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Editorial

Dear readers,

In this edition of *e-ifc* we present four papers:

"Higher Yields and Reduction of Incidence of Stem Brittle in White Carnation by Increasing Potassium Concentration and NO_3^-:NH_4^+ Ratio in the Fertigation Medium" from Israel.

"Effect of Applied Potassium in Increasing the Potential for Nitrogen Assimilation in Spinach (*Spinacia oleracea* L.)", which highlights research from India.

"Preliminary Field Observations on the Response of Wheat and Barley to High Rates of K Fertilization in Rainfed and Irrigated Regions in Lebanon".

"Potassium and CO_2 Sequestration" position paper.

These papers highlight the work of different research groups including results on advanced fertigated systems, physiological work conducted in the laboratory, and large-scale field observations on the response of wheat and barley to applied potassium.

But we need also to look to the future, and mitigation of greenhouse gasses (GHG) is undoubtedly one of the challenging issues ahead of us. We cannot claim to solve the problem of GHGs through better fertilization practices alone but, with the adoption of these practices, we are able to make a contribution in reducing emissions and also increase carbon sequestration. A model currently being developed by one of our members clearly demonstrates that, with adequate K fertilization, and to a larger extent, with improved overall nutrient management, the potential for carbon sequestration in the soil is markedly increased. To find out more, please read the IPI Position Paper on this issue.

Finally, we are excited to announce that the IPI website has a fresh look. We hope this will further increase the value of the information available.

I wish you all an enjoyable read.

Hillel Magen

Director

Carbon sequestration is on the agenda. Near Changsha, China, this experiment by the Institute of Soil Science, Chinese Academy of Sciences, in Nanjing, compares various treatments with mulching of paddy rice with the previous season's straw. Moreover, some of the treatments look at No Till practices in rice. These all may lead to increased organic matter content in soils, thus sequester more atmospheric carbon into the soil. Photo by IPI.

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Research Findings

I Higher Yields and Reduction of Incidence of Stem Brittle in White Carnation by Increasing Potassium Concentration and NO_3^-:NH_4^+ Ratio in the Fertigation Medium

Yermiyahu, U.[(1)]*, and U. Kafkafi*[(2)].

Abstract

Calyx splitting and high percentage of stem brittle was observed in the carnation (*Dianthus caryophyllus* L.), cv. Standard White Candy, grown under fertigation on a sandy loam soil, in the coastal plateau of Israel, 18 km east from the Mediterranean coast. The hypothesis was tested that the incidence of this disorder could be reduced by raising the potassium (K) concentration in the plant by increasing K and the N-NO_3:N-NH_4 ratio in the fertigation medium. Five different fertigation media supplied by trickle irrigation were compared in their effects on plant growth. In three of these media, the N-NO_3:N-NH_4 ratio was kept the same (5.3:3.7) using a commercial liquid 7-3-7, N-P_2O_5-K_2O fertilizer consisting of ammonium nitrate, phosphoric acid, potassium nitrate and potassium phosphate, with the level of K (supplied as K_2SO_4) being increased from 93, to 252 and 378 mg/L in treatments one to three respectively. In a fourth treatment, nitrogen (N) was supplied totally in the form of nitrate as KNO_3 with K at 378 mg/L and thus equivalent to the highest K treatment in which N was supplied with both N forms (Treatment 3). In all four treatments the level of N supplied was the same at 126 mg/L. General farmers' practice was compared as a fifth reference commercial treatment. A 5 x 5 Latin square arrangement was used in the experiment. Soil samples were collected three times during the season and flowers were picked three to four times a week. The total number of flowers - as well as the number in which calyx splitting was present - was recorded. The number of brittle stems was counted only once a week. Meteorological data was obtained from the Israel meteorological center in Bet Dagan, 15 km north of the field site. Soil pH in water-saturated paste decreased from 6.9 at the beginning of the season to 5.8, after 40 weeks of fertigation in the field in all treatments containing ammonium, N-NH_4. In the KNO_3 treatment soil pH was kept constant at 6.6-6.9. The increase in K levels in the fertigation media was reflected in the content of K in the plant dry matter (DM). The beneficial effects of the KNO_3 treatment probably resulted because of the absence of N-NH_4 in the fertigation media. These beneficial effects were expressed in the form of a 17 per cent increase in flower yield and a minimizing of calyx splitting. When compared to the ammonium-containing fertilizer in the irrigation water, flower quality - as measured by stem brittle - was improved by the highest level of K supply, irrespective of K-fertilizer form, KNO_3 or K_2SO_4. Two bursts of activity of stem brittle incidence were recorded four to five weeks after two cold nights below 8°C each followed by a clear sunny day. When the K content in leaf No. 5 below the tip of twigs without flower was above 3.1 per cent, 162 days after planting, a significant reduction (18 per cent) in stem brittle events was observed. These findings suggest that maintaining a continuous supply of K, at a much higher concentration in the soil solution than regarded as "sufficient" for maximum yield, may be regarded as an "insurance cost" against detrimental effects of unexpected climatic events of cold nights followed by sunny days. The treatment based on common farmers' practice resulted in similar yields as compared to the K_2SO_4 treatments, but was significantly lower than that for KNO_3. Calyx splitting and stem brittle in the farmers' practice treatment were not statistically different from any of the other treatments.

[(1)]*Gilat Research Center, Agricultural Research Organization, D.N. Negev 2 85280, Israel.*

[(2)]*The Hebrew University of Jerusalem, Department of Field Crops, Faculty of Agriculture, Rehovot, Israel.*

White carnation (Dianthus caryophyllus L.), cv. Standard White Candy. Photo by U. Yermiyahu.

Introduction

The carnation cv. Standard White Candy is prone to stem brittle and calyx splitting disorders resulting in heavy financial losses to growers. These disorders show up mainly in winter and spring (Skalska, 1983), because calyx splitting is caused by the formation of either large numbers of petals or by lateral buds inside the calyx at low temperatures (Beisland and Kristoffersen, 1969).

A systematic study of carnation mineral deficiencies reported by Messing (1958) suggests that a shortage of K, Ca, or Mg can result in poor quality blooms and weak stems. Pember and Adams (1921) reported that when N was added to the nutrient medium in large amounts the number of split calyces was reduced in the two top grades of flowers. Successive investigations have shown that increasing N concentration in the

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soil solution reduces calyx splitting (Adams *et al*., 1979). On the other hand, increasing phosphate fertilization is reported to increase calyx splitting (Winsor *et al*., 1970). Some workers have related these disorders to boron (B) deficiency on calcareous soils (Winsor *et al*., 1970). Acidification of irrigation water also significantly decreases calyx splitting of flowers (Motallebifard *et al*., 2003).

The effect of K on this disorder is controversial, with claims that increasing K concentration reduces (Adams *et al*., 1979), increases (Winsor *et al*., 1970) and is without effect on calyx splitting (Skalska, 1983). The findings of Criley *et al*. (1983) have demonstrated that calyx splitting appears in carnations when the K content in the leaves of the third flush drops below four per cent.

The influence of high cell K content on increasing frost tolerance by plants has been related to its effect on the osmotic potential of the cell sap (Beringer and Troldenier, 1980). A distinction between frost and chilling effects must be made clear. Chilling effects in the range of +5 to +10°C are commonly reported for plants of warm climates. The temperature in which a sudden change in membrane fluidity occurs is specific to each cell and dependent on the relative composition of the various phospholipids (Özcan *et al*., 2007). The higher the ratio of unsaturated/saturated fatty acids in the cell membrane, the more tolerant the tissue is to low temperatures (Beringer and Troldenier, 1980). Fertigation is a safe practical way to maintain a continuous high level of K in a soil solution of sandy soils and in plants growing in these soils (Kafkafi, 1994).

The purpose of this work was to test the hypothesis that maintaining high levels of K in plant tissue of White Carnation reduces the incidence of calyx splitting and stem brittle, as well as to report the effects of the $N-NO_3$:$N-NH_4$ ratio in the fertigation medium in this respect.

Materials and methods

Carnation (*Dianthus caryophyllus* L.), cv. Standard White Candy plants were supplied with a fertigation medium using trickle irrigation. The commercial fertilizer 7-3-7 ($N-P_2O_5-K_2O$) with a $N-NO_3$:$N-NH_4$ molar ratio of 5.3:3.7 was used as a medium in three of the treatments. In these three treatments, the concentration of K was increased from 93, to 252 and 378 mg/L in the form of K_2SO_4 (Treatments 1-3 respectively). In a fourth treatment potassium nitrate (KNO_3) as the sole N source was applied to supply K at the same K level as in the highest K_2SO_4 treatment (Treatment 3). The total N level of 126 mg/L was the same in all four treatments. A farmers' practice treatment (Treatment 5) was included in the experiment and based on application of commercial liquid fertilizers. The fertilizers used, and their concentration in the irrigation water, are specified in Table 1.

The carnation seedlings were planted on July 25 1988 in six rows, 15 cm apart on elevated beds in sheds with a roof cover of polyethylene. No side walls were used. The trickle lines were placed between two adjacent rows. The discharge rate of the emitters was two liters/hour (L/h) at a distance of 0.3 m. The experimental plots were situated within a commercial carnation plastic covered house and all other practices of crop handling were carried out by the professional grower.

The statistical design of a Latin square was used. Each plot was 3.5 x 1 m and each treatment was replicated five times. A water meter was attached to each main treatment to ensure exact delivery of water and nutrients. The fertilizers were supplied to the irrigation lines by stainless steel Venturi pumps. To ensure an accurate rate of application, the daily fertilizer supply was given before each irrigation cycle.

The fifth fully open leaf from the tip, from twigs without flowers, was sampled from 20 plants to determine their nutrients content. The leaves were dried at 60°C, ground to pass through a 30 mesh screen, and 100 mg DM were washed in 5 ml concentrated sulphuric acid and 20 drops of 30 per cent hydrogen peroxide. The solution was used to determine total K content.

Flowers were harvested three to four times a week starting on 24 January 1989 from the centre of 2 m^2 of each plot. The total numbers of cut flowers were counted for each plot and the number of flowers with split calyces noted. All the flowers from each plot were cut at 65 cm from the top of the flower and the stem was held by hand at the bottom and was tilted slightly. The number of brittle stems at the fifth joint below the flower was counted for one of the harvests each week.

Table 1. Fertilizers and amounts used in the fertigation practice.

Treatment	Fertilizer			Nutrient concentrations						Molar ratio	
	7-3-7[1]	K_2SO_4	KNO_3	$N-NH_4$	$N-NO_3$	Total N	K	S[2]	P	N:K	$N-NO_3$:$N-NH_4$
	L/m^3	*kg/m^3*	*kg/m^3*	*mg/L*						*ratio*	
1	1.5	0	0	52	74	126	93	0	24.1	9:2.4	5.3:3.7
2	1.5	0.4	0	52	74	126	252	65	24.1	9:6.4	5.3:3.7
3	1.5	0.7	0	52	74	126	378	117	24.1	9:9.6	5.3:3.7
4	0	0	0.97	0	126	126	378	0	24.1	9:9.6	9.0:0
5	Farmers' practice			89	128	217	161	0	41.7	15:4.1	9.1:2.3

[1]7-3-7 is a solution fertilizer with 7% N, 3% P_2O_5 and 7% K_2O.

[2]S values given in the table are from the fertilizers added. Irrigation water contains over 300 g m^{-3} SO_4.

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Data was analyzed using JMP 5.0 software (SAS Institute Inc., USA). Effects of the various treatment on carnation yield and quality were examined using analysis of variance (ANOVA), and whenever the F statistic was significant, differences between treatments were determined using Tukey-Kramer HSD test (at $P < 0.05$).

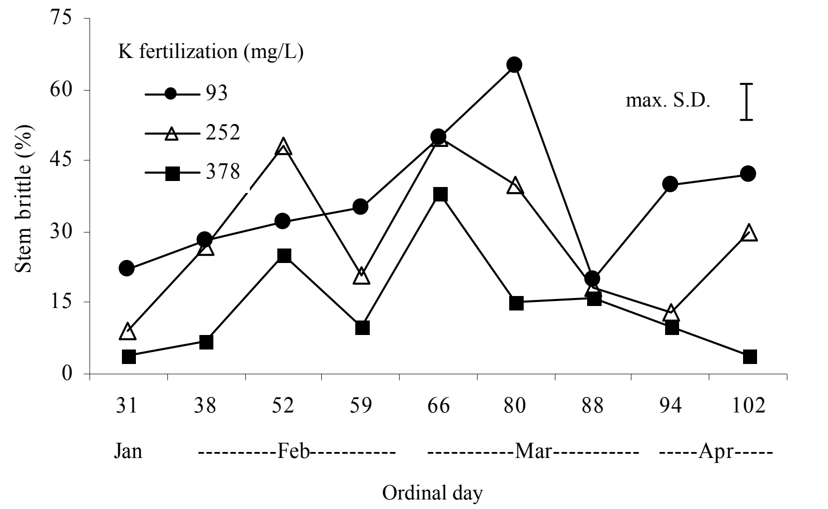

Fig. 1. Stem brittle rate as a function of time for different K fertilization rates with identical (5.3:3.7) N-NO_3:N-NH_4 ratios.

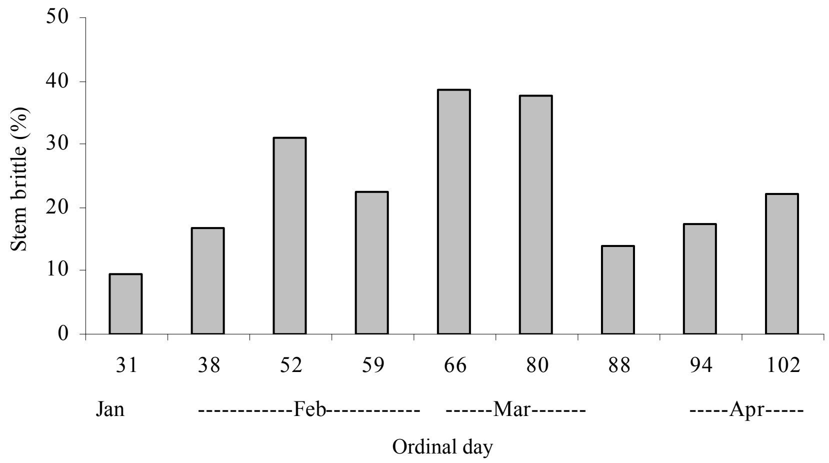

Fig. 2. Stem brittle rate as a function of time for all treatments.

Results and discussion

The percentage of stem brittle incidences showed a peak both on Feb 28 and Mar 14 (ordinal days 52 and 66; Fig. 1 and 2 respectively). These two peaks both occurred five to six weeks after cold night events below 8°C followed by clear sunny days. The K content in the fifth leaf at three specific growing periods and the overall yield per m^2 are shown in Table 2.

Throughout the experiment, higher K concentration in the fertigation was associated with lower flower yield loss due to stem brittle. When K in the fifth leaf from the apex was below four per cent, an overall seasonal average of about 31 per cent stem brittle was recorded with heavy losses to the grower. When K was above four per cent in leaves only, 18 per cent loss due to stem brittle was recorded (Table 2).

Similar responses to K levels in the leaves were reported regarding calyx splitting (Criley *et al.* 1983). Calyx splitting behavior during the growth season is presented in Fig. 3 and 4. Similar to stem brittle, calyx splitting incidences peaked twice; each event occurring a few weeks after a cold night (below 8°C) followed by a clear sunny day (Fig. 4). The peaking was most evident in treatment with ammonium (Fig. 3). The highest yield of flowers and the minimum calyx splitting was obtained in the KNO_3 treatment (210 flowers per m^2; Table 2). This treatment, in which all the N supplied was as nitrate (no ammonium), yielded about 17 per cent above the other treatments that contained ammonium in the daily fertigation. This result shows the beneficial effects from the increased nitrate. The fact that the K content of the leaves of the KNO_3 treatment was the same as that of the high K level in the K_2SO_4 treatment (with ammonium) suggests that the beneficial effect was not due to the depressing effect of ammonium on K uptake (Table 2). The flower quality, as measured by stem brittle, was improved by the highest level of K irrespective of the K-fertilizer form, KNO_3 or K_2SO_4 (Table 3). The treatment based on common farmers' practice resulted in similar yields as compared to the K_2SO_4 treatments but were significantly lower than for KNO_3. Calyx splitting and stem brittle in the farmers' practice treatment were not statistically different from any of the other treatments.

Stem brittle susceptibility was significantly reduced by maintaining high levels of K in the irrigation water throughout the season at a constant level of total N concentration. As long as the temperatures did not drop below 12ºC the high doses of K could have been regarded a luxury supply, or even a waste of K fertilizer, since no increase

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Table 2. Fertilizers and amounts used in the fertigation practice; effects on yield, percentage of split calyxes and brittle stems, water soluble K in the soil at 1:5 soil: solution weight ratio and K content of leaf No. 5.

Treatment	Fertilizer			Yield	Calyx splitting	Stem Brittle	Water soluble soil K content weeks after planting			K content of 5th leaf weeks after planting		
	7-3-7[1]	K_2SO_4	KNO_3				18	26	40	18	26	40
	L/m³	*kg/m³*	*kg/m³*	*flowers/m²*	---------%---------		-------------*mg/kg dry soil*-----------			------------*mg/kg DM*------------		
1	1.5	0	0	179.2 b	27.8 a	31.8 a	40 b	66 c	127 b	42.4 bc	32.4 b	24.6 c
2	1.5	0.4	0	179.6 b	29.9 a	30.9 a	145 a	162 b	300 a	45.8 ab	37.2 ab	27.2 b
3	1.5	0.7	0	179.6 b	25.0 ab	16.9 b	146 a	231 a	356 a	48.9 a	40.5 a	32.6 a
4	0	0	0.97	210.0 a	21.5 b	18.5 b	149 a	223 a	307 a	47.5 ab	40.4 a	29.8 ab
5	Farmers' practice			183.0 b	24.0 ab	24.7 ab	51 b	79 c	116 b	40.9 c	38.1 ab	26.5 bc

[1]7-3-7 is a solution fertilizer with 7% N, 3% P_2O_5 and 7% K_2O.

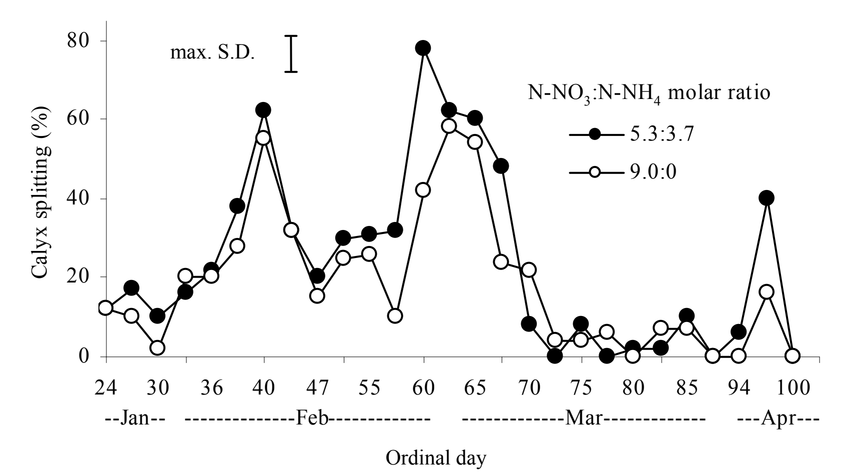

Fig. 3. Calyx splitting as a function of time for different N-NO_3:N-NH_4 ratios and constant K concentration (378 mg/L) in irrigation solution.

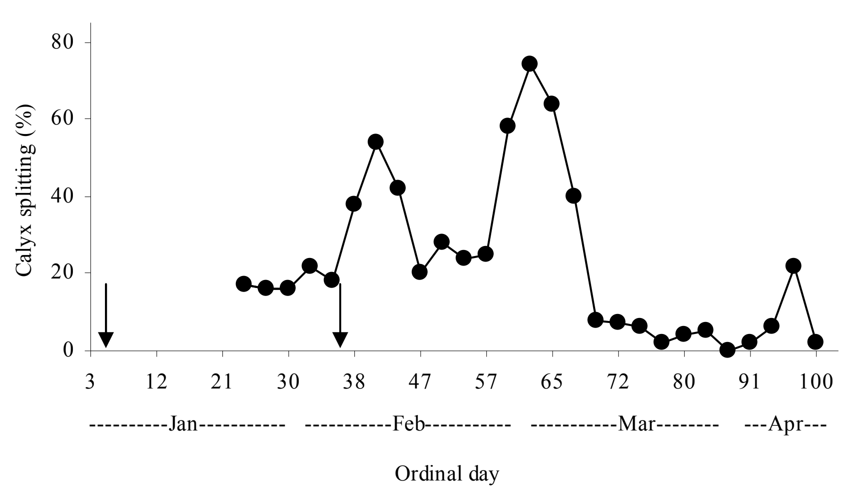

Fig. 4. Calyx splitting rate as a function of time for all treatments. The arrows indicate nights with below zero temperatures.

in flower yield or quality was observed. However, the economic benefits to the grower by maintaining high K in the soil solution is clear, even after only a single night event of low temperature. The financial consequence of the damage caused during this one night exceeds the total fertilizer costs for the whole season. The positive K effect in preventing stem brittle is only detected about five weeks after the cold night events, so it is difficult to directly relate the influence of K on flower quality. It may be suggested that the continuous supply of K, at a much higher concentration in the soil solution than regarded as "sufficient" for maximum yield, may be regarded as an "insurance cost" against unexpected climatic events.

High K content in the fifth leaf reduced stem brittle in the White Carnation. The point of breakage occurred in the tissue connecting the stem nodes, the weak point developing during the cold event, which later allowed breakage even with the stem only slightly tilted. A possible explanation of this phenomenon might be postulated as follows: The low temperature is most likely to have impaired the development of the cell wall structure in the youngest and most vulnerable joint of the stem but the resulting damage would not be immediately apparent. However, with progressive growth and increasing weight of the stem this weakened structure would become unstable with a

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break occurring in the fifth joint below the flower, as observed at flower harvest five weeks after the original damage.

The actual physiological mechanism operating in the carnation is not clear. The susceptibility to such cold events is also very much dependent on the plant variety. Huett (1994) in Australia reported that flowers produced in March had thinner (3.11 v. 5.24 mm diameter) and weaker stems than those produced in October.

The changes in varietal response to chilling effects might be due to differences in the fatty acid composition of their membranes since these membranes in root cells affect the rates of ion and water transport in the root, as well as the carbohydrate content of the plant and the translocation of nutrients and metabolites in the plant (Marschner, 1995).

In tomato production, high levels of K in the root medium results in increased K concentration in the leaf and improved fruit quality (Adams et al., 1979). Concentration of 100 and 300 ppm K in the liquid feed resulted in 4.8 and 7.0 per cent of K in the leaves respectively, with high leaf level producing the best quality fruit. High levels of K were also recommended to reduce hollow fruit in tomato, which is associated with low light in the greenhouse (Winsor, 1968).

The effect of soil temperature around the crown node of wheat on growth and nutrient translocation was studied by Boatwright *et al.* (1976). Careful chilling only to the crown zone enabled these workers to demonstrate that the cold zone restricted translocation of rubidium (^{86}Rb) to the top and, also by inference, that of K.

The concentration of K in the cytoplasm must be maintained at a constant level of 150 mM and that in the vacuole at a minimum level of 20 mM (Leigh and Wyn Jones, 1984). Any further decline below these values causes a severe reduction in plant growth. When the K supply is abundant, the cell accumulates K in the vacuole and, as a result, the total K content, as expressed as dry matter, increases. This increase in the content of K on the whole plant, without further increase in plant growth, is usually referred to in the agronomic literature as “luxury consumption” or range of high level (Bergmann and Bergmann, 1985). This “luxury consumption” may be considered a good “insurance policy” which growers may take out against environmental cold stresses. Such a policy might prove profitable when quality of the plant product is taken into account. Flower yield losses due to increased stem brittle and calyx splitting in winter seasons might be reduced when high K supply is maintained during the whole growing season.

Classification of carnation flowers before marketing. Photo by Sima Kagan.

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Carnation plants grown on a commercial soilless culture. Photo by Sima Kagan.

The paper "Higher Yields and Reduction of Incidence of Stem Brittle in White Carnation by Increasing Potassium Concentration and NO_3^-:NH_4^+ Ratio in the Fertigation Medium" appears also at:

K Center/Nitrogen and Potassium Interactions

Research Findings

II Effect of Applied Potassium in Increasing the Potential for Nitrogen Assimilation in Spinach (*Spinacia oleracea* L.)

Anjana[(1)], S. Umar[(1)], and M. Iqbal[(2)].

Abstract

Spinach (*Spinacia oleracea* L.) supplied with increasing levels of potassium (K) was grown in soil in a pot experiment under greenhouse conditions. The soil used, low in available potassium (40 mg/kg), was treated with a basal fertilizer application of nitrogen (100 mg N/kg soil) and phosphorus (30 mg P/kg soil) together with increasing amounts of potassium chloride (KCl; 0, 40, 80 and 120 mg K/kg of soil). Analysis of leaves from three-week old plants revealed that increasing amounts of applied potassium chloride (KCl) resulted in a progressive increase in the nitrate concentration (NO_3^-) as well as in the activities of the enzymes of the nitrogen metabolic pathway i.e. nitrate reductase (NR), nitrite reductase (NiR), glutamine synthetase (GS), glutamate synthase (GOGAT), and glutamine dehydrogenase (GDH). Highest accumulation of nitrate, as well as the activities of these nitrogen (N) assimilating enzymes, was observed in the K_{80} treatment. The results indicate the potential of potassium application for improving the nitrogen use efficiency (NUE) of spinach plants.

Introduction

In many parts of the world, there is a practice of imbalanced fertilization in which an excess supply of nitrogen is commonly accompanied by an inadequate supply of another nutrient. This may often be potassium (but it also applies to other nutrients e.g. phosphorus and sulphur), the lack of which restrict nitrogen uptake and utilization, and hence plant growth. When potassium is limiting, nitrogen fertilizers are used inefficiently by the crop. This nutrient imbalance is thus associated with low NUE of crop plants which is of detriment - not only to crop production directly, but also to the environment - because of the consequences of unused N by the crop. In addition to adverse environmental effects, a misuse of natural resources expended in producing the N fertilizers also has to be taken into account (Krauss, 2003). There is therefore a need to understand the importance of balanced fertilization in improving the NUE of plants. Identification and exploitation of positive interactions between nutrients provides a fundamental means of increasing returns in terms of yield, quality and NUE from applied N (Aulakh and Malhi, 2004).

Potassium plays a key role at various stages in N metabolism. At a basic level it is required in high concentrations in the synthesis of protein, which includes the binding of RNA to ribosomes. In green leaves chloroplasts account for about half the RNA and leaf protein. Since most chloroplast protein in green leaves is present as RuBP carboxylase, the CO_2 fixing enzyme in C3 plants, which requires potassium (as well as Mg) for activation, a lack of potassium inhibits photosynthesis and hence the ability for dry matter accumulation (Marschner, 1995). Engels and Kirkby (2001) envisage a cycling role for K^+ within the plant involving the transport and assimilation of nitrate (NO_3^-). During transport from root to shoot in the xylem, the negative charge of the nitrate is largely balanced by the positive K^+ charge as evident from chemical analysis of xylem sap. On assimilation of nitrate in the leaves, the negative charge is then transferred to organic compounds including carboxylic and amino acids which are transported together with K in the phloem from shoot to root. Nitrate uptake appears to be highly dependent on K. Without adequate K, nitrate accumulates in roots cells, which retards further nitrate uptake (Anjana *et al*., 2007a).

The significance of potassium in affecting uptake, translocation and reduction of NO_3^- is well documented (Ruiz and Romero, 2002). However, studies related to its effect on the enzymes of nitrogen assimilation and metabolism is meagre. Therefore, the present experiment considers the influence of potassium on foliar assimilation of nitrate as expressed by the nitrate concentration in the leaves and the activities of the most important nitrogen metabolizing enzymes involved namely nitrate reductase (NR), nitrite reductase (NiR), glutamine synthetase (GS), glutamate synthase (GOGAT), and glutamate dehydrogenase (GDH). The aim of this study was to help elucidate the mechanism for improving NUE with balanced potassium fertilization.

Crop plants absorb most nitrogen as nitrate, because ammonium is so readily oxidized to nitrate by nitrifying bacteria in soil. Reduction of nitrate to ammonium in plants occurs in two distinct reactions catalyzed by different enzymes, namely NR and NiR. Ammonium can be toxic to plant function and therefore must be rapidly assimilated into non-toxic organic compounds. In most plants, ammonium is assimilated into amino acids through the joint activity of two enzymes in the chloroplasts: GS and GOGAT. GS catalyzes the first step of ammonium incorporation into glutamate using ATP to yield glutamine. In the presence of reducing power from photosynthesis, GOGAT then catalyzes the transfer of the amide group of glutamine to 2-oxoglutarate resulting in the formation of two molecules of glutamate. One molecule of glutamate is thus produced from one molecule of

[(1)]Department of Botany, Jamia Hamdard, Hamdard Nagar, New Delhi-110062, India.

[(2)]Department of Plant Production, College of Food & Agricultural Sciences, King Saud University, Post Box # 2460, Riyadh 11451, Saudi Arabia.

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2-oxoglutarate and one molecule of ammonia. The effectiveness of these enzymes in ammonia assimilation is highly dependent on photosynthetic activity and would thus be expected to be indirectly dependent on potassium nutritional status. An alternative, but now generally recognized as a less important pathway for the formation of glutamate, involves the reductive amination of 2-oxoglutarate by ammonium, catalyzed by mitochondrial GDH. In this paper we present findings of the effects of K plant status on the activities of these N assimilating enzymes in the leaves of spinach.

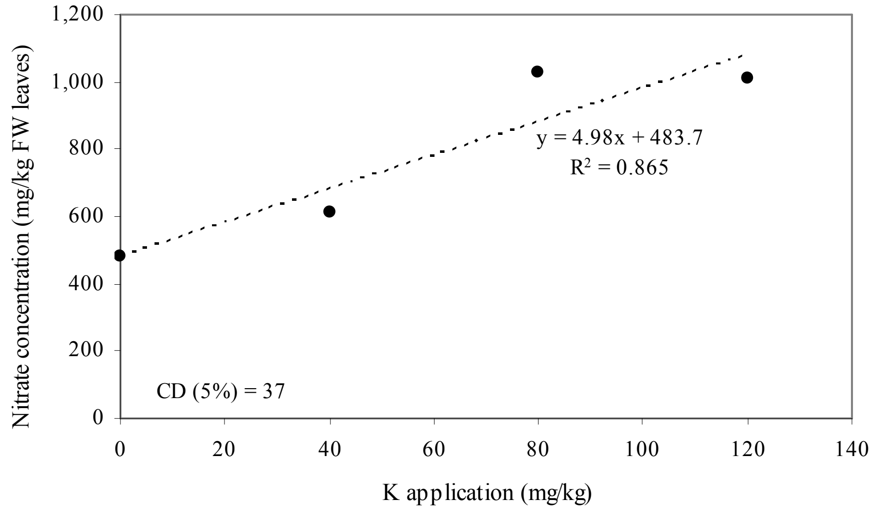

Fig. 1. Nitrate concentration in leaves with increasing application of K.

Materials and methods

A pot experiment was conducted at The Herbal Garden, Jamia Hamdard, New Delhi, during the winter season of 2005-2006 under greenhouse conditions. Prior to sowing, pots were lined with polythene bags and filled with 8 kg of soil low in available potassium (40mg K/kg soil). The soil (Lukhi soil series of Gurgaon) was loamy sand (83.6 per cent sand, 6.8 per cent silt and 9.6 per cent clay) with neutral reaction (pH 7.1). Its dry bulk density was 1.39 g/ cm^3. The available nitrogen (30 mg/kg), phosphorus (4 mg/kg) and potassium (40 mg/kg) contents were low (Anjana *et al.*, 2007b). Spinach seeds (*Spinacia oleracea* L.) were sown and cultivated at three plants per pot, supplied at uniform levels of nitrogen and phosphorus i.e. 120 and 30 mg/kg soil, respectively but with increasing levels of potassium i.e. 0, 40, 80 and 120 mg/kg of soil. The sources of N, P and potassium were ammonium nitrate (NH_4NO_3), sodium phosphate (NaH_2PO_4) and KCl, respectively. Leaves were analyzed for nitrate concentration and nitrogen assimilating enzymes simultaneously at the 3-week stage of plant growth.

Estimation of nitrate and *in vitro* assays of nitrate NR, nitrite reductase (NiR), glutamine synthetase (GS), glutamate synthase activity (GOGAT) and glutamate dehydrogenase (GDH) activities were carried out using the standard protocols followed in our laboratory.

Results and discussion

All the parameters of nitrogen metabolism analyzed in spinach leaves were directly influenced by potassium application.

Nitrate levels showed a linear response to potassium fertilization with maximum nitrate concentration at K_{80} (Fig. 1), representing 112 per cent increase with respect to the lowest concentration found at K_0 application rate. These results were expected since a close relationship exists between K^+/NO_3^- uptake and because K^+ has been demonstrated to be the major accompanying cation of NO_3^- during transport in the xylem (Blevins, 1985).

Nitrate reductase activity (NRA) also showed a linear and positive response with increasing potassium application with the highest activity at K_{80} (Table 1), an increase over the control of 101 per cent. This finding is in accordance with the increasing nitrate concentrations because NR is a substrate inducible enzyme.

Table 1. Effect of applied potassium on the activities of nitrogen metabolizing enzymes in spinach leaves at 3-week stage of plant growth.

Enzyme activity	Applied K (mg/kg)				CD (5%)
	K_0	*K_{40}*	*K_{80}*	*K_{120}*	
Nitrate reductase activity (NRA; µmoles nitrite h^{-1} mg^{-1} protein)	0.296	0.376	0.597	0.589	0.009
Nitrite reductase (NiR; µmoles nitrite h^{-1} mg^{-1} protein)	3.210	4.914	5.251	5.217	0.023
Glutamine synthetase (GS; µmoles GHA min^{-1} mg^{-1} protein)	0.1691	0.2015	0.2905	0.2893	0.004
Glutamate synthase (GOGAT; µmoles NADH min^{-1} mg^{-1} protein)	0.0332	0.0496	0.0534	0.0522	0.001
Glutamine dehydrogenase (GDH ; µmoles NADH min^{-1} mg^{-1} protein)	0.1928	0.2293	0.2719	0.2695	0.003

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Similarly, activities of all other enzymes of the pathway namely, NiR, GS, GOGAT and GDH continued to increase with increasing supply of potassium (K_{80}), leveling off thereafter. The increases in these enzymes at K_{80} in comparison to the control were 64 per cent, 72 per cent, 61 per cent and 41 per cent for NiR, GS, GOGAT and GDH, (Table 1) respectively.

The results indicate that increasing potassium application rates facilitates the uptake and transport of nitrate towards the aerial part of the plants, which in turn enhances the activities of the nitrogen assimilating enzymes. The highest levels of nitrate, as well as the nitrogen metabolizing enzymes at K_{80} indicate this to be the most efficient rate of application in promoting nitrate utilization in this soil. The parallel increase in activities of nitrogen assimilating enzymes with nitrate concentration in relation to the progressive increase in potassium application shows, moreover, that these enzymes act in a coordinated manner in order to assimilate nitrogen in the plants. Potassium thus appears to play a significant role in improving NUE of plants by means of enhancement of nitrate uptake with concomitant increase in nitrogen metabolizing capacity of the plants.

Conclusions

Under conditions of low availability of soil K, together with imbalanced N/K fertilization in spinach production, application of potassium enhanced nitrate uptake stimulated the activities of the nitrogen assimilating enzymes thus improving the NUE of the plants. Further studies on balanced fertilization need to be carried out using different crops and soils to prevent environmental degradation and wastage of natural resources.

Acknowledgement

The authors gratefully acknowledge the National Bureau of Plant Genetic Resources (NBPGR), Indian Agricultural Research Institute (IARI), New Delhi for providing the seeds of *Spinacia oleracea* L. The senior author is grateful to The Council of Scientific and Industrial Research, India for their financial support.

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The paper "Effect of Applied Potassium in Increasing the Potential for Nitrogen Assimilation in Spinach (*Spinacia oleracea* L.)**" appears also at:**

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[K Center/Nitrogen and Potassium Interactions]

Research Findings

III Preliminary Field Observations on the Response of Wheat and Barley to High Rates of K Fertilization in Rainfed and Irrigated Regions in Lebanon

Al-Zubaidi, A., A. Alameddine, and I. Bashour[(1)].

Introduction

The role of potassium (K) as an essential nutrient for agricultural crops is well established. Uptake of potassium is frequently as high as or even higher than that of nitrogen (N) (Mengel and Kirkby, 2001). About 50 enzymes, including those responsible for energy transfer and the formation of sugars, starch and proteins are activated by potassium so that its supply to the plant and its cellular concentration within the plant are of major importance (Krauss, 1997; Drast, 1992).

Adequate potassium nutrition results in superior quality cereal plants because of improved efficiency of photosynthesis, increased resistance to some diseases, and greater water use efficiency. It also helps maintain a satisfactory balance between carbohydrates and protein and, in addition, strengthens cereal straw and favors grain filling.

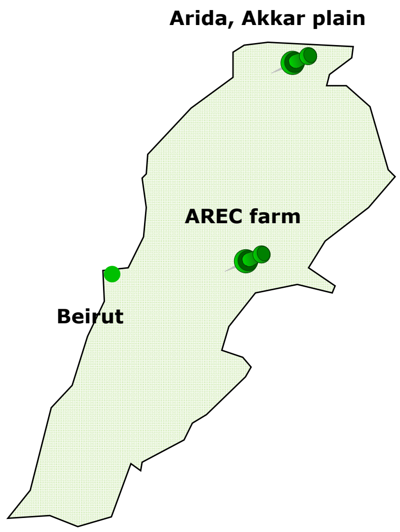
Older literature from Lebanon (Ryan and Hamze, 1981) indicates a lack of response of cereal crops to added potassium fertilizers on Bekaa clay soils containing 200 mg available K/kg soil. Recent investigations on K availability in Lebanese soils, however, has provided evidence of a possible positive response to K fertilization in Akkar soils, which are low in K content (Al-Zubaidi *et al.*, 2008a and 2008b). Recently, Darwish *et al.* (2007) also reported that in clay soils, potato responded to K application even when soil testing showed an available value close to 300 mg K/kg soil. Similarly, Al-Zubaidi (2003) observed that high doses of potassium were found to be beneficial for barley in some Iraqi soils.

There is limited information regarding the response of cereals to high rates of potassium fertilization in different Lebanese soils. The purpose of this field work was therefore to test the response of wheat to potassium application in irrigated soils of the Beqaa valley and the response of wheat and barley in rainfed soils of the Akkar plain in Lebanon (see map).

Field Trial No. 1: Response of irrigated wheat in the Beqaa Valley

A field experiment was conducted in the Beqaa area at the American Research and Educational Center (AREC) of the American University of Beirut (AUB), 80 km east of Beirut. Some physical and chemical properties of the soil (Table 1) were determined according to the methods described by Richards (1954). Different potassium forms (water-soluble: H_2O-K; potassium extracted by NH_4OAC: Exch-K; and potassium extracted by nitric acid: Acid-K) were determined by the methods described by Pratt (1965). The concentration of potassium in all extracts was measured by flame photometry.

The trial was carried out during 2006-2007. Each of the plots was 100 m^2. The fertilization treatments were as indicated in Table 2. At harvest, the grain was collected, weighed and yields of treatments compared.



Map of Lebanon with the experimental sites.

Table 1. Soil properties at AREC farm, Beqaa Valley.

Parameter	Unit	Value
EC	dS/m	0.28
pH	-	7.67
CEC	cmol/kg	31.0
$CaCO_3$	%	29.7
OM	%	2.6
Exch. cations		
Ca	mg/kg	5,670
Mg	mg/kg	274
Texture class	-	Clay
Potassium		
H_2O-K	mg/kg	4.5
Exch.-K	mg/kg	575
Acid-K	mg/kg	1,460
K-saturation	%	7.7

Table 2. Fertilization treatments applied in both locations.

Treatment	N-P_2O_5-K_2O	Fertilization
	---kg/ha---	
Control	0	0
N	170-0-0	810 ammonium sulphate
NP	170-170-0	810 ammonium sulphate + 350 superphosphate
NPK1	170-170-170	1,000 compound fertilizer (17-17-17)
NPK2	170-170-340	1,000 compound fertilizer (17-17-17) + 340 of potassium sulphate
NPK3	170-170-510	1,000 compound fertilizer (17-17-17) + 680 of potassium sulphate

Note: In addition to these nutrients, 100 kg N/ha was applied at the tillering/elongation stage in all treatments.

[(1)]*Faculty of Agricultural and Food Sciences, American University of Beirut, Lebanon. Corresponding author:* ib02@aub.edu.lb

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Results

The yield of wheat (grain) in kg/ha in different treatments is shown in Table 3.

The data shows that there was a marked increase in the grain yield of wheat in the treatments which received N-P or N-P-K in comparison with the control and N only treatment. The increase in the yield of wheat was observed, in particular, in treatments NPK2 and NPK3, which received double and triple doses of potassium fertilizers (340 and 510 kg K_2O/ha, respectively). This shows that applying high rates of potassium could be beneficial for wheat production in this region. We suggest that using 17-17-17 compound fertilizer (1000 kg/ha) for wheat may not supply enough potassium for maximum yield. It is also worth mentioning that the analysis of soil samples after harvest showed that the application of K fertilizer increased the amounts of water-soluble K, and exchangeable-K as well as in the ratio of exch-K/exch. Ca+Mg, indicating that the application of K-fertilizer had a positive residual effect on soil potassium (results not shown).

The results of a second experiment which were repeated during 2007-2008 at AREC farm confirmed the observations made during 2006-2007: there was a clear response of wheat to potassium fertilizer application in treatments NPK2 and NPK3, which received double and triple doses of potassium as compared to NPK1 treatment (Table 4). These findings also clearly indicate that the affect on yield was brought about by an increase in the 1000 grain weight.

Table 3. Yield of wheat (kg/ha) in different treatments, AREC farm.

Treatment	Yield
	kg/ha
Control	344
N	659
NP	1,496
NPK1	1,437
NPK2	1,888
NPK3	2,171

Table 4. Yield of wheat in different treatment for the year 2007-2008, AREC farm.

Treatment	Yield	1000 grain weight
	mt/ha	*gr*
NPK1	4.40	171
NPK2	5.07	181
NPK3	5.27	212

Table 5. Soil properties at Arida, Akkar plain.

Parameter	Unit	Value
EC	dS/m	0.34
pH	-	8.0
CEC	cmol/kg	29.0
$CaCO_3$	%	3.75
OM	%	2.65
Texture class	-	Sandy clay loam
Exch. cations		
Ca	mg/kg	3,560
Mg	mg/kg	793
K	mg/kg	45

Field trial No. 2: Response of rained wheat and barley at Akkar Plain

The response of high K fertilization under rainfed conditions was carried out in a field trial on rainfed farmers' fields in Arida, Akkar plain, North Lebanon during 2006-2007. The fertilization treatments were the same as those shown in Table 2. The area of each plot was one dunam (1,000 m^2). Soil properties are outlined in Table 5.

Results

This field observation was carried out on a large scale (one dunum for each treatment) in the farmers' fields. The relative yields were used for comparing the effect of each treatment with that of the control as indicated in Table 6. The results show that, in general, wheat responded much more to fertilization than barley. The greatest response of both crops was to treatment NPK2 (170 kg N, 170 kg P_2O_5 and 340 kg K_2O per ha) which received a double dose of potassium as compared to that of NPK1. In the case of wheat, the yield was 6.71 mt/ha (2 mt/ha or 43.4 per cent greater than the control) and for barley 4.64 mt/ha (only 0.6 mt/ha or 15 per cent greater than the control). At the highest rate of potassium application, treatment NPK3, the yield response of both wheat and barley declined, probably because of the nutrient imbalance introduced in this treatment. It was also observed that the wheat and barley straw in treatments NPK2 and NPK3 were taller and thicker than in the other treatments.

Conclusions

A positive response to doubling the rate of K fertilization was observed at both the Beqaa and Akkar Plain field trials. The increase in yield for wheat in the two field trials ranged between 20-26 per cent when comparing yield of NP to NPK2 treatments. For barley, however, the increase in yield was about 10 per cent when comparing NP to NPK2 treatments.

Under present international prices of wheat and barley (US$180-200/mt), expenditure on such an increase in potassium use may not be economically viable. But should international prices of cereals increase, such as occurred in 2008 to US$600-800/mt, then farmers should give due attention to the positive response of large applications of potash fertilization for cereals in Lebanese soils.

Table 6. Yields of rainfed wheat and barley crops, Arida, Akkar.

Treatment No	Yield		Relative Yield	
	Wheat	Barley	Wheat	Barley
	---------------*mt/ha*---------------		---------------%---------------	
Control	4.68	4.03	100.0	100.0
N	5.30	4.10	113.3	101.7
NP	5.59	4.23	119.4	104.5
NPK1	5.98	4.13	127.8	102.5
NPK2	6.71	4.64	143.4	115.2
NPK3	5.66	4.35	121.0	107.9

Research Findings

Acknowledgments

Special thanks go to the University Research Board (URB) at the American University of Beirut; The Institute of International Education's Scholar Rescue Fund (SRF); and the International Potash Institute (IPI) for their support to this work.

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The paper "Preliminary Field Observations on the Response of Wheat and Barley to High Rates of K Fertilization in Rainfed and Irrigated Regions in Lebanon" appears also at:

Regional Activities/West Asia and North Africa (WANA)

Papers from Lebanon

The following publications, papers and presentations from Lebanon appear on the IPI website:

1. **Evaluations of K Availability in Selected Soils from Lebanon.** Al-Zubaidi, S. Yanni, and I. Bashour. 2008. *e-ifc* No. 15, March 2008. View paper.
2. **Fertigation and Conventional Potassium Application to Field Grown Potato in Lebanon: Perspective to Enhance Efficiency.** Darwish, T., T. Atallah, N. Khatib, and F. Karam. 2004. Presented at the Potassium and Fertigation Development in WANA, Marrakesh, Morocco. View paper.
3. **Fertigation Potentials in the Near East Region.** Bashour, I., and M. Nimah. IPI Regional Workshop on Potassium and Fertigation Development in West Asia and North Africa, Rabat, Morocco, 24-28 November 2004. View paper.
4. **Balanced Fertilization in WANA Region.** Krauss, A. Presented at the IPI-NCARTT Regional Workshop on Potassium and Water Management in West Asia and North Africa, 5-8 November 2001, Amman, Jordan. View paper.

Position Paper

Potassium and CO_2 Sequestration

Background

The Kyoto Protocol imposed limits to industrial emission of six greenhouse gases (GHGs), mostly CO_2, by the years 2008–2012. Concomitantly, it recognized three mitigation actions, all associated with land-use, and known as the land-use, land-use change, and forestry actions. Within the land-use category, tillage, crop residue, and nitrogen management effects on carbon sequestration have been studied and evaluated (e.g. Schlesinger, 2000; Allmaras *et al*., 2004). Similarly, the capacity of global forests to sequester CO_2 has also been assessed but, due to variability in tree cover and biotic conditions, the current estimates are at best qualitative. No attempt has been made so far to evaluate the impact of plant nutrition on CO_2 sequestration, although this approach is embodied in the land-use mitigation category. Potassium is of particular interest since crops are very responsive to it. Additionally, it requires considerably less energy than nitrogen for fertilizer manufacture and at an adequate level in plants can enhance N-use efficiency (NUE). This improving effect of potassium on NUE thus optimizes N management, while contributing to a lowering in emission of CO_2 and other GHGs.

In 2001, the Soil Science Society of America drafted a position paper that included the following statement: “Worldwide, SOC (soil organic carbon) in the top 1 meter of soil comprises about 3/4 of the earth's terrestrial carbon; nevertheless, there is tremendous potential to sequester additional carbon in soil”.

In order to explore this potential further, a group of soil scientists working together with the International Potash Institute (IPI) are currently studying the contribution of potassium fertilization to sequester additional SOC. The study comprises mathematical modeling and comparison of the results from this modeling with experimental findings. In addition, the interpretation of this information is expressed in terms of the contribution of potassium to carbon sequestration.

About this paper

This paper was prepared by Agriecology. Agriecology is dedicated to assessing and solving problems related to agriculture, environment and their interface. This position paper was written by Prof. J. Ben Asher (soil physics) and Dr. B. Bar-Yosef (soil chemistry). The authors recently retired from The Ben-Gurion University and Volcani Center, Agricultural Research Organization (ARO), Ministry of Agriculture and Rural Development, Israel, respectively.

The IPI position

The unique IPI approach links two systems: (i) a soil-crop-atmosphere model, and (ii) the modeling of soil processes involving carbon sequestration. The integration of these two systems will be of particular value in assessing the beneficial effect of raising the K nutritional status of crops to increase carbon sequestration in the soil. The IPI approach is the attainment of increased crop production for the benefits of economic productivity, as well as for increased carbon sequestration at a global level. The IPI position can be realized by applying currently recognized best nutrient management practices based on a combination of modeling and scientific experience.

How potassium affects C sequestration

Raising the potassium status of the plant to an adequate level affects CO_2 sequestration in two ways, namely by: (i) stimulating photosynthetic activity thereby increasing dry matter (DM) production of all plant organs, including roots; (ii) increasing the root:shoot ratio as a consequence of activating shoot-root transport of photosynthates and thus also C allocation to the roots. Carbon released from roots into the soil as occurs, for example, when roots are sloughed off and decomposed to SOM is, to a large extent, sequestered in the soil. The processes of carbon mineralization and transport of soil CO_2 are well understood (Simunek and Suarez, 1993; Pumpanen *et al*., 2003) and are included in the comprehensive model which is described below.

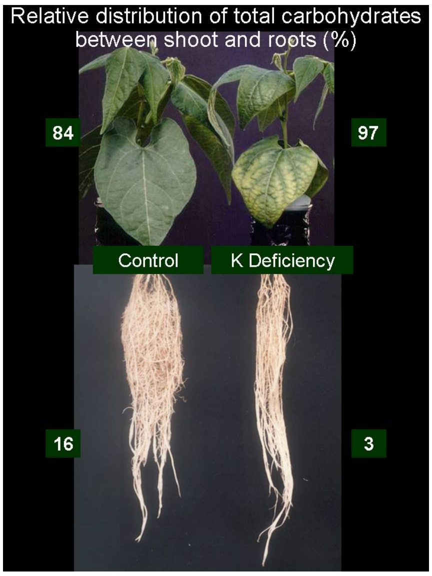
No till farming in Brazil. Brachiaria (Braquiaria ruziziensis) grown after a maize crop. Both crops contribute to elevating OM in the soil. Photo by IPI.

A model for assessing the role of K in C sequestration

The modeling approach is based on the measured effects of K-fertilizer on dry matter yields of tops and roots of major crops across the world. The model is modular in that it is based on a progressive build up of CO_2 sequestration. It starts from calculating the gross potential carbon sequestration (GPCS). This is the total carbon present in the DM production i.e. the sum of roots and tops. It then determines the role of potassium fertilization and the potential carbon sequestration (PCS), which is based on the calculated DM accumulation in the roots. The actual carbon sequestration (ACS) is then further calculated using more detailed data pertaining to the specific soil conditions as they affect mineralization and other soil-related processes. It

Position Paper

should be mentioned here that the model (as any model) is incomplete because it accounts only for the three major elements (N, P and K) and neglects crop response to other nutrients. The basis of the approach is that when K supply is inadequate, the root:shoot ratio will be low because the consequent low concentration of leaf K will impair photosynthate loading into the phloem and translocation to the roots. Raising the K supply will overcome this effect providing that other nutrients are not growth limiting. Moreover, the higher supply of K will not only increase the root:shoot ratio but also increase the absolute root weights and thus CO_2 sequestration. Magnesium is also particularly important as adequate amounts must be present because, in common with K, it is required both in photosynthesis and in the loading of photosynthates into the phloem and hence their translocation to the root (Cakmak and Kirkby, 2008).



Relative distribution of total carbohydrates under low K compared to control in bean (Phaseolus vulgaris) plants. Source: Cakmak, I. 1994: Activity of ascorbate-dependent H_2O_2-scavenging enzymes and leaf chlorosis are enhanced in potassium deficient leaves. J. of Exp. Botany 45, 1259-1266. With permission from I. Cakmak.

Model description

The GPCS calculations are based on a widely used soil-crop model known as DSSAT (Decision Support System for Agro-technology Transfer). It has been modified to account for crop response and CO_2 budget to combine with NPK application by coupling it with the QPAIS model (Zhang *et al*., 2007). Its output is the PCS. The ACS calculation is the third stage of the model. This uses PCS results as an input and takes into account mineralization and transport of soil carbon from the major sources. Currently the integrated model is tested and calibrated and parametric values are assigned based on literature data.

Example of calculations

The simulated total corn dry matter (DM) weight in an arbitrary control (N, P and K=200, 100 and 0 kg/ha. respectively) is 15,515 kg/ha (Table 1). Applying 100 kg/ha K (at N=200 and P=100) increases the DM yield to 20,357 kg/ha. The calculated GPCS in the control and K amended soils are of 7,137 and 9,364 kg/ha, respectively. Hence the application of 100 kg/ha K resulted in an additional 2,227 kg/ha C bound in the plant material (equivalent to ~8,166 kg/ha CO_2), or 22.3 kg/ha of C per 1 kg of K. This contribution of 100 kg/ha K to C sequestration is the calculated GPCS and is equivalent to 81.8 kg/ha CO_2/kg K.

The PCS (i.e. binding of carbon only in the root system under zero CO_2 efflux from soil) can be also evaluated from Table 1. Here, root DM increased from 1,875 to 2,852 kg/ha in the K amended soil. Hence the application of 100 kg/ha K resulted in 449 kg/ha C being bound in the roots (equivalent to 1,646 kg/ha CO_2), or 7.6 kg/ha CO_2/kg K. The model assumes that ACS is 30-70 per cent of the PCS, which leads to the calculation of ACS.

In summary

Carbon credits are a key component of national and international attempts to mitigate the increase in GHGs. We demonstrate here that potassium fertilization may assist in mitigation of GHGs, and possibly even provide some credits to users. The IPI approach uses a model to reliably estimate potential and actual carbon sequestration by crops in various soils and agro-climatic conditions, through a specific model-based calculation process.

Further reading

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Table 1. Example of model aided evaluation of the potential impact of K on the GPCS, PCS and ACS in maize. Data was obtained by the model assuming conventional N and P fertilization of maize under Mediterranean climate and clay soil. The model calculated range of ACS/PCA resulted from different soil organic C pools (SOC), pH, etc.

	Application rate (kg/ha)		
Nitrogen (N)	200	200	200
Phosphorus (P)	100	100	100
Potassium (K)	0	100	200
	DM and carbon potential		
Total DM (kg/ha)	15,515	20,357	21,720
GPCS (kg C/ha)	7,137	9,364	9,991
Root DM (kg/ha)	1,875	2,852	3,163
PCS (kg C/ha)	863	1,312	1,455
ACS (kg C/ha)	259-604	394-918	436-1018

Position Paper

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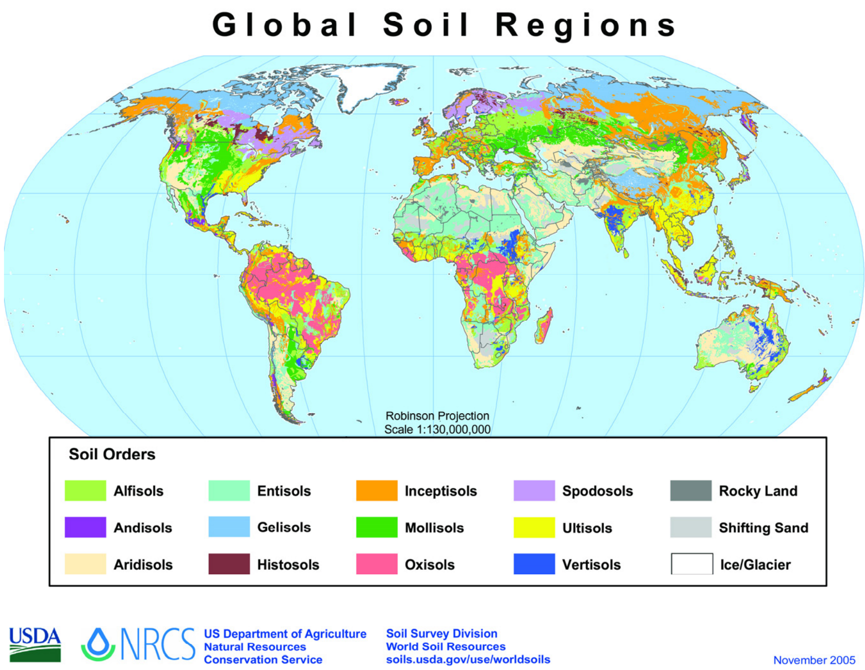
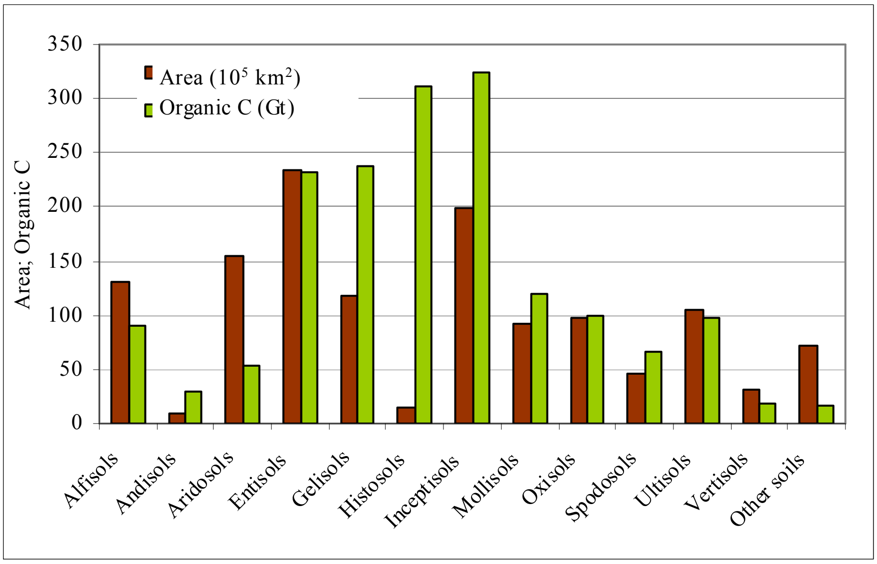
Zhang, K., D.J. Greenwood, P.J. White, and I.G. Burns. 2007. A dynamic model for the combined effects of N, P and K fertilizers on yield and mineral composition; description and experimental test. Plant and Soil, 298:81-98. ■

The position paper "Potassium and CO_2 Sequestration" appears also at:
IPI Position Papers.

Soil orders and their estimated carbon content



soils.usda.gov/use/worldsoils/mapindex/order.html



Estimated mass of carbon in the world's soils. *Source*: USDA. After Hillel and Rosenzwig, CSA News June 2009. www.agronomy.org/publications/csa-news.

IPI Events

July 2009

IPI-Corvinus University Budapest International Symposium on "Nutrient Management and Nutrient Demand of Energy Plants", 6-9 July 2009, Budapest, Hungary.

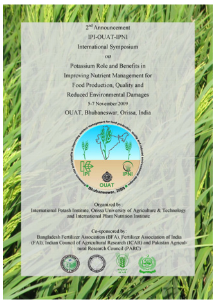
See the final program on the IPI website.

The symposium will be jointly organized by the International Potash Institute (IPI) and Corvinus University Budapest. The venue of the event is Mercure Hotel, Budapest, Hungary. Topics will include quality requirements of crops for biofuels, new and traditional crops for biofuels, energy and CO_2 balance of crops grown for biofuels, and optimal crop rotation and nutrient balance for biofuel plants. The post-symposium tour will be to a biofuels plant and farmers growing energy crops. Registration fee will cover participation at all oral and poster presentations, welcome reception, lunch, morning and afternoon coffee break during the two symposium days, and symposium dinner. The post-symposium tour will be charged separately. For more details see IPI website or contact IPI Coordinator Dr. T. Popp. ■

November 2009

IPI-OUAT-IPNI International Symposium on "Potassium Role and Benefits in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damages", 5-7 November 2009, Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, India.

See the 2nd circular on the IPI website.



The symposium will be organized by the International Potash Institute (IPI), International Plant Nutrition Institute (IPNI), and the Orissa University of Agriculture & Technology (OUAT). It is co-sponsored by the Indian Council of Agricultural Research (ICAR), Fertilizer Association of India (FAI), Bangladesh Fertilizer Association (BFA) and the Pakistan Agricultural Research Council (PARC). The scientific committee, chaired by Dr. J.S. Samra, has selected the following sessions: 1) Nutrient management to meet challenges of food security; 2) Potassium and nutrient use efficiency; 3) Role of potassium and mineral nutrition in alleviation of stress; 4) The effect of quality and nutritional value of agricultural products on human health: the role of potassium; 5) Spatial variability of soil properties and Site Specific Nutrient Management (SSNM); 6) The role of extension in increasing agricultural productivity; 7) Potassium and the environment; and 8) Nutrient mining and input-output balances.

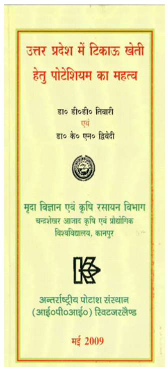
The draft program is available on IPI website.

More details will appear regularly on IPI and IPNI websites. ■

March 2010

IPI together with the Soil Science Association of El Salvador, organizes a regional symposium titled "Importance of Soil Management and Potash Fertilization for Sustainable Agricultural Development of Central America and the Caribbean". For more details see IPI website or contact IPI Coordinator Dr. A. Naumov. ■

New Publications



Importance of Potassium for Sustainable Agriculture in Uttar Pradesh (in Hindi). Tiwari, D.D., and K.N. Dwivedi. 2006. Available for download on the IPI website.

The leaflet describes the imbalanced nature of fertilization in UP, importance and deficiency symptoms of K in oil seeds and pulses and results of trials conducted at Kanpur on K effect on yield, oil and protein content of some oil seeds and pulses. ■

Aspectos Relacionados ao Mapeamento de Disponibilidade de Potassio nos Solos do Brasil. (in Portugese). Rachel Bardy Prado, Vinícius de Melo Benites, Pedro Luiz Oliveira de Almeida Machado, José Carlos Polidoro and Alexey Naumov (ed.). 2008. Embrapa Solos; Rio de Janeiro, RJ, Brazil. 33 p. (Documentos 104, Embrapa Solos, ISSN 1517-2627; Documentos 237, Embrapa Arroz e Feijao, ISSN 1978-9644).

"Aspects, Related to Mapping of Potash Availability in the Soils of Brazil". The publication is based on a research project carried out under a cooperation program between Embrapa (Brazilian Corporation for Agricultural Research) and IPI (International Potash Institute). It describes methods of GIS-

New Publications

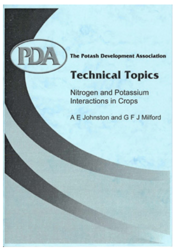
analysis, applied to mapping of nutrients availability in Brazilian soils. Data from soil profiles all over Brazil were extrapolated to the contours of soil types and landscapes of Brazil, which enabled detailed mapping of potash availability. According to the obtained results, soils on 23.8 per cent of Brazilian territory are classified as "low potash availability" (less than 60 mg/kg), and only 4.4 per cent as "extremely high potash availability" (more than 240 mg/kg). Most of the Brazilian Cerrado soils (latossolos, according to Brazilian soil classification) are poor in potash. The publication contains maps of potash availability by landscapes (biomes) and soil types of Brazil.

The publication (in Portuguese) is available from the Embrapa website (pdf 3.7 MB) ■

Publications by the PDA

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

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



Technical Notes/Potassium and Nitrogen Interactions in Crops. Johnston, A.E., and G.F.J. Milford. 2009. 16 p. This booklet presents evidence from field experiments in the UK which shows that the plant-available potassium (exchangeable K) status of a soil has a considerable influence on the uptake of nitrogen (N) by crops. See the full version on the PDA website.

Potash News/Potash Offtakes by Miscanthus and SRC Willow Bio-Energy Crops. See PDA website for full document. ■

K in the Literature

Efficiency of Diversified Rice-Wheat Cropping Systems Including Potato, Vegetable Peas and Groundnut Crops in Trans-Gangetic Plains. Singh, J.P, A. Salaria, K. Singh, and B. Ganwar. Potato Journal 35(1-2):53-60. 2008.

www.indianjournals.com/ijor.aspx?target=ijor:pj&volume=35&issue=1and2&article=009

Abstract:

Field experiment was conducted during 2000-2003 on diversified rice-wheat cropping systems involving potato, vegetable peas and groundnut, and water management treatments in rice to increase the production, economics and water use efficiency. Inclusion of potato, vegetable peas and groundnut in rice-wheat cropping system increased the production, economics and land use efficiency on an average by 95, 75 and 11 per cent, respectively. Rice equivalent yield (REY) was maximum in rice/groundnut/rice (R/G/R)-potato-wheat (24.60 t/ha/yr), which was at par with rice-potato-wheat (24.27 t/ha/yr) followed by rice-vegetable peas-wheat (19.02 t/ha/yr) as against traditional rice-wheat (11.63 t/ha/yr) system. Net returns was the highest in rice-vegetable peas-wheat (Rs.67540 ha/yr) system, which was at par with R/G/R-potato-wheat (Rs.67424/ha/yr) and rice-potato-wheat (Rs.64906/ha/yr) as against rice-wheat (Rs.38159/ha/yr) system. Irrigation to rice crop at hairline cracks (HC) in soil saved about 20 per cent of total water use on an average in different cropping systems compared to traditional system of irrigating rice at disappearance of ponded water (DP). Decline in available soil K ranging from 4.0 to 12.0 per cent and build up of available soil P from 41.7 to 62.5 per cent was recorded from initial soil test values after 3 years in different cropping systems. The apparent soil nutrient balance (gain/loss) was negative for K (243-440 kg/ha) and positive for P (57.6-151.1 kg/ha) with varying degrees in different cropping systems. ■

Effects of Different Potassium Fertilizers on Phytoavailability of Pb in Red Latersol and Paddy Soil. Liu, P., M.G. Xu, H.P. Shen, Z.G. Song, and W.B. Du. Plant Nutrition and Fertilizer Science 15(1):139-144. 2009.

www.plantnutrifert.org/qikan/epaper/zhaiyao.asp?bsid=879

Abstract:

Effects of four kinds of potassium fertilizer (KH_2PO_4, K_2SO_4, KNO_3, and KCl) at five levels (K 0, 60, 140, 240, 360 mg/kg) on the Pb concentration of rape and relationship between Pb content of paddy soil and red latersol solution with the content of Pb absorpted by rape were examined in pot trial. Results showed that the Pb concentration of soil solution significantly increased with application of KNO_3, KCl, and K_2SO_4. The application of KCl (360 mg/kg) and K_2SO_4 (240 mg/kg) can increase Pb content of soil solution up to 106.9% and 97.8%, respectively. There were similar effects of three kind of potassium on paddy soil and increased rate was lower than that of latersol soil. The main reason was that latersol soil had more inconstant charges and smaller CEC than paddy soil. However, Pb content of soil solution was significantly decreased with application rate of KH_2PO_4, moreover Pb content of rape shoot also decreased in both paddy soil and latersol, and under its highest application rate the decreased rates of Pb concentration in latersol and paddy

K in the Literature

soil were 45.0% and 63.8%, respectively, compared with the control treatment. In the second season in KH_2PO_4 treatment, there were positive correlations between Pb absorbed by shoots and roots of rape and Pb content of soil solution. ■

Impact of Long-Term Phosphorus and Potassium Fertilization on Alfalfa Nutritive Value-Yield Relationships. Lissbrant, S., S. Stratton, S.M. Cunningham, S.M. Brouder, and J.J. Volenec. Crop Sci. 49(3):1116-1124. 2009.

dx.doi.org/10.2135/cropsci2008.06.0333

Abstract:

Phosphorus (P) and potassium (K) increase alfalfa (Medicago sativa L.) yield, but little information is available on how forage nutritive value is affected by P and K fertilization. The objective of this study was to investigate the effect of long-term P and K fertilization on alfalfa yield-forage nutritive value relationships. A factorial experiment with four P and five K treatments was replicated four times. Beginning in 1998 and continuing through 2004, herbage samples were collected in May, June, July, and September. Samples were analyzed for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), in vitro true dry matter disappearance (IVTDMD), and acid detergent lignin (ADL) using near-infrared reflectance spectroscopy. Soils were also analyzed for P and K concentrations. Concentrations of NDF, ADF, and ADL were reduced by low P and K fertility. Addition of P fertilizer increased CP concentrations, while addition of K fertilizer reduced CP concentrations. Concentrations of NDF, ADF, and ADL and dry matter yield decreased with stand age and harvest within year. The low forage dry matter yield of unfertilized alfalfa was associated with higher IVTDMD. Yield of digestible nutrients per hectare (yield x IVTDMD) was highly correlated with yield but not IVTDMD concentration. Fertilizing for high yield, despite the slight reduction in forage nutritive value, remains the most viable strategy for maximizing digestible nutrient production per hectare in alfalfa. ■

Spatial and Temporal Distributions in Sandy Soils with Seepage Irrigation: II. Phosphorus and Potassium. Sato, S., K.T. Morgan, M. Ozores-Hampton, and E.H. Simonne. Soil Sci. Soc. Am. J. 73(3):1053-1060. 2009.

dx.doi.org/10.2136/sssaj2008.0114

Abstract:

Fertilizer management, particularly of P and K, on sandy soils is crucial to maximize production and minimize environmental impact in agricultural systems. Experiments were conducted at commercial tomato (Lycopersicon esculentum Mill.) farms in southwest Florida during the 2006 spring and winter growing seasons to elucidate P and K distributions in tomato beds and to determine leaching potential under seepage irrigation. Most P was found in the top (0-10 cm) and middle (10-20 cm) soil layers at the centerline (plant row) of the soil bed, and P concentration remained relatively constant. Phosphorus in the bottom layer (20-30 cm) and bed shoulder were similar or less than preplant levels, implying that P did not likely move outside the root zone. However, P fractionation and soil P storage capacity (SPSC) of the root zone samples revealed higher risk of P loss when applied P remained more in soil solution. Most K remained in the top layer of the fertilizer band in an order of magnitude higher concentration compared with the rest of the bed, where low and constant amounts of K were found throughout the season. This result indicated that little or no K leached during this study. Seepage irrigation may have limited downward water movement in the bed, thus nutrient leaching, therefore nutrient loss through surface runoff between growing seasons could be substantial. Current Best Management Practices (BMP) for tomato fertilization should be monitored and evaluated. ■

High-Yielding Corn Response to Applied Phosphorus, Potassium, and Sulfur in Nebraska. Wortmann, C.S., A.R. Dobermann, R.B. Ferguson, G.W. Hergert, C.A. Shapiro, D.D. Tarkalson, and D.T. Walters. Agron. J. 101(3):546-555. 2009.

dx.doi.org/10.2134/agronj2008.0103x

Abstract:

Nutrient management recommendations may change as yield levels and efficiency of crop production increase. Recommendations for P, K, and S were evaluated using results from 34 irrigated corn (Zea mays L.) trials conducted in diverse situations across Nebraska. The mean yield was 14.7 Mg ha^{-1} with adequate fertilizer applied. The median harvest index values were 0.52, 0.89, 0.15, and 0.56 for biomass, P, K, and S, respectively. Median grain yields were 372, 49, and 613 kg kg^{-1} of aboveground plant uptake of P, K, and S, respectively. The estimated critical Bray-1 P level for corn response to 20 kg P ha^{-1} was 20 mg kg^{-1} when the previous crop was corn compared with 10 mg kg^{-1} when corn followed soybean [Glycine max (L.) Merr.]. Soil test K was generally high with only three site-years <125 mg kg^{-1}. Over all trials, application of 40 kg K ha^{-1} resulted in a 0.2 Mg ha^{-1} mean grain yield decrease. Application of 22 kg S ha^{-1} did not result in significant yield increase in any trial. Soil test results accounted for twice as much variation in nutrient uptake when soil organic matter (SOM) and pH were considered in addition to the soil test nutrient values. The results indicate a need to revise the current recommendation for P, to maintain the current K and S recommendations, and to use SOM and pH in addition to soil test nutrient values in estimating applied

in the Literature

nutrient requirements for irrigated high yield corn production. ■

Mulberry Nutrient Management for Silk Production in Hubei Province. Chen, F., J. Lu, M. Zhang, K. Wan, and D. Liu. J.Plant Nutr. Soil Sci. 172(2):245-253. 2009.

dx.doi.org/10.1002/jpln.200800093

Abstract:

The silk industry is important for south China's rural economy. Leaves of mulberry (Morus spp.) are used for silkworm production. Hubei province is one of the main silk-producing provinces in China. The objectives of this research were to survey the fertilization practices in the mulberryproducing regions in the province and to determine the best nutrition-management practice for mulberry plantations. A survey and a series of field experiments with N, P, K, and micronutrients were conducted from 2001 to 2002. In addition, a silkworm-growth experiment was also conducted by feeding leaves harvested from various fertilization treatments. The results indicate that poor soil fertility and unbalanced fertilization were the main factors limiting mulberry-leaf yield and quality in Hubei province. Nitrogen fertilization of mulberry has reached a high level (454 kg ha^{-1} y^{-1}) in Hubei province, but P- and K-fertilization rates have not been matched with N-fertilization rates as farmers are not aware of the significance of P and K. Balanced fertilization showed positive nutrient interactions with respect to mulberry yield and quality. Potassium application increased yield and quality (protein and sugar concentration) of mulberry leaves. Silkworm growth and cocoon quality were improved when silkworms were fed with the leaves derived from K-fertilized plants in comparison with those taken from control plots. Application of 3 Mg, S, and B also significantly improved leaf sugar, essential and total amino acid concentrations, but did not increase leaf yield significantly. It is concluded that a fertilizer dose of 375 kg N ha^{-1}, 66kg P ha^{-1}, and 125 kg K ha^{-1} is suitable for the cultivation of mulberry in the Hubei province along with Mg, S, and B, wherever necessary, for the improvement of yield and quality of mulberry leaves. ■

Sulfur in Soils. Scherer, H.W. J. Plant Nutr. Soil Sci. 172(3):326-335. 2009.

dx.doi.org/10.1002/jpln.200900037

Abstract:

Sulfur (S) deficiency of crops, which has been reported with increasing frequency over the past two decades on a worldwide scale, is a factor that reduces yield and affects the quality of harvested products. Especially in Western European countries, incidence of S deficiency has increasingly been reported in Brassicaceae. For this reason, more attention should be paid to the optimization of S-fertilizer application, in order to cover plant S requirements whilst minimizing environmental impacts. In soils, S exists in inorganic and organic forms. While sulfate ($SO^{2-}{}_4$), which is a direct S source for plants, contributes up to 5% of total soil S, generally more than 95% of soil S are organically bound. Organic S is divided into sulfate ester and carbonbonded S. Although not directly plant-available, organically bound S may potentially contribute to the S supply of plants, especially in deficiency situations. Sulfur turnover involves both biochemical and biological mineralization. Biochemical mineralization, which is the release of $SO^{2-}{}_4$ from the ester sulfate pool through enzymatic hydrolysis, is controlled by S supply, while the biological mineralization is driven by the microbial need for organic C to provide energy. ■

Read on:

- **A Soil Science Renaissance.** Hartemink, A.E., and A. McBratney. Geoderma, 148(2):123-129. 2008.

  dx.doi.org/10.1016/j.geoderma.2008.10.006

- **Global Soil Map** (GlobalSoilMap.net). Partners are ISRIC - World Soil Information, The University of Sydney, The Earth Institute at Columbia University, NRCS National Geospatial Development Center, Embrapa, National Center of Soil Research, CSIRO Land & Water, European Commission, Tropical Soil Biology and Fertility Institute and Institute of Soil Science, Chinese Academy of Sciences. The GlobalSoilMap.net project aims to make a new digital soil map of the world using state-of-the-art and emerging technologies for soil mapping and predicting soil properties at fine resolution. This new global soil map will be supplemented by interpretation and functionality options that aim to assist better decisions in a range of global issues such as food production and hunger eradication, climate change, and environmental degradation. It is an initiative of the Digital Soil Mapping Working Group of the International Union of Soil Sciences (IUSS) and is led by academic and research centres in all continents. See at www.globalsoilmap.net/

- **The Feeding of the Nine Billion Global Food Security for the 21st Century**. Evans, A. Chatham House Report. 2009. ISBN 978 1 86203 212 5. www.chathamhouse.org.uk/

- **Do Increases in Agricultural Yield Spare Land for Nature?** Ewers, R.M., J.P.W. Scharlemann, A. Balmford, and E.E. Green. Global Change Biology 15:1716–1726. 2009.

K in the Literature

DOI: 10.1111/j.1365-2486.2009.01849.x.
www3.interscience.wiley.com/

- **Nutrient Imbalances in Agricultural Development.** Vitousek, P.M., R. Naylor, T. Crews, M.B. David, L.E. Drinkwater, E. Holland, P.J. Johnes, J. Katzenberger, L.A. Martinelli, P.A. Matson, G. Nziguheba, D. Ojima, C.A. Palm, G.P. Robertson, P.A. Sanchez, A.R. Townsend, and F.S. Zhang. Science 19 June 2009: 324(5934):1519-1520. DOI: 10.1126/science.1170261.
www.sciencemag.org/ ■

For more K literature go to www.ipipotash.org/literature/

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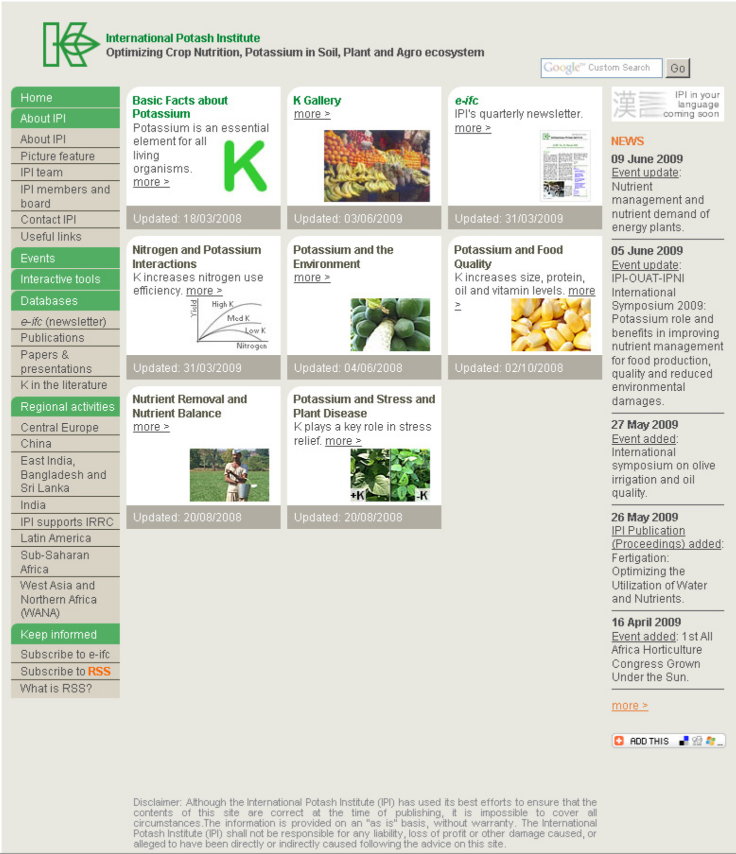

The IPI website has a fresh look. The content remains the same, but the appearance and style has improved. Soon, we will be adding a new "language tool" as well as more K centers. Go to www.ipipotash.org.

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Layout & design	Martha Vacano, IPI
Address	International Potash Institute P.O. Box 569 Baumgärtlistrasse 17 CH-8810 Horgen, Switzerland
Telephone	+41 43 810 49 22
Telefax	+41 43 810 49 25
E-mail	ipi@ipipotash.org
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