Better Crops International

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Nutrient Balance of Nitrogen, Phosphorus and Potassium under Triple Cropping Systems Based on Rice (China)

Canola Needs Sulphur (Australia)

Balanced Fertiliser Use Increases Crop Yield and Profit (India)

and much more…

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Our Cover: Soybeans in cerrado region of Brazil.
Photo source: Dr. T. Yamada and Dr. M.D. Stauffer

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Nutrient Balance of Nitrogen, Phosphorus and Potassium under Triple Cropping Systems Based on Rice

By Wang De-ren and Lu Wan-fang

Applications of organic and inorganic fertilizers in rice-based triple cropping systems produce high, sustainable yields and increase economic efficiency while maintaining soil nutrient balance.

The north of Zhejiang province in China is an intensively cultivated area under triple cropping systems that are based on rice. Water supply is adequate to support this level of crop production. The region has a large population dependent on a limited land base. One solution to this problem is to increase the cropping index. With an increasing cropping index and popularization of regionally adapted, high yielding varieties, plant nutrient requirements will increase.

It is recognized that sustainable high yield systems require both adequate nutrient supplies to growing crops as well as continual improvements to the soil's nutrient status and quality. To compensate for chemical fertilizer shortages, especially potassium (K), it was determined that rational applications of both organic and inorganic fertilizers were required. This has become a main approach to plant nutrient management and conservation of paddy soils under triple cropping systems.

To identify the correct proportions of organic and inorganic fertilizers to apply for nutrient balance and high yields in this system, a 4-year field experiment was conducted.

(continued on page 4)

More About Our Cover Photos

Brazil grows more than 11 million hectares of soybeans. No-till practices are gaining popularity. In the cerrado region, with improved varieties such as the Uirapurú cultivar shown in the close-up, yields up to 6 tonnes/ha are reported. BCI

Treatments were comprised of 2-year cycles of six cropping patterns that were replicated twice. Each plot of 1,000 m^2 was randomly arranged. The total trial area equaled 12,000 m^2. Soil analysis revealed the initial content of organic matter, total nitrogen (N), P_2O_5, and K_2O to be 3.71, 0.23, 0.14, and 1.81 percent, respectively. Available phosphorus (P) was 14.3 mg/kg and available K 61.3 mg/kg.

Results

Grain yields for the six individual treatments ranged from 22.2 to 31.6 t/ha/2 years and the overall average equaled 25.3 t/ha/2 years (**Table 1**). The 2-year yields from 4 years of continuous cropping in a "barley-rice-rice" system were 13.2, 17.2, 16.2, and 17.0 t/ha. Results show that rational applications of organic and inorganic fertilizer not only increase yield, but can also sustain a stable production level.

Table 1. Rate of fertilizer application and average yield in different periods under various multiple cropping rotation patterns.

	Yield, t/ha						Total grain output	Fertilizer application			
	First year			Second year				Organic	Inorganic, kg/ha/2 yrs.		
	1st season	2nd season	3rd season	1st season	2nd season	3rd season		t/ha/2 yrs.	N	P_2O_5	K_2O
Crop	Barley	Soybean	Late hybrid rice	Field pea	Corn	Late rice					
Yield	1.7	1.3	6.1	2.0	5.6	6.9	23.6	62	681	345	461
Crop	Rapeseed	Early rice	Soybean	Barley	Early rice	Corn					
Yield	2.1	6.9	0.8	3.5	7.4	4.7	25.4	82	672	245	320
Crop	Barley	Corn	Late rice	Rapeseed	Early rice	Soybean					
Yield	1.5	4.2	5.6	2.1	7.3	1.5	22.2	79	842	242	294
Crop	Green manure	Early rice	Late hybrid	Barley	Soybean	Late hybrid					
Yield	37.5	6.3	6.1	2.4	1.5	6.4	22.7	68	592	216	525
Crop	Barley	Early rice	Corn	Green manure	Early rice	Late rice					
Yield	3.4	6.6	3.6	37.5	6.8	6.1	26.5	59	914	207	642
Crop	Barley	Early rice	Late rice	Barley	Early rice	Late rice					
Yield	2.7	6.6	5.3	3.3	7.3	6.4	31.6	68	1,252	413	621
Average							25.3	70	826	278	478

For all treatments, average offtake (output) of N, P_2O_5 and K_2O from harvestable portions was calculated to be 736, 282 and 419 kg/ha/2 years, respectively. Average organic fertilizer application was 70 t/ha/2 years (**Table 1**), which was calculated to supply approximately 29.6 percent, 50 percent and 39.6 percent of the total N, P_2O_5 and K_2O, respectively. Therefore, the 2-year supply totals from the respective inorganic and organic fertilizers were approximately 826 + 348 (N); 278 + 278 (P_2O_5); and 478 + 314 (K_2O) kg/ha. Based on this, the output to input ratios for the N, P_2O_5 and K_2O were 0.63, 0.51 and 0.53, respectively. It is apparent that continued use of this type of practice should result in a build up of soil fertility and increased soil productivity.

Rate of Fertilization and Soil Nutrient Balances

After 4 years, 33 of the 36 indicators of soil fertility increased. The average increase in organic matter, total N, and available P and K was 0.36 percent, 0.12 percent, and 4 mg/kg and 5.1 mg/kg, respectively (**Table 2**). This points toward a positive nutrient balance and improved soil fertility and quality. This evidence clearly shows the consequence of mining soil nutrients and the benefits of fertilizer requirements needed to re-establish adequate fertility levels. In particular, the low initial levels for K suggest that the process of soil fertility remediation must be a long-term objective. Less fertile, highly buffered soil systems are less efficient at supplying nutrients to the crop. In such cases, fertility programs designed to compensate only for crop removal fall short of meeting crop demand.

Table 2. Increases (+) in soil nutrient levels after 4 years of six different crop rotations.

Treatment number	Organic matter, %	N	P_2O_5 %	K_2O	Available P, mg/kg	Available K, mg/kg
1	+0.45	+0.26	+0.15	+0.29	+7.2	+11.2
2	+0.19	+0.01	+0.03	+0.33	+1.2	+2.7
3	+0.15	+0.06	+0.03	+0.28	+3.7	+4.2
4	+0.29	+0.12	+0.04	+0.31	+3.7	+3.2
5	+0.62	+0.25	+0.02	+0.25	+4.7	+2.7
6	+0.45	+0.14	+0.09	+0.26	+3.7	+6.7
Average	+0.36	+0.14	+0.05	+0.29	+4.0	+5.1

Effect of Organic Plus Inorganic Fertilizer on Nutrient Utilization and Efficiency

Nutrient utilization rates of N, P_2O_5 and K_2O from organic manure were estimated based on ^{15}N uptake. Approximately 16 percent of the N, 10 percent of the P_2O_5, and 16 percent of the K_2O from manure was used by the crop, or about half the amount contributed by inorganic fertilizer. Compared to inorganic fertilizer alone, the combination of organic and inorganic fertilizers reduced the cost of nutrients and increased net income by 11 percent.

This fertilization strategy is the principal recommendation for sustainable agricultural development in triple cropping systems based on rice. As shown, this recommendation sustains high yields economically and provides the opportunity to either build or maintain plant nutrients in the soil. Organic fertilizer when used in sufficient quantity can effectively complement inorganic nutrient input. **BCI**

Wang De-ren and Lu Wan-fang are senior agriculturists with the China National Rice Research Institute, Hangzbou, Zhejiang province, People's Republic of China.

Canola Needs Sulphur

By A.J. Good and John S. Glendinning

Canola is a crop of increasing importance in Australian agriculture. Because of the particular growing season, canola is grown during the winter period even though the varieties grown are all spring varieties. The crop is planted in late autumn, about the month of May, and harvested in spring during the October to November period.

Sulphur (S) deficiency in canola was recognised as a serious problem in the crop in New South Wales (NSW), Australia, in 1992, although symptoms were noticed on numerous occasions before that time. Since then, research has shown that the problem can be effectively diagnosed in ample time to enable recommendations for remedial action which is optimum fertilizer application for the growing crop.

Results from this research were adopted as standard practice by over 90 percent of canola growers in NSW within 2 years of this project being started.

The Research Programme

This research was carried out in commercial fields which were being surveyed as a part of a wider investigation into farmer practices. The trial sites were selected at random from the survey fields and were not based on soil characteristics or previous cropping history. Soil analyses were carried out after the sites were finalised.

The broad objectives of the research programme were to:

- Determine the optimum rate of S and nitrogen (N) fertilizer in relation to soil type, previous cropping history, soil fertility, and N fertilizer use.
- Develop a soil test to indicate the likelihood of response by canola to S fertilizer.
- Develop a tissue test to diagnose S deficiency in young canola crops that would enable deficient crops to be treated in time to achieve an economic yield increase in the current season.

Cooperating organisations were CSIRO Division of Plant Industries, Canberra, and the University of New England in Armidale, Northern NSW. The field programme was conducted by Incitec Ltd.

Results

The optimum rate of S fertilizer to apply is affected by previous cropping history of a field, the level of N fertility, balanced nutrition with phosphorus (P), potassium (K), and other important nutrients, and soil type.

The average seed yield response to 40 kg/ha S fertilizer at responsive sites was 1,285 kg/ha after pasture and 280 kg/ha after a cereal crop (**Table 1**).

All plots received adequate P for the soil and conditions. In addition, all plots, whether following a previous cereal crop or pasture, responded significantly to N fertilizer at rates up to 160 kg/ha. Data from Canada substantiate the benefit of balanced nutrition as depicted in **Figure 1**.

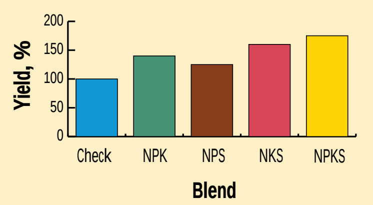


Figure 1. Balanced fertilization increases canola yields (Alberta data).

Another effect of S treatment was to improve the oil content of the canola seed. The most significant effects were found where canola was grown after a legume-dominant pasture, as shown in **Table 2**. Failure to apply S resulted in a drop in oil content of up to 8 percent (not shown) and an average of nearly 3.0 percent.

Table 1. The effect of S fertilizer and previous crop on yield of canola.

Rate of S fertilizer, kg/ha	Yield, kg/ha, after:	
	Cereal	Pasture
0	2,629	3,248
10	2,754	4,119
20	2,820	4,380
40	2,909	4,533

Table 2. Effect of S fertilizer and previous crop on oil content of canola seed.

Rate of S fertilizer, kg/ha	Oil content, %, after:	
	Cereal	Pasture
0	43.73	39.07
10	44.10	39.90
20	44.10	41.72
40	44.07	42.01

Soil Tests

Soil analysis by the KCl-40 test provides a useful guide to the S fertilizer needs of the canola crop. Interpretation of the results of analysis of soil samples for canola fields takes into account the soil S level in both surface samples (0 to 10 cm) and deep samples (10 to 60 cm). In this research, on soils that tested in the low range for S and where no S fertilizer was applied, the crop exhibited obvious visual symptoms of S deficiency and suffered yield losses greater than 1,000 kg/ha. On soils testing in the medium range and that received no S fertilizer, yield losses were less than 500 kg/ha. The crop showed no obvious visual symptoms of S deficiency.

Plant Tests

The tissue sampling and testing procedure developed enables growers to collect samples early in the life of the crop so that a corrective fertilizer S treatment would effect a significant economic response.

Of prime importance is the need to ensure simplicity in the sampling procedure. This work showed that samples of whole tops are as effective as the usual youngest fully expanded leaf (YFEL). This is an important consideration with canola because growth stages become very difficult to distinguish once stem elongation takes place.

Critical levels of total S in the whole tops have been determined for the “flower bud visible” (FBV) growth stage. At this stage, the critical level for low yielding crops was shown to be 0.3 percent S, while for high yielding crops it is 0.45 percent S.

The N:S ratio in plant tissue, widely used in assessing the S

This photo shows a general view of the trial site at Wellington. The low and nil S treatments are those which appear grey.

nutrition in the winter type canola varieties grown in Europe, seems to be of little value for the "spring" varieties grown in Australia.

Sulphur Application

When S deficiencies are known to exist, it is common practice to apply the crop's S requirement either at or before planting time. However, there are occasions when S deficiencies are not recognised until after the crop has emerged. Unfortunately, little information was available to guide those in this situation.

The application of 40 kg/ha of S fertilizer before stem elongation occurs (about 70 days after planting) gave almost total yield and quality recovery. The comparison effect of post-planting applications of S fertilizer versus treatment at planting, on yield and other measurements of the canola crop, are shown in **Table 3**.

Table 3. Effects of time of application of 40 kg/ha of S to canola.

	Stage of application					
	Sowing	RS	BV	SE	FL	Control (nil S)
Yield – t/ha	2.17	2.30	2.04	2.16	1.84	1.01
Oil content – %	43.4	42.6	42.9	42.8	41.6	33.6
S concentration – %	0.45	0.46	0.47	0.46	0.46	0.24
Glucosinolate – %	5.92	6.90	6.80	6.74	7.50	0.35

Note: RS = 5-6 leaf rosette; BV = flower buds visisble; SE = stem elongation; FL = start of flowering

Recommendations

Sulphur removal and uptake efficiencies can vary considerably. Recommended rates of application obviously depend on the previous fertilizer and cropping history, but are particularly influenced by the availability of N, P, K, boron (B), and other nutrients.

In general, it can be said that for growing canola on soils testing low in S, a 40 kg/ha S application is recommended. Where higher S levels exist...whether measured by soil test or estimated by previous history, 20 kg/ha S is the recommended rate of application. BCI

Mr. Good is a Market Development Agronomist with Incitec Ltd, based in Cowra, NSW, Australia. Mr. Glendinning is a consultant with Agrow Australia Pty Ltd, based in Sydney.

Maximising Yield of a Rice-Wheat Sequence in Recently Reclaimed Saline-Sodic Soils

By K.N. Tiwari, G. Dev, D.N. Sharma, and U.V. Singh

In India, saline-sodic soils account for approximately 7 million ha. Of this area, about 3.25 million ha are presently reclaimable due to the availability of good irrigation water and soil amendments. About 2 million ha of these soils occur on the Indo-Gangetic Plain, with a large area in Uttar Pradesh. Successful crop production on these soils will impact agricultural production in India and will contribute to meeting its growing demand for food.

Rice-wheat cropping sequences can be successfully adapted to recently reclaimed saline-sodic soils. However, there is an urgent need to increase the productivity of this crop rotation by adopting best management practices (BMPs) that correctly combine inorganic nitrogen (N), phosphorus (P), and potassium (K) fertilisers with organic manures, including green manure (GM), while maintaining proper plant populations and planting methods. Current recommendations for rice growing conditions are to apply fertiliser at 120-60-60 kg/ha of N-P_2O_5-K_2O using a plant population of 444 x 10^3 hills/ha. Wheat is commonly sown on flat land with fertiliser applied at 120-60-40 kg/ha of N-P_2O_5-K_2O. This study evaluated different practices for maximising yields in a rice-wheat sequence.

Field experiments were conducted for 3 years on a recently reclaimed saline-sodic soil at C.S. Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh. In rice, the treatments consisted of combining factors of (1) farm yard manure (FYM) applied at 12.5 t/ha and in-situ green manuring with *Sesbania aculeata*; (2) N levels of 120, 150 and 180 kg N/ha; and (3) plant populations of 444 x 10^3 (15 x 15 cm spacing), 667 x 10^3 (15 x 10 cm spacing), and 1,000 x 10^3 hills/ha (10 x 10 cm spacing). In wheat, the treatment factors were (1) the residual effect of the previous FYM/GM in rice; (2) N applied at 120, 150 and 180 kg N/ha; and (3) planting on flat land, east-west facing ridges, or north-south facing ridges. Soil properties for

Table 1. Selected soil properties of the reclaimed saline-sodic soil, Uttar Pradesh.

Soil classification	Texture	pH	Electrical conductivity (EC) mmhos/cm	Exchangeable sodium percentage (ESP)	Sodium adsorption ratio (SAR)
Typic Halaquept	Silty clay loam	9.8	4.9	70.6	101.2

Table 2. Rice yields (t/ha) due to different treatments, Kanpur, Uttar Pradesh.

Treatment	Year 1	Year 2	Year 3	Mean
Organic manuring				
Control	3.155	3.865	2.570	3.197
FYM	3.467	4.302	2.860	3.543
GM	3.639	4.456	3.030	3.708
C.D. (5%)	0.110	0.148	0.099	
$N-P_2O_5-K_2O$, kg/ha				
120-75-75	3.056	3.832	2.540	3.143
150-75-75	3.536	4.334	2.910	3.593
180-75-75	3.669	4.444	3.030	3.714
C.D. (5%0	0.108	0.085	0.130	
Population (x 10^3 hills/ha)				
444	3.253	3.929	2.600	3.261
667	3.470	4.319	2.880	3.556
1,000	3.538	4.374	3.001	3.641
C.D. (5%)	0.108	0.085	0.099	

Table 3. Wheat yields (t/ha) due to different treatments, Kanpur, Uttar Pradesh.

Treatment	Year 1	Year 2	Year 3	Mean
Residue of organic manuring				
Control	2.685	2.930	1.740	2.452
FYM	3.061	3.149	2.190	2.800
GM	3.181	3.270	2.120	2.857
C.D. (5%)	0.059	0.150	0.105	
$N-P_2O_5-K_2O$, kg/ha				
120-75-75	2.661	2.832	1.710	2.401
150-75-75	3.093	3.189	1.950	2.744
180-75-75	3.177	3.322	2.030	2.843
C.D. (5%0	0.045	0.088	0.118	
Sowing method				
Flat land	2.728	2.885	1.750	2.454
East-west ridges	3.161	3.261	1.960	2.794
North-south ridges	3.042	3.163	2.200	2.802
C.D. (5%)	0.086	0.088	0.105	

the experimental site are outlined in **Table 1**.

Rice and wheat yield responses to the different factors over 3 years are outlined in **Figure 1**.

Rice yields increased significantly with either FYM or *Sesbania* GM applied before rice transplanting (**Table 2**). However, GM was more efficient as it increased rice yield by 16 percent over the control, while the increase from FYM was 11 percent. Application of 150 kg/ha N increased rice yield by 14 percent over yields obtained with 120 kg N/ha.

The successive yield increase obtained by applying 180 kg N/ha was an additional 4 percent. The study determined 1,000 x 10^3 hills/ha to be the most productive plant population, increasing yield by 12 percent over the conventional practice (444 x 10^3 hills/ha). Rice planted at 667 x 10^3 hills/ha yielded 9 percent more than conventional practice.

Wheat yields were improved as a consequence of residual nutrients supplied from either FYM or GM applied for the previous rice crop (**Table 3**). Similar to rice, the residual effect of GM was greater than that resulting from FYM application. Wheat yields were increased by 17 percent with green manure residue and by 14 percent with FYM. Successive levels of N significantly increased wheat yield, the effect being higher from 120 to 150 kg N/ha (14 percent increase) than from 150 to 180 kg N/ha (4 percent increase).

With respect to the method of planting, sowing wheat on ridges was more effective than on flat land. Flat land wheat yields were 14 percent lower than yields obtained on soil that was ridged in a north-south direction and 14 lower than soil ridged in an east-west direction. Over the 3 years studied, a consistent difference could not be found between wheat planted on ridges facing north-south or east-west bearings.

The BMPs for maximising yield in a rice-wheat sequence on reclaimed saline-sodic soils are to apply either 12.5 t FYM/ha or use in-situ *Sesbania aculeata* as a GM source in rice. These organic amendments should be combined with fertiliser applied at 150-75-75

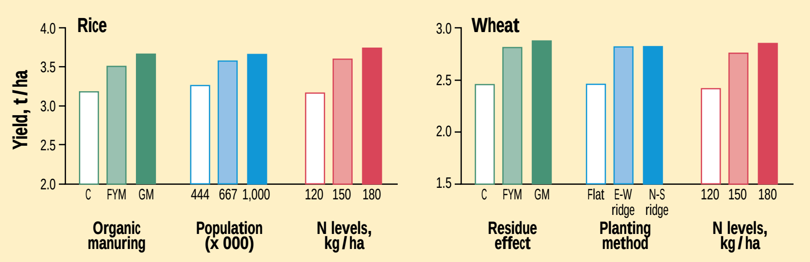
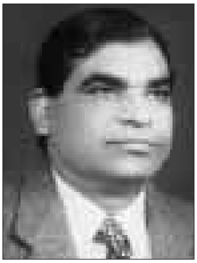


Figure 1. Yield of rice and wheat due to different treatments (mean of 3 years), Kanpur, Uttar Prodesh.

kg/ha N-P_2O_5-K_2O. A plant population of 667 x 10^3 hills/ha should also be adopted. In wheat, fertiliser applied at 150-75-75 kg/ha N-P_2O_5-K_2O combines well with any residual nutrients from the previous rice crop. It appears that planting wheat on ridged land is preferred over flat land. **BCI**

Dr. Tiwari is Deputy Director, PPIC-India Programme, Kanpur, Uttar Pradesh. Dr. Dev is Director, PPIC-India Programme, Gurgaon, Haryana. Mr. D.N. Sharma and Mr. U.V. Singh are Assistant Scientists, Department of Soils, C.S. Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh.

Dr. K.N. Tiwari Joins Staff of PPIC-India Programme



Dr. Kashi Nath Tiwari has joined the staff of the PPIC-India Programme. He will be located in Kanpur, Uttar Pradesh, as Deputy Director for East India. PPIC-India Programme headquarters are in Gurgaon, and another Deputy Director for South India is located at Hyderabad (Andhra Pradesh).

Dr. Tiwari received his Ph.D. in Agricultural Chemistry from Kanpur University in 1974. He has served as principal investigator of 15 research projects related to soil fertility and fertilizer sponsored by councils and institutes in India and internationally. In addition to numerous honors, Dr. Tiwari has received academic recognition as a Fellow of the Indian Society of Soil Science, Fellow of the Indian Society of Agricultural Chemists, and awards by other highly respected groups. He is the author of six books, as well as numerous bulletins, project reports, research papers, and technical articles.

During his association with extension programmes in Uttar Pradesh, Dr. Tiwari has been closely involved with transfer of technology related to balanced use of fertilizers, integrated nutrient management, reclamation and management of salt-affected soils, efficient use of saline/alkaline waters, and diagnosis of nutritional disorders in crops. **BCI**

Potassium Increases Cassava Yield on Alfisol Soils

By H. Suyamto

Symptoms of potassium (K) deficiency are common in cassava grown on marginal soils in Indonesia. Consequently, a K fertility experiment was conducted in South Malang, East Java, in order to develop a set of balanced fertiliser recommendations.

Cassava is an important root crop to Java-Indonesia. Among tropical root crops, it has the highest ratio of K to nitrogen (N) in its harvested tuber and extracts the largest amount of K from soil. Typical N, phosphorus (P), K, calcium (Ca), and magnesium (Mg) removals per tonne of cassava root are 4.91, 1.08, 5.83, 1.83 and 0.79 kg/ha, respectively. Despite this large nutrient demand, cassava is often grown on marginal uplands (Alfisols) with low fertility. Traditionally, cassava farmers have not applied fertiliser, and attempts that are more progressive have only concentrated on applying N and farmyard manure (FYM). Average farmer yields are low at approximately 12 tonnes of fresh root/ha.

Table 1. Fertiliser treatments on cassava, Malang, East Java.

Tratments	Rates, kg/ha N	P_2O_5	K_2O	FYM, t/ha
N-P	92	36	–	–
N-P-K1	92	36	30	–
N-P-K2	92	36	60	–
N-P-K3	92	36	120	–
N-P-K3-FYM	92	36	120	10

Table 2. Effect of K and farmyard manure on cassava yield, Malang, East Java.

Treatments	Fresh root yield, t/ha	Root number per plant	Plant height, cm
N-P	11.88	7.6	109
N-P-K1	18.42	9.2	116
N-P-K2	22.80	9.5	138
N-P-K3	23.46	9.0	147
N-P-K3-FYM	29.84	10.0	184
LSD 0.05	9.1	0.9	ns*
CV (%)	25.1	6.3	26

*Not significant at 5% level.

A local variety of cassava (Menyok) was planted at a spacing of 1 m x 1 m in November 1996 at the beginning of the rainy season. Plots were 6 m^2 in size and were replicated three times. Fertiliser treatments were arranged as shown in **Table 1**.

Soil analysis before planting indicated low organic matter (1.1 percent), P (Bray 2) very low at 1.56 parts per million (ppm), and K very low at 0.07 meq/100g. Both Ca and Mg were high, with Ca at 9.7 meq/100g and Mg at 2.6 meq/100g.

Data indicate that K was a major limiting factor for efficient cassava production on marginal upland Alfisol soils. Application of N and P alone resulted in the lowest yield at 11.88 tonnes fresh root/ha (**Table 2**). Exclusion of K also resulted in the lowest number of roots per plant at 7.6. Yields showed a curved response to successive increases in K up to 120 kg K_2O/ha (**Figure 1**).

Separate combinations that added either 30 or 60 kg K_2O/ha increased yields over the N-P treatment by 55 and 92 percent, respec-

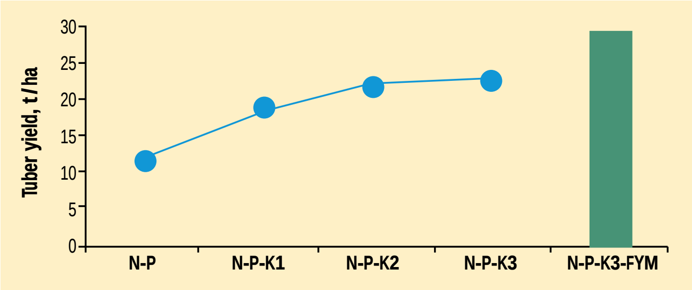


Figure 1. Cassava root yield response to successive increases in K, and yield obtained with further addition of FYM, Malang, East Java.

tively. The treatment that combined 10 tonnes FYM/ha with the highest rates of N, P and K resulted in 29.84 tonnes fresh root/ha. The number of roots per plant increased significantly by including 30 kg K_2O/ha with N and P, but no additional increase in root number was observed with higher rates of fertiliser or manure.

Recommendation

The study proved that cassava planted on marginal Alfisol areas responded significantly to K fertiliser. The application of 60 kg K_2O/ha in addition to adequate N and P should be recommended for this area. Further if available, manures in combination with inorganic fertiliser is a very effective part of efficient cassava production in Java. **BCI**

Dr. Suyamto is a Soil Scientist/Director of the Research Institute for Legume and Tuber Crops (RILET), Malang, Indonesia.

Australia: Deep-Placed Potassium for Dryland Peanuts Grown on Oxisol Soils

Increasing incidences of potassium (K) deficiency for dryland peanut crops in Australia, particularly during extended dry periods, has prompted a study on K nutrient dynamics and fertiliser placement options on Oxisol soils. Native soil K reserves for high producing areas have been depleted from 50 years of cropping and a confinement of available K in the top 10 to 15 cm layer of dry soil. Researchers are working to characterise K uptake by peanut on these soils and are examining corrective management options.

Field trials found placement of potash in a deep band 25 to 30 cm below the surface improved mid-season K contents of crops grown on soils with initial subsoil K values below 0.20 cmol (+)/kg. Work continues on identifying appropriate rates and frequencies for deep-banded K in Oxisols. **BCI**

Source: *White, J., M. Bell, N. Menzies 1997. ACIAR Food Legume Newsletter 26.*

Research into Early Senescence Syndrome in Cotton

By Philip Wright

A nutritional disorder resembling the so-called premature senescence syndrome (which has affected cotton in the U.S.) has become quite common to Australia in recent years. The disorder is thought to be related to many factors that influence the supply and distribution of potassium (K) in the plant. Recent efforts by Australian researchers are providing new insights and management options.

Cotton field in eastern Australia shows premature senescence symptoms. Leaves near the top of the canopy turned red during early boll filling. Note how the edge row is unaffected.

Typical symptoms of premature senescence...area between veins turning red.

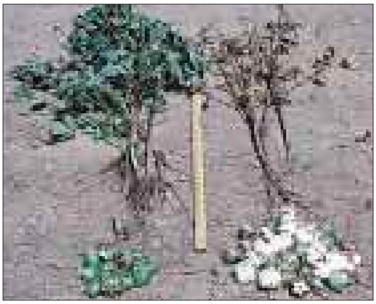
Cotton is grown on about 400,000 ha (one million acres) in Australia, mainly in New South Wales (NSW) and Queensland. While there has been some development of dryland production, the major portion of cotton is grown under flood irrigation within the latitudes of 24 to 32 degrees south. Crop yields are among the highest in the world, averaging over 6 bales/ha (3 bales/A). Individual fields have exceeded 12 bales/ha (4.5 bales/A).

The majority of Australian cotton is grown on highly fertile soils, classified as Vertisols, with very high levels of available K...more than 400 parts per million (ppm) K to depths of over one meter. Yet the disorder occurs in crops growing on these soils as well as on crops growing on low K soils. The "classical" symptoms of K deficiency usually occur first on the older leaves of the cotton plant. However, in the case of this problem, the younger leaves are the first to exhibit symptoms. The K levels in young leaves of affected plants are below the critical level of 0.9 to 1.2 percent K, and are often as low as 0.2 percent K. In some seasons the symptoms can be so severe that eventually the whole plant is defoliated.

This article discusses causes of this problem as related to the interaction of high boll loads and to K distribution in the plant.

Plants with or without symptoms of premature senescence within the same commercial field were compared for nutrient concentrations and plant growth. At each site at least five plants were sampled with or without the symptoms. Five different fields were used, all with available K levels in the soil greater than 200 ppm (ammonium acetate extract).

A cultivar with a reputation for high susceptibility (Siokra 1-4) was compared with a cultivar with reputed low susceptibility (Sicala V-2) at the Australian Cotton Research Institute near Narrabri NSW. A randomized complete block design was used with four replicates. Dry matter was determined regularly (about two-week intervals) and the plants partitioned into different plant parts. These were analysed for K concentration using atomic absorption spectrophotometry, and uptake curves were derived for individual organs and the crop.



Plants with premature senescence have much higher boll loads than other plants without premature senescence in the same field.

The effect of soil applied K was examined in a series of six experiments. Potassium (as KCl) was applied prior to sowing at 100 kg K/ha offset 5 cm from the plant line and at 20 cm depth. In a further series of experiments foliar applications were examined. Potassium (as KNO_3) was applied at 4 kg K/ha on four occasions, starting 7 to 10 days after first flower and then every 7 to 14 days. Each experiment was a randomised complete block with at least four replicates of each treatment.

It was found that the leaves of plants showing symptoms had about half the concentration of K and three-quarters the concentration of nitrogen (N) compared with the leaves of plants in the same field which did not show the symptoms, as shown in **Table 1**.

Plants which showed the symptoms had a far greater fruit load than plants that did not show any symptoms, even though there were only very small differences in the amount of leaf and stem tissue in each case (**Figure 1a**). Equally dramatic differences occurred in boll numbers with affected plants having about twice the boll numbers of unaffected plants (**Figure 1b**).

Table 1. Leaf N and K concentrations were dramatically lower in affected plants compared to healthy plants.

Leaves	Dry matter K content, %	Dry matter N content, %
Healthy plants	0.90	4.66
Affected plants	0.38	3.53
Significance	P<0.001	P<0.05

These large differences in boll load mean that the source/sink relationships of the plants in **Figure 1** are substantially altered. For example the ratio of boll mass to leaf mass in healthy plants was 2.7, while in affected plants it was much greater at 6.1. A further observation which highlights the importance of boll load in the early senescence syndrome is that the transgenic varieties carrying the Bt gene seem to be more susceptible to the problem. These varieties suffer less insect damage in their early stages, and so may be able to retain a greater percentage of their early fruit. Therefore, Bt varieties would carry a much higher early boll load than conventional varieties.

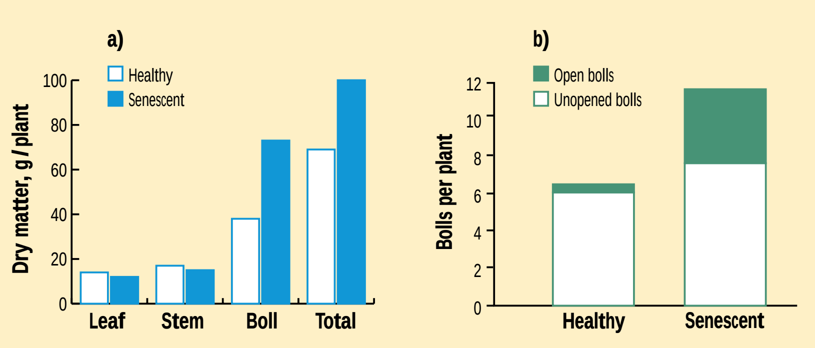


Figure 1. Dry matter a) and boll numbers b) were greater in plants with premature senescence than in plants without symptoms when compared in the same field.

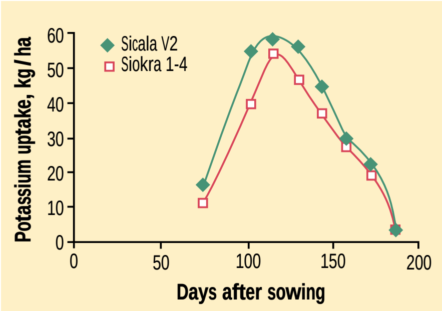


Figure 2. A non-susceptible cultivar (Sicala V2) stored more K in its leaves than a cultivar susceptible to premature senescence (Siokra 1-4).

Although there was little difference in the total amount of K taken up by non-susceptible and susceptible cultivars, there were quite significant differences in the way that they partitioned K.

The varieties compared were Sicala V-2, a non-susceptible variety, and Siokra 1-4, a susceptible variety. Both varieties took up similar amounts of K (207 and 202 kg K/ha respectively), at similar maximum rates of uptake (3.8 and 3.6 kg K/ha/day, respectively). However, Siokra 1-4 stored considerably less K in its leaves throughout the growing season than did Sicala V-2 (**Figure 2**).

Soil applied K fertilizer increased yield in only one out of six trials, and foliar applied K fertilizer increased yield in only one out of four trials, although there was a weak indication of increased yield in one other trial. In these trials, K application had little effect on fibre quality.

Conclusions

Premature senescence is becoming of widespread importance in the Australian cotton industry. While it appears to be connected with the supply of K, the reasons for it are not simple, and it can occur on soils with high or low K levels. Factors such as boll load, weather conditions, supply of phosphorus (P) and other nutrients, variety, and other conditions seem to be implicated. Transgenic varieties which carry the Bt gene seem to be more susceptible than the conventional varieties because of their higher retention of early fruit.

In some conditions, soil applied K fertilizer has led to increased yields. In other situations, foliar applied K has increased yields.

At this stage, good agronomy and choice of variety seem to be the most important management options available to growers to reduce the incidence of premature senescence. Thus, good irrigation scheduling and good field layout, both of which reduce waterlogging, will as a consequence also reduce premature senescence. Minimising soil compaction by carrying out tillage operations at appropriate moisture contents will have the added benefit of reducing premature senescence. The importance of K fertilizer, whether soil or foliar applied, is also likely to increase, especially as more transgenic varieties are planted, yields continue to rise, and the removal of K from the soil increases. **BCI**

Dr. Wright is a Cotton Research Scientist working at the Co-operative Research Centre for Sustainable Cotton Production at Narrabri, New South Wales, Australia.

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Balanced Fertiliser Use and Liming Sustain High Yields in Corn-Wheat Rotation on Acid Soil

By A.K. Sarkar, S. Lal, and G. Dev

Using an existing long-term manure experiment on acid soil, researchers in India developed a sustainable yield index (SYI) capable of comparing the cumulative effect of applying inorganic nitrogen (N), phosphorus (P), and potassium (K) fertilisers with farmyard manures and lime.

Red and lateritic soils cover an area of about 91 million hectares in India, representing 31 percent of the country's geographical area. These soils are moderately to highly weathered with high concentrations of secondary forms of iron (Fe) and aluminium (Al). They are also low in organic matter and depleted in bases. Therefore, soil acidity is a limiting factor for the production of major crops such as pulses, oilseeds, corn, wheat, cotton, and others.

Erosion of the soil surface in sloped areas often aggravates the problem of soil management. Here balanced fertiliser use with proper soil amelioration can sustain productivity and boost crop yields.

This research utilised one of the oldest soil fertility experiments in India, which is a long-term manure study initiated in 1956 at Ranchi, India. Important soil characteristics for this site include: clay loam texture, pH 5.5, 0.53 percent organic carbon (C), and cation exchange capacity (CEC) 10.5 cmol (+)/kg.

Researchers compared six treatments in a corn-wheat cropping sequence replicated 4 times in a randomised block design. Plot cropping history included improved crop varieties (corn Var. Kalimpong, wheat Var. R 319) up to 1969-70, after which high yielding varieties of corn (Var. Ganga Safed 2 Hybrid) and wheat (Var. Sonalika) were tested. Until 1994, the fertiliser sources were strictly ammonium sulphate

Table 1. Treatment effect on corn and wheat yield (t/ha) from 1956 to 1994, Ranchi, India.

	1956-69		1970-79		1980-89		1990-94	
Treatment	Corn	Wheat	Corn	Wheat	Corn	Wheat	Corn	Wheat
No fertiliser	0.6	0.5	0.5	0.6	0.5	0.7	0.5	1.0
FYM	2.0	1.2	2.0	1.6	2.5	2.4	3.9	3.7
N	1.5	0.4	0.3	0.3	0.03	0.0	0.02	0.06
NP	2.1	1.3	1.5	2.3	0.1	0.5	0.05	0.9
NPK	2.4	1.4	2.0	2.6	0.3	1.2	0.1	1.3
NPK + lime	3.0	1.7	3.6	3.3	4.1	4.0	4.8	5.0

Table 2. Treatment effect on the SYI for corn and wheat, Ranchi, India.

Treatment	Average grain yield from 1970 to 1994 Corn yield, t/ha	Yield loss[1], %	Wheat yield, t/ha	Yield loss[1], %	Sustainable yield index (SYI) Corn	Wheat
No fertiliser	0.50	87.9	0.76	81.5	0.06	0.09
FYM	2.80	32.7	2.50	39.0	0.30	0.23
N	0.11	97.3	0.12	97.1	–	–
NP	0.55	86.8	1.20	70.7	–	–
NPK	0.80	80.8	1.70	58.5	0.07	0.14
NPK + lime	4.16	–	4.10	–	0.58	0.47

[1]Relative to the NPK + lime treatment.

$[(NH_4)_2 SO_4]$, single superphosphate (SSP), and muriate of potash (MOP). From 1956 to 1969, N, P_2O_5 and K_2O were supplied at 44 kg/ha, after which rates were increased to 100-60-40 kg/ha. From 1976 to 1994, fertiliser rates were increased once more to 110-90-70 kg/ha. The farmyard manure (FYM) treatment included an annual application based on the amount of N added to non-manured treatments. Burned lime was applied at 50 percent of the requirement.

Results from the last 4 decades (**Table 1**) show consistently higher grain yields were obtained by applying lime + NPK. It was also noted that crop yields were lowest in the N-only treated plots.

A Sustainable Yield Index (SYI) was calculated over the last 25 years using the following relation:

$$SYI = \frac{\overline{Y} - ó}{Y_{max}}$$

where; $\overline{Y}$ = average yield over years;
ó = standard deviation;
Y_{max} = maximum yield obtained with any treatment.

A high SYI would indicate a more progressive management practice capable of producing high yields over the past 25 sampled years. Results show SYI values for NPK + lime plots were highest at 0.58 for corn and 0.47 for wheat (**Table 2**). The SYI for organically manured plots was 0.30 for corn and 0.23 wheat. Control and NPK treatments had the lowest calculated SYI values.

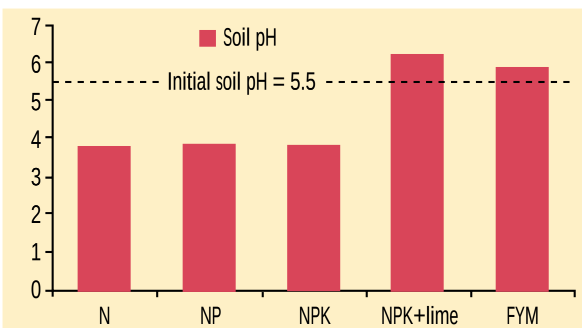

Figure 1. Change in soil pH with continuous cropping and fertiliser use in an acid soil (pH in control plot = 5.8), Ranchi, India.

Through continual monitoring of changes in soil properties, the

(continued on page 19)

Dr. Shihua Tu Joins PPIC Staff as Deputy Director, China Program

Dr. Shihua Tu joined the staff of PPIC in the new position of Deputy Director, Southwestern China. He will work from a newly inaugurated office in the Sichuan Academy of Agricultural Sciences (SAAS) in Chengdu, Sichuan province. PPIC offices are already established in Hong Kong, Beijing, and recently in Wuhan.

Dr. Tu received his B.Sc. degree at Sichuan Agricultural University in 1982 and began his career with the Soil and Fertilizer Institute of the Sichuan Academy of Agricultural Sciences. He later continued his education at the University of Manitoba, Canada, earning his M.Sc. in Soil Science in 1989 and completing his Ph.D. in Soil Chemistry in 1993.

In 1994, Dr. Tu rejoined the Soil and Fertilizer Institute of the Sichuan Academy of Agricultural Sciences. He is a leading soil scientist on soil chemistry and fertility research. In 1995 and 1996, he was appointed Vice-Director of the Institute, and in December 1996 became Director, continuing until May of 1998.

Dr. Tu will direct programs in agronomic research and education related to market development for potash and phosphate in Sichuan, Chongqing, Yunnan, and Guizhou provinces. BCI

Balanced Fertilizer Use...*(continued from page 18)*

study determined soil pH was most affected in fertilized plots that were unlimed (**Figure 1**). The use of NPK + lime or FYM did not result in a significant increase in soil acidity.

Long-term experimentation reveals that acid soils of eastern and northeastern India would clearly benefit from balanced fertiliser use along with adequate liming. This best management practice (BMP) has been proven to produce high yields in corn and wheat crops. The application of FYM caused no appreciable effect on soil acidity, but produced yields that were about one-half to two-thirds of those obtained with a combined treatment of NPK + lime. BCI

Dr. Sarkar is Professor and Head and Professor Lal is Senior Scientist (Soil Science), at Birsa Agricultural University, Ranchi, Bihar, India. Dr. Dev is Director, PPIC-India Programme, Gurgaon, Haryana, India.

Sugar Cane Response to Nitrogen, Phosphorus and Potassium Application in Andisol Soils

By Ovidio Perez and Mario Melgar

Volcanic ash soils (Andisols) cover 25 percent of the sugar cane production area in Guatemala. These soils are rich in allophane minerals, which give them special abilities to accumulate organic carbon (C) and fix plant-available forms of phosphorus (P) and sulphur (S). Therefore, nutrient fixation is perhaps the main chemical constraint of Andisols, which demand special crop management practices in sugar cane.

Guatemala's sugar cane region is located on its southern coast and includes both the volcanic lowland (piedmont) and coastal valleys that extend from sea level to 800 m above. The total area producing sugar cane is approximately 180,000 ha, with potential for production on 320,000 ha.

Fertilization of Sugar Cane in Guatemala

Amounts, sources and method of fertilizer application vary according to the sugar factory policy and demand for their product. However, to date, sugar cane fertilization in Guatemala is largely concentrated on nitrogen (N). Phosphorus is applied only once every 5 to 6 years when plantations are renovated or when new fields are established. Potassium (K) application in this region is even less frequent. Within each sugar factory (Ingenio) field, generalized fertilizer recommendations are used for all soils and plantations.

Sugar cane response to 84 kg P_2O_5/ha is shown at Ingenio Madre Tierra, Guatemala.

In 1993-94, the Guatemalan Center for Research and Training on Sugar Cane (Centro Guatemalteco de Investigacion y Capacitacion de la Caña de Azucar, CENGICAÑA), initiated a series of field studies aiming to obtain detailed information on N, P and K. The specific objectives were to (1) determine the relative importance of N, P and K in Andisols; (2) determine the best rates of N, P and K for high yield sugar cane; (3) determine the magnitude of the effect of residual P and K on sugar and sugar cane yields in the second growing cycle; and (4) determine the effect of splitting 50 percent of the recommended P and K rates between the first and second crop cycles.

Sugar cane plants at left in photo show response to equally splitting P and K fertilizer over 2 years.

Research was conducted for 4 years in the fields of four sugar cane companies; ‘El Baul’, ‘Madre Tierra’, ‘Concepción’ and ‘Pantaleón’. Soils at each site were Typic Hapluand Medial or Pachic Melanudand with pH values ranging from 5.8 to 6.1 and organic matter levels ranging from 7.3 to 11.9 percent. Extractable soil P and K levels were less than 2.7 mg/kg and 0.27 to 1.40 meq/100 g, respectively. Twelve treatments were arranged using 4 levels of N (50, 100, 150, and 200 kg/ha) and 4 levels of P_2O_5 and K_2O (0, 50, 100 and 150 kg/ha). Four additional treatments were tested to evaluate the effect of splitting P and K applications. The study also included zero N (0-100-100) and control (0-0-0) treatments. Nitrogen was banded and covered in both years. Split N applications were made 30 and 90 days after sowing or after the first harvest. Phosphorus and K were applied at the bottom of the furrow before planting.

Table 1. Main effects of N, P and K for the first and second years of sugar cane in four Andisols in Guatemala.

		El Baul (var. CP 722086) t/ha		Madre Tierra (var. CP 722086) t/ha		Concepción (var. Mex 68P23) t/ha		Pantaleón (var. Mex 68P23) t/ha	
Nutrient	kg/ha	Year 1	Year 2	Year 1	Year2	Year 1	Year 2	Year 1	Year 2
N	0	137.2	116.8	143.2	121.1	159.5	150.2	178.6	123.6
	50	139.8	118.0	147.2	125.8	163.7	167.9	175.0	122.3
	100	—	121.7	—	131.2	—	179.8	—	122.3
	150	144.0	126.4	144.0	130.2*	172.6	172.5*	168.3	119.5
P_2O_5	0	131.7	121.7	131.1	125.6	169.9	166.4	167.1	120.2
	100	152.3	123.0	160.7	130.7*	166.4	173.8	176.0	121.4
K_2O	0	140.0	118.7	143.0	127.5	167.2	170.9	169.2	120.4
	100	143.8	125.3	149.0	128.7	169.2	169.8	175.0	121.3
Variation coef.	CV (%)	5.6	7.6	7.4	5.7	7.3	8.4	9.7	7.4
Yield avg.	t/ha	141.3	121.4	145.5	127.6	167.0	168.9	172.7	121.4

*Significant NP positive interaction.

Table 2. Statistically significant coefficients of the regression model (first harvest year).

	Yield,	Terms and coefficients									Rate,[1]
Place	t/ha	N	N^2	P	P^2	K	K^2	NP	NK	PK	kg/ha
Concepción	157.12	0.217	-0.009								80 N
El Baul	131.6			0.307	-0.0018			0.0011			94 P_2O_5
Madre Tierra	132.0			0.707	-0.0039						84 P_2O_5

[1]Fertilizer rate for maximum economic yield with Q[2]4.60 kg/N (Concepción); Q 65.00/t sugar cane (Concepción); Q 4.46/kg P_2O_5 (El Baul and Madre Tierra); Q 75.00/t sugar cane (El Baul and Madre Tierra).
[2]Q refers to Quetzales, the official currency of Guatemala.

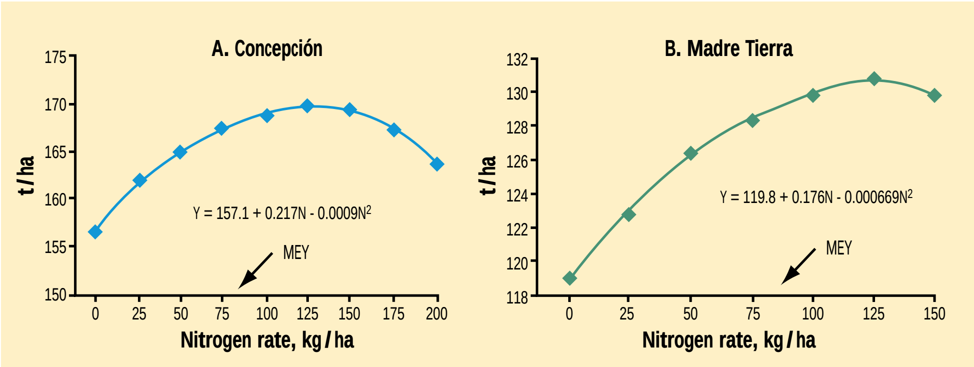

Figure 1. (A) Estimated sugar cane response to N fertilization (first year), variety CP-722086 in Concepción.
(B) Effect of N on sugar cane yield (ratoon crop, second year).

Results

The effects of N, P and K on sugar cane yield for the first year and second year are summarized in **Table 1**. Nitrogen fertilization resulted in a significant yield response in El Baul and Concepción with both sugar cane varieties (*CP 722086* and *Mex 68P23*). During the second year, a response to N was observed in Madre Tierra and Concepción.

Significant yield responses to N at these 2 locations were obtained despite organic matter levels greater than 9 percent. However, at Pantaleón an even higher organic matter level of 11.9 percent likely prevented a significant N response.

Highly significant responses to P fertilization were found in El Baul and Madre Tierra with sugar cane variety *CP 722086*. Phosphorus fertilization at 100 kg/ha of P_2O_5 increased the average first year sugar cane yield by 20.6 t/ha in El Baul and 29.6 t/ha in Madre Tierra and confirms the importance of annual P application in these soils.

The residual effect of P applied at 100 kg/ha of P_2O_5 was only significant at the Madre Tierra site where yield was increased by 5.1 t/ha. Small but not statistically significant residual effects on yield were observed with 100 kg/ha of P_2O_5 at all other sites. These results are not surprising due to the dominant presence of allophane minerals in the test soils. Allophanes adsorb and 'fix' fertilizer P over the crop year and further reduce fertilizer use efficiency and subsequent plant availability in the second crop year.

Fertilizer rates needed to achieve maximum economic yield (MEY)

Table 3. Effect of P and K split applications during the second cycle (year) in sugar cane yield.

P_2O_5	K_2O	Year applied,	Yield response, t/ha			
kg/ha		%	El Baul	Madre Tierra	Concepción	Pantaleón
100	100	Year 1 (100)	—	—	—	—
100	100	Year 1&2 (50/50)	4.55 ns	12.43[1]	8.4 ns	5.53 ns
		CV (%)	7.6	5.7	8.4	7.4
		X (t/ha)	123.0	128.8	169.2	121.0

[1]150 kg N/ha in both years in each treatment.

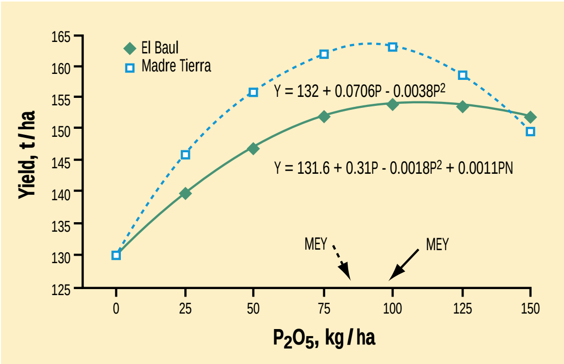

Figure 2. Regression models for P response in sugar cane in two Andisols used to estimate MEY.

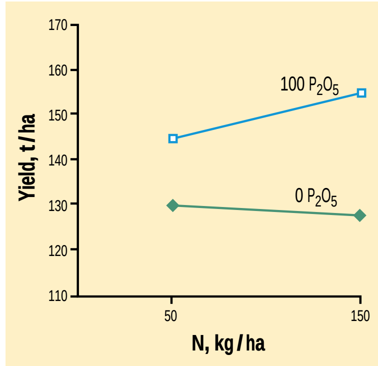

Figure 3. Effect of N in sugar cane yield (first year) with and without P fertilization in 'El Baul'.

are presented through regression analysis (**Table 2**). At Concepción, the most economic N rate was 80 kg/ha (**Figure 1**). In the case of P, the most economic rate ranged from 84 to 94 kg/ha P_2O_5 depending on the site (**Figure 2**). The El Baul site had a significant linear interaction between N and P (**Figure 3**).

Split Phosphorus and Potassium Applications

A 50-50 split of P and K between the first and second years increased sugar cane yield in Madre Tierra by over 12 t/ha. Sugar cane yield responses at Concepción (8.4 t/ha), Pantaleón (5.5 t/ha) and El Baul (4.5 t/ha) were not statistically significant (**Table 3**). However, these results do suggest that higher yields are possible through the practice of splitting P and K.

Potassium Response and Sugar Production

Small, but not statistically significant, increases in sugar content were found with the application of 100 kg/ha K_2O at all four sites. Sugar concentrations fluctuated between 9.1 percent (La Concepción) to 13.6 percent (Pantaleón). Therefore, any observed increase in yield was directly related to greater cane production. Further research is needed with higher K doses to study possible interactions between N and K. The effect of time of K application on sugar content and subsequent sugar produced also needs further study.

Guatemala's sugar cane region is on the southern coast, including the volcanic lowland and coastal valleys.

Conclusions

Phosphorus was identified as the key-limiting nutrient in sugar cane production and ratoon crops. Split P applications may significantly increase yields of sugar cane in Andisols with high P fixation capacity. Optimizing P rates near 94 kg/ha may increase yields by over 32 t/ha in low P soils. In these high organic matter soils, a 10 t/ha yield

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China: Balanced Fertilization for Sustained Yield and Quality of Tea

A survey of Chinese tea gardens revealed over half the sampled areas to be deficient in potassium (K). Deficiencies were concentrated in the southern provinces of Guangdong, Guangxi and Yunnan, which had an average available K content of 80 mg/kg. The northern regions appeared well managed, but only 16 percent of samples from Jiangsu, Anhui and Hubei had plant-available K levels greater than 150 mg/kg. The survey identified a close relationship between K deficiency and low magnesium (Mg) availability. Unbalanced fertilizer programs based on urea and other ammonium-nitrogen (NH_4-N) fertilizers promoted Mg uptake by tea and aggravated leaching losses due to increased soil acidity.

A 4-year field trial in southern China examined the effect of K and Mg fertilization on black, oolong and green tea yield and quality. The combination of K and Mg created greater nutrient use efficiency and increased yields by 17 to 28 percent for green tea, 9 to 38 percent for oolong tea, and 10 to 18 percent for black tea. Leaf quality characters such as free amino acids, polyphenols and caffeine were significantly improved by combining K and Mg. Reseachers recommend a post-harvest application during plant dormancy as the optimum time to adopt this balanced approach. **BCI**

Source: Hardter, R. 1997. ASIAFAB, 17: 31-33.

Sugar Cane Response... *(continued from page 23)*

response can still be expected with the application of 80 kg/ha of N. Annual banded applications of P_2O_5 and K_2O at 50 kg/ha each year would be preferable to a combined biannual application of 100 kg/ha at planting. This practice produced significant yield response at all sites and produced a highly significant response at Madre Tierra. Management of P fertiliser in Andisols utilizing split applications every year may become a very important tool to maximize sugar cane yields in Guatemala and other regions of Central America. **BCI**

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Balanced Fertiliser Use Increases Crop Yield and Profit

By G. Dev

Balanced fertilisation refers to the application of essential plant nutrients in optimum quantities and proportions. Balanced nutrient supply is a best management practice (BMP) that should also include proper application methods and timing for the specific soil-crop-climate situation. This BMP ensures efficient use of all nutrients, maintenance of soil productivity, and conservation of precious resources.

The importance of balanced fertilisation is clearly visible from the large number of long-term experiments conducted on cropping sequences throughout different agro-climatic zones in India (**Tables 1** and **2**). Balanced fertilisation's positive effect on farm income is self evident both before and after the governmental price restructuring process that took place in 1992 (**Figure 1**).

Research is showing the advantages of improved crop production with balanced fertilisation.

Ratio as an Indicator of Balanced Fertiliser Use

The nitrogen (N), phosphorus (P), and potassium (K) use ratio is valuable as an index of balanced fertilisation if comparing large regions of diversified crops and soils such as a states or countries. As an example, grain based sys-

Table 1. Effect of balanced nutrition on yield of different crops, India.

Crop	Season and condition	Number of trials	Nutrients $N-P_2O_5-K_2O$, kg/ha	No fertiliser, t/ha	Yield increase over control, %		
					N	NP	NPK
Rice	Kharif, unirrigated	380	120-60-40	2.42	49	74	99
Rice	Kharif, irrigated	9,634	120-60-60	2.96	27	51	56
Rice	Rabi, irrigated	5,686	120-60-60	3.20	28	51	53
Wheat	Rabi, irrigated	10,133	120-60-60	1.55	59	95	114
Sorghum	Kharif, unirrigated	367	90-60-60	1.10	51	80	97
Sorghum	Rabi, unirrigated	389	90-60-60	0.61	56	92	120
Maize	Kharif, unirrigated	53	90-60-60	1.23	85	107	129
Pearl millet	Kharif, unirrigated	207	90-60-60	0.50	54	110	130
Finger millet	Kharif, unirrigated	120	90-60-60	1.25	46	96	118
Chickpea	Rabi, unirrigated	1,325	20-40-20	0.75	36	59	77
Pigeon pea	Kharif, unirrigated	53	20-40-20	0.30	97	210	227

Source: Randhawa, N.S. and H.L.S. Tandon (1992). Fertiliser News 27(2) 11-26.
Note: Kharif season is planting in June-July. Rabi season is planting in October-November.

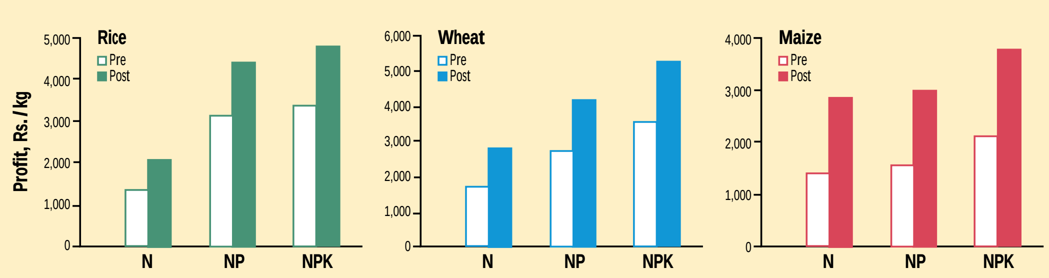

Figure 1. Profit from 9,634 rice, 10,133 wheat and 53 maize production trials before (pre) and after (post) fertiliser price changes in August 1992. Price in Rs./kg before August 1992: N=6.65, P_2O_5=7.57, K_2O=2.83, paddy rice=2.7, wheat= 2.75, maize=2.10. Prices after August 1992: N=7.96, P_2O_5=14.63, K_2O=6.62, paddy rice=3.8, wheat=4.15, maize=3.60.

tems in developing agriculture systems such as in India have a target NPK use ratio of 4:2:1. However, the nutrient use ratio provides no indication of the actual amounts of nutrients being applied in that region and does not give an accurate assessment of fertiliser use among crops.

Different crops demand soil nutrients in ranging proportions. For example, legumes may need nutrients in a ratio of 0:1:1, 1:2:2, or 1:2:3; root crops in a ratio of 2:1:2, etc. Therefore, crop requirements should only be based on fertiliser response data, nutrient offtake through harvest, and the specific nutrient supplying status of the soil.

Through considerable efforts, NPK use ratios in India narrowed to 5.9:2.4:1 in 1991-92 (**Table 3**). However, August of 1992 brought about the removal of subsidies on P and K fertilisers and a 10 percent decrease in the controlled price of urea. This intervention caused a drastic reduction in P and K consumption and widened India's NPK use ratio for years since. It may be noted that the NPK use ratio for 1996-97 had still not recovered to the level obtained in 1991-92.

Table 2. Average grain yields (kg/ha) in long-term (17 year) trials, India.

Location	Crop	Treatment: Control	N	NP	NPK	NPK+FYM	CD (5%)	CV
Barrackpore	Rice	1,947	3,952	4,245	4,398	4,468	176	13
	Wheat	785	2,083	2,245	2,342	2,430	90	12
Ludhiana	Maize	413	1,408	1,893	2,483	3,232	46	6
	Wheat	891	2,732	3,961	4,686	4,801	67	3
Coimbatore	Finger millet	687	945	2,640	2,604	3,093	138	15
	Maize	585	703	2,666	2,902	3,388	145	16
Jabalpur	Soybean	1,047	1,296	2,093	2,217	2,438	–	–
	Wheat	1,125	1,625	3,698	3,854	4,327	–	–
Hyderabad	Rice, kharif	1,630	2,756	3,276	3,499	4,086	–	–
	Rice, rabi	1,706	3,176	3,552	3,574	4,333	–	–
Ranchi	Soybean	952	502	1,125	1,470	1,753	–	–
	Wheat	1,175	640	2,248	2,488	2,624	–	–
Bhubaneswar	Rice, kharif	1,677	2,344	2,405	2,925	3,427	143	13
	Rice, rabi	1,493	2,465	2,824	3,076	3,682	143	12
Palampur	Maize	258	995	2,547	3,222	4,691	249	17
	Wheat	396	656	2,079	2,609	3,303	147	14

Source: Nambiar, K.K.M. (1994). Soil fertility and crop production under long-term fertiliser use., ICAR, N. Delhi.

Imbalanced Use of Nitrogen Accelerates Depletion of Other Nutrients in Soil

Neither yield nor profit can be sustained using imbalanced application of fertilisers as the practice may result in accelerating deficiencies of other soil nutrients. As an example, application of N alone in various crop sequences commonly depletes available soil P (**Table 4**).

Table 3. NPK (N-P_2O_5-K_2O) use ratios for India.

Year	NPK ratio
1970-71	6.3:2.3:1
1975-76	7.7:1.7:1
1980-81	5.9:1.9:1
1985-86	7.0:2.5:1
1991-92	5.9:2.4:1
1992-93	9.5:3.2:1
1993-94	9.7:2.9:1
1994-95	8.5:2.6:1
1995-96	8.5:2.5:1
1996-97	10.0:2.9:1
1997-98	7.9:2.8:1

Secondary and Micronutrients Are Equally Important in Balanced Fertiliser Use

Balanced fertilisation programmes must be developed to remove all yield-limiting factors. Therefore, nutrient balance must be considered beyond N, P and K. Shifts in consumption from low to high analysis fertilisers can create secondary and micronutrient deficiencies. Sulphur (S) application is now needed in pulse and oilseed based cropping systems. Yield responses to S in cereals are often recorded. In rice-wheat cropping systems, zinc (Zn) is now considered a deciding factor for crop success or failure. Average wheat yield responses (kg/ha) to different secondary and micronutrients in India are: S, 813; Zn, 360; iron (Fe), 190; manganese (Mn), 590; copper (Cu), 380; and boron (B), 380.

Table 4. Soil P depletion from use of N only in intensive cropping systems, India.

Location	Soil	Cropping sequence	kg/ha P_2O_5 removed by crops: Control plot	kg/ha P_2O_5 removed by crops: N only plot
Barrackpore	Alluvial	Rice-Wheat-Jute	321	642
Ludhiana	Alluvial	Maize-Wheat-Cowpea	183	412
New Delhi	Alluvial	P. Millet-Wheat-Cowpea	160	366
Coimbatore	Black	F. Millet-Wheat-Cowpea	344	458
Jabalpur	Black	Soybean-Wheat-Maize	275	366
Hyderabad	Red	Rice-Rice	527	847
Bhubaneswar	Laterite	Rice-Rice	275	458
Palampur	Hill	Maize-Wheat-Potato	155	252
Pantnagar	Terai	Rice-Wheat-Cowpea	893	1,420

Source: Beaton, J.D., Dev, G., and Halstead, E.H. (1993). FAI Seminar, SVI-3/1-3/8.

Soil Test Based Fertiliser Use Means Balanced Use

Soil test based fertiliser recommendations ensure balanced fertiliser use. India has 514 (including 133 mobile) soil testing laboratories with a total capacity for analysing about 6.8 million soil samples per annum. Despite this extensive network, there is a strong need to strengthen existing laboratories by increasing the number of plant nutrients they determine and by increasing their capacity to provide a faster and more meanigful service to farmers.

Conclusion

Balanced and adequate fertilisation is essential for increasing crop yields and ensuring sustainable agriculture. No developed or developing country in the world has been able to increase agricultural production without expanding the use of balanced fertilisation. In fact, in countries where consumption of plant nutrients is low and imbalanced, agricultural production is also low, and yields are stagnant or declining. India is no exception to this phenomenon. **BCI**

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Potash Increases Productivity for Fish Ponds

By G.N. Chattopadhyay, S. Neogy, and G. Dev

India has 1.6 million ha of fresh water with aquacultural potential, and demand for fish products is growing rapidly. During 1994-95, production of fish in India was 4.79 million tonnes. Fish productivity can be increased through intensification of cultural practices. One important aspect is efficient nutrient use. Proper fertilisation enhances production of primary organisms upon which fish feed, in turn affecting fish growth rates.

At present, it is common for fish pond nutrient management schemes to include nitrogen (N) and phosphorus (P) fertilisers along with organic manures and lime. Information on potassium (K) fertilization of fish ponds is limited worldwide. It is commonly believed that wetland soils with high clay content, high organic matter, and alkaline reaction maintain adequate amounts of K in pond soil and water phases. Therefore, application of K in fish ponds is often assumed unnecessary. Fish ponds on red and lateritic soils exhibit a different picture as they often have light textures, acid reactions, poor organic matter, and a low available K status. These red and lateritic soils represent 91 million ha in India.

Table 1. Properties of red and lateritic soil samples and their correlation to primary organism productivity, West Bengal, India.

Soil property	Range	r-value
Silt + Clay, %	5 to 79	0.105
Organic C, %	5.2 to 8.0	0.151
CEC, meq/100g	11.2 to 19.0	0.256
Available N, mg/kg	202 to 376	0.023
Available P, kg/ha	2 to 17	0.507*
Available K, kg/ha	68 to 410	0.447*
pH	5.2 to 8.0	0.486*

*Significant at 5% level.

Relationship between Soil Properties and Primary Organism Productivity of Fish Ponds

Soil and water samples were collected from 23 fish ponds from various red and lateritic soil zones in West Bengal. Samples were analysed for texture, organic carbon, pH, cation exchange capacity (CEC), and available N, P, and K. The resulting ranges are presented in **Table 1**. Important links were highlighted as primary organism productivity of pond waters was significantly correlated with available P, K, and soil pH.

Potash Improves Fish Pond Productivity

Laboratory studies were conducted in glass aquariums involving five pond soils added at a soil to water ratio of 1:30. The K treatments consisted of four levels: 0, 15, 30 and X kg K_2O/ha (where X kg/ha refers to the fertiliser level added to maintain water soluble K at the suggested critical level (1.3 mg/l) for fish production. Potash was combined with currently recommended rates of N and P fertiliser.

Table 2. Average net primary organism productivity (mg/cm^3/ha) under different rates of K.

Soil number	Treatment, kg K_2O/ha 0	15	30	X
1	0.41	0.79 (92.7)*	0.76 (85.4)	0.75 (83.0)
2	0.56	0.96 (71.4)	0.78 (39.3)	0.58 (3.6)
3	0.53	0.94 (77.3)	0.71 (34.0)	0.55 (3.8)
4	0.78	1.24 (59.0)	1.10 (41.0)	0.69 (-11.5)
5	0.60	0.98 (63.3)	0.86 (43.3)	0.67 (11.7)
Average	0.58	0.98 (69.0)	0.84 (44.8)	0.65 (12.1)

*Indicates percent increase in primary organism productivity over the zero K treatment.

Two years of study showed the combination of K with N and P fertiliser resulted in a positive increase in productivity of primary fish food in all treatments except one case (**Table 2**). Among the K levels tested, application of 15 kg K_2O/ha was more effective than 30 kg K_2O/ha. The practice of maintaining water-soluble K at the current recommendation of 1.3 mg/l (X) resulted in inferior production of primary food stocks.

Interaction among Potash, Manure and Lime

Use of organic manure and lime are popular practices for increasing fish pond productivity. This practice is especially important for fish ponds situated in red and lateritic soils since these soils are generally acidic and low in organic matter. In view of this, another laboratory study was conducted to assess the effect of K on primary productivity in the presence of cow manure and lime. Manure was applied at 0, 5 and 10 (the currently recommended rate) t/ha. Lime was applied at 0, 50 and 100 percent of the lime requirement. Potassium was applied at either 0 or 30 kg K_2O/ha.

Table 3. Average net primary organism productivity (mg/cm^3/ha) with applied K under organic manure and lime treatments.

Soil number	Organic matter (Percent of recommended rate)	Lime requirement (Percent of recommended rate)	Treatment, kg K_2O/ha 0	30	Increase, %
1	0	0	0.09	0.16	77.8
2	0	50	0.09	0.16	77.8
3	0	100	0.14	0.20	42.8
4	50	0	0.13	0.19	46.2
5	50	50	0.18	0.20	11.1
6	50	100	0.10	0.19	90.0
7	100	0	0.06	0.11	83.3
8	100	50	0.07	0.13	85.7
9	100	100	0.11	0.22	100.0

Application of K increased the primary organism productivity levels in all treatments (**Table 3**), ranging from 11.1 to 100 percent. Responses to applied K were higher in the presence of manure and lime. These results suggest that K may be a yield-limiting factor in many fish ponds where N, P, manure, and lime are applied in adequate concentrations.

Conclusions

Potash application is an important component for efficient fish production in ponds located over red and lateritic soils. Its application increases production of primary food stocks for fish. Current recommendations prescribing application of inorganic N and P along with manure and lime amendments should be adjusted to include adequate K. **BCI**

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Balanced Fertilisation and the Law of the Minimum

By G. Dev

The importance of balanced fertilisation in increasing crop yields is recognised world-wide. Nutrient imbalance produces low yields, low fertiliser use efficiency, and low profits for farmers. It also results in further depletion of the most deficient nutrients in the soil. Once the critical level of any one plant nutrient is reached, crop yields will fall despite the fact large amounts of other nutrients are applied.

The idea of balanced fertilisation is not new. In fact, Justus von Liebig, a German chemist, defined the Law of the Minimum in 1867. He outlined the need to provide plants with a correct balance of nutrients. Liebig recognised that any one deficiency could limit growth and leave other available nutrients unused or poorly utilized by the plant. This concept is equally applicable in today's modern agriculture. Diagrammatically, the Law of the Minimum is shown in **Figure 1**. The process of balancing crop nutrients involves adjustment of fertiliser recommendations to a particular crop, soil, yield goal, fertiliser availability, or resource level of the farmer. This process can be achieved using response curves already established through well-conducted research.

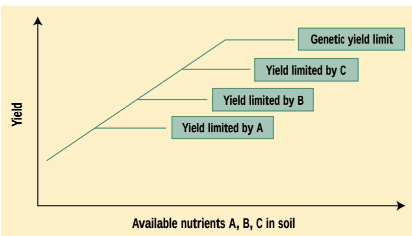

Figure 1. Schematic of von Liebig's Law of the Minimum.

The following example presents results from a long-term experiment (1979-90) on a maize-wheat sequence conducted at Punjab Agricultural University, Ludhiana. Wheat response curves to applied nitrogen (N), phosphorus (P), and potassium (K) are shown in **Figure 2**. The figure outlines the fertiliser combinations required to obtain a specific wheat yield. A balanced application of 120-80-40 kg/ha of N-P_2O_5-K_2O produced a yield of 4.7 t/ha.

However, in the event that a farmer fails to apply K due to a lack of funds or product availability, the yield benefit that would have accrued due to K is lost. Thus, extrapolating the curve to 0 kg K_2O/ha results in a lower expected yield of 4.4 t/ha. In this situation, the required fertiliser levels work out to be 112-72-0 kg/ha of N-P_2O_5-K_2O.

In an even more limiting example, if either P or K fertiliser is unavailable or no funds exist to purchase P and K, the expected yield for wheat will be reduced to 2.2 t/ha. As in the previous case, extrapolating the curves results in a fertiliser recommendation of 40-0-0 kg/ha of N-P_2O_5-K_2O.

This process of nutrient balancing can be performed to suit other situations involving different yield goals, resources of the farmer, etc. In fact, the principle of the Law of the Minimum can be applied to any factor that could

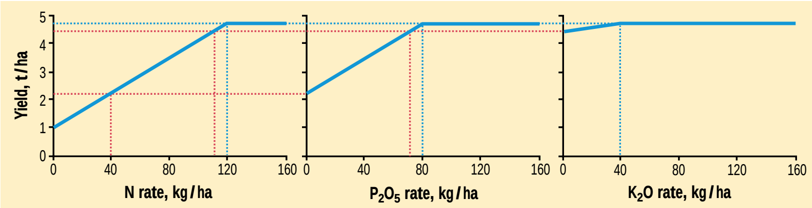

Figure 2. Balancing of nutrients applied to wheat in a long-term maize-wheat experiment (1979-90); 120-80-40 kg/ha of N-P_2O_5-K_2O gives a yield of 4.7 t/ha.

limit yield (water, farmer management, temperature, soil physical contraints, etc.). These types of limiting factors are found in every farmer's field. This lends credibility to the saying that "every field has something limiting yield." Liebig's Law of the Minimum focused only on plant nutrients, but the principle fits other conditions in cropped fields. No farmer or researcher has achieved the genetic yield potential (**Figure 1**) of any crop. Agricultural extension agencies should use this knowledge to assist farmers in adapting to different cropping situations and to focus on correcting limiting factors. This tool will enable farmers to obtain their highest yield, fertiliser use efficiency, and profit. **BCI**

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U.S.A.: Potassium-Rich Foods May Reduce Risk of Stroke

Foods containing higher levels of potassium (K) and related nutrients may help reduce the risk of stroke, especially in people with high blood pressure. Bananas, tomatoes, spinach, and oranges are good sources of K in the diet.

An 8-year study of nearly 44,000 men in the health care field parallels the results of earlier, smaller studies. It found that men who ranked in the top fifth according to how much K they consumed had a 38 percent lower risk of stroke than those in the bottom fifth. The major difference in the diets of the top fifth and bottom fifth groups in the study was the amount of fruits and vegetables. The highest-K group had about nine servings per day, compared with four in the lowest.

"There is strong support for a stroke-preventive effect from diets rich in potassium, magnesium, and cereal fiber," said Dr. Alberto Ascherio, MD, a professor of nutrition and epidemiology at the Harvard School of Public Health, Boston, Massachusetts.

Researchers caution that K supplements should not be taken without a doctor's supervision because high levels of such products can be harmful, especially for people with kidney problems.

Potassium intake in the diet can be increased by substituting fruits, vegetables, and their natural juices for low-K processed foods and sodas. **BCI**

Source: Circulation, 1998; 98:1198-1204, a journal of the American Heart Association, Inc.

Food Policy and Fertiliser

Without phosphorus, there is no cell, no plant, and no grain.
Without phosphorus, there is a lot of hunger...
And this goes for potassium, nitrogen, sulphur, zinc, and so forth.

I use this homily when addressing the issue of fertiliser use in food production.

It is unfortunate that in too many countries of the world, food policy either doesn't exist or it is solely directed towards reducing the cost of food. In either case, primary agricultural producers are inevitably given too little compensation for their efforts, and progress is slowed. Hence, too many people suffer the ravages of insufficient food, malnutrition, or both.

The appropriate use of plant nutrients – fertiliser – in high yielding and progressive crop production is essential if the world is to feed itself. When nutrients are supplied at adequate rates and in balanced formulations, the environment is much better protected as are farmers' incomes and society's supply of food. U.S. President Franklin Delano Roosevelt astutely observed that: "The nation that destroys its soil destroys itself." This is a true and guiding principle for sustainable development...for today and tomorrow. It is as appropriate now as it was in the 1930s when President Roosevelt made that comment.

Food policy becomes the fulcrum on which we balance risk versus benefit in adding fertiliser to the environment. It provides the perspective for developing technologies that improve the quality and quantity of food and the efficiency by which it is produced. The world can no longer be content with a simplistic food policy.

Each and every nation needs clear direction in developing meaningful food production strategies. The readers of this publication have great 'stories' to tell; information on how we can produce food better with fertiliser applications. Tell it!

Dr. Mark D. Stauffer
Senior Vice President,
International Programs, PPI
and President, PPIC

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