IFA AGRICULTURE CONFERENCE

Optimizing Resource Use Efficiency
for Sustainable Intensification of Agriculture

Kunming, China
27 February – 2 March 2006

BALANCED CROP NUTRITION: FERTILIZING FOR CROP AND FOOD QUALITY

H. MAGEN
IPI, SWITZERLAND

International Potash Institute (IPI)
POB 569, CH-8810 Horgen
Switzerland
Tel. +41 43 810 49 22 Fax +41 43 810 49 25
E-mail: ipi@ipipotash.org web: www.ipipotash.org

IFA AGRICULTURE CONFERENCE

Kunming, China – 27 February – 2 March 2006

Optimizing Resource Use Efficiency for Sustainable Intensification of Agriculture

"Balanced crop nutrition: Fertilizing for crop and food quality"

H. Magen
International Potash Institute (IPI), Switzerland

Abstract

Globally the ratio of $N:P_2O_5:K_2O$ has changed from 2.5:1.3:1 in the 80s to 3.6:1.4:1 in 2002 as N consumption has outstripped that of K. Regardless of their decreased nutrient consumption, developed countries maintained a modest increase in agricultural production. Positive and similar growth rates for agricultural products and nutrient consumption prevail in developing countries, but with the use of 35% more nitrogen (N) to potassium (K) ratio than in developed countries.

The outcome of a negative K balance is presented here using examples from India, China, Egypt and Bulgaria. Reasons for a negative K balance stem mostly from farmers' lack of knowledge and socio-economic factors. Maintaining a negative K balance results in decreased soil fertility and stagnating and even decreasing productivity.

Balanced and timely application of nutrients needs to be demonstrated through different parameters according to the prevailing agro-climatic conditions. Long-term experiments and intensive investment in educational activities play an important role in demonstrating the benefits of balanced fertilization. Nutrient applications in organic agriculture may not suffice to meet a crop's requirement in quantity and time of application and this creates soil nutrient mining and pollution. Farmers also benefit from balanced fertilization by reducing pest and disease infestation and by achieving higher returns through larger yields, better quality, and in future, through reduced pollution. Site-specific nutrient management practices with higher inputs significantly increase the income of South East Asia's farmers via much higher returns.

How common is unbalanced fertilization?

Globally the ratio of $N:P_2O_2:K_2O$ consumption in 1980 was 2.5:1.3:1, but this has changed dramatically as nitrogen (N) consumption outstripped that of P and K, and now the ratio is 3.6:1.4:1. In fact, since 1980, production of agricultural products has changed little in developed countries, whilst it has increased significantly in developing countries (Figure 1). Such growth is maintained by larger inputs of fertilizers, and indeed, when comparing nutrient consumption in developed and developing countries, there is the same growth pattern (Figure 2).

Figure 1

Comparing growth trends in agricultural production to those of nutrient application, show that over the last 25 years, growth rates of the main crop groups and meat production in developed countries ranged from 0.2 to 3.4% per annum, whilst consumption of N, P_2O_5 and K_2O decreased over the same period at 0.8, 3.0 and 2.8% per annum, respectively (Table 1). However, in developing countries, crop and meat production and nutrient consumption increased. Production increased by 1.9 to 6% per annum fueled by average annual growth rates of 3.8, 4.1 and 5.8% for N, P_2O_5 and K_2O, respectively (Table 1).

Figure 2

These changes led to an improvement in the N: P_2O_5: K_2O ratio in developing countries from 6.2:2.6:1 in 1980 to 4.3:2.5:1 in 2002, reflecting much larger K application rates. However, there is still a wide gap between the developing and developed countries. In developed countries, N consumption is 2.8 times that of K_2O, while in developing countries, relative N consumption is 4.3 times that of K_2O.

Crop / factor	Developed countries			Developing countries		
	1980	2004	Ave. annual growth rate	1980	2004	Ave. annual growth rate
	Million ton			Million ton		
Cereals	783.7	990.7	*1.4*	766.2	1,273.3	*2.2*
Fruit & Vegetables	271.8	301.2	*0.5*	355.6	1,067.9	*4.7*
Roots and tubers	184.4	182.7	*0.2*	337.8	532.7	*1.9*
Soybean	51.1	91.6	*3.4*	29.9	112.7	*6.0*
Meat	89.7	81.6	*0.8*	47.0	150.6	*5.0*
Nutrient consumption (%)			*N= (0.8)* *P_2O_5 = (3.0)* *K_2O = (2.8)*			*N= 3.8* *P_2O_5 = 4.1* *K_2O = 5.8*

Table 1: Production and growth rates of major crop groups and averaged nutrient consumption in developed and developing countries (1980-2004). (Source: FAO http://faostat.fao.org/faostat/collections , last accessed December 2005).

Although the nutrient requirement of crops may differ, the amount of N and K removed by many of them tends to be the same, except for many fruits and vegetables, when the amount of K removed exceeds that of N. The supply of N and K in soils also differs and depends on soil organic matter, soil texture, mineralogy and climate. Policy issues also affect nutrient consumption, and a higher subsidy to a specific nutrient will no doubt increase its use. But the final decision on how much N and K to apply is taken by the farmer, based on his knowledge. Market conditions, yield expectation and climate, will affect the farmer's short-term decisions, whilst his knowledge and education will affect his decisions related to the sustainability and long term fertility of his soil.

Outcome of unbalanced crop nutrition

This paper presents four different country examples of negative K balances. In India, the slow but continuous reduction of the soil's K supply in the Indo Gangetic plains may lead to stagnating or reduced yields. In China, the demand for K in regions with highly weathered soils and an insufficient K supply, when accompanied by a positive balance for N and P, causes a large negative K balance. In Egypt, on the highly productive in irrigated land there is a severe negative K balance, especially on soils of low fertility. In Bulgaria, a recent assessment of farm gate and regional nutrient balances shows a decline in soil fertility.

India

Use of mineral fertilizers in India almost tripled from 5.5 million tonnes (Mt) in 1980 to currently (2002) 15.1 Mt of N, P_2O5 and K_2O of which only ~10% are potash fertilizers. At the same time, production of cereals increased significantly from 140.5 to 233.4 M t between 1980 and 2004 and that of fruits and vegetables more than doubled from 56.3 to 127.7 Mt in the same period. Do current fertilization rates support such large increases in production and ensure the sustainability of the system?

Yadvinder-Singh *et al*. (2004) studied the long term effects of organic inputs on yield and soil fertility in the typical Rice–Wheat crop rotation practiced in the Indo Gangetic plains in India. After the dramatic rise in productivity during the 1970s and early 1980s, yields in this region have either remained stagnant or declined (Yadvinder-Singh *et al*., 2004). Yields of cereals in the Punjab are the largest in India (3,953 kg/ha; FAI, 2005) and they receive the most nutrients (368 kg/ha), yet with very little K of only about 10 kg ha^{-1} (FAI, 2005). The detailed balance calculation of input/output for K showed that over a 12 year period, the negative K balance has varied between -932 to -1810 kg K/ha, depending on the treatment and consequent yield and K input through straw and farmyard manure (FYM) (Figure 3).

Figure 3

The addition of K through organic matter appears to be significant, yet it is not sufficient to supply and replenish for the K removed. The balance calculation shows that for a zero net balance an additional ~90 kg K/ha/year as fertilizer would have been sufficient for both crops (wheat and rice).

Such negative balance may lead to a decrease in exchangeable potassium (K_{ex}) in soil. Figure 4 shows the long term effects of applying no K in the Control + 150N treatment. There has been a decrease of approximately 30% in K_{ex}, as compared to the application of FYM+150N, which showed only a slight reduction.

Figure 4

The authors comment that "Current K fertilizer recommendations for P and K are inadequate in the long run" and they also rule out the possibility of decline in soil organic matter as the reason of negative yield trends. Finally the authors conclude that the adverse changes in climate along with a decreased soil supply of available K may be the possible reasons associated with yield decline.

China

The spatial and temporal variability of N, P and K balances for agro-ecosystems in China were described by Shen *et al*. (2005). Inputs of nutrients in fertilizers and organic matter (from crop residues and human and animal excreta) were calculated and compared with their removal in harvested produce. Balances were calculated at Province level, which represent the major agro-ecosystems of China.

Large N and P positive balances were found in almost all regions, as also reported by others (Peng *et al*., 2005; Cui *et al*., 2005). In sharp contrast, negative K balances were found in almost all provinces (Figure 5), and they were very serious in Shanghai, Jiangsu, Zhejiang, Beijing and Xinjiang, where the negative K balance exceeded 72 kg K/ha/year (Shen *et al*., 2005).

Low fertilizer input alone appeared to be the main reason for the K deficit in Xinjiang and Beijing. However, in the Eastern Provinces the negative K balance was due to too small a K input (even though it was quite large) to replenish the large amount of K removed in the harvested crops and losses by leaching. In addition, large areas of East and South East China suffer from a negative K balance ranging from 48-72 kg K/ha/year (Figure 5). Interestingly, these provinces are also associated with large surplus applications of N, which aggravate the negative K balance.

Figure 5

The authors related the nutrient balances to economic and social factors. They pointed to the correlation between GOVA (per capita gross output of value of agriculture), especially in North China and to NIRH (per capita net income of rural households). The lower these socio-economic factors are, the higher is the negative K balance. These findings demonstrate the important role of socio-economic development on nutrient balances.

Egypt

Potassium fertilization in Egyptian irrigated agriculture has become very important since the completion of the High Dam in Aswan, which prevented the continuous deposition on farmers' fields of the Nile silt-rich in K bearing minerals (Abdel Hadi, 2004). In addition, Nile alluvial soils with high clay content can have a high K fixing capacity. Thus, even with a high K_{ex} level there might not be sufficient available K for various crops (El-Fouly and El-Sayed, 1997). Also the newly reclaimed soils (approximately 800,000 hectare, 25% of the total cultivated land) are sandy and calcareous, poor in organic matter and macro- and micro-nutrients (Abd El Hadi, 2004).

Using the average yields in 2002-2004 of rice, wheat, fruit and vegetables, the amount of K removed was calculated. Approximately 250,000 ton K_2O (conservative calculation, with all straw of rice and wheat returned to the field) and 489,650 ton K_2O (with all straw of rice and wheat removed from the field) are removed annually (Table 2).

During this period, potash consumption (input of K) in Egypt was only 57,000 ton K_2O, (FAO, 2005). This means that the negative balance for potash was between183,000 and 433,000 ton K_2O, or between 3 and 8 times the amount of potash used. This calculation is valid for 75% of the cultivated land in Egypt.

Crop	Area ('000 ha)	Production ('000 ton)	Yield (t/ha)	K_2O removed (ton) [(1)]	
				Straw removed	Straw left in field
Rice	626	6,143	9.8	168,000	25,000
Wheat	1,045	6,882	6.6	140,000	41,800
Fruit	443	7,447	16.8	66,450	66,450
Vegetables & melons	576	14,854	25.8	115,200	115,200
Total				489,650	248,450

Table 2: Mean (2002-2004) area, production, yield and calculated removal of potassium in various crops in Egypt.
Source: FAO http://faostat.fao.org/faostat/collections , last accessed December 2005
(1) Source: K+S / Nutrient removal; accessed December 2005 http://www.kali-gmbh.com/duengemittel_en/TechService/NutrientsRemoval/graincrops.cfm

The production of fruit and vegetables is considerable and therefore, very significant in K_2O consumption. We estimate that currently these crops are responsible for approximately half of the K_2O removed in Egypt (Table 2). In future, with increased production of fruit and vegetables on the newly reclaimed land, with its poor K-supplying capacity, there should be a need for higher K_2O consumption.

Bulgaria

Nutrient consumption in Bulgaria was at its peak during the mid 1980s, but fell dramatically to about 20, 0 and 0% for N, P_2O_5 and K_2O of its peak use during the mid and late 1990s. During this period, fruit production fell by 75%, vegetables by 30% and cereals by 20%.

Nikolova (2005) Calculated K balances at farm gate, regional and national levels. Only diary farms showed a positive K balance (145 kg K/ha). Arable and mixed farms in 7 regions of Bulgaria, representing all types of soils and regions all showed a negative K balance due to the very small amounts of K applied. The author concludes that the mean annual K deficiency varies between 43 to 79 kg/ha, and the national K balance is approximately -200,000 ton K/year, a similar level since 1990s.

The long-term consequences of a negative K balance on soil fertility are obvious. In 13 years (1989-2002), the frequency of "Low" K status soils doubled and that of "High" K status fell from 71 to 27% (Figure 6)

Figure 6

Balanced and timely nutrient application

The following examples demonstrate various consequences of correcting unbalanced nutrient management. These are related to i) long term fertilization; ii) organic agriculture; iii) the effect of balanced fertilization on yields, quality and pest and disease infestation and iv) the economics of balanced fertilization.

Long term observations

Fertilization is a decision taken by the farmer, according to economic parameters. When there is no short-term economic response to applied K, the farmer tends to eliminate this factor from his manuring policy.

In a three-year experiment in cotton grown on vermicultic soil, an increase in cumulative yield in the order of 13 to 21% was found for applying 120-240 kg K/ha, however at 480 kg K/ha, an increase of 42% was achieved (Dobermann *et al*., 2005; Figure 7). This data may mislead, because in 1985 there was only a very small increase in yield from the applied K compared to that of 1987. In addition, application of 480 kg/k/ha was the only rate in which yields were increasing in all three years. In contrast to the large K application, where no K was applied, there was a decrease in organic matter and of available soil K that caused K fixation and resulting in a three-year downward trend in yields. This example illustrates the need to consider the longer-term effect of repeated K fertilization, especially with high K rates in heavy soils with fixation capacity.

Figure 7

Organic agriculture

Organic agriculture is often perceived as a clear cut solution for better crop production. A mixture of beliefs and scientific data hinders the real questions and consequences from a long-term practice of organic agriculture. Can organic farming match today's large requirements for balanced and timely nutrient application? Soil fertility status after 21 years of organic agriculture shows a greater decline in available K in soil than where fertilizers have been used.

A 21-year long-term experiment at Forschungsinstitut für biologischen Landbau (FiBL) in Frick, Switzerland, compares four farming systems differing mainly in the management of fertilization and plant protection (Mäder *et al.*, 2002). Four basic treatments were compared: two organic systems (biodynamic and bioorganic) that used farmyard manure and slurry corresponding to a certain amount of livestock per area unit; one conventional system using the same amount of farmyard manure as the organic systems but with the addition of mineral fertilizers to reach the plant-specific Swiss standard recommendation; and another conventional system using no fertilizer during the first crop rotation, then mineral fertilizers exclusively, as in regular non-livestock farming. The results show that yields of winter wheat, potatoes and grass clover were 20% higher with the two non-organic treatments by an amount corresponding to lower input costs, including fuel.} However, there was a negative K balance with the organic treatment (-36 K_2O/ha), compared to a positive balance with mineral NPK. There was a negative N balance with all four systems but it was larger with the organic systems (-173 kg N/ha) compared to that (-108 kg N/ha) with mineral NPK fertilizers (Figure 8).

Figure 8

In contrast, organic diary farms have reported positive nutrient balances, mainly due to larger inputs of nutrients in animal feed (Öborn *et al*., 2005).

Timely application of nutrients from organic sources is complicated. Nitrogen supply is highly dependant on mineralization of the organic matter, which can be assessed in terms of total N supply, but for practical reasons is usually insufficient to meet the requirements of a crop at the appropriate time (Johnston and Poulton, 2005). Dahlin *et al*. (2005) discussed the use of N from organic material. They showed that the expected leaching loss of N from poultry manure is far greater when that from ammonium nitrate (Figure 9) and that N uptake from ammonium nitrate is much higher than that from red clover manure. Clearly, the precise timing and split application of ammonium nitrate can supply N in a much more controllable way than can be achieved with organic materials.

Figure 9

However, efficiency of phosphate use from single superphosphate (SSP) or poultry litter compost was equal (Sikora and Enkiri, 2005). Even greater efficiency of phosphate use is achieved with fertigation systems, when P is added in very frequent applications of water and fertilizer (Silber, 2005). In fact, both P and K efficiency were increased by daily and even more frequent application of water and nutrients.

In summary, organic agriculture may cause soil nutrient mining due to insufficient nutrient application and may lead to large losses, especially that of nitrogen and potassium, but not necessarily in diary farms. In contrast, using mineral fertilizers which can be applied at flexible timing and rates can increase the uptake of nutrients and thus reduce loss to the environment.

Effect on yields, quality and plant health

Nutrient application is highly unbalanced in Punjab. In 2004/05, the state consumed 1.562 Mt of nutrients, of which 1.2; 0.32 and 0.043 Mt was N, P_2O_5 and K_2O, respectively. The N:P_2O_5:K_20 ratio of 28:5:1 is highly unbalanced, due to the very high N application (282 kg N/ha) compared to the very small K application (10 kg K_2O/ha). In order to evaluate the effect of potassium in a typical crop rotation performed in districts of Punjab, IPI has initiated a research and extension activities at the KVK Bahowal, Directorate of Extension of Punjab Agriculture University. The effect of K was demonstrated in farmers' fields in 5 districts on a typical pea-sunflower-maize crop rotation, grown on sandy loam soil. This project has a specific extension character and includes demonstration plots, farmers' field days and literature in the local language (Punjabi). Both scientific and extension was possible in these experiments.

Response to K was apparent in all three crops, and ranged between 5% (in peas, with little applied K) to 45% (in sunflower, with 90 kg K_2O/ha) (Figure 10). K application also brought the following benefits:

- increased the seed / grain weight in all crops (Figure 10),
- increased the number of filled grains and seeds in maize and sunflower (+25% and +11%, respectively),
- decreased lodging in maize (-65%)
- increased the 'shininess' of grains.

Figure 10

Nutrient application is highly unbalanced also in Madhya Pradesh: in 2004/05, consumption was about 1 M t nutrients, of which N, P_2O_5 and K_2O were 617,723; 393,253 and 55,296 t, respectively. The $N:P_2O_5:K_2O$ ratio of 11:7:1 is highly unbalanced, reflecting a very low application of potash (3.7 kg K_2O/ha).

Soybean is grown on about 4.5 million ha in the State of Madhya Pradesh and production accounts for 59% of India's total. In 2004, the Secretary of Agriculture of the State declared that in 8 districts 100,000 ha of soybean, had been completely damaged by pests and insects. Total area affected was almost 1 million hectare, about 25% of the total area growing soybean in the State.

Often better plant nutrition decreases the susceptibility of crops to attacks by insects and diseases, and this reduces the need for pesticides and insecticides. Results from various experiments made by IPI and by IRRI show that applying K reduces the damage caused by insects and disease. The effect of potash application on soybean was demonstrated in an IPI experiment in Indore, Madhya Pradesh through the project "Studies on role of potassium nutrition in balanced fertilization of Soybean-Wheat cropping system" (IPI, 2005). One of the major effects for potash application was consistent reduction of infestation and incidence of various insects and disease (Table 3, Figure 11).

Level of K_2O (kg/ha)	Insect infestation				Disease incidence	
	Blue beetle (*Cneorane spp.*)	Stem fly- Stem tunnelling (*Melanagromyza sojae Zehnt.*)	Defoliators	Girdle beetle (*Oberia brevis)*	Collar rot (caused by *Sclerotium rolfsii)*	Myrothecium leaf spot
	mrl	% infestation	mrl	% infestation	% mortality	PDI
0	5.9	13.91	1.3	8.35	9.17	38.57
25	2	3.87	1	2.17	6.07	28.45
50	1.8	2.87	0.8	2.06	4.61	22.58
75	1.3	0	0.7	1.91	2.22	25.41

mrl = meter raw length; PDI = percent disease incidence (1-9 scale)

Table 3: Effect of potash application on infestation of blue beetle (*Cneorane spp*.), stem fly (*Melanagromyza sojae Zehnt.*, defoliators and girdle beetle (*Oberia brevis)* and of incidence of collar rot (caused by *Sclerotium rolfsii)* and Myrothecium leaf spot. (Source: IPI 2005: IPI-ICAR project, annual report 2004).

A reduction of 50 to 75% of the damage was observed in farmers' fields, resulting in large savings of pesticides and insecticides. In addition, potash application increased nodule number and dry weight (60-100% respectively) and consequently the yield (35%) (IPI, 2005).

Perrenoud (1990) reviewed almost 2450 literature references on this subject and concluded that the use of K decreased the incidence of fungal diseases in 70% of cases. The corresponding decrease of other pests was bacteria 69%, insects and mites 63% and viruses 41%. Simultaneously, K increased the yield of plants infested with fungal diseases by 42%, with bacteria by 57%, with insects and mites by 36%, and with viruses by 78%. Kafkafi *et al*., (2001) recently reviewed the role of both K and chloride on the suppression of diseases and stresses in plants. Potassium may exert its greatest effect on disease through specific metabolic functions that alter the compatibility relationship of the host-parasite environment (Huber and Arny, 1985).

A number of possible mechanisms may be involved. These include: (i) enhanced host tolerance due to increased water potential that restricts infection by pathogens and, in consequence, plants are better able to withstand disease. (ii) suppression/inhibition of pathogens through lower tissue NO_3^- (which decreases crop susceptibility), nitrification inhibition and to increased soil NH_4^+ and NH_4^+ uptake, resulting in rhizosphere acidification (Magen and Imas, 2004).

Figure 11

Better nutrient management, which involved reduced and split N application, along with increased P and K application, reduced the intensity of disease by 50% and increased yield by 12.5% (Table 4). These results from the Site Specific Nutrient Management (SSNM) project in the Philippines demonstrate the positive effect of nutrient management on plant health (Buresh *et al*., 2005).

N management	Disease intensity (%)	Grain yield (t/ha)
Fixed time and rate	33 (6)	4.0 (0.8)
SSNM, real time	21 (11)	4.5 (0.2)

Values within parentheses are SD.
Table 4: Effect of real-time N management on sheath blight () intensity and rice yield in the 2001 wet season at IRRI in the Philippines (Source: Buresh *et al*., 2005).

The economics of balanced fertilization

The “Reaching Toward Optimal Productivity” (RTOP) workgroup of the Irrigated Rice Research Consortium (IRRC) has been instrumental in the development, evaluation, and promotion of site specific nutrient management (SSNM) as an approach for increasing the profit of Asian rice farmers through more efficient use of plant nutrients. It operates through partnerships with the national agricultural research and extension systems (NARES) in Bangladesh, China, India, Indonesia, Myanmar, Philippines, Thailand, and Vietnam. In 2005, RTOP activities were incorporated into the new “Productivity and Sustainability” workgroup of Phase III (2005-2008) of the IRRC (IRRI, 2005). The project demonstrates the importance of N management through the use of the Leaf Color Chart (LCC) in increasing N use efficiency and yields, and consequently larger P and K requirements. Potassium fertilization recommendations are calculated through SSNM plots on farmers’ fields, taking into account also the amount of straw recycled back to the field.

The economics of SSNM have been analyzed for recent years. Table 5 shows the increased net profit gained from using the SSNM approach. Farmers in Southern India increased their net profit by 47%, while those in Southern Vietnam by only 4.25%. This calculation does not take into account additional benefits, even though not directly related to the farmers, of smaller N losses to the environment through emissions to the atmosphere and leaching.

Site	Annual net benefit (USD / ha / year)		
	SSNM	FFP	Difference
Southern India	520	352	168 (+47%)
Central Luzon, Philippines	1,218	1,078	140 (+13%)
Southern Vietnam	834	800	34 (4.25%)

Table 5: Annual net benefits for SSNM and farmers' fertilizer practice (FFP) as determined through focus-group discussions (total of two rice crops, 2002-2003). (Source: IRRI, 2005).

The RTOP workgroup is supported also by IFA, IPI and PPI.

Educational and extension activities are performed both at the scientific level and by meetings at the field level. Recommended K levels (set by the local extension service) match the latest findings of SSNM in the Old Delta in Southern India, reflecting the need to promote these to farmers. However, in the New Delta, the higher K rates recommended by SSNM (Table 6) need to be addressed at research, extension and farmers levels to be brought into practice to benefit farmers.

Parameter	Fertilizer K (kg/ha)	
	Old Delta	New Delta
Current recommendation	42	42
Use by surveyed farmers	21	37
SSNM recommendation	42	65

Table 6: SSNM recommendation for K, as compared to the current recommendation and farmers' practice, in the dry season in the Cauvery Delta of southern India. (Source: Buresh *et al*., 2005).

Conclusions

Long-term negative K balances, mainly caused by insufficient K fertilization and limited use of crop residues required for increased yields, cause deterioration of soil fertility that leads to stagnating and decreased production. Common reasons for inadequate K use are the farmers lack of knowledge, and frequently of their advisors, as well as socio-economical factors. The constant shift from staple low cost crops, to high value horticultural crops is a major driver in correcting unbalanced fertilization.

Long-term experiments with various fertilization treatments reveal valuable processes that cannot be seen in short-term experiments. Even though long-term experiments may lack immediate economical results, they have value for the longer term sustainability of food production and thus require support and advice.

Balanced and timely nutrient application contributes to sustainable growth of yield and quality; influences plant health and reduce the environmental risks. Balanced nutrition with mineral fertilizers can assist in integrated pest management and reduce damage from infestations of pests and diseases and save inputs required to control them.

Balanced fertilization generates higher profits for the farmers, not necessarily through reduced inputs. The role of education and extension in delivering the up-to-date knowledge on nutrient management is crucial, challenging and continuous.

References

Abdel Hadi, A.H. (2004). Country report on Egyptian Agriculture. A paper presented at the IPI workshop on “Potassium and fertigation development in West Asia and North Africa region”. Rabat, Morocco, 24-28 November.

Buresh, R.J., C. Witt, Alam, M.M., Ramanathan, S., Chandrasekaran, B., Laureles, E.V. and M.I. Samson. (2005). Site-specific nutrient management for rice: principles and implementation. *In*: Plant nutrition for food security, human health and environmental protection. 15th Int. Plant Nut. Coll. (IPNC). Beijing, China. pp 1062-1063.

Cui, Z.L., Chen, X.P., Zhang, F.S., Li, J.L., Xu, J.F. and Shi, L.W. (2005). Nitrogen fertilization recommendation for winter wheat / summer maize rotation system towards high yield friendly environment. *In*: Plant nutrition for food security, human health and environmental protection. 15th Int. Plant Nut. Coll. (IPNC). Beijing, China. pp 1178-1179.

Dahlin, S., Kirchmann, H., Kätterer, T., Gunnarsson, S. and L. Bergström. (2005) Possibilities for Improving Nitrogen Use From Organic Materials in Agricultural Cropping Systems. AMBIO; Vol. 34, No. 4, pp 288–295.

Dobermann, A., Cassman. K. G., Walters, D. T. and C. Witt. (2005). Balancing short – and long-term goals in nutrient management. *In*: Plant nutrition for food security, human health and environmental protection. 15th Int. Plant Nut. Coll. (IPNC). Beijing, China. pp 60-61.

El-Fouly, M.M. and A.A. El-Sayed. (1997). Potassium status in soils and crops, recommendations and present use in Egypt. *In*: Food security in the WANA region, the essential need for balanced fertilization. Proceedings of the regional workshop of IPI, Bornova, Izmir, Turkey, 26-30 May. pp 50-65.

FAI, (2005). Fertilizer Association of India. Fertilizer Statistics, 2004-2005. New Delhi, India.

FAO, (2005). Food and Agriculture Organisation Rome, Italy; web FAOSTAT. www.fao.org.

Huber, D. M. and D. C. Arny. (1985). Interactions of potassium with plant disease. *In*: Potassium in Agriculture. America Society of Agronomy. Madison, Wisconsin, USA. pp 467-479.

IPI, (2005). Annual report (internal). International Potash Institute, Horgen, Switzerland.

IRRI, (2005). International Rice Research Institute (Technical report submitted to IPI, December 2005 (ref DPPC2005-02).

Johnston, A. E. and P. R. Poulton. (2005). Soil organic matter: its importance in sustainable agricultural systems. Proceedings No. 565, International Fertiliser Society, York, UK.

Kafkafi, U., Xu, G., Imas, P., Magen, H. and J. Tarchitzky. (2001). Potassium and Chloride in Crops and Soils: The Role of Potassium Chloride Fertilizer in Crop Nutrition. IPI research topic No. 22. International Potash Institute, Horgen, Switzerland.

Mäder P, Fließbach A, Dubois D, Gunst L, Fried P, Niggli U. (2002) Soil fertility and biodiversity in organic farming. Science, V. 296, pp 1694-1697.

Magen, H. and P. Imas. (2004). Potassium chloride and suppression of disease. Poster presented at the XVTH International Plant Protection Congress, Beijing, China, May 11-16.

Nikolova, M. T. (2005). Potassium balance on field, farm and country level in Bulgaria. *In*: N. Fotyma (eds) “Fertilizers and Fertilization”, Polish Fertilizer Society – CIEC, Pulawy, Poland. V3: (24). pp 89-104.

Öborn, K., Modin-Edman, A.K., Bengtsson, H., Gustafson, G.M., Salomon, E., Nilsson, S.I., Holmqvist, J., Jonsson, S. and H. Sverdrup. (2005). A Systems Approach to Assess Farm-scale Nutrient and Trace Element Dynamics: A Case Study at the Öjebyn Dairy Farm. Ambio, Vol. 34, No. 4-5.

Perrenoud, S. (1990). Potassium and plant health, (2nd completely revised edition). IPI research topic No. 3. International Potash Institute, Horgen, Switzerland.

Shen, R. P., Sun, B. and Q. Zhao. (2005). Spatial and temporal variability of N, P and K balances for agroecosytems in China. Pedosphere, 15(3): 347-355.

Peng, S.B., Buresh, R.J., Huang, J.L., Yang, J.C., Zou, Y.B., Zhong, X.H. and G.H. Wang. (2005). Over-application of nitrogen fertilizer in intensive rice system in China. *In*: Plant nutrition for food security, human health and environmental protection. 15th Int. Plant Nut. Coll. (IPNC). Beijing, China. pp 62-63.

Yadvinder,Singh, Bijay,Singh, Ladha, J. K., Khind, C. S., Gupta, R. K., Meelu, O. P., and E. Pasuquin. (2004). Long-Term Effects of Organic Inputs on Yield and Soil Fertility in the Rice-Wheat Rotation. Soil Sci. Soc. Am. J. 68:845-853.

Silber, A. (2005). Fertigation frequency and nutrient uptake by plants: benefits and constrains. Proceedings No. 571, International Fertiliser Society, York, UK.

List of figures

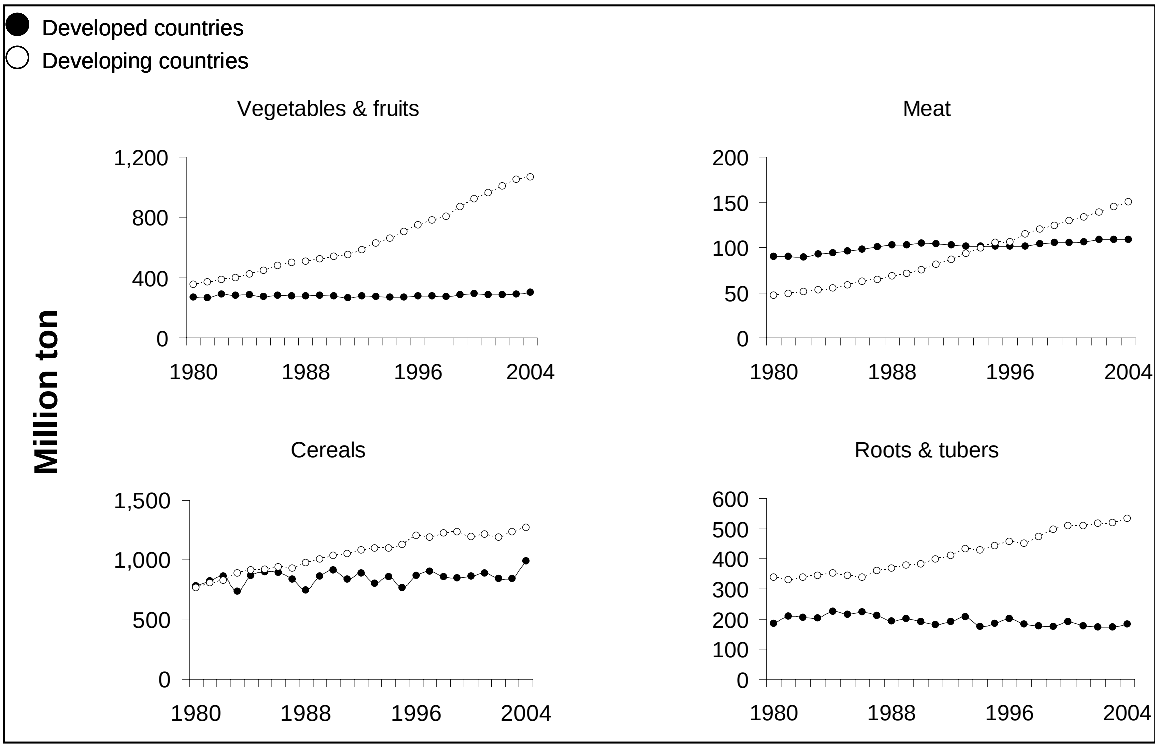

Figure 1: Production of major crop groups and meat in developed countries and developing countries, 1980-2004. (Source: FAO http://faostat.fao.org/faostat/collections , last accessed December 2005).

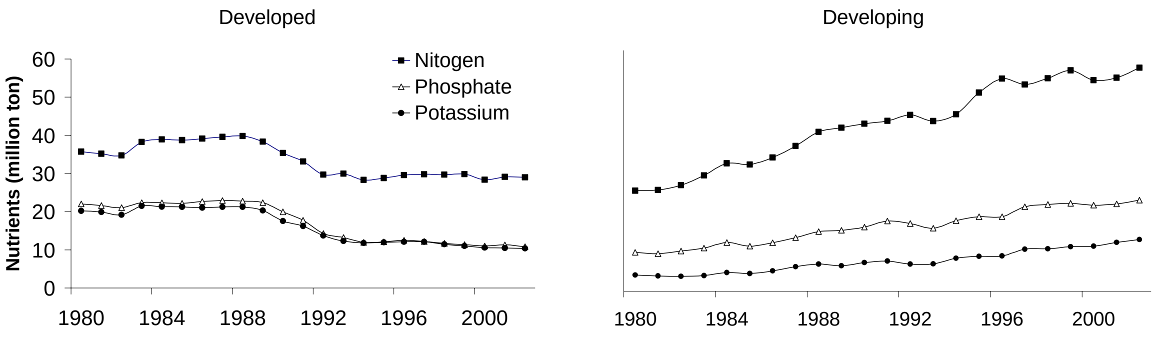

Figure 2: Nutrient consumption in developed and developing countries, 1980-2004. (Source: FAO http://faostat.fao.org/faostat/collections , last accessed December 2005).

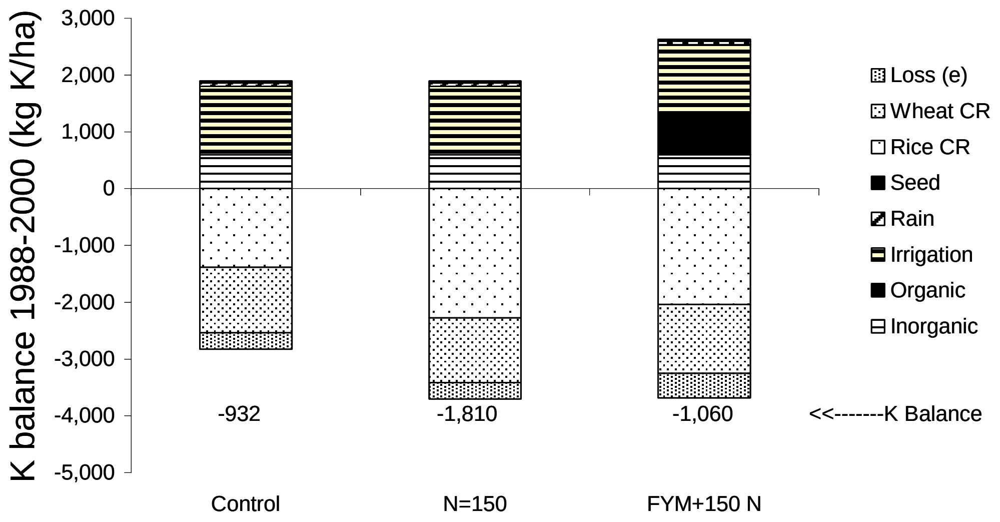

Figure 3: Apparent K balance during 1988-2000 in a long-term rice-wheat experiment, Punjab, PAU. (Adapted from Yadvinder Singh *et al*., 2004)

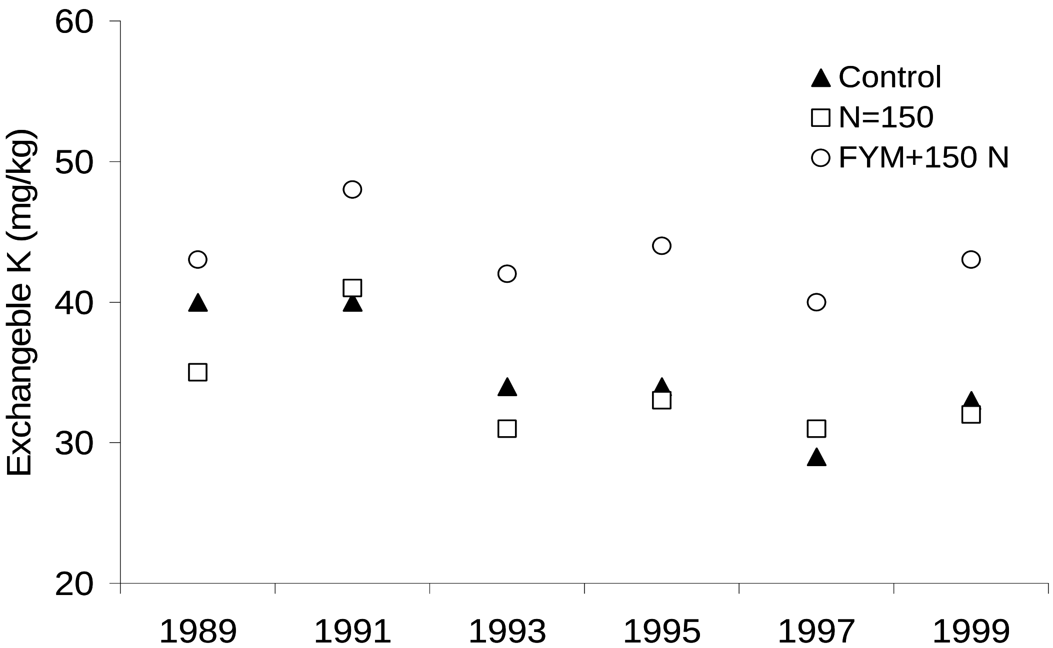

Figure 4: Long-term effects of inorganic and organic inputs on available K content in soil. (Adapted from Yadvinder Singh *et al*., 2004)

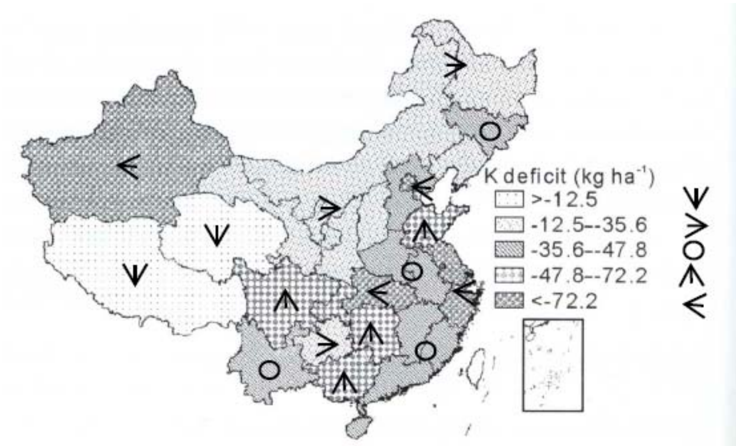

Figure 5: Change of K balance in the agro-ecosystems in China from 1997 to 2001. (Adapted from Shen *et al*., 2005).

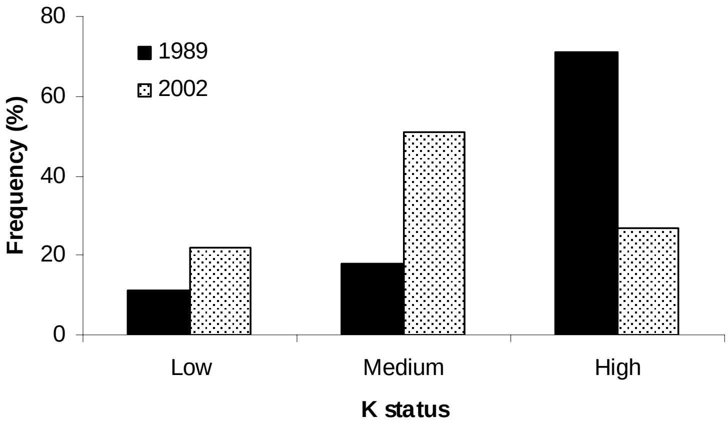

Figure 6: Change in K status in soils, 1998-2002. (Source: Nikolova, 2005).

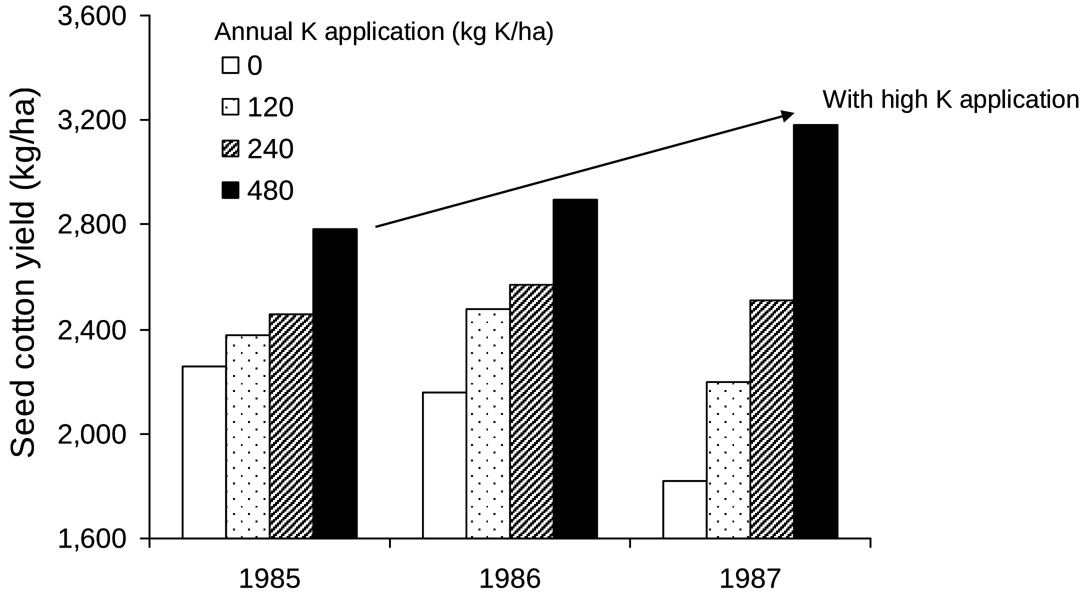

Figure 7: Response of Response of annual seed cotton yield to annual K applications on a vertisol (adapted from Dobermann *et al*., 2005)

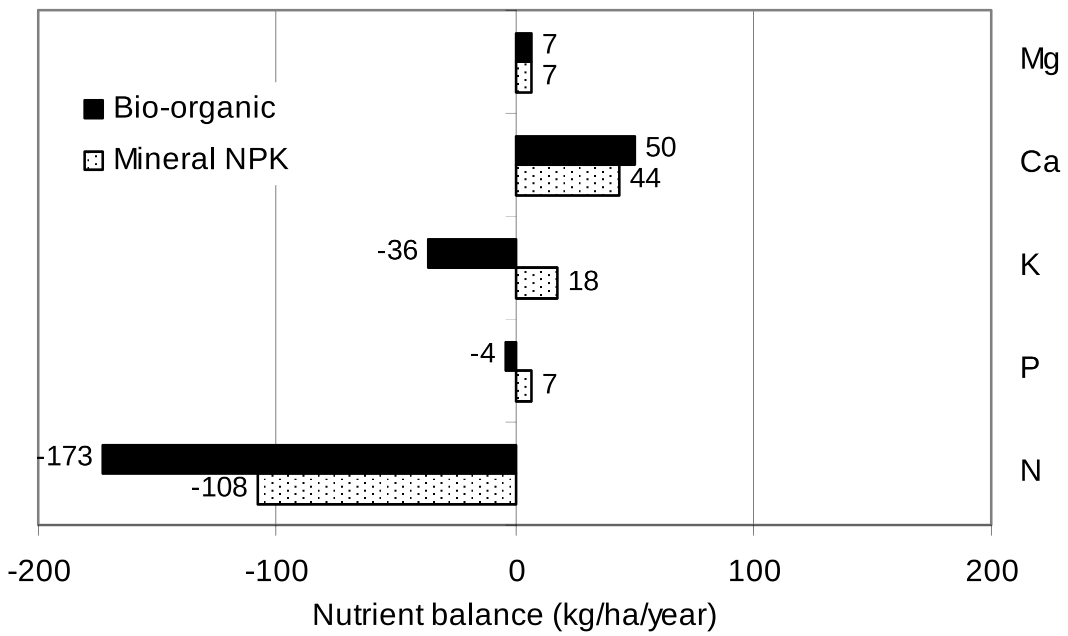

Figure 8: Nutrient balance after 21years comparing organic and mineral fertilization treatments (adapted from Mäder *et al*., 2002).

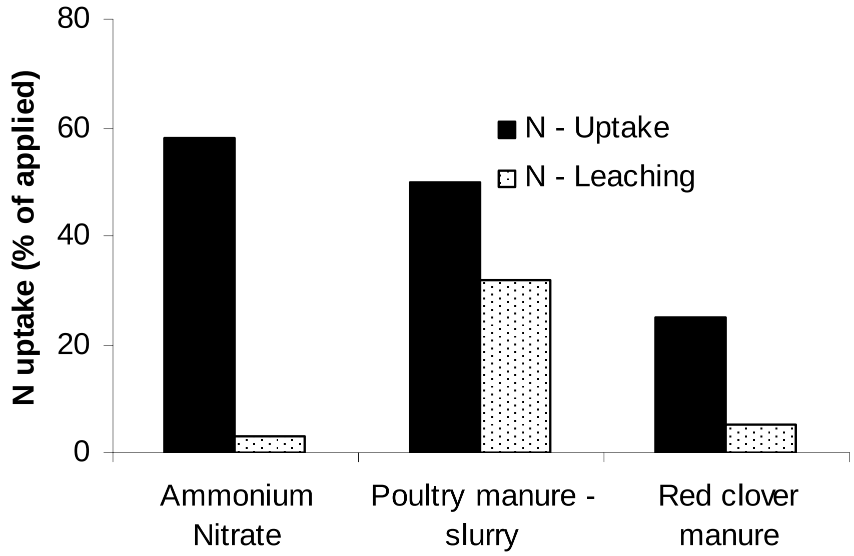

Figure 9: Nitrogen in harvested crops and leaching as affected by various N sources (adapted from Dahlin *et al*., 2005).

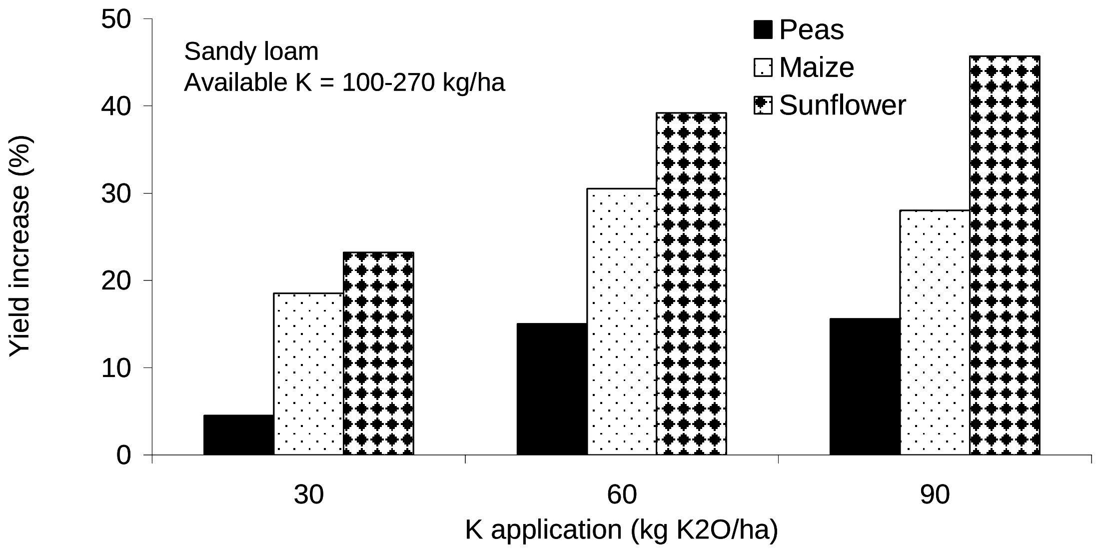

Figure 10: Potassium effect on yield increase in peas, maize and sunflower. (Source: IPI, 2005).

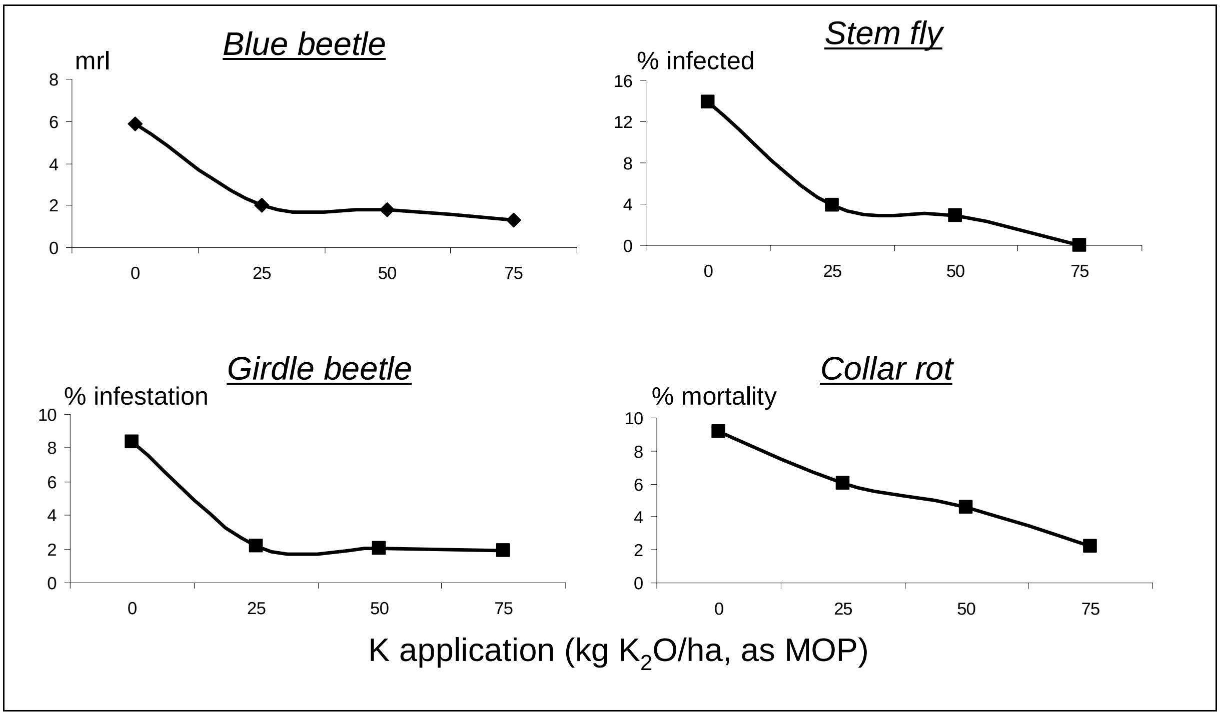

Figure 11: Effect of K on infection of soybean from various insects and disease. (Source: IPI, 2005)