BETTER CROPS SOUTH ASIA

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In This Issue...

Fertiliser Rate and Timing Effects on Rubber

Managing Fertilisers and Organics on Acid Soils

Integrating Foliar K for Improved Mango Yield

Also:

IPNI Scholar Awards in South Asia

...and much more

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BETTER CROPS–SOUTH ASIA

Volume 5, Number 1, December 2011

Our cover: Immature rubber plantation at Taranagar, Block Mohonpur, Dist., West Tripura, Tripura, India.

Photo by Mr. Bhaskor Dutta, Scientist, RRII, Agartala

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Introduction to Better Crops South Asia 2011

On behalf of the International Plant Nutrition Institute (IPNI) its a pleasure to introduce our 2011 edition of *Better Crops South Asia*. This is the fifth Issue–released annually each December–that follows a format similar to our quarterly publication known as *Better Crops with Plant Food*. However, *Better Crops South Asia* features research articles and information pertinent to this specific region. The research featured in this issue is a tribute to the scientific progress that is continually being made in the fields and laboratories throughout South Asia. Once again, we at IPNI wish to congratulate and thank the many cooperators, researchers, farmers, industry representatives, and others who are working in a positive mode for South Asian agriculture.

Dr. Terry L. Roberts, President, IPNI

2011 Scholar Award Recipients Announced by IPNI

The 2011 winners of the Scholar Award sponsored by the International Plant Nutrition Institute (IPNI) have been selected. The awards of USD 2,000 (two thousand dollars) are available to graduate students in sciences relevant to plant nutrition and management of crop nutrients.

"We had a higher number of applicants for the Scholar Awards this year, and from a wider array of universities and fields of study," said Dr. Terry L. Roberts, IPNI President. "And the qualifications of these students are impressive. The academic institutions these young people represent and their advisers and professors can be proud of their accomplishments. The selection committee adheres to rigorous guidelines in considering important aspects of each applicant's academic achievements."

In total, twenty graduate students were named to receive the IPNI Scholar Award in 2011, with the most widespread geographic distribution ever for the awards. The winners from the South Asia Region are:

Gopal Ramdas Mahajan, Indian Agricultural Research Institute, New Delhi, India

Shahid Hussain, University of Agriculture, Faisalabad, Pakistan

Sumanta Kundu, Institute of Agricultural Sciences, Calcutta University, Kolkata, India

Funding for the Scholar Award program is provided through support of IPNI member companies, primary producers of nitrogen, phosphate, potash, and other fertilisers. Graduate students attending a degree-granting institution located in any country with an IPNI programme region are eligible. Following is a brief summary for each of the winners from South Asia.


Gopal Ramdas Mahajan

Mr. Gopal Ramdas Mahajan is pursuing his Ph.D. in Soil Science and Agricultural Chemistry at the Indian Agricultural Research Institute (IARI) in New Delhi, India. His dissertation title is "Development of Site-Specific Integrated Nutrient Management for the Hybrid Rice-Wheat Cropping System Using Soil Test Crop Response Correlation Studies." Mr. Mahajan earned his Masters in 2009 from Banaras Hindu University, Varanasi, Uttar Pradesh and a Bachelors degree in 2007 at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. Mr. Mahajan's research is focused on developing individual as well as whole crop system soil test-based recommendation systems for target yields of hybrid rice and wheat and to develop in-situ spectral methods of fertilizer recommendation for the same cropping system. Mr. Mahajan has a strong rural background and his intentions are to work as a scientist at a grass roots (village) level in an effort to increase awareness about balanced plant nutrition with the goal of maximizing local benefits both in terms of farm profitability and environmental protection


Shahid Hussain

Mr. Shahid Hussain is working toward a doctorate degree at University of Agriculture in Faisalabad, Pakistan. His dissertation is titled "Bioavailable Grain Zinc in Wheat Varieties of Pakistan and Strategies for Biofortification." This study aims to evaluate zinc fertilisation and other agronomic means to increase grain zinc concentrations and to decrease the phytate-to-zinc molar ratio (an indicator of zinc bioavailability) in wheat grains. For the future, Mr. Hussain hopes to become an agricultural scientist and to continue his research efforts on biofortification of cereal grains with essential minerals.


Sumantu Kundu

Mr. Sumanta Kundu is completing requirements for his Ph.D. Program in Agronomy at the Institute of Agricultural Sciences in Calcutta University, India. His dissertation title is "Improving Nutrient Use Efficiency and Profitability through Conservation Tillage and Improved Nutrient Management in the Maize-Horsegram Cropping Sequence in Rainfed Alfisols." This research [located at the Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad] is aimed to develop a set of best management practices that include a sustainable nutrient management strategy in combination with conservation tillage and soil amendments. BC-SA

Rate and Time of Fertiliser Application Influences Growth of Immature Rubber and Soil Fertility in Tripura

By D. Mandal, T. K. Pal, M. Choudhury, and S. K. Dey

Rate and time of NPK fertiliser application did not affect the growth of immature rubber in the first 3 years of a field study. However, from the fourth year, they had a significant effect on the girth of rubber plants and number of tappable plants. A decline in available K in surface soil even at the highest level of K application suggests K vulnerability of the rubber growing soils of northeastern India.

In India, the cultivation of natural rubber (*Hevea brasiliensis*) has generally been confined to a narrow tract in the southwest region located between 8⁰N to 12⁰N. But increased domestic rubber demand and the scarcity of land in the traditional rubber-growing area has led to farmer's cultivating rubber in non-traditional areas like in the northeastern (NE) region of India.

Nutrient requirements of rubber are likely to be higher in the NE region compared to the the traditional rubber-growing region as the majority of the soils in the NE region are degraded and poor in fertility due to shifting cultivation (Chowdhury et al., 2001, 2004; Krishnakumar and Potty, 1989a, 1989b, 1990). Moreover, rubber has a long gestation period of 7 years, and in the NE region, this period often gets increased by one more year due to abiotic stresses like low winter temperature, soil moisture deficit between January-March, hail storms, etc. Application of higher doses of NPK during early years was reported to reduce the immature period of rubber (Dijkman, 1951, Owen et al., 1957, Bolton, 1960). In the traditional rubber growing region, fertilisers are generally applied in two equal split doses (once in April/May and once in September/October) synchronizing with the two peak rainfall seasons (southwest and northeast monsoons) of this region. But in the NE region of India, only the southwest monsoon is active from June through September. This is followed by a cool period from October to November. Therefore, low soil moisture together with low air temperature after the post-monsoon fertiliser application often lead to poor absorption of nutrients and poor girthing of plants. The challenge therefore is to develop a fertiliser recommendation package that is relevant to the soil and climatic conditions of the NE region. The present field experiment was initiated in 2004 to optimise time and level of fertiliser application for young rubber grown in the NE state of Tripura.

The experiment was conducted in 2004 in a farmer's field at Amtali, Agartala (Latitude: 23⁰45'N; Longitude: 91⁰27') with clone RRIM 600 as the planting material. The experimental soil is an Alfisol with clay-loam texture. The trial was laid out in a factorial randomized block design with ten treatments and four replications. Each block had 25 gross plants with nine net plants. Growth and tappability of plants were recorded from the inner nine plants only to eliminate the border effect of other treatments.

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

Table 1. Recommended NPK rates (kg/ha) in different years of rubber growth.

	N	P_2O_5	K_2O
First year	14	14 (7)*	7
Second year	50	50 (25)	25
Third year	65	65	35
Fourth year	50	50	25
Fifth year	35	35	35

*Values in parentheses denote water soluble P_2O_5 (kg/ha) supplied through SSP

Table 2. Influence of rate and time of fertiliser application on mean girth* (cm) during late immature phase of rubber plantation.

Treatments	4th year	6th year	7th year
Control	18.3	32.1	39.8
50% RDF	21.6	36.2	43.7
100% RDF	24.5	41.4	47.5
150% RDF	21.7	39.2	46.5
50% RDF (two equal splits)	22.7	37.2	44.6
100% RDF (two equal splits)	26.1	42.2	49.1
150% RDF (two equal splits)	24.1	40.4	47.7
50% RDF (2/3:1/3 split)	22.2	38.0	45.8
100% RDF (2/3:1/3 split)	23.6	40.2	47.6
150% RDF (2/3:1/3 split)	24.2	41.3	48.6
Mean	22.9	38.8	46.2
CD (p = 0.05)	3.7	4.8	5.5

*Stem girth measured at 150 cm height from bud union; RDF = recommended dose of fertiliser, presently followed.

Treatments used in the experiment are detailed as follows:

A. Fertiliser levels (4)
- i. No fertiliser (control)
- ii. 50% of the recommended dose of fertiliser (RDF)
- iii. 100% RDF
- iv. 150% RDF

B. Timing of fertiliser application (3)
- i. Single application (pre-monsoon)
- ii. Two equal, split applications (pre- and post-monsoon)
- iii. 2/3rd during pre-monsoon and 1/3rd during post-monsoon.

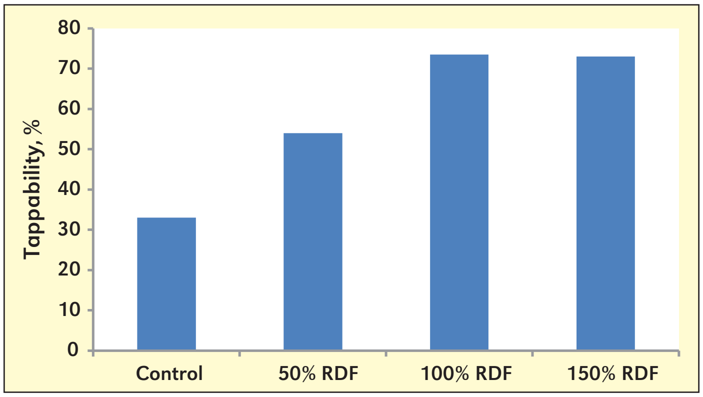

Figure 1. Influence of fertiliser rates on tappability of plants (end of 7th year).

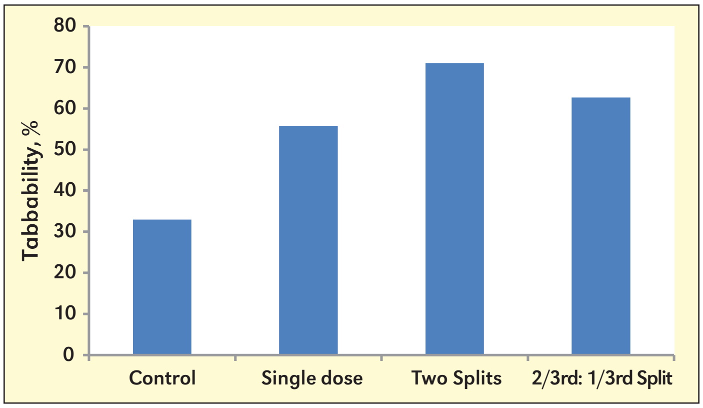

Figure 2. Effect of split fertiliser application on tappability of plants (end of 7th year).

The fertiliser rates used in the present experiment were recommended by Rubber Research Institute of India (RRII) and are shown in **Table 1**. Nitrogen was supplied as urea and potassium as muriate of potash. In the initial 2 years, 50% of the applied P was supplied using rock phosphate (citrate-soluble P) and the rest was applied using SSP (water-soluble P) for good root development and early establishment of plants. Routine culture operations were carried out following the recommendations of the RRII. For the first 4 years of rubber growth, fertiliser was applied over a circular band of about 30 to 75 cm width around the plant base. The applied fertiliser was slightly forked into the soil as practiced in the NE region while it was broadcasted in the subsequent years. Trunk diameters (girth) of the plants were measured from the bud union at a height of 25 cm for the initial 2 years and thereafter at a height of 150 cm. Tappability of plants was computed based on the percent of plants attaining trunk girth of 50 cm. Replicated soil samples were collected from the experimental area at depths of 0 to 30 cm and 30 to 60 cm prior to the commencement of the experiment. At the end of 4th and 6th years, soil samples were again collected from each plot and analyzed for pH, organic carbon (OC), available P, and available and non-exchangeable K following standard procedures (Baruah and Barthakur, 1997). At the end of the 4th and 6th years of plantation, leaf samples were also collected from each plot and analyzed for NPK content.

A view of a tapped, mature rubber plantation located in northeast India.

Growth of Plants

Growth data for the initial 3 years of plantation showed no significant difference in girth of the plants due to nutrient treatments. However, at the end of the 4th year, rubber plants responded significantly to the application of N, P, and K fertilizers **(Table 2)**. The girth difference between plants receiving NPK fertilisers and no fertiliser ranged from 3.9 to 9.3 cm. The recommended rate of NPK applied in two equal splits registered the highest average girth (49.1 cm) among all the treatments.

Influence of split fertiliser application on the growth of rubber was compared between two regimes, viz., regime I (April to September: Southwest monsoon period) and regime II (October to March: Post-monsoon cool period) **(Table 3)**. In regime I, fertiliser applied in a single dose or on the 2/3rd: 1/3rd basis contributed 74 to 77% towards the annual mean increment. The corresponding value for fertiliser applied in two equal splits was 68%. In regime II, fertiliser application in two equal splits contributed about

Table 3. Influence of split application of fertiliser on the growth of rubber.

Treatments	Annual mean girth increment, cm	% increment (April-Sept) Southwest monsoon	% increment (Oct-March) Cold period
Control	5.1	76 (3.87)	24 (1.23)
50% RDF	5.7	78 (4.45)	22 (1.25)
100% RDF	6.2	77 (4.77)	23 (1.43)
150% RDF	6.1	77 (4.69)	23 (1.41)
50% RDF (two equal splits)	5.8	69 (4.01)	31 (1.79)
100% RDF (two equal splits)	6.4	69 (4.41)	31 (1.99)
150% RDF (two equal splits)	6.2	67 (4.15)	33 (2.05)
50% RDF (2/3:1/3 split)	5.9	75 (4.42)	25 (1.47)
100%RDF (2/3:1/3 split)	6.2	74 (4.58)	26 (1.62)
150% RDF (2/3:1/3 split)	6.3	76 (4.78)	24 (1.52)
CD (p = 0.05)	0.9	(0.56)	(0.28)

Values in parentheses are girth increment in cm; RDF = recommended dose of fertiliser.

Table 4. Influence of rate and time of fertiliser application on nutrient content of rubber leaves.

Treatments	N, % 4th year	N, % 6th year	P, % 4th year	P, % 6th year	K, % 4th year	K, % 6th year
Control	2.67	2.71	0.16	0.17	0.83	0.86
50% RDF*	2.68	2.76	0.15	0.19	0.91	0.93
100% RDF	2.69	2.98	0.18	0.18	0.94	0.95
150% RDF	2.70	3.10	0.16	0.20	0.97	0.96
50% RDF (two equal splits)	2.82	2.90	0.20	0.21	0.96	1.02
100% RDF (two equal splits)	2.85	2.96	0.19	0.20	1.07	1.10
150% RDF (two equal splits)	2.87	2.98	0.18	0.22	1.04	1.10
50% RDF (2/3:1/3 split)	2.85	2.90	0.17	0.19	0.90	0.93
100%RDF (2/3:1/3 split)	2.80	2.92	0.16	0.21	0.92	1.05
150% RDF (2/3:1/3 split)	2.82	2.97	0.16	0.21	0.98	1.12
Mean	2.77	2.91	0.17	0.20	0.95	1.01
CD (p = 0.05)	ns	0.18	ns	ns	0.13	0.14

*RDF = recommended dose of fertilizer.

32% towards the annual mean growth of rubber, while the corresponding values for single fertiliser application and the 2/3rd: 1/3rd application (i.e. T_8-T_{10}) ranged between 23 and 26%. Because rubber is a tropical crop, it showed higher girthing during the southwest monsoon period (regime I) when favorable agro-climatic conditions prevailed. This period was the active growth period. During regime II, plant growth is retarded due to low winter temperature, soil moisture stress, and other abiotic factors. Thus, our experiment showed that the application of fertiliser at the right rate and at right time helped lessen the effect of growth-retarding factors and ensured higher girthing during non-favorable times of rubber growth.

Tappable Plants

A trunk girth of 50 cm is important for commercial exploitation of rubber plants. Therefore, the influence of fertiliser doses on rubber plants attaining tappable girth was evaluated **(Figures 1 and 2)**. At the end of the 6th year, tappable plants ranged from 0 to 18%, while at the end of the 7th year, these ranged from 33 to 84%. Among the fertiliser rates, highest tappability (71%) was obtained with the recommended dose of fertilisers **(Figure 1)**. Correspondingly, fertiliser applied in two equal splits helped the highest (71%) number of plants to attain tappable girth **(Figure 2)**. Higher tappability under two equal split applications may be due to better utilization of nutrients by plants, whereas a single application of NPK or application of higher doses before pre-monsoon might have lead to more losses of nutrients by leaching or by greater fixation in soils.

Leaf Nutrient Content

Leaf samples were analyzed for N, P, and K contents after 4 and 6 years of rubber plantation **(Table 4)**. The data revealed a significant improvement in N and K content of leaves due to fertiliser application. Critical level for leaf N for rubber is 3 to 3.5%. In the present case, leaf N varied from 2.7 to 3.1% with a mean value of 2.9%. The critical values for leaf K are 1 to 1.5%. After the 6th year of plantation, leaf K content ranged from 0.86 to 1.12% with a mean value of 1.01%. A significant improvement in leaf K values was observed with application of higher doses of K fertiliser. Also, this effect was more pronounced when K was applied in two equal splits. Increased leaf N and leaf K values for the plants in the treated plots suggested higher uptake of N and K resulting in higher girthing of plants over the control plot.

Soil fertility

Effect of different fertiliser treatments on soil fertility status

Table 5. Potassium balance in the experimental plots

Treatments	Applied K fertiliser, kg/ha	Initial values, kg/ha I*	Initial values, kg/ha II*	After 4th year, kg/ha I	After 4th year, kg/ha II	After 6th year, kg/ha I	After 6th year, kg/ha II	After 4th year, Increase (+) or decrease (-) I	After 4th year, Increase (+) or decrease (-) II	After 6th year, Increase (+) or decrease (-) I	After 6th year, Increase (+) or decrease (-) II
Control	0	123	85	85	94	70	101	-38	9	-54	16
50% RDF**	66	114	87	76	101	65	110	-38	14	-49	22
100% RDF	133	131	98	74	116	72	141	-57	18	-60	43
150% RDF	199	129	110	105	90	72	125	-14	-20	-47	16
50% RDF (two equal splits)	66	124	85	81	94	72	128	-43	9	-52	42
100% RDF (two equal splits)	133	125	109	121	96	101	110	-4	-12	-25	1
150% RDF (two equal splits)	199	129	74	83	112	83	121	-46	38	-46	47
50% RDF (2/3:1/3 split)	66	125	110	94	108	78	119	-31	-2	-47	9
100%RDF (2/3:1/3 split)	133	131	75	81	101	69	137	-50	25	-61	62
150% RDF (2/3:1/3 split)	199	125	95	98	110	78	114	-27	14	-47	19
	Mean	126	93	90	102	76	120	-35	9	-49	28
	CD(p=0.05)	ns	ns	ns	ns	ns	ns	-	-	-	-

*I: 0 to 30 cm soil depth and II: 30 to 60 cm soil depth.
**RDF – Recommended dose of fertiliser.

was also evaluated. No significant improvement in OC content of soil was observed in surface and sub-surface soils due to fertiliser application (data not shown). Available P content in acid soils of Tripura is quite low. In the present study, a general soil analysis done prior to the start of the experiment showed poor available P status (1.1 to 2.7 kg/ha). After the 6th year of plantation, P values were only marginally improved (4.2 to 4.5 kg/ha) (data not shown). This might be due to higher P fixation in acid soils. Plant available K content of these soils **(Table 5)** varied from low to medium (i.e. critical values between 112 to 280 kg/ha), and these values were found to decrease over time particularly in the surface soil. At the end of the 6th year of plantation, no significant difference in available K was found among any of the treatments used in the study. The slow reduction in soil available K values in the surface soil could be attributed to higher K fixation capacity of these soils, leaching loss due to high rainfall, and percolation of K in soil profile as evident from the gradual increase in available soil K within the sub-surface layer **(Table 5)**. A net negative K balance of -49 kg/ha was observed in the surface (0 to 30 cm) soil over a period of 6 years **(Table 5)**, whereas accumulation of 28 kg/ha K occurred in the sub-surface (30 to 60 cm) soil. However, considering the amount of K application, it becomes quite evident that a substantial amount of K was either washed away or fixed. Therefore, K management in the rubber growing soils of Tripura calls for special attention.

Conclusion and future needs

Application of the recommended rates of NPK fertilizers in two equal splits increased girth and tappability of rubber trees. However, the recommended nutrient rates did not improve the native fertility of the experimental soil. In fact, they led to the depletion of K in the soil. More studies are needed to optimize nutrient rate and timing of fertilizer application to achieve the twin goals of productivity improvement and sustenance of soil fertility in rubber growing areas of Tripura.

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Integrated Nutrient Management for Groundnut and Redgram on Acid Soils in Odisha

By Sushanta Kumar Pattanayak, U.K. Misra, A.K. Sarkar, and K. Majumdar

On-farm experiments for 3 years in 130 farmers' fields showed that soil test-based fertiliser application, integrated with inorganic and organic ameliorants, significantly improved productivity, crop quality parameters, and economic return in groundnut and redgram in acid upland soils of Odisha. Post harvest soil analysis showed improved status of organic C, N, and P in treated plots, but available K status declined—emphasising the need for close monitoring and appropriate K application in such soils.

About 100 million hectares (M ha) of land in India is designated as acidic, half of which is under cultivation. Soil acidity and poverty are synonymous in the state of Odisha where 80% of soils are acidic. Low water holding capacity, high bulk density, and soil crusting along with chemical constraints like low pH, low CEC, low base saturation (16 to 67%), high Al, Fe and Mn saturation, and high P fixing capacity (80 to 91%) are major reasons for low crop productivity in such soils (Misra et al., 1989). Acid soils are generally deficient in Ca, Mg, P, Mo, B, and Si. The availability of Fe, Mn, Cu and Zn is high, sometimes reaching toxic levels. These problems can be managed by inorganic and organic ameliorants. Lime application (inorganic) increases pH, base saturation, and CEC; and reduces Al, Fe, and Mn availability, acidity and P fixation (Panda and Koshy, 1982; Misra et al., 1989; Sahu and Patnaik, 1990; Mishra and Pattanayak, 2002). Organic ameliorants (FYM/compost) reduce exchangeable Al in soil through precipitation with OH-ions (Hue, 1992; Iyamuremye et al., 1995). The organic acids released from organic ameliorants complex with Al and Fe, reducing their availability and harmful effects. Combined use of organic and inorganic ameliorants simultaneously controls soil acidity, reduces Al and Fe toxicity, and increases nutrient availability (Misra and Das, 2000; Mohanty and Pattanayak, 2000) leading to better crop growing conditions in these soils.

The present study was conducted in Dhenkanal, Balasore, and Mayurbhanj districts of Odisha covering 16 villages and 130 farmers over three consecutive years (2006, 2007, and 2008). The soils of the study area are classified as Alfisols, Inceptisols and Entisols. These coarse-textured soils are generally low in basic cations due to crop removal and leaching. The soils of the study area were acidic (pH 4.6 to 5.3), with low status of organic C (2.5 to 4.2 g/kg soil), N (105 to 128 kg/ha), P_2O_5 (3.8 to 5.8 kg/ha), and K_2O (28 to 97 kg/ha). Six different fertilisation strategies including: (i) Farmers' Practice or Control, (ii) 100% NPK based on soil test, (iii) 50% of soil test-based NPK + Lime, (iv) 100% of soil test-based NPK + Lime, (v) 50% of soil test-based NPK + Lime + FYM at 2 t/ha, and (vi) 100% soil test-based NPK + Lime + FYM at 2 t/ha were studied in the common groundnut-redgram intercropping system comprised of six rows of groundnut sown alternatively with two rows of redgram. The soil test-based 100% NPK fertiliser rates for both crops was determined by matching soil N, P, and K fertility levels (low, medium, and high) with the corresponding fertility level-based recommendations from the State. Thus the 100% NPK recommendation was 20-40-40 kg N-P_2O_5-K_2O/ha for both the crops. The primary nutrients were applied through urea, single superphosphate, and potassium chloride. Farmers only use FYM at 2 t/ha. The lime requirement (LR) of these soils ranged from 3.3 to 4.0 t/ha. Lime was applied at 0.2 LR in the form of paper mill sludge (PMS), a locally available liming material (60% $CaCO_3$ equivalent),

Common abbreviations and notes: Al = aluminium; B = boron; C = carbon; Ca = calcium; CEC = cation exchange capacity; Cu = copper; Fe = iron; FYM = farmyard manure; K = potassium; Mg = magnesium; Mn = manganese; Mo = molybdenum; N = nitrogen; NH_4OAcK = ammonium acetate extractable K; P = phosphorus; S = sulphur; OH = hydroxide; OM = organic matter; Si = silicon; Zn = zinc.

Resource poor farmers growing groundnut and redgram were able to improve their income with an integration of 50% of the recommended NPK dose with lime plus FYM.

Table 1. Influence of nutrient management and soil amelioration on yield of redgram and groundnut.

Treatments	Redgram seed yield	Groundnut pod yield	Dry biomass
	-------------	kg/ha	-------------
Farmers' practice	470 (-48)	1,080 (-36)	7,400 (-33)
100% NPK	900	1,690	11,100
50% NPK + PMS	920 (2)	1,770 (5)	10,950 (-2)
100% NPK + PMS	1,040 (16)	1,810 (7)	11,900 (7)
50% NPK + PMS + FYM	1,100 (22)	2,000 (18)	12,230 (10)
100% NPK + PMS + FYM	1,200 (33)	2,080 (23)	13,000 (17.0)
CD (p = 0.05)	142	103	900

Data in the parenthesis indicate percent increase/decrease compared to 100% NPK.

Table 2. Crop quality as influenced by nutrient management and soil amelioration.

Treatments	------- Groundnut ------- Shelling, %	Oil, %	-- Redgram -- Seed Protein, %
Farmers' practice	63.0	43.1	26.3
100% NPK	65.0	44.9	30.0
50% NPK + PMS	65.0	44.6	29.5
100% NPK + PMS	65.3	45.1	30.8
50% NPK + PMS + FYM	67.0	45.9	30.9
100% NPK + PMS + FYM	67.9	45.8	31.4
CD (p = 0.05)	1.3	0.8	1.6

Table 3. Effect of nutrient management and soil amelioration on combined uptake of nutrients (kg/ha) by the intercrop system.

Treatments	N	P	K	Ca	Mg	S
Farmers' practice	180.0	11.7	97.3	59.0	17.6	9.0
100% NPK	310.8	20.3	132.3	105.5	32.5	18.6
50% NPK + PMS	312.2	18.0	118.8	109.9	40.9	17.3
100% NPK + PMS	318.0	22.0	134.1	111.3	42.1	19.3
50% NPK + PMS + FYM	376.2	23.0	124.2	134.0	54.4	19.9
100% NPK + PMS + FYM	379.1	23.3	135.4	138.3	56.3	20.3
CD (p = 0.05)	20.0	1.8	10.0	6.0	2.9	1.2

Table 4. Treatment effects on extra gain of N over farmers' practice and apparent recovery (%) of nutrients in the intercrop system.

Treatments	Extra N gain, kg/ha	APR	AKR ---------- % ----------	ASR
100% NPK	130.8	48	105	32
50% NPK + PMS	132.2	70	124	55
100% NPK + PMS	138.0	54	110	34
50% NPK + PMS + FYM	196.2	62	158	68
100 % NPK + PMS + FYM	199.1	61	124	35
CD (p = 0.05)	6.2	-	-	-

APR, AKR, and ASR denote apparent P, K, and S recovery.

below the seed zone at the time of sowing.

Results

The seed yield of redgram (**Table 1**) varied between 470 and 1,200 kg/ha and that of groundnut pod between 1,080 and 2,080 kg/ha. Application of soil test-based nutrient rates, with or without soil ameliorants, increased redgram seed and groundnut pod yield compared to the farmers' practice. Combining FYM and lime with 100% NPK increased redgram seed and groundnut pod yields significantly by 33 and 23%, respectively, compared to yields due to 100% NPK alone (**Table 1**). Combined application of FYM and lime with 50% of recommended NPK increased redgram seed and groundnut pod yields by 22 and 18.4% compared to 100% NPK alone. No significant yield difference was observed between 100% and 50% of soil test-based nutrient application when applied in combination with lime or lime + FYM. This might be related to the issue of balanced nutrition of crops that goes beyond the context of N, P, and K. Addition of high rates of N, P, and K as part of the treatment may stimulate deficiencies of secondary or micronutrients, which probably was adequate for the 50% NPK rates (Johnston et al., 2009). Acid soils are often deficient in S, B, and Mo and utilization and efficiency of applied N, P, and K can be severely restricted by the deficiencies of such nutrients.

Crop quality was significantly influenced by combined application of fertiliser, lime, and FYM (**Table 2**). The shelling percent and oil content of groundnut pod increased from 63 to 67.9% and 43.1 to 45.8% respectively, by applying the 100% NPK dose of fertiliser with lime and FYM. There was no significant difference in the above parameters between the 50% and 100% NPK doses combined with lime and FYM. Seed protein content of redgram increased from 26.3% with farmers' practice to 31.4% with 100% NPK combined with lime and FYM. Combining nutrients and ameliorants again showed no significant difference in protein content of redgram seed between the 50% and 100% NPK doses.

Removal of nutrients by the test crops (**Table 3**) followed the order N (180 to 379.1 kg/ha) > K (97.3 to 135.4 kg/ha) > Ca (59.0 to 138.3 kg/ha) > Mg (17.6 to 56.3 kg/ha) > P (11.7 to 23.3 kg/ha) > S (9.0 to 20.3 kg/ha). Organic and inorganic ameliorants, either alone or together, created better growing conditions in acid soils which favored (doubled) the uptake of essential nutrient elements. This resulted in extra gain of N, ranging from 131 to 200 kg/ha, and recovery of P, K, and S from 48 to 70%, 105 to 158%, and 32 to 68%, respectively (**Table 4**).

The post harvest soil properties (**Table 5**) indicated that the soils had the tendency of turning more acidic where ameliorants were not applied. Lime (PMS) application, either alone or with FYM, maintained higher pH in the soil by neutralizing the acidity and by buffering action of FYM. The organic C status in soil had increased except under farmers' practice. Mostly the leaf shading property of the crops and FYM addition (in specific treatments) increased organic C status in soil. Both the crops were N fixing leguminous crops, which not only benefited the crops, but also improved the residual N balance in the soil in the form of readily available NH_4^+ and NO_3^--N. The available P status in soil declined significantly under farmers' practice and 50% NPK treatments where addition was low, but maintained the P status in 100% NPK treatments. Maintaining available P status through adequate P application is critical for sustainable production in acid soils. Irrespective of K application rates, available K levels declined sharply in all the treatments except in the farmer's practice, where yield levels are half of the maximum yield achieved in both the crops. This is probably due to mismatch between application rates and crop removal as well as leaching loss of K in coarse-textured soils under high rainfall. This suggests that we need to critically assess the K recommendations for pulses and oilseeds in these depleted, coarse-textured acid soils where recommendations often do not consider yield target, crop uptake, and the possibility of nutrient leaching in a way that could a realistically achieve the twin goals of high productivity and sustained soil fertility.

Acidity in soil increased where no ameliorant was applied and a reverse trend was observed in PMS and organic

Table 5. Average post harvest soil properties after groundnut-redgram intercropping.

Treatments	pH	Organic Carbon	$NH_4^+ + NO_3^-$	Bray IP	NH_4OAcK	Acidity, cmol+	Exchangeable Ca per kg soil
		----- g/kg -----		----- kg/ha -----			
Farmers' practice	4.56	3.0	57	12.0	206	1.66	1.02
100% NPK	4.60	4.3	168	18.0	102	1.62	0.97
50% NPK + PMS	5.58	4.2	102	13.0	113	0.40	1.62
100% NPK + PMS	5.68	4.3	171	16	98	0.39	1.60
50% NPK + PMS + FYM	5.08	4.4	157	14.4	124	0.68	1.52
100% NPK + PMS + FYM	5.74	4.5	168	15	120	0.57	1.54
Initial	4.66	4.0	46	14.0	220	1.56	1.10
Range	4.6-5.3*	2.5-4.2	41-83	9.0-15.3	107-240	1.42-1.61	1.04-1.23
CD (p = 0.05)	0.04	0.03	7.0	1.1	12.0	0.31	0.40

ameliorated soils (**Table 5**). This is due to the loss of basic cations either by crop removal or leaching. This was reflected in the exchangeable Ca status where lime ameliorated treatments maintained exchangeable Ca status while it decreased in farmers' practice and 100% NPK only treatments.

The economic analysis of different nutrient management practices (**Table 6**) indicated that there was a sharp increase in net income in the 100% NPK treatment compared to farmers' practice. Net income was further improved when lime and FYM were added to soil test-based nutrient recommendation. Both inorganic (PMS) and organic (FYM) amelioration of the acid soils in the study area had strong economic impact when applied in conjunction with recommended fertiliser rates. Even 50% of the recommended NPK rate, applied in combination with lime and FYM, increased farmer income by about 70% over the current practices, which can have a strong impact on livelihoods. This prioritizes the importance of soil amelioration, along with proper nutrient management, for increasing the productivity and farmer profit from crops grown on acid soils.

Table 6. Effect of improved nutrient management and soil amelioration on economics of production.

Practices	Expenditure, INR/ha	Gross Income, INR/ha	Net Income, INR/ha	Benefit-to-Cost ratio
Farmers' practice	10,360	31,000	20,640	2.99
100% NPK	17,000	51,800	34,800	3.05
50% NPK + PMS	16,000	53,800	37,800	3.36
100% NPK + PMS	17,100	57,000	39,900	3.33
50% NPK + PMS + FYM	17,000	62,000	45,000	3.65
100% NPK + PMS + FYM	18,100	65,600	47,500	3.62

Costs/Prices used are: N = INR 12/kg, P_2O_5 = INR 143/kg, K_2O = INR 16.2/kg, PMS = INR 10/50 kg, FYM = INR 100/100 kg, redgram = INR 20/kg, and groundnut = INR 20/kg.

Summary

This study highlights that unproductive/less productive acid upland soils (Alfisols, Inceptisols, and Entisols) can improve crop yields through application of soil test-based nutrient rates, integrated with organic and inorganic soil ameliorants. The resource poor farmers in the region growing groundnut and redgram can select an integration of 50% of the recommended NPK dose with lime and FYM and can still improve their income substantially. Farmers with higher resource capacity should aim for higher yield targets through soil test and yield target-based nutrient application. Acid soils are often deficient in S, B, and Mo that can limit the expected responses of applied NPK rates. Further studies are required to look into the secondary and micronutrient deficiencies in these soils and their integration in the fertilisation schedule for further improvement in yield and economics of production.

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Increasing Use Efficiency of Nitrogenous Fertilisers in Fish Ponds

By Amrita Thakur, Abira Banerjee, and G.N. Chattopadhyay

High amounts of nitrogenous fertilisers are usually recommended in fish ponds to encourage the growth of primary fish food organisms, and thereby, the growth of fish. However, use efficiency of these fertilisers tends to be low under a submerged environment. Adoption of some simple management practices can improve the efficiency of nitrogenous fertilisers in fish culture operations.

The major objective of fertilising fish ponds is to improve the nutrient status of the pond soil-water environment for enhancing the growth and abundance of fish food organisms (Mandal and Chattopadhyay, 1992). Among different pond fertilising nutrients, high rates of N fertilisers are usually recommended, ranging from 200 to 400 kg/ha (Boyd et al., 2002). However, only a small portion of this added N gets transmitted to fish, while the rest is lost from the pond environment through various processes like volatilization, leaching, denitrification, etc. (Bouldin et al, 1974; Chattopadhyay and De, 1991). These processes result in significant loss of added N from fish pond systems causing substantial reduction in fertiliser N use efficiency (NUE). Major pathways for N loss from fish pond environments are shown in **Figure 1**. Schroeder (1987) found this efficiency to be as low as 18% of the total N added to the pond as manure and fertiliser. On the other hand, Gross et al. (2000), while working on channel cat fish ponds, observed about 31.5% of the added N to be ultimately transmitted to fish flesh. Their study also showed that the loss of N from the fish pond through denitrification and leaching was about 40.5%, while that from volatilization was around 12.5%. Such large-scale losses not only add to the cost of an aquaculture operation, but are also likely to affect the quality of ground water through leaching of NO_3^--N.

Mandal and Chattopadhyay (1992) suggested that maintaining higher amounts of NH_4^+-N than NO_3^--N in the pond environment may increase NUE. Since NH_4^+ ions can be adsorbed by bottom soil colloids in an easily exchangeable phase, N loss will be less and, as a result, N availability to primary fish food organisms will be improved. However, NH_4^+ ions are also subject to loss through volatilization under highly alkaline conditions—a typical situation encountered in productive fish ponds, especially during high sunshine periods. But the magnitude of this loss is quite less in a fish-pond system when compared with the loss from upland soils (Chattopadhyay, 2004). This paper discusses possibilities of using different N management practices to prevent the loss of N mainly in NO_3^- form and, thus, increase NUE in pond fish culture system.

In rice soils, use of different nitrification inhibitors is gaining popularity for increasing NUE. In view of the similarity between fish ponds and submerged rice soils (Hickling, 1971), Thakur et al. (2004) carried out a mesocosm study to assess the effects of three nitrification inhibitors, viz., neem (*Azadirachta indica*) extract, Karanj (*Pongamia glabra*) and Sodium Azide (NaN_3), on the primary productivity of water under simulated fish pond conditions. All three nitrification inhibitors were used at 1 % w/w with urea added to the submerged soil-water system at 100 kg N/ha rate and incubated under illuminated conditions. The study revealed that the use of nitrification inhibitors resulted in a substantial increase in NH_4^+/ NO_3^- ratios in soil and water, as compared to the treatment without any nitrification inhibitor (**Figure 2**). Nitrification inhibitors helped maintain larger amounts of N in readily available forms

Common abbreviations and notes: Mesocosm = simulated fish pond environment in large aquariums (term modified from "microcosm" that describes simulated fish pond environment in small glass containers); N = nitrogen; NH_4^+ = ammonium ions; NO_3^- = nitrate ions; OM = organic matter.

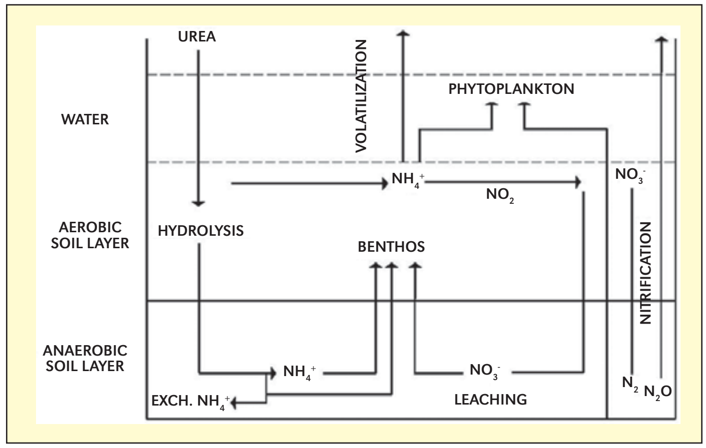

Figure 1. Major pathways for loss of nitrogen from fish pond environment.

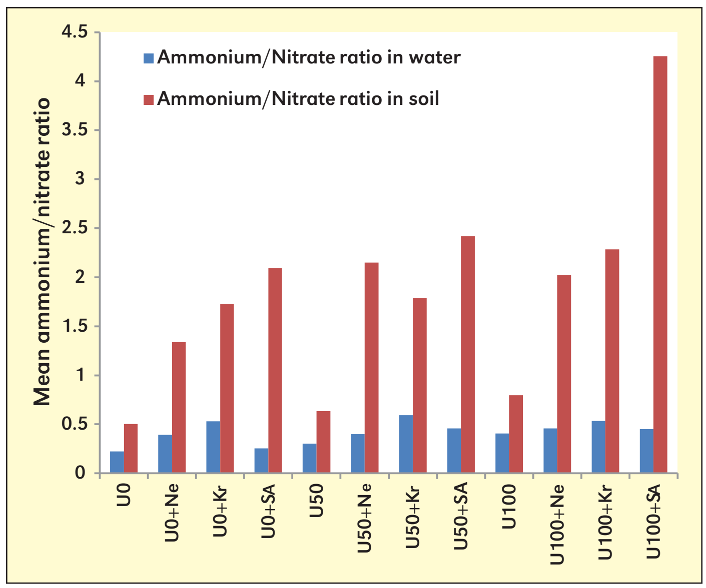

Figure 2. Mean ammonium/nitrate ratio in soil and water under different treatments with nitrification inhibitors. U_0 = no fertilisation, U_{50} = 50 mg N (supplied as urea)/kg soil, U_{100} =100 mg N (supplied as urea)/kg soil, Ne = neem (Azadirachta indica) extract, Kr = karanj (Pongamia glabra) extract, SA = Sodium azide (NaN_3).

Table 1. Effect of nitrification inhibitors on water soluble nitrogen ($NH_4^+ + NO_3^-$ mg/l).

Treatment	15	30	45	60	75	Average
	Days of Incubation					
U_0	3.47	7.77	5.20	23.8	18.2	11.7 g
U_0+Ne	6.77	8.40	9.52	28.2	24.9	15.6 ef
U_0+Kr	4.81	8.96	6.26	27.7	26.6	14.9 f
U_0+SA	5.25	9.03	7.98	26.7	23.4	14.5 f
U_{50}	4.14	9.33	8.17	25.3	21.7	13.7 f
U_{50}+Ne	8.51	10.1	11.6	38.9	32.9	20.4 bc
U_{50}+Kr	6.60	10.1	11.0	45.1	30.6	20.7 b
U_{50}+SA	7.05	13.1	8.95	34.0	30.0	18.6 cd
U_{100}	6.02	10.3	10.5	27.8	30.2	17.0 de
U_{100}+Ne	10.2	11.0	14.5	43.7	38.6	23.6 a
U_{100}+Kr	7.95	12.2	12.4	51.6	33.6	23.3 a
U_{100}+SA	8.00	14.0	13.6	37.1	32.3	21.0 b
CD (p=0.05)	1.64	2.01	2.76	13.5	5.96	

Adapted from Thakur et al. (2004). U_0 = no fertilisation, U_{50} = 50 mg N (supplied as urea)/kg soil, U_{100} = 100 mg N (supplied as urea)/kg soil, Ne= neem (Azadirachta indica) extract, Kr = karanj (Pongamia glabra) extract, SA = Sodium azide (NaN_3). Averages followed by the same letter in the column are not statistically different.

Table 2. Effect of organic matter on readily available nitrogen and gross primary productivity under simulated fish pond condition.

Treatment	Mean water soluble N ($NH_4^+ + NO_3^-$), mg/l	Mean mineralised N ($NH_4^+ + NO_3^-$) in soil, mg/kg	Mean gross primary productivity of water, mg C/m^3/h
N_0SA_0	10.1	101	124
N_0 SA_{100}	11.0	114	154
N_0 SA_{200}	12.4	124	176
N_{50} SA_0	16.0	139	158
N_{50} SA_{100}	16.4	150	207
N_{50} SA_{200}	17.1	164	250
N_{100} SA_0	15.4	171	182
N_{100} SA_{100}	16.8	173	264
N_{100} SA_{200}	17.6	176	301
CD (p=0.05)	1.6	6.14	46.6
SEM	0.52	2.05	15.6

N_0, N_{50}, N_{100} = N at 0, 50, and 100 mg/kg soil, respectively; SA_0, SA_{100}, and SA_{200} = 0, 100, and 200 mg organic material (starch)/g urea, respectively.

($NH_4^+ + NO_3^-$) in soil and water (**Table 1**).

High amounts of organic manures are often used in the fish pond systems in Asian countries (Prowse, 1966). Generally, manures and mineral fertilisers are recommended to be used separately keeping an interval of 15 days in a month (Anon, 1985). During the period of decomposition of organic manures, the dissolved oxygen in water is used by decomposer microbes. As a result, a semi-aerobic or even anaerobic condition may develop near these decomposing organic materials. The magnitude of such development will depend on the decomposability and quantity of the organic load. It was thought that this behaviour of organic manures may be effectively utilized for improving the use efficiency of urea under fish pond conditions. Combined use of organic matter and urea is likely to develop a semi-aerobic environment around the added fertiliser, thus restricting the rapid transformation of the nutrient into NO_3^- form in the absence of adequate availability of oxygen.

Taking this hypothesis into consideration, another mesocosm study was carried out to assess the effect of using urea along with organic matter on NUE (Thakur et al., 2004). In this study, starch was used as OM and was mixed with urea at 0, 1%, and 2% (w/w). Urea, mixed with and without starch, was added to the soil-water system at 0 and 50 kg N/kg soil. Use of the starch treated urea maintained higher levels of NH_4^+-N and NO_3^--N in both soil and water phases and also helped to increase the gross primary production of water from 45 to 66% over the no OM treatment (**Table 2**). In fish culture, fertilisers are generally applied once a month. However, in view of the large-scale loss of N fertilisers from the fish ponds, it was hypothesized that split application of N fertilisers may provide a steady source of N to the primary fish food organisms. This is also expected to prevent high accumulation of N in the soil-water system at any point of time, thus helping to reduce the loss of unutilized N from the culture system. To assess the efficiency of this concept, use of 100 kg N/ha/yr was split into once-a-month, once-a-fortnight, and once-a-week treatments, keeping the total N application rate same under each of these three treatments. The study revealed that more frequent application of urea resulted in higher production of primary fish food organisms as compared to once-a-month urea application (**Figure 3**).

Since these container studies appeared to be quite effective in improving N availability to primary fish food organisms, an on-farm trial was conducted with the objective of assessing the efficiency of combined use of these N management practices under actual field conditions. For this purpose, two fish ponds of similar nature were selected at Goalpara village of Birbhum district of West Bengal, India. Both ponds were treated with similar nutrient rates, viz., N at 100 kg/ha/yr, P_2O_5 at 100 kg/ha/yr, and K_2O at 20 kg/ha/yr. In one pond, the fertilisers were used at once-a-month intervals as per the conventional norm of fish pond fertilisation practiced in India. In the second pond, N was mixed with neem extract at 1% w/w and cow dung slurry at 1:10 urea: slurry ratio and was applied in once-a-fortnight intervals. P_2O_5 and K_2O were applied once-a-month just like in the other pond. All other fish culture operations were carried out in similar manner in both the ponds. The beneficial effects of N management practices were reflected in primary productivity of the pond water. Improved N management practices increased gross and net production of primary fish pond organisms by 35 and 30%, respectively, over

Table 3. Effect of N management practice on some chemical and biological parameters of fish pond soil and water.

Parameters (Mean values)	Conventional fertilisation	Developed fertilisation
$NH_4^+ + NO_3^-$ nitrogen in soil, mg/kg	156	142
$NH_4^+ + NO_3^-$ nitrogen in water, mg/kg	16.9	17.5
Gross primary productivity, mg C/m³/h	543	733
Net primary productivity, mg C/m³/h	397	515

conventional practices (**Table 3**). However, the mean value of mineralized N in the soil phase was found to be marginally lower in the case of developed pond fertilisation. This may be due to the larger uptake of N by primary fish food organisms and also slower release of N into mineralised forms.

It is well established that in any natural pond system, growth and yield of fish are directly dependant on primary productivity levels of the pond (Lavrentyeva and Lavrentyev, 1996). Olah et al. (1986), while working on the productivity of fish ponds under different management practices in India, stated that, on an average, about 2% of the carbon synthesized through gross primary productivity of water is converted into fish flesh. Using this value, Mandal and Chattopadhyay (1992) suggested that for achieving a fish production of 1,000 kg/ha/yr fish pond water should have the capacity to assimilate 13.7 g C/m³/day through photosynthesis under Indian conditions. The improved N management practice in our on-farm trial resulted in additional primary production of 190 mg C/m³/h or 2.30 g C m³/day over the conventional nutrient application system. Using the value from Olah et al. (1986), this additional primary production may be considered equivalent to about 168 kg of fish production per hectare pond area. At an estimated fish price of INR 100/kg, the increased primary production is likely to fetch an additional gross income of INR 16,800.

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A view of farmers harvesting fish from a fish pond.

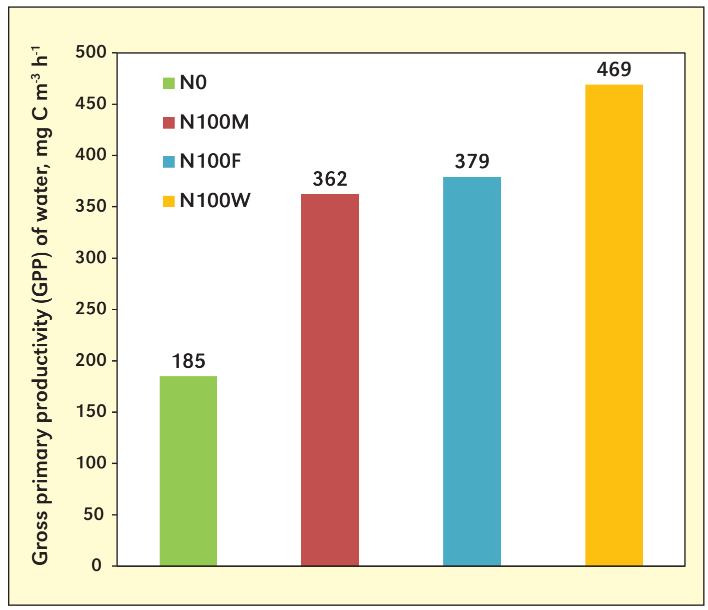

Figure 3. Gross primary productivity (GPP) of water under varying intervals of fertiliser application N0 and N100 = 0 and 100 mg/kg/yr of fertiliser N, respectively; M, F and W = once-a-month, once-a-fortnight, and once-a-week N fertiliser application, respectively.

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Sulphur and Boron Improves Yields of Oilseed Sesame in Sandy Loam Soil of Onattukara

By Jeena Mathew and Sumam George

The growing demand for sesame as an edible oil with good export potential provides an opportunity for farmers to take up its cultivation for better economic returns. However, the crop is generally grown under poor soil fertility and low input use conditions resulting in low yields. Our study showed that along with the recommended doses of N, P, and K, applications of S and B helped increase yields of grain and bhusa (i.e. dry weight of plants after harvest of capsules) and as a result, profitability.

Of all the edible oilseeds grown in India, sesame (*sesamum indicum L.*), commonly known as 'Til', is one of the most important. Sesame seed production in India is estimated to be about 800,000 tonnes, and the growing domestic demand for edible oil products coupled with the emergence of sesame as a strong export crop provides good opportunity for farmers. The sandy loam belt of the Onattukara region in Kerala is considered to be the home of sesame and farmers in this region grow sesame as a third crop (summer) in the rice fallows after two crops of paddy. The relative low water requirement and short duration (less than 3 months) make sesame an ideal crop in this area. The region covers the taluks of Karunagappally, Karthikapally and Mavelikara of Kollam, and the Alleppy districts of Kerala. But the gap between the actual and achievable yields for sesame is wide and better nutrient management practices—with special emphasis to secondary and micronutrients like S and B—offers a solution to bridging the yield gap.

Two field experiments were conducted in two consecutive summer seasons of 2008 and 2009 in the paddy fields of the Onattukara Regional Agricultural Research Station, Kayamkulam, Kerala. The area is located at 90° 30' North latitude and 76° 20' East longitude at an altitude of 3.05 m above mean sea level. The experimental soil is characterized by its coarse-texture, low cation exchange capacity, and a predominance of primary and micronutrient deficiencies. Some physical and chemical properties of the surface (0 to 15 cm) soil were determined (**Table 1**) using standard methods as outlined in Jackson (1973).

The experiment was laid out in factorial randomized block design. Treatments (**Table 2**) included four levels each of S and B: S_0 (0 kg S/ha), S_1 (7.5 kg/ha), S_2 (15 kg/ha), and S_3 (30 kg/ha); B_0 (0 kg/ha), B_1 (2.5 kg/ha), B_2 (5.0 kg/ha), and B_3 (7.5 kg/ha). Gypsum (18% S) and borax (11% B) were used as sources of S and B. Nitrogen, P, K, and FYM were applied uniformly in all treatments at 30, 15, 30, and 5,000 kg/ha, respectively, according to university recommendations (Kerala Agricultural University, 2008). The N, P, and K were applied as urea (46% N), bone meal (21% P_2O_5), and potassium chloride (60% K_2O). Bone meal was chosen as a P source to exclude conventional P sources like rock phosphate and superphosphate which contain S in appreciable quantities. The crop received half the N and K as a basal dressing (at sowing) and the remainder was topdressed 15 days after sowing. All P, S, and B were applied basally. Observations were collected on yield parameters for both years and were analysed using standard statistical tools. Data on harvest index and BCR were also reported for each treatment.

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulphur; B = boron; FYM = Farmyard manure; BCR = Benefit-to-Cost ratio; C = carbon; Ca = calcium; Mg = magnesium.

Table 1. Some chemical properties of soil at the experimental site

Parameters	Values	Category
pH	5.1	Acidic
EC, dS/m	0.3	Non-saline
Organic C, %	0.3	Low
Available P, kg/ha	6.5	Low
Available K, kg/ha	62	Low
Exchangeable Ca, cmol+/kg	0.48	Low
Exchangeable Mg, cmol+/kg	0.03	Low
Available S, kg/ha	10.2	Low
Available B, ppm	0.18	Low

Results

Data on grain and bhusa yields of sesame as influenced by the application of different levels of S and B applications are presented in **Tables 3 and 4**. The maximum grain yield of sesame was recorded with applications of S and B at 30 and 7.5 kg/ha, respectively (**Table 3**). The State recommendation in which only N, P, and K were applied resulted in the lowest grain yield of 562 kg/ha, whereas, application of S and B irrespective of varying rates resulted in an average increase in yield of 87%, respectively. The highest percent increase in yield (155%) was recorded with highest levels of S and B application. This shows that both S and B play an important role in the production of oilseed crops. Sulphur helps in primordial floral initiation resulting in a greater number of capsules per plant and an increasing number of seeds per capsule. Also, S is required for the synthesis of S-containing amino acids and proteins, increases oil content, helps in the

A close up of sesame in flower. Sesame has developed into the most imported edible oilseed crop for India.

Table 2. Treatment details used in the experiment.

No.	Details†
T_1	$N_{30}P_{15}K_{30}S_0B_0$
T_2	$N_{30}P_{15}K_{30}S_0B_{2.5}$
T_3	$N_{30}P_{15}K_{30}S_0B_5$
T_4	$N_{30}P_{15}K_{30}S_0B_{7.5}$
T_5	$N_{30}P_{15}K_{30}S_{7.5}B_0$
T_6	$N_{30}P_{15}K_{30}S_{7.5}B_{2.5}$
T_7	$N_{30}P_{15}K_{30}S_{7.5}B_5$
T_8	$N_{30}P_{15}K_{30}S_{7.5}B_{7.5}$
T_9	$N_{30}P_{15}K_{30}S_{15}B_0$
T_{10}	$N_{30}P_{15}K_{30}S_{15}B_{2.5}$
T_{11}	$N_{30}P_{15}K_{30}S_{15}B_5$
T_{12}	$N_{30}P_{15}K_{30}S_{15}B_{7.5}$
T_{13}	$N_{30}P_{15}K_{30}S_{30}B_0$
T_{14}	$N_{30}P_{15}K_{30}S_{30}B_{2.5}$
T_{15}	$N_{30}P_{15}K_{30}S_{30}B_5$
T_{16}	$N_{30}P_{15}K_{30}S_{30}B_{7.5}$

†Subscripted numbers following each nutrient refer to rates (kg/ha) of N, P_2O_5, K_2O, S, and B. FYM was applied to all treatments at 5 t/ha.

formation of chlorophyll, biotin and thiamine, and plays an important role in the metabolism of carbohydrates, proteins, and fats. On the other hand, B is needed for carbohydrate transport as well as cellular differentiation and development. It also enhances pollen-producing capacity of anthers, viability of pollen tubes, pollen germination, and pollen tube growth.

As with grain yield, S and B also had a significant effect on the bhusa yield (**Table 4**). However, unlike the grain yield response, bhusa yield was highest with relatively lower levels of B and S. Sulphur, like N, improves cell division and cell elongation and has a favourable influence on chlorophyll synthesis. This might have contributed to the increased bhusa yield. The positive influence of S and B in improving yield and yield attributes of sunflower was reported earlier by Shekawat and Shivay (2008). Harvest Index was also significantly influenced by S and B applications at varied levels (**Table 5**).

The economics of sesame cultivation was evaluated via BCR. Results indicated that plots receiving nutrients as per the State recommendation generated less favourable economic returns when compared with treatments using varying levels of S and B. A highest BCR of 4.5 was observed with application of 30 kg S/ha and 2.5 kg B/ha, but this was on par with the treatment providing 30 kg S/ha and 7.5 kg B/ha.

Conclusion

Inclusion of S and B at 30 and 2.5 kg/ha, respectively, within the State fertiliser recommendation has the potential to improve yield, harvest index, and economics of growing sesame in Kerala. BC-SA

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Application of S and B is traditionally ignored in sesame crops, but the practice offers a significant opportunity to its growers.

Table 3. Effect of treatment on grain yield† of sesame (kg/ha).

Treatment	S_0	$S_{7.5}$	S_{15}	S_{30}	Mean
B_0	562	734	1,008	951	814
$B_{2.5}$	1,109	1,026	1,017	1,275	1,107
$B_{5.0}$	1,056	954	1,128	895	1,008
$B_{7.5}$	980	1,088	1,032	1,434	1,134
Mean	927	950	1,046	1,139	
CD (p = 0.05) (S) = 15		(B) = 15		(S x B) = 30	

†Data is the average for 2 years (2008 and 2009).

Table 4. Effect of treatment on bhusa† yield of sesame (t/ha).

Treatment	S_0	$S_{7.5}$	S_{15}	S_{30}	Mean
B_0	13.6	14.72	22.48	17.63	16.63
$B_{2.5}$	19.6	14.65	14.02	25.92	19.04
$B_{5.0}$	22.8	14.99	23.30	15.0	18.54
$B_{7.5}$	13.7	21.59	18.27	19.93	21.61
Mean	15.2	17.49	20.52	22.62	
CD (p = 0.05) (S) = 7		(B) = 7		(S x B) = 14	

†Bhusa refers to dry weight of plant after harvest of capsules.

Table 5. Effect of treatment on the harvest index of sesame (%).

Treatment	S_0	$S_{7.5}$	S_{15}	S_{30}	Mean
B_0	4.0	4.8	4.3	5.1	4.6
$B_{2.5}$	5.4	6.5	6.8	4.7	5.8
$B_{5.0}$	4.4	6.0	4.6	5.6	5.2
$B_{7.5}$	6.7	4.8	5.3	6.7	5.9
Mean	5.1	5.5	5.2	5.5	

Table 6. Effect of treatment on the economics (benefit-to-cost ratio) of sesame cultivation.

Treatment	S_0	$S_{7.5}$	S_{15}	S_{30}	Mean
B_0	2.05	2.36	2.56	3.28	2.56
$B_{2.5}$	3.68	2.38	3.24	4.52	3.46
$B_{5.0}$	3.36	2.64	3.55	2.81	3.09
$B_{7.5}$	2.86	2.88	3.11	4.38	3.31
Mean	2.99	2.57	3.12	3.75	
CD (p = 0.05) (S) = 0.24		(B) = 0.24		(S x B) = 0.49	

Input prices (INR) were: urea = 6/kg, bone meal = 20/kg, potassium chloride (KCl) = 6/kg, gypsum = 6/kg, borax = 55/kg. Sesame seed was valued at INR 90/kg.

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Effect of Different Sources of Potassium on Yield, Quality, and Leaf Mineral Content of Mango in West Bengal

By P. Dutta, B. Ahmed, and S. Kundu

Foliar spray of K_2SO_4 proved more effective than KCl and KNO_3 in increasing the yield, quality, and shelf life of mango grown in the New Alluvial Zone of West Bengal. Irrespective of the K sources used, K application increased N, P, K, Zn, and Mn contents of mango leaf.

Potassium has an important role in influencing both yield and quality of many fruits (Dutta and Dhua, 2000). The application of adequate K along with N and P is well recognized for its contribution to fruit yield and quality responses (Muradov, 1975). Comparisons between K sources often suggest yield and quality (e.g. colour, texture, etc.) advantages associated with selection of K_2SO_4 over KCl (Su, 1969). Dutta (2004) observed that the application of K_2SO_4 (2% solution) improved fruit quality (i.e. total soluble solids, total sugar, ascorbic acid) of guava (*cv. Sardar*). The lack of available information for mango led to the establishment of this study, which examines the effect of different sources of K on yield, quality, and leaf mineral content of the crop.

This study was conducted at the Horticultural Research Station, Mondouri, and in the Post Harvest Technology Laboratory of Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India, for three successive years. The soil at this site was alluvial in nature and sandy loam in texture. Soil pH was 6.6 and it had 0.69% organic C, 0.39% available N, 94 kg P_2O_5/ha, and 280 kg K_2O/ha. The experiment was conducted in a randomised block design with seven treatments and three replications. Fixed doses of N (500 g) and P (250 g) were applied to mango [*cv. Amrapali*, (*Dashehari* × *Neelum*)] plants. This hybrid is precocious, distinctly dwarf, highly regular, late maturing, prolific in bearing, and is more suitable for high density orchards. Its pulp is deep orange red, and it has about 2.5 to 3.0 times more β-carotene than its parents. Because of its attractive flesh colour, this variety is well-suited to the international market.

Various K salts (i.e. K_2SO_4, KCl, and KNO_3) were sprayed four times on the leaves of the whole plant, at either 0.5 or 1.0% concentration, between September and December using 0.1% teepol as a surfactant. The fruits were harvested in the middle of June and brought to the laboratory for physical and chemical analysis using standard methods as outlined by Ranganna (2000). Leaf mineral primary and micronutrient content was also determined. The shelf life of fruit at ambient room temperature (36 to 39°C) and the physiological loss in weight (PLW) were also recorded.

Yield and Fruit Characteristics

Foliar spray of the different K sources showed significant differences for yield or physical and chemical characteristics of the mango fruit. Potassium sulfate (1%) significantly increased fruit weight, fruit length, and yield (**Table 1**). Improvement in fruit yield and quality were more evident with higher levels of K, particularly with K_2SO_4, compared to their lower concentrations (**Table 1 and 2**). Singh et al. (1979) recorded a significant improvement in yield and quality of berry fruit by spraying 1.0% K_2SO_4. Cline and Bradt (1980) also observed a greater increase in berry yield with K_2SO_4 or KCl treatments than with KNO_3. Cohen (1976) observed that K application not only increased the fruit size, but also improved the rind

Common abbreviations and notes: K_2SO_4 = potassium sulphate; KCl = potassium chloride; KNO_3 = potassium nitrate; N = nitrogen; P = phosphorus; K = potassium; Zn = zinc; Mn = manganese; Fe = iron; C = carbon; ppm = parts per million; ATP = adenosine triphophate; NADPH = nicotinamide adenine dinueleotide.

Mango *cv. Amrapali* performs well in high density stands and has many fruit quality traits that are sought-after in international markets.

Table 1. Effect of different sources of potassium on physical characters of mango fruit.

Treatment	Yield, fruit/tree	Fruit weight, g	Fruit length, cm	Pulp, %
K_2SO_4 (0.5%)	173	167.7	9.11	68.1
K_2SO_4 (1.0%)	184	172.2	9.72	69.7
KCl (0.5%)	172	167.2	9.10	67.1
KCl (1.0%)	174	167.4	9.12	67.0
KNO_3 (0.5%)	169	159.0	8.92	64.1
KNO_3 (1.0%)	171	163.0	8.95	64.9
Control	163	158.6	8.12	60.1
SEm ±	0.6	0.2	0.01	0.4
CD (p = 0.05)	1.9	0.6	0.02	1.3

Table 2. Biochemical changes on ripening of mango fruit as influenced by foliar spray of different potassium salts.

Treatment	Total soluble solids, °Brix	Total sugar, % fresh wt.	Acidity, % fresh wt.	Starch, % fresh wt.	Total phenol, % dry wt.	Ascorbic acid, mg/100 g/pulp	β-carotene, μg/100 g
K_2SO_4 (0.5%)	19.80	14.83	0.24	1.93	0.68	39.14	7,200
K_2SO_4 (1.0%)	20.40	15.11	0.23	1.81	0.66	38.11	7,412
KCl (0.5%)	17.40	13.12	0.27	1.94	0.71	39.00	7,100
KCl (1.0%)	17.80	13.72	0.24	1.84	0.67	38.72	7,215
KNO_3 (0.5%)	17.20	14.00	0.27	1.93	0.74	39.72	7,110
KNO_3 (1.0%)	17.80	14.14	0.26	1.92	0.69	38.14	7,310
Control	16.80	13.11	0.31	2.10	0.72	49.14	6,340
SEm ±	0.004	0.003	0.003	0.01	0.02	0.50	18
CD (p = 0.05)	0.012	0.009	0.010	0.03	0.06	1.52	55

thickness in citrus fruit. The increase in the number and size of fruits due to K application may be attributed to the improvement in vegetative growth of the plant as well as efficient transfer of photosynthates to the economic part of the plant. According to Nijjar (2000), K might have acted as activators for a number of complex enzyme systems and these enzymes catalyze metabolic reactions related to the carbohydrates, nucleic acid and nucleotides, amino acids, protein, and folic acid.

Table 3. Effect of different salts of potassium on mineral content of mango leaf.

Treatment	Nitrogen, % dry wt.	Phosphorus, % dry wt.	Potassium, % dry wt.	----- Micronutrients, ppm ----- Zn	Mn	Fe
K_2SO_4 (0.5%)	1.61	0.13	0.92	42.10	91.80	386.00
K_2SO_4 (1.0%)	1.69	0.19	1.11	40.22	92.11	397.00
KCl (0.5%)	1.49	0.14	0.89	39.11	91.30	371.00
KCl (1.0%)	1.50	0.15	0.91	41.72	91.70	361.00
KNO_3 (0.5%)	1.47	0.11	0.91	39.90	95.10	374.11
KNO_3 (1.0%)	1.51	0.19	0.94	41.82	97.11	363.11
Control	1.36	0.12	0.81	36.11	90.11	401.00
SEm ±	0.01	0.04	0.02	0.08	0.12	0.57
CD (p = 0.05)	0.04	0.13	0.07	0.21	0.36	1.73

Fruit Quality

The present study showed considerable improvement in fruit quality with K application. Application of K decreased starch and phenol content of fruit and increased the total soluble solids, total sugar, and β-carotene content of mango (**Table 2**). Starch, titratable acidity, and ascorbic acid content of fruits were lower in K-treated fruits than that of control. This may be attributed to faster rate of ripening with K application. Higher fruit quality, especially higher sugar content, can be explained by the role of K in carbohydrate synthesis, breakdown and translocation and synthesis of protein, and neutralization of physiologically important organic acids (Tisdale and Nelson, 1966). Potassium is responsible for energy production in the form of ATP and NADPH in chloroplast by maintaining balanced electric charges. Besides this, K is also involved in phloem loading and unloading of sucrose and amino acids and storage in the form of starch in developing fruits by activating the enzyme starch synthase (Mengel and Kirkby, 1987). The timing of this study's foliar K application also favours the conversion of starch into simple sugar during ripening by activating the sucrose synthase enzyme. Neutralization of organic acids due to high K level in tissues could have also resulted in a reduction in acidity (Tisdale and Nelson, 1966). Ramesh and Kumar (2007) observed similar results in banana. They obtained 28.9% TSS, 22.36% total sugar, and a 97.64 sugar-to-acid ratio with minimum (0.23%) acidity, due to application of 1.5% K_2SO_4.

Leaf Mineral Content

Irrespective of different K sources, application of K increased the N, P, K, Zn, and Mn content in mango leaf while Fe content declined. Potassium applied as K_2SO_4 showed a higher improvement in N, P, K, Zn, and Mn content of the leaf (**Table 3**).

Table 4. Effect of different sources of potassium on shelf life and physiological loss in weight (PLW) of ripe fruit.

Treatment	Shelf life in days	PLW, %
K_2SO_4 (0.5%)	6	11.72
K_2SO_4 (1.0%)	8	10.42
KCl (0.5%)	4	12.11
KCl (1.0%)	5	12.00
KNO_3 (0.5%)	4	12.41
KNO_3 (1.0%)	4	12.11
Control	3	13.11
SEm ±	0.6	0.48
CD (p = 0.05)	1.5	1.46

The PLW from harvested fruits, especially under tropical condition, causes severe economic losses. Mango trees receiving foliar spray as K_2SO_4 (1%) had a significant reduction in PLW. Fruits treated with K_2SO_4 (1%) recorded a maximum (8 days) shelf-life at ambient room temperature (**Table 4**). This

Table 5. Economics of different sources of potassium on Amrapali mango.

Treatment	Treatment cost†, INR/ha	Total cost, INR/ha	Total yield, kg/ha	Gross income††, INR/ha	Net income, INR/ha
K_2SO_4 (0.5%)	10,000	90,000	11,418	228,360	138,360
K_2SO_4 (1.0%)	20,000	100,000	12,659	253,180	153,180
KCl (0.5%)	9,100	89,100	11,490	229,800	140,700
KCl (1.0%)	18,200	98,200	11,624	232,480	134,280
KNO_3 (0.5%)	8,000	88,000	10,749	214,980	126,980
KNO_3 1.0%	16,000	96,000	11,150	223,000	127,000
Control	-	80,000	10,302	206,040	126,040
CD (p = 0.05)	12	10	10	144	123

† Cost of 500 g of KCl, KNO_3, and K_2SO_4 = INR 455, 400, and 500, respectively.
††Average Price of 1 kg mango = INR 20.

might be due to the fact that K_2SO_4 contains considerably more SO_4-S than other sources. However, Haifa (2009) obtained a most beneficial effect with the application of KNO_3. Extension of shelf life with the application of K_2SO_4 was also observed by Ramesh and Kumar (2007) in banana.

Summary

Foliar spray of different sources of K improved final fruit yield and net income (**Table 5**). The 1.0% K_2SO_4 treatment was most profitable and significantly more income was generated compared to the control. Yield, quality, and economic traits all suggest the advantages from applying 1.0 % K_2SO_4. Finally, it is recommended to integrate sulphate forms of foliar K into the nutrition of mango *cv. Amrapali* along with recommended doses of N and P. BC-SA

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A Review on the Effect of Integrated Nutrient Management on Yield and Quality of Major Seed Spice Crops in India

By O.P. Aishwath, H.S. Khurana, and M.M. Anwer

Research indicates that a combined application of 50 to 75% of the recommended dose of fertilizers and 25 to 50% of organics leads to higher yield and better quality of seed spices as opposed to the application of organics alone.

Seed spices include a group of annuals whose dried fruit or seeds are used as spices. These are characterised by pungency, strong odour and sweet or bitter taste. Coriander, cumin, fennel, and fenugreek occupy the largest area among the seed spices grown in India, while ajowan, dil, celery, anise, nigella, and caraway are the other important seed spices. A majority of seed spices are grown in India in the states of Rajasthan and Gujarat, although Chattisgarh, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, and Uttar Pradesh also have some area under them. In 2008-09, the export of seed spices from India was 471,000 t. This helped earn INR 54,915 billion worth of foreign exchange.

Integrated nutrient management (INM) includes the combined use of organics (i.e. manures, composts, biofertilizers, green manures, crop residues, etc.) and inorganic fertilisers to increase crop yields and farmer profits, improve crop quality and minimise nutrient losses to the environment. This article reviews studies that evaluate the effect of INM on yield and quality of the major seed spice crops of India.

Coriander (*Coriandrum sativum*)

Kumar et al. (2002) studied the effect of N fertilizer (0, 30, 60, or 90 kg/ha) and biofertilizer (i.e. *Azotobacter*, *Azospirillum*, and *Azotobacter* + *Azospirillum*) on the yield and quality of coriander (cv. RCr-435). They found a positive response up to 60 kg N/ha and with the use biofertilizers. Inoculation with *A. chroococcum* or *A. brasilense*, combined with *G. mossese* (VAM), gave significant increases in vegetative growth, total carbohydrates, photosynthetic characteristics, essential oils, seed parameters, N, P and K content, and linalool (Abou and Gomaa, 2002). In red, sandy loam soils, Manure et al. (2000) reported that yield attributes, seed and oil yield, and oil content were all enhanced by the application of N, S, and Zn fertilisers. Sharma et al. (1996) recommended the application of 10 to 20 t/ha of well-decomposed FYM or compost at the time of field preparation along with 20 kg N, 30 kg P_2O_5, and 20 kg K_2O/ha from inorganic fertilizers. Prabu et al. (2000) reported that seed yield of coriander was significantly higher with 25% recommended dose of fertiliser + FYM applied at 10 t/ha + *Azospirillum* + VAM over other combinations of nutrient sources and individual sources of nutrients at their recommended doses. However, Choudhary and Jat (2004) reported higher yield and net return at 100% inorganic N + *Azospirillum* + 5 t FYM **(Figure 1)**.

Common abbreviations and notes: AS = ammonium sulphate; Cu = copper; DAS = days after sowing; Fe = iron; FYM = farm yard manure; N = nitrogen; P = phosphorus; K = potassium; PSB = phosphorus solubilising bacteria; SSP = single superphosphate; VAM = vesicular arbuscular mycorrhizas; $ZnSO_4$ = zinc sulphate

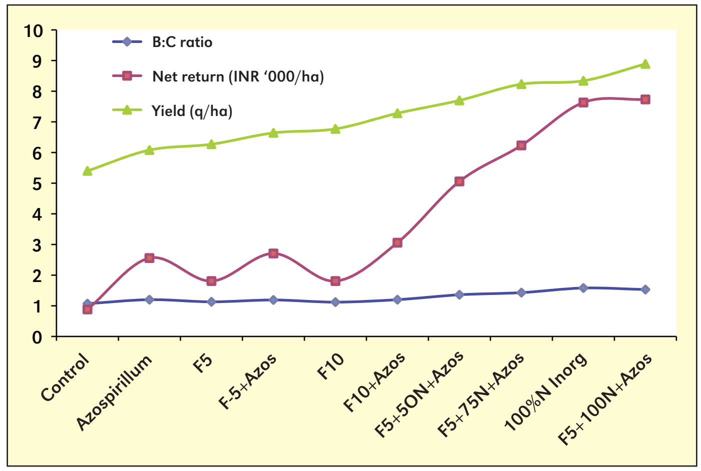

Figure 1. Yield, net return, and benefit-to-cost (B:C) ratio in coriander with different INM treatments. (F5 and F10 indicate FYM added at 5 t and 10 t/ha respectively, Azos refers to azospirillum, and Inorg refers to inorganic)

Cumin (*Cuminum Cyminum*)

Application of 15 to 20 t of FYM is sufficient for the nutrition of rain-fed cumin, but an additional 30 kg of N fertiliser/ha is recommended for irrigated conditions (Peter et al., 2000). Patel et al. (2004) reported that application of the recommended dose of N through mustard-cake and fertiliser in 1:1 ratio recorded the maximum seed yield (869 kg/ha), net return (INR 70,765/ha), and benefit-to-cost ratio (4.4:1) **(Table 1)**. Additionally, cumin grown on loamy sand soils with 30 kg N, 20 kg P_2O_5, and 30 kg K_2O/ha reduced wilt incidence (Champawat and Pathak, 1988). Cumin grown in sequence with pearl-millet responded significantly to the recommended dose of 30 kg N and 15 kg P_2O_5/ha in loamy sand soils of Jodhpur, Rajasthan (Yadav and Poonia, 1996), while an application of 20 kg/ha of $ZnSO_4$ along with 30 kg N/ha significantly increased the seed yield in loamy sand soils of Jobner, Rajasthan (Meena and Chaudhary, 1998).

Cumin Crop

Figure 2. Examples of coriander (left) and fennel (right) plants in unfertilised (top) and fertilised (bottom) plots. Dr. Aishwath (first author) and Dr. Anwer (third author) are pictured on the left and right, respectively.

Fennel (*Foeniculum vulgare*)

Application of 10 to 15 t/ha of well-decomposed FYM or compost at the time of field preparation, 90 kg N/ha in three equal splits (0, 30, and 60 DAS), and 40 kg P_2O_5/ha at the time of sowing produced significantly higher fennel seed yield than obtained with no N application (Sharma et al., 1996). A combined application of 50% inorganic N (90 kg/ha) + *Azospiriullum* + 5 t FYM/ha produced yields on par with 75 and 100% N through inorganic source + *Azospirillum* + 5 t FYM/ha as well as with 100% inorganic N alone, but proved superior to applied 5 t FYM+ *Azospirillum*, 5 and 10 t FYM alone, *Azospirillum* alone and control (Chaudhary, 2004). This indicated that we can substitute some of the inorganic fertiliser application with organics, but not all. On loamy sand soils of Jobner, Rajasthan, soil application of 20 kg $ZnSO_4$/ha along with recommended doses of N, P, and K increased the fennel seed yield by 8% over the control (Sharma, 1998). Multi-nutrient deficiency symptoms in coriander and fennel are clearly visible **(Figure 2)**.

Fenugreek (*Trigonella foenumgraecum*)

Growth and seed yield of fenugreek increased with the applications of 15 t/ha of FYM and 40 kg P_2O_5/ha (Khiriya, et al., 2001). Similarly, combined inoculation of rhizobium and PSB resulted in significantly higher number of nodules per plant, plant height, and dry matter accumulation over individual inoculation and control treatments (Purbey and Sen, 2004). Highest fenugreek seed yield (1.26 t/ha), net returns (INR 9,761/ha) and B:C ratio (6:1) were recorded with 100% inorganic N alone closely followed by 100% inorganic N + Rhizobium applied at 1.5 kg/ha + 5 t FYM/ha (Jat and Chaudhary, 2004). For achieving optimum yield of fenugreek, it was recommended to apply 15 t of FYM/ha and 25 kg N, 25 kg P_2O_5, and 50 kg K_2O/ha (Rethinum and Sadanandan, 1994).

Fenugreek Crop

Nutrient interactions

Synergistic effects between N and P and N and S were observed for seed and essential oil yield in coriander (Sivakumaran et al., 1996). Again, application of 250 kg AS and 120 kg SSP was found to be most suitable for maximum yield and improved quality of cumin (Chandola et al., 1970). Positive interaction among P, S, and growth regulators was found in fenugreek (Rethinum and Sadanandan, 1994).

Micronutrients play an important role in sustaining higher crop yields and improved crop quality. However, carbonates or sodium bicarbonate, either present in soil or in irrigation water, negatively trigger absorption of Cu, Fe, and Zn in coriander, while adversely affecting the translocation of Fe and cases of induced chlorosis have been observed in the calcareous soils of Rajasthan (Aishwath and Anwer, 2010).

Conclusions

An application of 50 to 75% of the recommended dose of inorganic fertilisers and the remaining 25 to 50% through organics gave higher yield and good quality seed spice crops when compared with the application of 100% recommended dose of inorganic fertilisers or organics alone. Micronutrients play a significant role towards improving growth, yield, and quality of seed spices. BC-SA

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Table 1. Yield and economics of cumin with different INM treatments.

Treatment	Seed yield, q/ha	Net return**, INR/ha	Benefit-to-Cost ratio
RD-N* as caster-cake	6.53	49,070	3.02
RD-N as FYM	6.70	50,890	3.16
RD-N as caster-cake + fertiliser (1:1)	7.23	56,585	3.60
RD as fertiliser (NP)	7.59	60,383	3.89
RD-N as FYM + fertiliser (1:1)	7.69	61,245	3.19
RD-N as fertiliser (N)	7.46	59,372	3.90
RD-N as mustard-cake	7.74	60,330	3.53
RD-N as mustard-cake + fertiliser (1:1)	8.69	70,765	4.39
CD (p = 0.05)	0.78		

*RD-N refers to recommended dose of N.
**Approximate costs (including application) (INR/q): Castor cake = 3,720; FYM = 3,516; Fertiliser (NP) = 2,753; Fertiliser (N) = 2,744; and Mustard cake = 3,081.

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Assessing the Contribution of Nutrients to Maximize Transgenic Cotton Yields in Vertisols of Northern Karnataka

By D. P. Biradar, Y. R. Aladakatti, M. A. Basavanneppa, D. Shivamurthy, and T. Satyanarayana

Although cotton production in India increased after the introduction of transgenic cotton, its productivity is still very low when compared both to its potential yield within India and the world's average. This article indicates that the principles of site-specific nutrient management (SSNM) offer a good opportunity to reverse this trend.

Cotton is one of the most important fiber and cash crops of India and plays a dominant role in the industrial and agricultural economy of the country. India has the largest area cultivated under cotton at 9.5 million (M) ha, which constitutes 27% of world's area. As a result, India has emerged as the world's second largest producer of cotton—estimated at 31 M bales during 2010-11. Cotton production in India increased from 470 to 525 kg lint/ha with the first introduction, and increased adoption, of transgenic Bt cotton between 2004 and 2008. After which, Bt cotton area declined and productivity fell to 486 kg lint/ha during 2009-10.

In Karnataka, the total area under cotton is 3.9 lakh (390,000) ha with an average productivity of 392 kg lint/ha (Anonymous, 2009). In Northern Karnataka, area under cotton is of about 300,000 ha, out of which 70% is currently under Bt cotton, and this is expected to increase in the coming years. Though the yield potential for Bt cotton is high, the average productivity of cotton in the State is very low at 231 kg lint/ha. Also there is apprehension that the quality of fiber from transgenic cotton is poor, and therefore, of lower market value. Imbalanced nutrition could be one of the reasons for low productivity and poor fiber quality, but information on nutrient management of transgenic cotton is very limited in the State. This research project was initiated to explore the possibility of improving productivity of transgenic cotton through yield target-based fertiliser application following the principles of SSNM in the black cotton soils of Northern Karnataka.

Two experimental sites were selected, located at the main agricultural research station of the University of Agricultural Sciences in Dharwad, Karnataka and at Agricultural Research Station in Siruguppa, Karnataka. Field experiments were conducted for two consecutive years under rainfed and irrigated conditions, during the *Kharif* seasons of 2009-10 and 2010-11, respectively. The soil at Dharwad was slightly alkaline (pH 7.4) and the EC measured in 1:2.5 soil:water suspension was non-saline (0.4 dS/m). Available N, P_2O_5, and K_2O contents were low (195 kg/ha), medium (18.8 kg/ha), and high (333 kg/ha) with sufficient available Ca, Mg, S, Zn and Fe contents, the values being 25, 4, 36, 1, and 3 ppm, respectively. The experimental soil at Siruguppa was alkaline (pH 8.5), non-saline EC (0.4 dS/m), low organic C (0.41%), medium available P_2O_5 (21.2 kg/ha), and high available K_2O (430 kg/ha).

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulphur; B = boron; Fe = iron; Zn = zinc; C = carbon; Bt = *Bacillus thuringiensis* (a gram-positive, soil-dwelling bacterium whose toxins are made to express in crops to make crops tolerant to insect-pests); DAS = days after sowing; $CaSO_4$ = calcium sulphate; $MgSO_4$ = magnesium sulphate; $FeSO_4$ = iron sulphate $ZnSO_4$ = zinc sulphate; ppm = parts per million; EC = electrical conductivity.

Before the start of the experiment, the targeted seed cotton yield was set at 3 t/ha considering the available information on nutrient uptake and soil test values from the experimental sites. The experiment was set up in a randomised block design with 11 treatments including an absolute control and three replications. An omission plot technique was adopted to assess different nutrient contributions towards yield of transgenic cotton. The treatments (**Table 1**) consisted of complete SSNM treatment (T_1), nine nutrient omission plots for N, P, K, Ca, Mg, S, Zn, Fe, and B (T_2 to T_{10}) and a control (T_{11}) with no nutrient application. Both locations used the cotton hybrid RCH-2Bt (BG-II). All nutrients were applied at sowing with the exception of N and K, which were applied in three splits (i.e. 25% basally, 50% at 30 DAS, and 25% at 60 DAS). Uniform cultural practices and plant protection measures were adopted in all treatments. The observations on growth and yield parameters were recorded at both the locations and the average of 2 years data is reported in this paper. We also calculated gross returns, net returns, and benefit-to-cost (B:C) ratios from the average prevailing cotton price during the experimental year.

Table 1. Treatment details imposed in the experiment.

Treatment	Description
T_1 - SSNM†	• 165-75-120 kg N-P_2O_5-K_2O/ha • 20 kg/ha $CaSO_4$ and $MgSO_4$ • 10 kg S/ha • 20 kg/ha $ZnSO_4$ and $FeSO_4$ • 0.1% B (two foliar sprays)
T_2 - N omission	T_1 – N
T_3 - P omission	T_1 – P
T_4 - K omission	T_1 – K
T_5 - Ca omission	T_1 – Ca
T_6 - Mg omission	T_1 – Mg
T_7 - S omission	T_1 – S
T_8 - Zn omission	T_1 – Zn
T_9 - Fe omission	T_1 – Fe
T_{10} - B omission	T_1 – B
T_{11} - Control	No fertiliser

† Designed for a 3 t/ha yield target.

Results

Omission of nutrients had a significant effect on different growth parameters of transgenic cotton (**Table 2**). At both locations, N omission drastically reduced plant height compared to the effect of omitting other primary and micronutrients. Next to the control, the number of monopodial branches and the number of bolls per plant were considerably low under N omission at both locations signifying the importance of N in promoting the growth and yield attributing parameters of

P omission

K omission

SSNM treatment

N omission

The trials with transgenic (Bt) cotton indicated that N was the most significant yield-limiting factor, followed by K, then P.

transgenic cotton. Omission of N recorded the lowest number of sympodial per plant (19.8) compared to other treatments at Dharwad.

Nutrient application for a yield target of 3 t/ha resulted in a seed cotton yield of 3,392 and 2,383 kg/ha at Dharwad and Siruguppa, respectively (**Table 3**). At these yield levels, higher net returns of INR 68,970/ha, with a B:C of 3.5, were observed at Dharwad compared to returns of INR 42,141/ha and a B:C of 2.6 at Siruguppa (**Table 4**). The difference in targeted and measured yields in Siruguppa might be because of the late sowing (28 days) caused by a late release of canal water during the first year. This undermined the fact that time of sowing in addition to better nutrient management plays an important role in attaining the desired yield targets. Omission of nutrients caused a yield loss that varied between 2 to 41% at Dharwad and yield loss was the highest due to exclusion of N (41%) followed by K (20%), P (11%), and Zn (8%) omission. Omission of other secondary and micronutrients had little impact on yield loss. The data clearly indicates that providing optimum rates of NPK nutrients is important at Dharwad where cotton is grown under rainfed conditions. Zhang et al. (2008) also reported that N was the first yield-limiting factor in cotton followed by P and K based on a 5 year omission plot study.

Yield loss at Siruguppa due to nutrient omission varied between 1 to 17%, with the yield loss due to N omission being highest at 17%, and losses of 15% each was observed due to omission of Ca, Mg, S, and Fe, respectively (**Table 3**). This clearly suggests the need to apply secondary and micronutrients in balanced proportions along with N for growing transgenic cotton under irrigated conditions. The field research demonstration in Northern Karnataka on SSNM in cotton also reported similar observations (Biradar et al., 2006).

The treatment with N omitted, as expected, gave the least net returns per ha of INR 34,663 and 33,487 and low B:C values of 2.5 and 2.4 at Dharwad and Siruguppa, respectively. These were about 50 and 13% less than those obtained with SSNM applied for the yield target of 3 t/ha (i.e. INR 68,970/ha and INR 42,141/ha). Omission of K also resulted in a 25% reduction in net income (INR 52,624/ha) at Dharwad. Omission of other primary and micronutrients did not impact net returns to a great extent at both locations (**Table 4**). Efforts to test and confirm these results at the farmer participatory level at different locations within the cotton-growing area, and to disseminate these results to farmers through training programmes, are also being considered as a part of the study.

Conclusion

Omission of N reduced the seed cotton yield and net income by about 41 and 50% followed by omission of K and P. Omission of N also resulted in lower net income compared to other nutrients. However, omission of secondary nutrients such as Ca, Mg, S, and micronutrients such as Zn, Fe, and B had no drastic negative effect on cotton yields. Hence, N followed by K and P were the major nutrients contributing to higher yield of Bt cotton. The delayed sowing, erratic rainfall, late release of canal water and non-availability of irrigation water during critical crop growth stages could lower the yields of cotton in spite of providing better nutrient management, therefore

The research cooperators visiting the cotton experimental site at Agricultural Research Station, Siruguppa (Karnataka), (From L to R): Dr. M. Basavanneppa, Dr. D.P. Biradar, Dr. T. Satyanarayana, Dr. Y.R. Aladakatti, and Dr. Rajakumar.

Table 2. Effect of SSNM and nutrient omission on different growth parameters of transgenic cotton.

	Dharwad				Siruguppa			
Treatment	Plant height, cm	No. of monopodia per plant	No. of sympodia per plant	No. of bolls per plant	Plant height, cm	No. of monopodia per plant	No. of sympodia per plant	No. of bolls per plant
T_1 - SSNM	122.2	4.2	25.7	57.3	131.5	1.3	25.9	44.5
T_2 - N omission	96.7	3.6	19.8	27.3	121.9	1.6	23.6	32.5
T_3 - P omission	110.5	4.1	23.9	50.7	122.8	1.6	24.3	36.7
T_4 - K omission	108.5	3.8	20.6	38.5	124.3	1.7	23.5	40.6
T_5 - Ca omission	110.1	4	22.5	48.4	124.2	1.7	24.8	39.1
T_6 - Mg omission	115	4.1	23.1	48.8	129.8	1.6	22.3	40.8
T_7 - S omission	117.1	4.2	24.4	55.3	130	1.5	24.8	44.3
T_8 - Zn omission	113.3	4.1	21.9	46.4	132.3	1.7	24.2	41.5
T_9 - Fe omission	114.4	4.2	22.5	54.2	133	1.7	25.2	40.6
T_{10} - B omission	118.4	4.2	24.7	56.6	132.7	1.7	26.1	41.9
T_{11} - Control	80.5	3.1	17.2	24.9	111.5	1.3	22.6	21.6
CD (p = 0.05)	10.5	0.59	2.7	9.5	5.4	0.3	NS	3.7

Table 3. Effect of SSNM and different nutrient omission treatments on transgenic seed cotton yield.

	Dharwad			Siruguppa		
Treatment	Yield, kg/ha	Yield response, kg/ha	Yield loss, %	Yield, kg/ha	Yield response, kg/ha	Yield loss, %
T_1 - SSNM	3,392	-	-	2,383	-	-
T_2 - N omission	2,003	1,389	41	1,981	402	17
T_3 - P omission	3,018	374	11	2,090	293	12
T_4 - K omission	2,727	665	20	2,085	298	13
T_5 - Ca omission	3,285	107	3	2,016	367	15
T_6 - Mg omission	3,291	101	3	2,016	367	15
T_7 - S omission	3,333	59	2	2,026	357	15
T_8 - Zn omission	3,134	258	8	2,170	213	9
T_9 - Fe omission	3,230	162	5	2,036	347	15
T_{10} - B omission	3,326	66	2	2,369	14	1
T_{11} - Control	1,552	1,840	54	1,030	1,353	57
CD (p = 0.05)	71	-	-	27	-	-

due care has to be taken on the said factors in ensuring better yields of transgenic cotton. BC-SA

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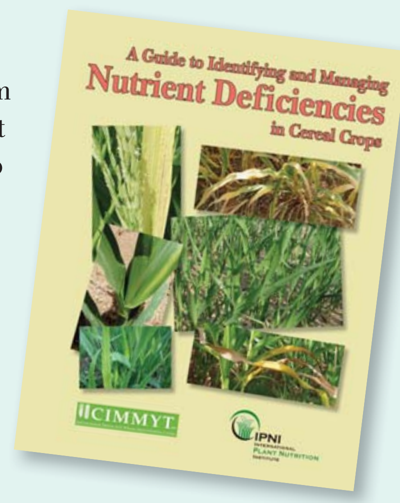
Table 4. Effect of SSNM and different nutrient omission treatments on economics of transgenic cotton.

Treatment	Dharwad: Gross returns, INR/ha	Dharwad: Net returns, INR/ha	Dharwad: B:C	Siruguppa: Gross returns, INR/ha	Siruguppa: Net returns, INR/ha	Siruguppa: B:C
T_1 - SSNM	96,676	68,970	3.5	67,925	42,141	2.6
T_2 - N omission	57,080	34,663	2.5	56,449	33,487	2.4
T_3 - P omission	86,020	61,049	3.4	59,555	36,,306	2.6
T_4 - K omission	77,705	52,624	3.1	59,432	35,353	2.5
T_5 - Ca omission	93,618	67,381	3.6	57,456	33,791	2.4
T_6 - Mg omission	93,794	67,141	3.5	57,456	33,391	2.4
T_7 - S omission	94,984	67,576	3.5	57,750	33,009	2.3
T_8 - Zn omission	89,321	62,860	3.4	61,854	37,203	2.5
T_9 - Fe omission	92,043	65,344	3.4	58,017	33,702	2.4
T_{10} - B omission	94,795	67,954	3.5	67,507	42,460	2.7
T_{11} - Control	44,237	32,007	3.6	29,345	17,821	2.5
CD (p = 0.05)	20,216	18,443	0.57	7,596	6,930	NS

Price details (INR): N = 11/kg, P_2O_5 = 24/kg, K_2O = 8/kg, S = 15/kg, $CaSO_4$ = 60/kg, $ZnSO_4$ = 30/kg, $MgSO_4$ = 40/kg, $FeSO_4$ = 30/kg, Borax (B) = 70/kg, Seed cost = 1,665/kg, Seed market price = 28.50/kg.

A Guide to Identifying and Managing Nutrient Deficiencies in Cereal Crops



A new field guide has been developed by the IPNI South Asia Program in cooperation with the International Maize and Wheat Improvement Center (CIMMYT). It is a 50-page booklet (8 1/2 x 11 in. size, wire-o bound) designed to describe the appearance and underlying causes of nutrient deficiencies in maize, wheat, rice, sorghum, pearl millet, and barley. Tips are also included on how they might be prevented or remedied. Hundreds of excellent deficiency photographs provided by the authors and IPNI will allow the user of this field guide to understand the development of nutrient deficiency symptoms through the growth stages of the crop.

Details on obtaining a copy of this booklet can be found at the IPNI on-line store at: http://info.ipni.net/nutridefcereal

Guinea Grass Forage Production under Varying Tree Shade Levels and Potassium

By M.R Anita, S. Lakshmi, and T. Satyanarayana

Availability of land for fodder cultivation in Kerala is very low due to fragmentation and shifts in cropping patterns from food to cash crops. The State's current deficit in fodder production highlights a need for intensified fodder production, and given adequate nutrient management, raising guinea grass as an intercrop with coconut appears to be a viable solution.

The land devoted for fodder cultivation in Kerala is very negligible—only 1% of the cultivable area or 5,395 ha (Government of Kerala, 2011). It is estimated that out of the requirement of 23.2 million (M) t of fodder, only 5.1 M t is produced in Kerala. The only immediate opportunity is to increase productivity per unit area. Raising fodder as an intercrop within existing crop systems has been a common solution to this problem. Studies conducted at Central Plantation Crops Research Institute, Kasargode, on rooting pattern of coconut showed that actively growing palms had a spread of roots confined to an area of 2 m surrounding the tree base. Thus the remaining area is available for intercropping and will most likely not affect the yield of coconut. The total coconut plantation area in Kerala is about 700,000 ha.

Guinea grass (*Panicum maximum*) is a popular fodder grass of the tropics suited to the agro-climatic conditions of agro-forestry systems and grows well under coconut and other trees. Approximately 80 to 100 t/ha of green fodder is commonly obtained per year. The grass makes good, palatable hay and silage, and it is highly valued for its productivity, palatability, and good persistence. Experiments conducted under the All India Co-ordinated Research Project on Forage crops, at Vellayani, Kerala showed that guinea grass is a suitable fodder crop for intercropping in coconut gardens. But its fodder yield is highly variable under partial shade. Shading has both direct and indirect effects on forage production as it can alter morphological development and yield (Kephart and Buxton, 1996).

A field experiment was conducted during 2002 in the upland area of the Instructional Farm of College of Agriculture, Vellayani, Thiruvananthapuram, Kerala. The farm is located at 8.5°N latitude and 76.9°E longitude at an altitude of 29 m above mean sea level. The average rainfall is 151 cm distributed over a period of 107 days. The rainfall from southwest and northeast monsoons are received in plenty, and the period from November to April is mildly hot. The humidity is 80 to 85% and the area receives on an average 10 hours of sunshine per day. The mean maximum and minimum temperature recorded during the cropping season ranged from 26°C to 31°C and 20°C to 25°C, respectively. The soil of the experimental site was a red, sandy clay loam (Oxisol, Vellayani series). It had a pH of 5.5, 282 kg/ha available N, 25 kg/ha available P_2O_5, and 181 kg/ha available K_2O.

The experiment was laid out in a split-split plot design with three replications. Three levels of shade (0%, 25%, 50%), three levels of K (50, 100, 150 kg K_2O/ha), and two varieties of guinea grass (cv. Hamil and Haritha) were combined to form 18 treatment combinations. The recommended dose of K_2O for guinea grass is 50 kg/ha (KAU, 2006). Shade levels were maintained through the use of nets. Farmyard manure (FYM) was applied uniformly at 10 t/ha to all plots at the time of final land preparation. The entire dose of P was given as basal at 50 kg P_2O_5/ha. Nitrogen at 200 kg/ha was given in two equal splits (i.e. one basally at the time of planting and one after the second harvest). Healthy slips of guinea grass varieties as per treatments were planted at 40 × 20 cm spacing at 2 slips/hill. Harvesting of the crop was done at a height of 15 cm from the base. Six cuts were taken at 45 day intervals. Six observational plants were selected from each plot and observations were taken on green fodder yield and uptake of N, P, and K were also estimated. The green matter yield from the net plot area was recorded after each harvest as was total green fodder yield for the entire year.

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; B:C = benefit-to-cost ratio.

Table 1. Effect of shade levels, varieties and K on yield, uptake of nutrients and net returns of guinea grass.

Treatment factors	Green fodder yield, t/ha	Uptake of Nutrients, kg/ha N	P_2O_5	K_2O	Net returns, INR/ha	Benefit-to-cost ratio
Shade						
0% (S_0)	100	311	34.0	461	53,502	2.24
25% (S_1)	95.5	310	30.1	446	44,482	2.00
50% (S_2)	67.2	218	24.2	313	26,499	1.71
SE	0.1	0.4	0.1	0.6	18	0.06
CD (p = 0.05)	0.2	1.5	0.3	2.3	72	0.22
Variety						
cv. Hamil (V_1)	89.6	283	30.8	415	43,935	2.06
cv. Haritha (V_2)	85.8	277	28.2	398	39,053	1.90
SE	0.1	0.4	0.1	0.4	17	0.04
CD (p = 0.05)	0.2	1.4	0.2	1.5	60	0.15
Potassium						
50 (K_1)	80.0	259	28.6	369	34,998	1.78
100 (K_2)	90.1	287	29.3	417	42,668	2.05
150 (K_3)	92.9	294	30.4	434	46,816	2.11
SE	0.1	0.5	0.1	0.6	14	0.06
CD (p = 0.05)	0.2	1.6	0.2	1.9	42	0.16

†Values (INR/kg) include: N = 14.7/kg, P_2O_5 = 27.5/kg, K_20 = 6.6/kg, FYM = 1/kg, Planting material = 0.20/slip, Market price of fodder = 7.5/kg. The authors consider B:C values above 1.0 as optimal.

Table 2. Effect of shade on K requirement of guinea grass.

Treatment	Green fodder yield, t/ha	Uptake of nutrients, kg/ha N	P_2O_5	K_2O	Net returns,† INR/ha	Benefit-to-cost ratio
$S_0 K_1$	89.1	278	32.4	405	41,343	1.90
$S_0 K_2$	104	324	34.8	479	55,732	2.45
$S_0 K_3$	107	331	35.6	498	63,432	2.37
$S_1 K_1$	87.0	289	29.2	407	39,674	1.88
$S_1 K_2$	97.8	315	30.1	454	45,914	1.95
$S_1 K_3$	102	327	31.0	478	47,858	2.17
$S_2 K_1$	63.9	209	24.2	295	23,979	1.58
$S_2 K_2$	68.1	221	23.6	317	26,360	1.75
$S_2 K_3$	69.6	225	24.6	327	29,158	1.79
SE	0.1	1	0.1	1	25	0.10
CD (p=0.05)	0.3	3	0.3	3	73	-

†Values (INR/kg) include: N = 14.7/kg, P_2O_5 = 27.5/kg, K_20 = 6.6/kg, FYM = 1/kg, Planting material = 0.20/slip, Market price of fodder = 7.5/kg. The authors consider B:C values above 1.0 as optimal.

Table 3. Optimum dose of K for guinea grass under different shade intensities.

Shade level	Optimum maximum dose, kg K_2O/ha	Optimum economic dose, kg K_2O/ha
0%	130	129
25%	149	143
50%	152	150

Results

Shade levels and K significantly influenced the green fodder yield. The response of guinea grass to K fertilizer was larger with higher light intensity (i.e. less shade) and this response decreased proportionally as shade level increased. Application of 150 kg K_2O/ha (K_3) recorded significantly higher green fodder yield (**Table 1**). Mullakoya (1982) also obtained maximum green fodder yield in guinea grass (cv.Mackuenii) under the study's highest level of K application. The higher green fodder yield at high K levels could also be attributed to increase in tiller numbers from 22 to 26 with the corresponding increase of K_2O levels from 50 to 150 kg/ha, respectively (data not shown).

Uptake of N, P and K was significantly higher in unshaded conditions and with the highest level of K (**Table 2**). According to Wong and Wilson (1980) N accumulation in all the plant components of green panic was markedly improved by shading. George (1996) recorded an N uptake of 139 kg/ha/yr and P_2O_5 uptake of 24 kg/ha/yr in guinea grass (cv. Hamil) under partially shaded conditions within coconut gardens. Potassium is absorbed by forage grasses in larger amounts than any other mineral element except N and in some cases, Ca. Potassium is required in plants as a catalyst and plays an essential role in the metabolic processes of plants and is required in adequate amounts in several enzymatic reactions. Potassium is also an essential key in the carbohydrate metabolism, a process by which energy is obtained from sugar. This is very important in forage grass survivability. Application of K will balance the ill effects of high soil N availability, increase rates of photosynthesis, improve overall yield potential and quality (Phillips and Kee, 1998). Jacob (1999) reported that K applied at 50 kg K_2O/ha increased the uptake of N, P, and K in congosignal grass (*Brachiaria ruziziensis*). Meerabai et al. (1993) obtained maximum response for guinea grass green fodder yield with up to 90 kg K_2O/ha.

Results indicated that guinea grass could be economically cultivated under shade intensities up to 50% where the B:C is 1.71 compared to 2.24 under open conditions. However, application of 100 kg K_2O/ha resulted in highest net returns and B:C in open conditions; whereas 150 kg K_2O/ha was required to achieve the highest net returns and B:C in 25% and 50% shade conditions (**Table 2**). The relationship between applied K and green fodder yield was estimated by fitting a quadratic response surface as follows:

Under 0% shade;

$Y = 0.8656 + 109.0722 \times -25.9196 X^2$

F for regression = 214.653

$R^2 = 96.62\%$

Under 25% shade;

$Y = 0.8296 + 103.1753 \times -24.4870 X^2$

F for regression = 223.583

$R^2 = 96.75\%$

Under 50% shade;

$Y = 0.5765 + 72.0418 \times -17.1457 X^2$

F for regression = 258.726

$R^2 = 97.18\%$

The resulting maximum (physical) and economic optimum doses for K are provided in **Table 3**.

Summary

While forage yield was significantly reduced by shading, the optimum K dose for guinea grass was found to increase with shade intensity. This was due to the increase in K content of fodder under 50% shade conditions. Since the tiller number and green fodder yield of guinea grass (cv. Hamil and Haritha) increased with higher K application under shaded conditions as evidenced from the high economic optimum dose of K, it can be concluded that the present State recommendation of 50 kg K_2O/ha for guinea grass is less than optimal, but further studies are required to confirm the results of this investigation. BC-SA

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Current Research Supported by IPNI South Asia Programme

At the heart of IPNI's regional educational programmes is its support of local research. Below is a listing of the current research being funded throughout the IPNI South Asia Region. More details on these projects can be obtained from IPNI staff or from our on-line research database found at: http://www.ipni.net/research.

North & East India and Bangladesh

Assessment of Potassium Supplying Capacity from Soil Nutrient Reserves and Dissemination of Nutrient Management Technologies through Nutrient Manager

Appraisal of Multi-Nutrient Deficiencies and their Redressal through Site-Specific Nutrient Management

Comparative Evaluation of Nutrient Dynamics under Conventional and No-Till Systems of Crop Establishment in Rice-Wheat and Rice-Maize Cropping Systems

Evaluating Production Systems Approaching Attainable Yields and Profits

Fertility Mapping and Balanced Fertilization for Sustaining Higher Productivity of Pearl Millet-Wheat System, Agra District

GIS-Based Spatial Variability Mapping of Agricultural Holdings for Precision Nutrient Management in Red and Lateritic Soil Zones

Global Maize Project in India: Ranchi, Jharkhand

Importance of Soil Test-Based Nutrient Application through Farmers' Participatory Approach in Red and Lateritic Soils of West Bengal

Site-Specific Nutrient Management for Rice-Maize Cropping Systems in Bangladesh

Site-Specific Nutrient Management for Rice-Wheat System in Punjab

Site-Specific Nutrient Management for Rice-Wheat System in Haryana

Site-Specific Nutrient Management for Rice-Maize System in Bihar

South India and Sri Lanka

Fertility Mapping through Spatial Variability in Rice Growing Soils of Cuddalore District, Tamil Nadu

Global Maize Project in India: Dharwad, Karnataka

Improving Nutrient Use Efficiency and Profitability in Rainfed Production Systems

Maximizing Yield of Groundnut through Improved Nutrient Management Practices in Acid Soils of Orissa

Site-Specific Nutrient Management for Chili in Kalliyoor Panchayat, Kerala

Site-Specific Nutrient Management in Maize Growing Districts of Tamil Nadu

Site-Specific Nutrient Management for Maximum Economic Yield and Quality of Transgenic Cotton in Northern Karnataka

Site-Specific Nutrient Management for Optimizing Productivity of Rice-Maize Cropping in Krishna and Godavari Agro-Climatic Zones, Andhra Pradesh

Site-Specific Nutrient Management for Rice-Rice and Rice-Maize Systems in Tamil Nadu

West India

Development of Soil Fertility Maps as a Decision Support Tool for Fertilizer Recommendations in Citrus

Inventory of Available Potassium Status and Modeling its Relationship with Potassium Content, Yield and Quality of Sugarcane for Site-Specific Nutrient Management in Maharashtra

IPNI South Asia Programme regions are staffed by Dr. Kaushik Majumdar, Director (North & East India and Bangladesh), and Dr. T. Satyanarayana, Deputy Director (South India and Sri Lanka). BC-SA

Crop Nutrient Deficiency Photo Contest Entries Due by December 13

December 13, 2011, is the deadline for entries in the annual IPNI contest for photos showing nutrient deficiencies in crops. An individual can submit an entry for each of the four categories: nitrogen (N), phosphorus (P), potassium (K), and other nutrient deficiencies (i.e. secondary nutrients and micronutrients).

Preference is given to original photos with as much supporting/verification data as possible. Cash prizes are offered to First Place (USD 150) and Second Place (USD 75) in each of the four categories, plus a Grand Prize of USD 200 will be awarded to the photo selected as best over all categories. Entries can only be submitted electronically to the contest website: www.ipni.net/photocontest

For further details and instructions, please visit the contest website.

Winners will be announced in January 2012 ... also look for details on the 2012 edition of this contest.

New Publication for 2012

4R Plant Nutrition

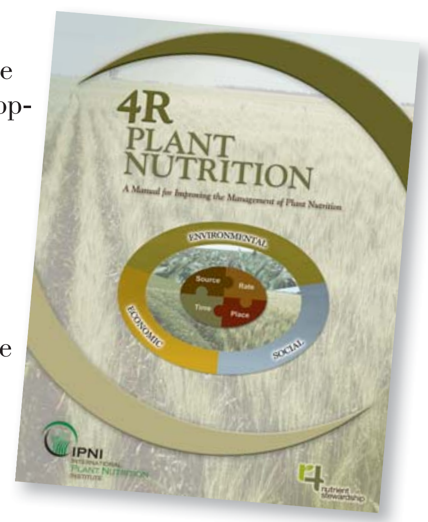
A Manual for Improving the Management of Plant Nutrition

The challenge to increase food production in an economically viable way while retaining the ecological integrity of food systems is the underlying aim of sustainable agriculture. The 4R Nutrient Stewardship approach is an essential tool in the development of sustainable agricultural systems because its application can have multiple positive impacts on natural capital, social capital, human capital, physical capital, and financial capital.

There is an immediate connection between applying the right nutrient source, at the right rate, right time, and right place.

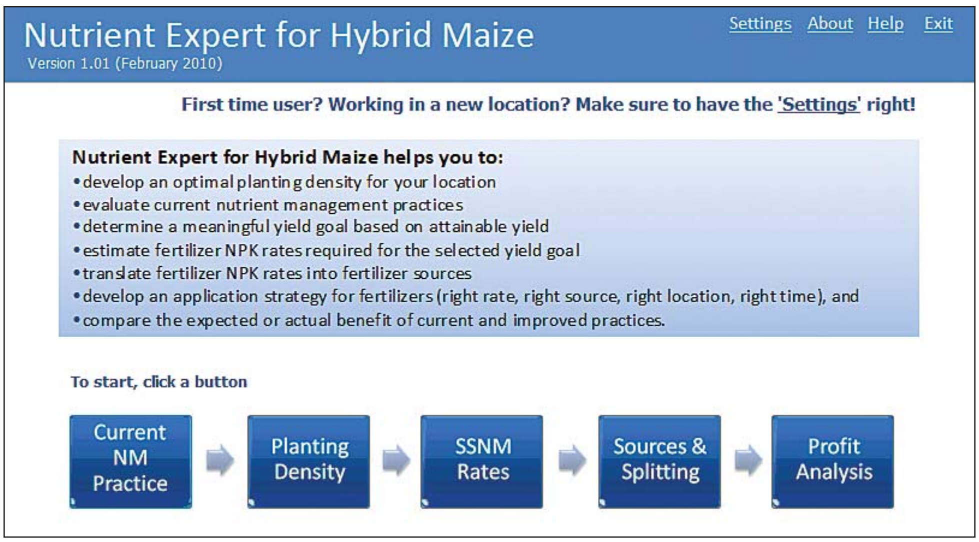
The full-color 4R Plant Nutrition Manual is filled with informative illustrations, charts, graphs, learning modules, and case studies. The publication will be available in hard copy and electronic formats.

Look for it in 2012.



Nutrient Expert for Wheat and Hybrid Maize: Novel Tools for Large-scale Adoption of SSNM in India

Site-specific nutrient management (SSNM) is an oft-repeated terminology in the field of nutrient management. This approach provides scientific principles for optimally supplying crops with nutrients as and when needed for specific fields in a particular cropping season. The SSNM approach is, however, a knowledge-intensive technology that requires information on specific local conditions for crop yield, crop residue management, past fertiliser use, input of nutrients from other external sources as well as the nutrient supplying capacity of the soil. Such knowledge requirements have slowed the wide-scale promotion and adoption of SSNM by the farmers. The need for more rapid uptake of the technology by farmers led IPNI to consolidate the research into simple delivery systems, such as *Nutrient Expert* for Wheat and Hybrid Maize that enable farmers to rapidly implement SSNM.



The Nutrient Expert for Wheat and Hybrid Maize are new, computer-based decision support tools developed to assist local experts to quickly formulate fertiliser guidelines for the above crops grown in India. The software, developed by IPNI, is based on the principles of SSNM and allows scientists and extension experts to jointly formulate novel nutrient management strategies that are expected to help farmers increase their yield and profit.

The software utilizes information provided by a farmer or a local expert to suggest a meaningful yield goal for his location and develop a fertiliser management strategy required to attain the yield goal. The required information about the production system is gathered through a set of simple, easily answerable questions that analyses the current nutrient management practices and develops guidelines on fertiliser management (and more) that are tailored for a particular location (i.e. growing environment). The software also does a simple profit analysis comparing costs and benefits between the farmer's current practice and the recommended alternative improved practice.

T*he Nutrient Expert* tool was designed in a way that it can be used as a learning tool—providing quick helps, instant summary tables and graphs, plus allowing a great amount of flexibility in navigating through the modules in the software.

In conclusion, the *Nutrient Expert* for Wheat and Hybrid Maize in India help to:

- develop an optimal planting density for a location (Hybrid Maize);
- evaluate current nutrient management practices;
- determine a meaningful yield goal based on attainable yield;
- estimate fertiliser NPK rates required for the selected yield goal;
- translate fertiliser NPK rates into fertiliser sources;
- develop an application strategy for fertilisers (right rate, right source, right time, right place);
- compare the expected or actual benefit of current and improved practices. BC-SA

International Certified Crop Adviser Program—India's Journey Thus Far

The pilot exam for the India Certified Crop Adviser (CCA) Program took place in August 2010 in New Delhi. Out of 22 candidates, 19 passed and were awarded certificates from the American Society of Agronomy (ASA). Two open exams were also held in the months of December 2010 and June 2011 at three locations—New Delhi, Hyderabad, and Chandigarh, where around 200 candidates took the exam.

The CCA program has been recognized by the public and private sector around the world as a tool to enhance and upgrade one's knowledge in agriculture. The certification not only prepares the extension work force to do its job more efficiently and effectively, but it also provides better job opportunities. Most of all, CCA certification helps guarantee that this new breed of crop advisers has attained a level of knowledge and experience and is most qualified to work in the field with farmers, who are in dire need of the advisers' expertise.

Presently, the total number of CCAs in India has reached 146. Several agribusiness companies in India have endorsed this program as a skill enhancement and continuing education tool for their employees in the field. Companies have made the CCA program a part of their employee goal sheet and other major companies in the agribusiness sector are looking towards CCAs as a source of prospective employees.

Information regarding the exam is available at www.certifiedcropadviser.org/india. Candidates can also get the information regarding the India CCA exam from Indian Society of Agribusiness Professionals at +91-11-43154100 and through e-mail at indiacca@isapindia.org or by contacting Mr. Saveen Randhawa, India CCA Program Manager at saveen@isapindia.org. BC-SA

Conversion Factors for U.S. System and Metric

Because of the diverse readership of our publications, this Table is provided as a convenience to those wishing to convert results provided within *Better Crops – South Asia* into U.S. System standard units.

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

To convert Col. 1 into Col. 2, multiply by:	Column 1	Column 2	To convert Col. 2 into Col. 1, multiply by:
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in.	2.54
	Area		
2.471	hectare, ha	acre, A	0.405
	Volume		
1.057	liter, L	quart (liquid), qt	0.946
	Mass		
1.102	tonne[1] (metric, 1,000 kg)	short ton (U.S. 2,000 lb)	0.9072
0.035	gram, g	ounce	28.35
	Yield or Rate		
0.446	tonne/ha	ton/A	2.242
0.891	kg/ha	lb/A	1.12
0.0159	kg/ha	bu/A, corn (grain)	62.7
0.0149	kg/ha	bu/A, wheat or soybeans	67.2

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

Finding the Tools to Support Sustainable Nutrient Management

Changing the way we manage nutrients – that is the focus of the fifth issue of Better Crops – South Asia. When asked how we run our institute, I often respond that we are in the business of making small holder farmers more efficient and profitable, while leaving for their children a better soil resource for future food security. Sounds rather simple, but it really does wrap together all of the issues we focus on each day in our work at IPNI.

Targeting improved fertilizer use efficiency remains our principle scientific focus. How often have you heard a presentation on nutrient management that does not attempt to bring improved efficiency into the discussion? Whether it is building on low yields with balanced use of macronutrients, or optimizing production with secondary and micronutrients, there are a number of ways to improve on efficiency. The challenge becomes making improvements in efficiency which remain profitable and easily within reach of the farmer client.

Soil testing has been, and remains, a major component of making efficient fertilizer recommendations. The only problem we have encountered is that most farmers do not have access to soil testing services which are price sensitive or timely for their cropping practices. Combine this with the massive number of individual fields, relative to the soil testing infrastructure, and you are left with what has evolved over time in the country, blanket state recommendations.

Plant-based nutrient recommendation systems have potential to support farm level Site-Specific Nutrient Management (SSNM) recommendations. In fact, our recent work using the decision support tool 'Nutrient Expert' for wheat and maize in South Asia has shown that we can achieve considerable accuracy in making fertilizer nutrient recommendations that help a farmer achieve a target yield. In addition, we can make that recommendation using the fertilizer products locally available to the farmer, include modifications to account for his previous crop and management practices which impact on nutrient responses, and provide some economic analysis to guide him in his final decision making. All this from the office of his local farm adviser, such as an industry agronomist or extension agent.

Finding tools which support sustainable nutrient management practices remains the goal. Balanced fertilization remains one of core principles with all of our research and development work, world wide. Add to this our growing knowledge of the spatial distribution of nutrients and how this variability can be managed. Ultimately, using decision support tools like Nutrient Expert will contribute to the set of tools we can equip agronomists with.

At IPNI we continue to evaluate and consider all options for the economic and environmentally sustainable use of plant nutrients in South Asian cropping systems.

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