Future Needs and Prospects for Research on Potassium

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Overview

- Introduction
- Need for knowledge dissemination
- K in soils, present knowledge
- K in plant physiology, present knowledge
- Needs for future research - soil, plant and human nutritional aspects
- Summary and prospects

IPI – OUAT – IPIN
International Symposium
Potassium Role and Benefits in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damages
5. – 7. Nov. 2009, Bhubaneswar, Orissa, India

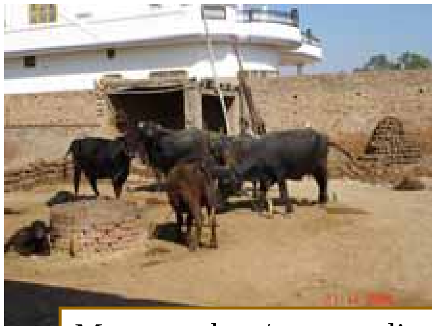
Introduction

- Concerns of progressive crop yield decline (stagnation) in Indian agriculture!

- Increasing use of animal waste and crop residues as a bio-energy source with inadequate recycling of the ash or sludge back to farming land!

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Concerns of ongoing yield decline in India! *Causes??*



Manure cakes / no recycling / decline in productivity /crisis!

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As consequence of lack of adequate recycling comes a worsening in soil structure and a decline in soil fertility as already discussed by J.v.Liebig (1876).

TAZ 3.10.2009

SCHWERSTE ÜBERSCHWEMMUNGEN SEIT JAHRZEHNTEN

Mindestens 300 Inder starben in Fluten

(Flooding in India, Oct. 2009)

Additionally, the annual flooding in India is partially a consequence of this damage of soil structure!

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Increasing events of drought and other abiotic stresses as consequence of global warming,
also require a specially high supply of K besides various micronutrients for stress mitigation!

Under drought conditions in the field, farmers in Germany often act irrationally by decreasing K supply.

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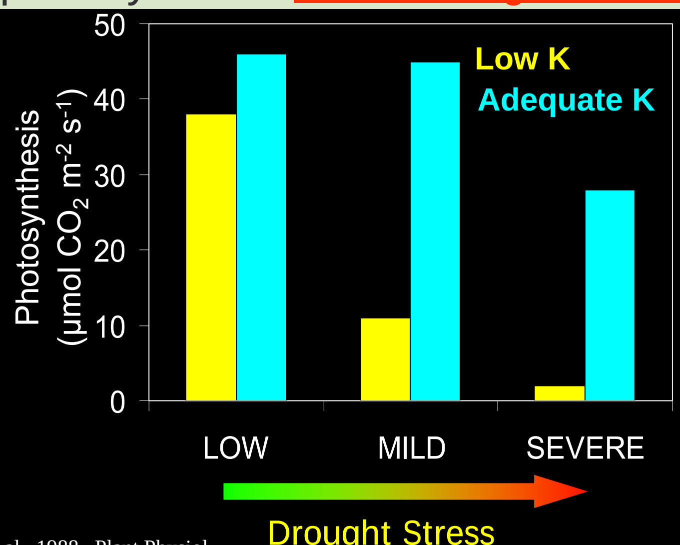
Improved potassium nutrition will enhance photosynthesis under drought stress



Sen Gupta et al., 1988, Plant Physiol.

Need for knowledge dissemination (two examples)

(Shandong Province, China)

High K-induced Mg deficiency?

Farmers report depressed fruit growth and tomato fruits with low sugar content (low fruit quality)!

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High K-induced Mg deficiency in Kiwi (Italy) side by side with **K deficiency** (in both cases low fruit quality!)

Soil and plant analyses confirm the conclusion of an **inappropriate recommendation for K fertilizer use**, even in Italy!

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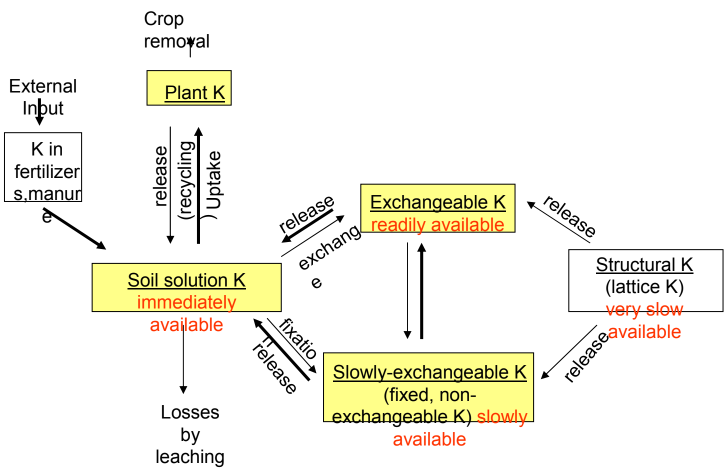
■ K in soils, present knowledge:

Different potassium forms in soils of relevance to plant uptake (according to J.K.Syers, 2002)



- Water soluble K (immediately available K) is very fast depleted (in few hours) in the rhizosphere due to an active uptake of K by plant roots!
- Thus a replenishment from different soil K pools is required (from easy exchangeable pool) and even from the slowly exchangeable K pool (SEK).
  This can be easily demonstrated by a simple calculation)
- Basic knowledge is well known and might need to be taken into account for a better implementation and in extension work!

Nutrient balance sheets at yard gate and field level

Due to internal losses of K within a farm, the field balance is often more negative than the yard gate balance.

K balance sheet of an organic-managed farm (33.5ha) at Stuttgart-Ruit, Germany estimated on farm level (yard gate balance) and on field level (field balance) for 1993/94

	A. Yard gate balance		B. Field balance	
	kg a^{-1}	kg ha^{-1} a^{-1}	kg a^{-1}	kg ha^{-1} a^{-1}
Input	233	7	3910	117
Output	472	14	5105	152
Balance	-239*	**-7**	-1195*	**-36**

* farm internal losses: 1195-239=956kg K a^{-1}

(1 tone potassium loss per annum in a farm!!)

(according to Mayer, 1997)

Leaching of nitrogen is given much more consideration than that of K. However, K leaching can not be ignored in relation to the K balance.

Average K leaching as affected by the rate of K fertilization for a sandy top soil of North Germany during the winter seasons 1989/1990 until 1994/1995

K fertilization rate (kg K ha^{-1} a^{-1})	K leaching (kg K ha^{-1} a^{-1})
0	22
60	42
120	79
180	133

(according to Wulff et al.,1998)

→ Considerable amounts of K can be leached out in a farm on a sandy soil in North-Germany with a humid climate. In Orissa with red soils the position is comparable!

These measured or calculated K losses might appear rather small compared with the total stock of K in some top soils. But model calculation indicate a relative fast rate of K depletion in K poor sandy soils.

*Required time for K depletion of a top soil assuming a negative balance sheet (**nutrient mining**): A model calculation*

□ K content in top soil

0.1 - 3.3% = 7 000 - 228 800kg K ha^{-1}

□ Required years for assumed depletion

Normal scenario:

Balance -5kg K $ha^{-1}a^{-1}$; 50% depletion of top soil with 3.3% K

$$\frac{228\,800 \cdot 50}{5 \cdot 100} = 22\,800 \text{ years}$$

(clay soil)

Worst case scenario:

Balance -40kg K ha^{-1} a^{-1}; 25% depletion of top soil with 0.1% K

$$\frac{7\,000 \cdot 25}{40 \cdot 100} = 44 \text{ years}$$

(sandy soil)

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- Even on K-rich clay soils, K deficiency symptoms can be observed **during summer drought spells, particularly in dicots.**
- Thus, beside the nutrient balance sheet, the nutritional status of a soil **together with root growth data** and **adverse soil factors** (compaction, low temperature, low soil water content) has also to be considered for optimal K nutritional status of crop plants!
- It is becoming increasingly obvious, that even K-rich clay soils might require regular K fertilization under frequently occurring stress conditions!

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This particular higher K requirement under stress conditions (drought stress, heat stress, disease pressure, low temperature, submergence) is not in accordance with general K fertilization management e.g. in Canada, China, India and most developing countries.

Crop removal vs. fertilizer use for K , Canada, 1996

	Phosphate			**Potassium**		
Prov	Removal	Fert Use	Fert/Removal %	**Removal**	**Fert Use**	**Fert/Removal %**
MB	258.4	263.7	102	331	92.2	**28**
SK	672.7	493.9	73	640.1	58.5	**9**
AB	451.1	393.1	87	607	127.9	**21**

Soil Total P and K as Affected by Plant Nutrient Management *(K. Kapoor, India)*

Treatments	P (mg/kg)	K (mg/kg)
Fallow-Wheat, FYM	736	6450
Sorghum-Mustard , FYM	787	7852
Bottlegourd-Cauliflower, FYM	793	7406
Rice-Chickpea, No additions	653	5375
Fallow-Chickpea, No additions	693	5556
Fallow-Mustard, No additions	612	6882
Rice-Onion, FYM +N	774	4775
Maize-Cauliflower, FYM +N	731	4509
Rice-*Celosia*, FYM +N	844	4807
Rice-Wheat, N + P	587	3520
LSD (P=0.05)	18	110

In particular, in cereal dominating crop rotations without FYM return and K fertilization, a successive decline in the K status can be observed.

K in plants, present knowledge:

General physiological functions of K

- Osmoregulation and cell extension
- Stomatal movement
- Activation of enzymes (such as ATPase)
- Protein synthesis
- Photosynthesis
- Phloem loading and transport
- Because of the important role of K in phloem loading, high K supplies are needed during grain filling or fruit growth.
- In addition, for stress tolerance, disease resistance and quality reasons, a high K nutritional status is of importance too.

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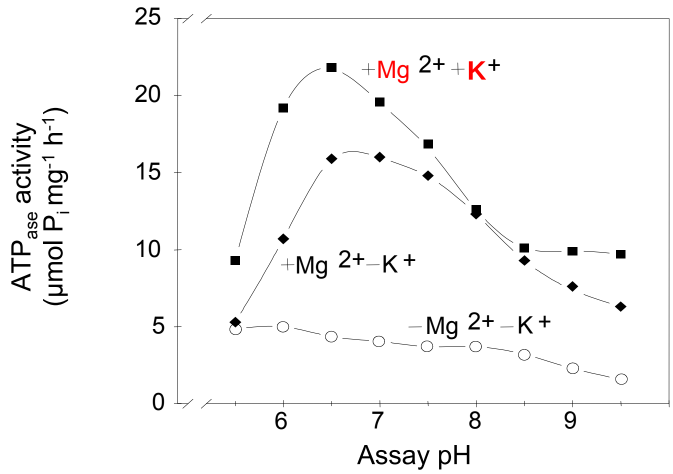
Importance of K and particularly Mg for the ATP_{ase} activity of the plasma membrane of roots.



Effect of pH, Mg (3mM) and K (50mM) on ATP_{ase} activity of the plasma membrane protein of maize roots (after Marschner, 1995)

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Effect of an **adequate K supply** or a high K / N ratio on soluble (low molecular weight) constituents (amino acids, sugars) and high molecular weight proteins, starch and cellulose

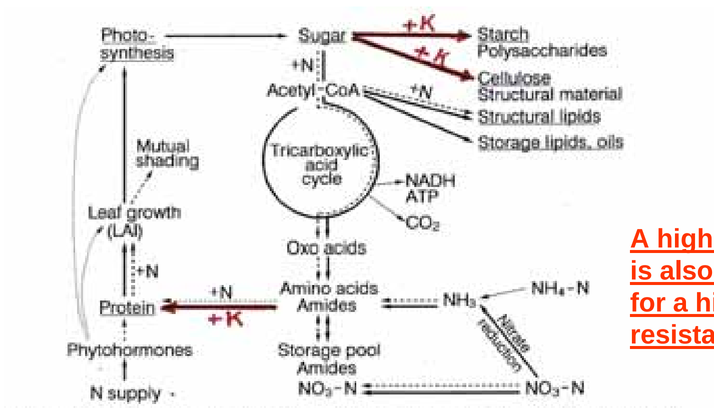

Fig. 8.17 Model of the effects of nitrogen supply on leaf growth and on various plant constituents. Key: ——→, suboptimal to optimal nitrogen supply; - - - -→, high to excessive nitrogen supply. ➡ adequate K supply

A high K supply is also important for a high pest resistance!

(Marschner, 1995)

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As already mentioned above, dissemination of scientifical knowledge to farmers is urgently needed (see: tomato production in China and kiwi production in Italy).

But there are still **future needs in basic and particularly applied research on K.**

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Needs for future research
- soil aspects:

In addition to the well known chemical availability of K (soil analysis) more consideration must be given to spatial availability!

Spatial availability for crop plants is dependent on growth and activity of roots, which is not measured by soil chemical analysis in the lab!
A spade/showel is needed!!

(See: drought- or high N-induced K deficiency)

Recognition necessary by farmers and extension workers!

Significance of rooting density for spatial nutrient availability for maize on a sandy loam

root length density (cm/cm^3 soil)	share of soil volume which delivers P and K to roots (%)	
	P	K
>> 2 (good rooting	20	50
< 2 (poor rooting)	5	12

(from Fusseder and Kraus, 1986, Flora 176, 11-16)

Thus, root growth is an important aspect for K acquisition particularly under stress conditions with inhibited root growth such as drought, low pH (Orissa), salinity or extreme soil temperature.

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K-PROG System developed by K+S, Germany

(Recommendation system for K fertilizer application)

In this system a site specific evaluation of K availability is made for different crop plants in West Europe.

The following is considered:

- various K pools in different soils for various crop plants
- weather conditions (precipitation, temperature), e.g. relation to drought)

- No need for future basic research. Recognition necessary by farmers and extension workers!

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Needs for future research - plant aspects:

- Role of K in frost resistance

Important in N.China, N.India, and many other countries and particularly in W.Canada (Alberta) with a vegetation period of less than 100 days.

There are observations that foliar sprays with mineral nutrients (**K**, Zn, B, Ca, P) ***as pre- or post-frost application*** as well as seed dressing can prevent or alleviate this frost damage!

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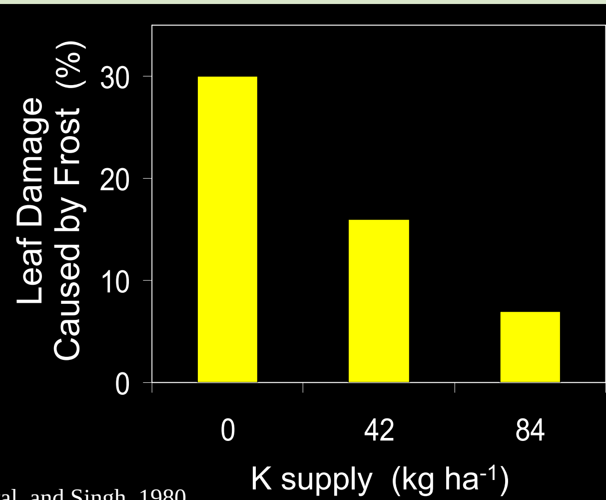
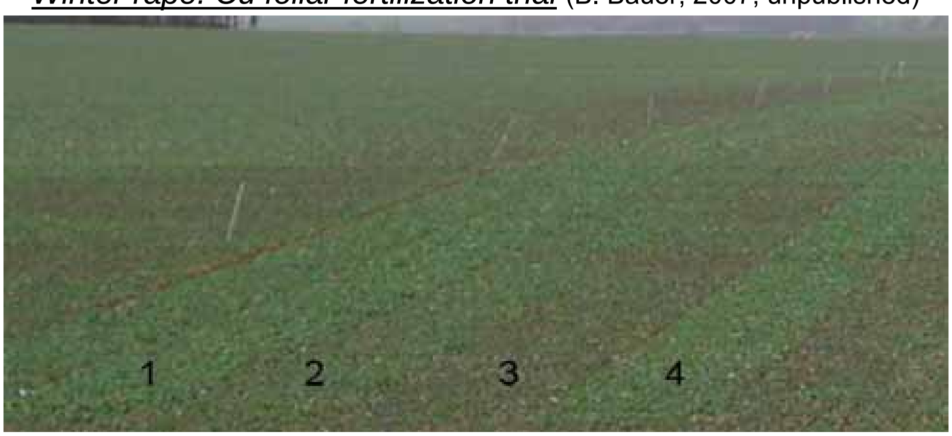
Alleviation of frost damage by K supply in potato



Grewal, and Singh, 1980

The role of K in frost resistance has been well known for many years; but this aspect is much more complex and involves micronutrients as shown in the following slide:

Winter rape: Cu foliar fertilization trial (B. Bauer, 2007, unpublished)



1. Ammonium sulfate (granules) (21 kg N/ha)
2. Ammonium sulfate (normal) (21 kg N/ha)
3. Ammonium nitrate (21 kg N/ha)
4. **Ammonium nitrate + 200g Cu** (21 kg N/ha)

→ foliar applied Cu before winter: enhanced frost resistance

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This Cu effect on frost resistance was again demonstrated in a farmer's field last year;

in addition, it was observed, that B foliar application also improved frost resistance of winter rape,
but only when combined with potassium application!
(B.Bauer, 2009, pers.communi.)

Thus, there is a need for more basic critical research, including nutrients stabilizing plasma membranes
and not just only plus / minus K!

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Needs for future research
- plant aspects:

- Role of K in frost resistance
- Role of K in disease and pest resistance

No information on the actual K nutritional status of the plants!

Potato affected by *Phytophthora infestans* **(-/+ K)**

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Needs for future research
- plant aspects:

- Role of K in frost resistance
- Role of K in disease and pest resistance
- Role of K in heat and drought resistance /

Deep placement of K will induce deeper rooting and thus a better exploitation of soil water in the lower soil profile.

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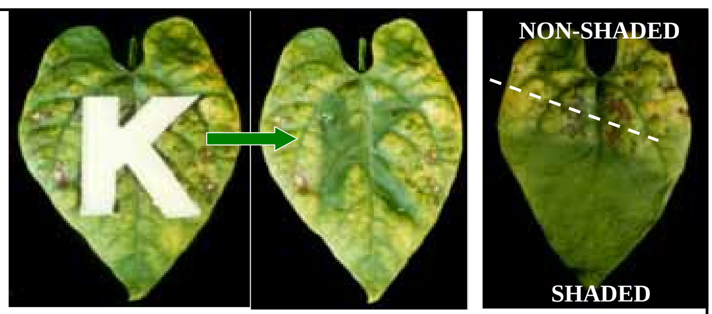
Partially shaded K-deficient bean leaves
(Cakmak et al.)



Sunscald damage in Fig is stimulated by low K supply (Irget et al., 2008)

Under high light plants require more K (and Mg)!

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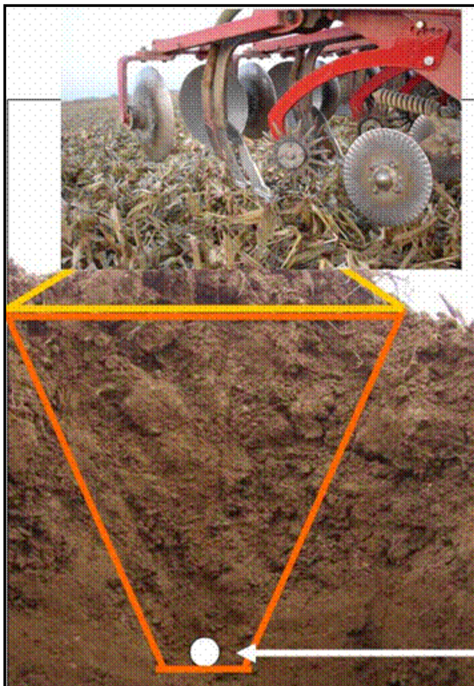

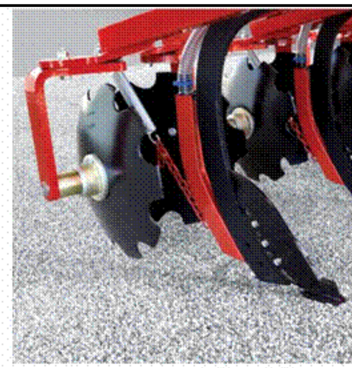

Deep placement: 25 – 45 cm , Horsch/Bavarian

Deep rooting for a higher drought resistance

Deep placement of **K** together with small amounts of P or N for signaling root growth deeper in the soil profile!

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Needs for future research
- plant aspects:

- Role of K in frost resistance
- Role of K in disease and pest resistance
- Role of K in drought and heat resistance / Deep placement of K
- Role of K in a better fruit quality / Late foliar application of K for a better retranslocation of sugars

Due to the role of K together with Mg in phloem loading and transport, a late foliar application of K might be worthwhile for a better growth and a higher sugar content of fruits. **This needs to be tested under field conditions!** (see observations in tomato and kiwi production above!)

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Needs for future research
- plant aspects:

- Role of K in frost resistance
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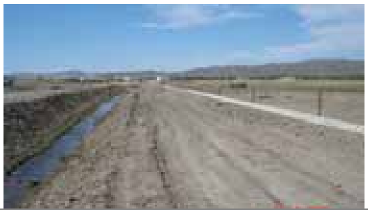
- Role of K in drought and heat resistance / Deep placement of K
- Role of K in a better fruit quality / Late foliar application of K for a better retranslocation of sugars
- Role of K in salt resistance



Needs for future applied research to mitigate salinity stress!

- Balanced fertilization with K (Mg), preferentially as K_2SO_4 (MgSO4) to counteract high Na uptake.
- Improved micronutrient status for a better detoxification of oxygen radicals formed under salinity
- Application of gypsum
- Supply of silicon (Si) to increase resistance to salt
- Application of bio-fertilizers with salt-resistant strains (see below)

Needs for future research
- plant aspects:

- Role of K in frost resistance
- Role of K in disease and pest resistance
- Role of K in drought and heat resistance / Deep placement of K
- Role of K in a better fruit quality / Late foliar application of K for a better retranslocation of sugars
- Role of K in salt resistance
- Initiation of cluster root formation by placement of stabilized ammonium in other plant species than Proteaceae or *Lupinus albus* e.g. for a better use efficiency of K besides of P

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Shen et al. unpubl.)

Placed NH_4 for induction of artifical „cluster roots“ in crop plants, as a possible tool ***to***

- improve efficiency of mineral fertilizer use (K, P, N)
- improve internal N use efficiency besides fertilizer use efficiency (Ni supplementation into the placement)
- improve pollination under high light and temperature stress (addition of Zn, B, Mn, Mo and K into the NH_4 placement)
- improve drought resistance (deep placement of NH_4 +K)
- **Integration of NH_4 “induced-cluster root formation” in intercropping systems**

There is need for further basic and applied research!

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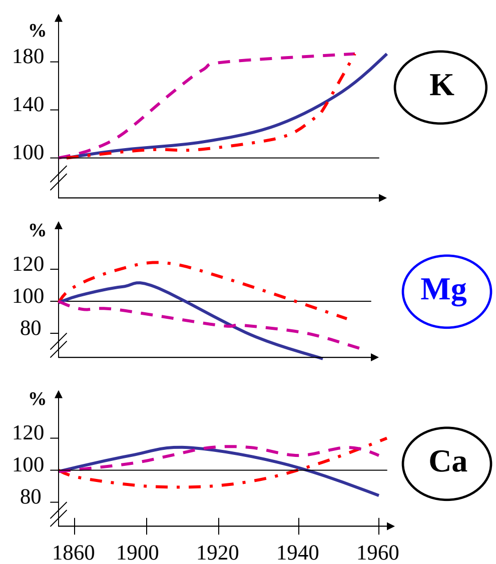
■ <u>Needs for future research</u>
<u>- human nutrition aspects:</u>

- <u>Role of K application in K and Mg status of plants</u>
- Need for K supplementation for a better K/Na ratio in food?
- Role of K and particularly of KCl in Cd uptake by crop plants

*<u>Historical change in **K** and Mg status of fodder plants</u>*

Change of Mg, Ca and K concentration of some fodder plants over the last 100 years



meadow hay

potatoes

oat straw

Similar changes can be assumed for vegetable plants for human consumption due to exclusively promoted K fertilizer use in the past and **<u>needs future field research!</u>**

(<u>Arzet</u>, H.R.; Landw. Forsch. 25, 1972)

<u>Nutrition Facts:</u> High Na and low Mg and K contents in most food products!

Promotion of heart attacks due to high blood pressure!

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<u>Supplementation with extra K and Mg for human health possible!</u>

Should we try to produce high K containing crops?

No need for future research in crop production, but future research activities in food processing industry!

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• Role of K application in K and Mg status of plants

• Need for K supplementation for a better K/Na ratio in food?

• Role of K and particularly of KCl in Cd uptake by crop plants

There are numerous reports in literature that chloride in e.g. KCl results in enhanced mobilization and uptake of Cd.

However, this enhancing effect could be only shown at unrealistic high application rates of chloride as KCl (more than 5 000 kg KCl/ha) (Cakmak et al., unpublished).

On the other hand, the report by S. Umar et al. (2008), that potassium reduces the uptake of Cd in mustard (*Brassica campestris* L.) can not get confirmed after a critical evaluation of the published data!

Thus there is no need for future research for this K/Cd aspect!

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Summary and prospects:

- During the past few days it has again become very clear that many aspects of the role of K in soils and plants are scientifically well understood
- The greatest need now is for the transfer of this information to farmers
- **There are however areas for future basic, and particularly applied research** to respond to ongoing environmental and social-economical changes
- Scientists thus need to become more aware of the real world of agriculture and the problems faced by farmers!

These are the great challenges for our future work!

Thanks for your attention!

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