K uptake at 2 of the 14 trials, and did not affect yield. Potassium seldom had a starter effect on corn. Starter K may not increase corn early growth or yield unless the soil is deficient in K and broadcast K is not applied. ■

Potassium Fertilization on Maize under Different Production Practices in the North China Plain. Junfang Niu, Weifeng Zhang, Xinping Chen, Chunjian Li, Fusuo Zhang, Lihua Jiang, Zhaohui Liu, Kai Xiao, Menachem Assaraf and Patricia Imas. Agron. J. 103 (3):822-829, 2011.

Abstract:

Potassium fertilization is uncommon in the North China Plain (NCP), especially in maize (*Zea mays* L.) production. Our specific objectives in this study were to determine yield response to K fertilization as affected by conventional as well as high-yielding production practices. Seven field experiments were conducted in the NCP. The factorial study compared three levels of K fertilization (K0 = no K; K1 = medium K rate; K2 = high K rate) and two levels of production practices: conventional (CP) and high yielding (HP). At all sites, HP outperformed CP in terms of maize grain yield except at ZD in 2006. On average, maize grain yields were enhanced by 9.9 and 14.9% under CP and 15.7 and 21.0% under HP at the K1 and K2 levels, respectively. Maize yield response, as well as economic profit from applied K, were greater under HP than CP, on average, across seven site-years. Medium K inputs improved partial factor productivity (PFP) of applied N and P, while higher rates had inconsistent results. Overall, PFP and agronomic efficiency of applied K were improved under HP, as was the apparent recovery efficiency of applied K, which suggests positive interactions among K and other high-yielding production practices. Negative K balances were observed in all of the K0 and K1 treatments in both years and under both production practices, especially under HP. In intensive agricultural soils of the NCP with higher K content relative to South China, optimal K fertilization will improve soil fertility and support high grain yield. ■

Re-Visiting Potassium and Phosphate Fertilizer Responses in Field Experiments and Soil-Test Interpretations by Means of Data Mining. Kuchenbuch, R.O., and U. Buczko. J. Plant Nutr. Soil Sci, 174 (2):171-185, 2011.

Abstract:

Currently, potassium (K)- and phosphate (P)-fertilizer recommendation in Germany is based on standardized soil-testing procedures, the results of which are interpreted in terms of nutrient availability. Although site-specific soil and plant properties (*e.g.*, clay and carbon content, pH, crop species) influence the relation between soil nutrient content and fertilizer effectiveness, most of these factors are not accounted for quantitatively when assessing fertilizer demand. Recent re-evaluations of field observations suggest that even for soil nutrient contents well within the range considered to indicate P or K deficiency, fertilizer applications often resulted in no yield increase. In this study, results from P- and K-fertilization trials (in total about 9000 experimental harvests) conducted during the past decades in Germany and Austria were re-analyzed using a nonparametric data-mining procedure which consists of a successive segmentation of the data pool in order to elaborate a modified recommendation scheme. In addition to soil nutrient content, fertilizer-application rates, nutrient-use efficiency, and site properties such as pH, clay content, and soil organic matter, have a distinct influence on yield increase compared to an unfertilized control. For K, nutrient-use efficiency had the largest influence, followed by soil-test K content, whereas for P, the influence of soil-test P content was largest, followed by pH and clay content. The results may be used in a novel approach to predict the probability of yield increase for a specified combination of crop species, fertilizer-application rate, and site-specific data. ■

Nutrient Management Strategies in Rainfed Agriculture: Constraints and Opportunities. Srinivasa Rao, Ch. Indian J. Fert. 7(4):12-25, 14 p. April 2011.

Abstract:

Dryland soils are not only thirsty but also hungry. Low productivity from rainfed regions is due to water deficit, recurring droughts, degraded lands (mostly affected due to water erosion causing soil loss up to 16 t ha^{-1} year^{-1}), poor soil health, water and nutrient

in the Literature

stress, multi-nutrient deficiencies, high evaporation rate, low infiltration rate and poor crop management factors. Moisture stress further affects the nutrient availability to the crop since nutrient mobility depends on optimum soil moisture. As top fertile soil layer is eroded in absence of soil cover, low soil organic matter and deficiency of secondary and micronutrient have emerged as important productivity constraints. Therefore, improving nutrient and water use efficiency is crucial for sustainability of rainfed production systems. Hence concerted efforts are needed to develop soil and crop management factors to mitigate the water and nutrient stress to maximize food production with minimum environmental degradation. Potential yield increase in rainfed agriculture, soil fertility issues, importance of soil health and on farm demonstration of livelihood impacts of balanced and integrated nutrient management and strategies for improving nutrient use efficiency are discussed in the paper. ■

Fertiliser Response and Nutrient Management Strategies for Cotton. Venugopalan, M.V., D. Blaise, M.S. Yadav, and Rachana Dehmukh. Indian J. Fert. 7(4):82-94, 13 p. April 2011.

Abstract:

Soil related constraints, notably fertility, are a major impediment in realizing potential cotton yields. Insufficient nutrient additions compared to nutrient uptake leads to a decline in soil fertility. Across cotton growing regions, nutrient balance was negative except for P. To mitigate nutrient stress and improve productivity, a balanced nutrient management plan is the only option. This paper presents the nutrient response to fertilisers of the conventional non-Bt and the recently introduced Bt transgenics. Recommendations pertaining to site-specific nutrient management and integrated nutrient management are also discussed. ■

Nutrient Management Strategies in Tropical Tuber Crops. Byju, G., and C.S. Suchitra. Indian J. Fert. 7(4):98-113, 16 p. April 2011.

Abstract:

Tropical tuber crops are the primary staple food of the wet tropics and in India these crops are cultivated as a secondary staple as well as for many commercial applications such as production of starch and sago. These crops are adapted to low fertility tropical soils with high acidity and low inherent nutrients levels. Cassava, sweet potato, yams and aroids are the important ones in this group and all these crops respond well to application of manures and fertilisers. During the past 45 years, a lot of research studies have been done to develop different nutrient management strategies for these crops. The nutrient removal, nutrient deficiency symptoms, index tissues for plant analysis and critical nutrient concentrations were identified for nutrient management. Initially the yield of these crops could be substantially increased by developing blanket fertiliser recommendations. Later on, soil test based fertiliser recommendations for targeted yields were conducted to develop target yield equations and these equations were developed for cassava and sweet potato only, that too for limited regions. Later on, site-specific nutrient management (SSNM) technology has been developed for cassava and effectively implemented in farmers' fields for field scale nutrient recommendations in major cassava growing regions. Under the SSNM technology, spatial and temporal variability of soil and canopy properties are considered using tools such as simulation models, leaf colour charts and chlorophyll meter for making variable rate fertiliser recommendations. Development of SSNM technology in other tropical tuber crops is also being envisaged. ■

Read on:

- **IWMI Research Report 140: An Assessment of Crop Water Productivity in the Indus and Ganges River Basins: Current Status and Scope for Improvement.** Cai *et al.* 2010. ISBN 978-92-9090-735-0.
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- **IFA Wiki: Welcome to the Crop Nutrition Wiki.**
- **The Economist: Hindering Harvests: Changes in the climate are already having an effect on crop yields - but not yet a very big one.** 5 May 2011.
- **ECOS: Australia's Carbon Farming Initiative: A World First.** Michele Sabto, M., and J. Porteous. CSIRO Publishing, 4 May 2011.
- **Journal of Functional and Environmental Botany: Nitrogen Assimilation and Yield of *Lepidium sativum* [L.] As Affected by Potassium Availability**. Nidhi Gauba Dhawan, Shahid Umar, Tariq O. Siddiqi and Muhammad Iqbal. Indian Journals.com. 1(1):1-10, 2011.
- **Pakistan Journal of Agricultural Sciences: Potassium Application Reduces Bareness in Different Maize Hybrids under Crowding Stress Conditions.** M. Ahmad alias Haji A. Bukhsh, Riaz Ahmad, Javaid Iqbal, Safdar Hussain, Atique ur Rehman and M. Ishaque. 48(1):31-38, 2011 ISSN (Print) 0552-9034, ISSN (Online) 2076-0906. http://www.pakjas.com.pk.
- **Communications in Biometry and Crop Science: Distribution of ^{14}C into Biochemical Components of Soybean Exposed to Water Deficit and Potassium.** Kamel *et al.* 5(1):27-33, 2010. International Journal of the Faculty of Agriculture and Biology, Warsaw University of Life Sciences, Poland.

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- **Nature: Agriculture: Beyond Food versus Fuel.** Graham-Rowe, D. 474:6-8, 23 June 2011.
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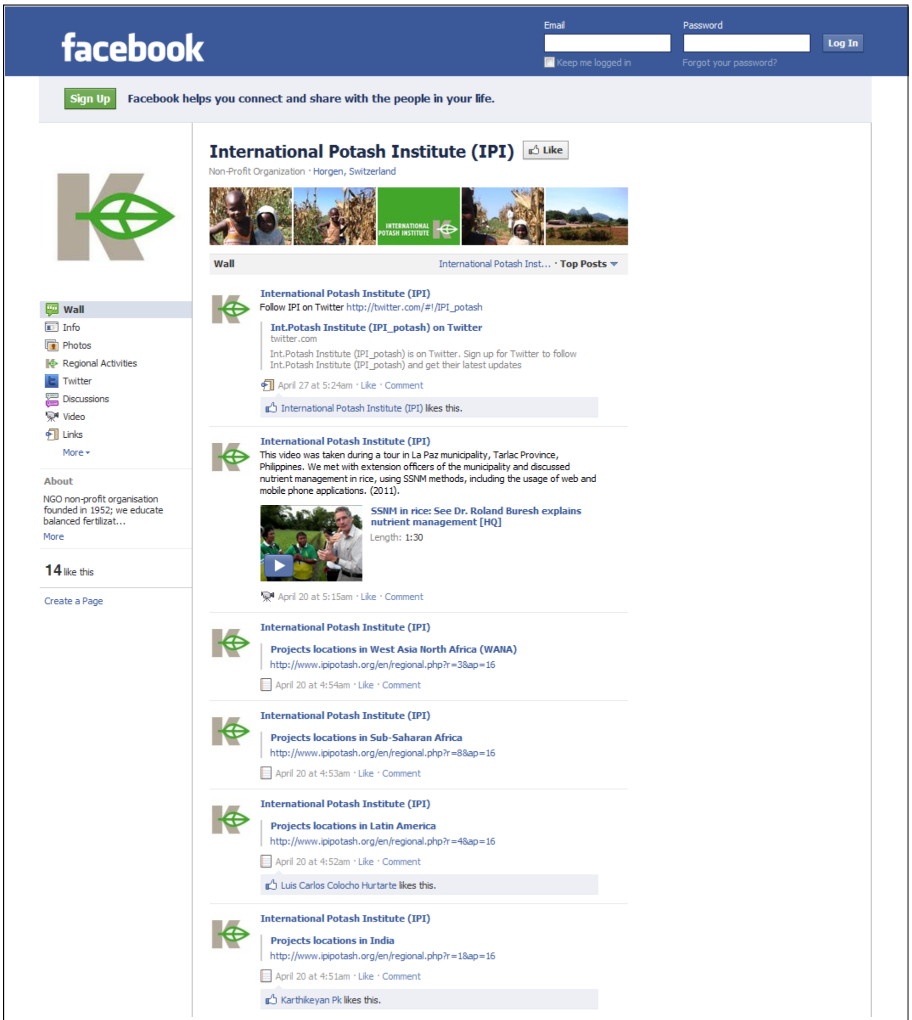

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