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Editorial

Dear readers,

With 2013 behind us, we should reflect and question: 'What are the most burning issues that require our focus in 2014 and beyond?'

To me, connecting farmers to knowledge and ensuring that research is based on their needs are the most important areas to be involved in, with the highest and most immediate yield potential in terms of agricultural production.

Having the opportunity to meet many farmers around the world, and to observe the various conditions of soil, crops, weather and policy - all, which are factors in the agricultural production cycle - I am convinced that investing in these above-mentioned priorities deserves our strongest efforts and work.

I wish you a fertile 2014.

Hillel Magen
Director

Photo cover page: Drip and fertigation systems in maize crop at IPI-CAU field experiment in North East China. Photo by E. Sokolowski.

Research Findings

Photo by IAWP NAAS.

Sunflower Cultivation in Ukraine: Role of Fertilizers in Sunflower Seed Production

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Introduction

Sunflower is a strategically important oilseed crop in Ukraine, which plays a key role in the agricultural sector and accounts for 70 percent of all oilseed crops grown. In terms of world sunflower seed production, Ukraine holds first place at 25 percent, followed by Russia (22%) and Argentina (9%). In addition, around 57 percent of total world exports of sunflower oil come from Ukraine (State Statistics Service of Ukraine).

Sunflower sown area and productivity

Since the end of the 1990s, the land area devoted to sunflower cultivation in Ukraine has increased more than 2.5 fold from 2 million ha in 1995 to 5.1 million ha in 2012, which over the past four years has stabilized (Fig. 1). The main areas of production are located in the Kirovograd, Kharkov and Dnepropetrovsk regions, which account for over 30 percent of the sunflower area sown in the country or 10.8%, 10.5% and 9.5% for these regions,

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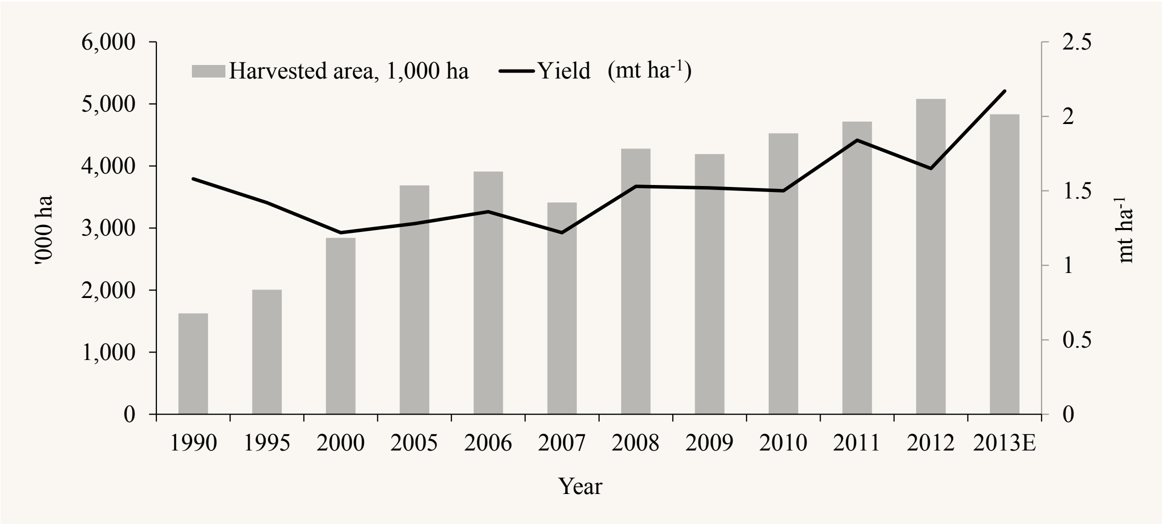

Fig. 1. Harvested area and yield of sunflower seeds in Ukraine from 1990 to 2013 (estimated for 2013).

respectively (State Statistics Committee of Ukraine). The most favorable conditions for sunflower establishment are in the forest-steppe and steppe zones, with the exception of the southern regions of the steppe zone (Kirichenko, 2010).

After the breakup of the Soviet Union, sunflower yield in Ukraine dropped significantly from 1.58 mt ha^{-1} in 1990 to 0.91 mt ha^{-1} in 1994, productivity being restored only in 2008 (1.53 mt ha^{-1}). Since then, yield has increased by 20 percent to 1.84 mt ha^{-1} in 2011. Despite this high increase, however, actual yields in Ukraine are below 50-60 percent of the biological potential of the crop (Kirichenko, 2010; Kirichenko, 2013) and many big enterprises use advanced technology to obtain yields of about 2.5-3.5 mt ha^{-1} (Kirichenko, 2010; Perepyatko, 2013). Modern hybrids have an even greater potential of 4.5-5 mt ha^{-1}. Currently, more than 350 hybrids are included in the Public Register.

The relatively low yield of sunflower in Ukraine can be accounted for by a number of factors:

- low fertilizer consumption, including potassium (K),
- failure to rotate crops and the need for improved farming technology,
- low seed quality,
- the spread of diseases (Sclerotinia head rot, Gray mold, *Phomopsis* and broomrape).

Although sunflower is a drought-resistant crop, its cultivation in the arid regions of the southern steppe has a restraining effect on crop growth (Kirichenko *et al.*, 2010; Andriyenko *et al.*, 2011).

Sunflower is the most profitable crop grown in Ukraine, the mean profitability (percent of net profit from total production costs) over the period of 1996-2012 being 51 percent (Fig. 2), and 20 percent in unfavorable seasons. As a consequence, sown areas have been increasing from year to year. One of the advantages of sunflower is that sunflower seed oil yield is much higher than that of other oilseed crops with an average of 750 kg ha^{-1} throughout the country (Denisenko, 2013).

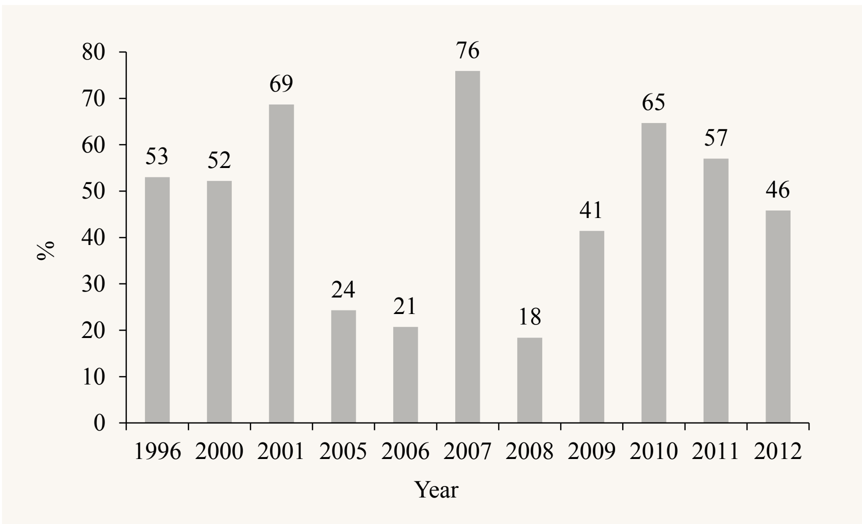

Fig. 2. The level of profitability of sunflower in Ukraine expressed as percent (%) for different years.

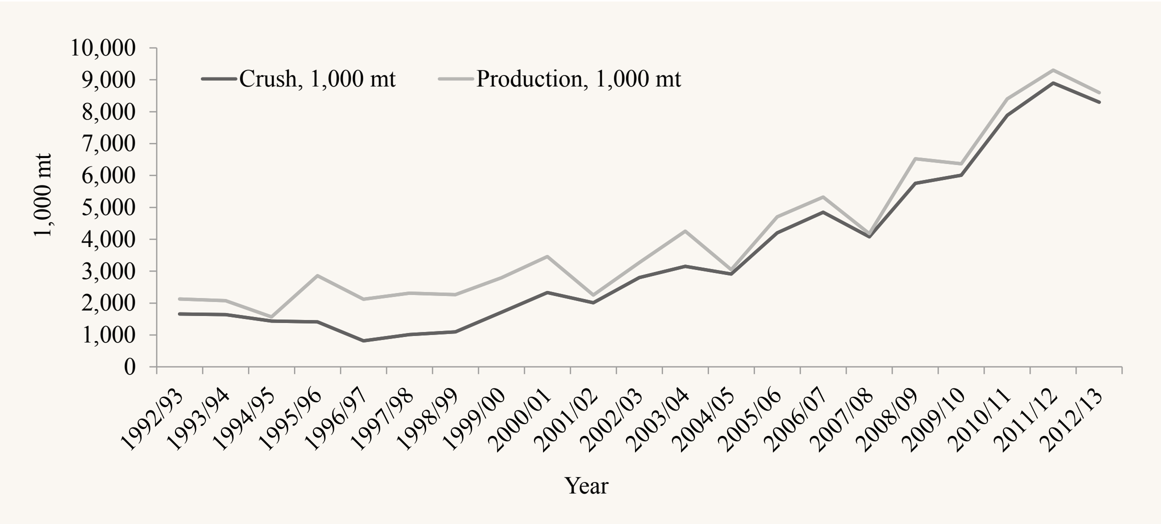

Fig. 3. Production and crush of sunflower seeds in Ukraine.

Sunflower production and crush in Ukraine

Ukraine is the world leader in sunflower production. Before 2000, sunflower production was below 3 million mt (Fig. 3). However, over the decade since 2000, production has increased threefold from 2.8 to 8.4 million mt in 2010. This has been achieved not only because of the expansion of sown areas, but also because of the increase in sunflower yields. Sunflower is cultivated mainly in the large agricultural enterprises of the country, which amounted to 84.1 percent of total production in 2011 (Perepyatko, 2013).

These agricultural agro-holdings have additional funding at their disposal to invest in the improvement of technology, which has greatly increased yields over the past few years allowing a record output of 9.3 million mt of sunflower seeds in 2011/2012. More than 95 percent of sunflower seeds produced are used in crushing plants.

The development of oilseed industry in Ukraine

Since 1990, crush capacity of Ukrainian plants has increased significantly, amounting to 13.3 million mt per year in 2012. According to The Ukroliyaprom Association (a voluntary association of oil sector enterprises), crush capacity is expected to reach around 15 million mt in 2015, close to the level of oilseed production in Ukraine (http://latifundist.com). Development in the sunflower oil industry in Ukraine has been stimulated by the introduction of export duties on seeds (currently standing at 10%), leading to a drop in exports of seeds from 1 million mt in 2000/2001 to 0.3 million mt in the last few years (USDA).

Due to the significant investment in modernization of crushing plants as of 2000, oil production in Ukraine significantly increased from about 1 million mt to 3.7-4.3 million mt in 2011-2012 (Table 1).

Domestic oil consumption, despite the slight increase, is about 590 mt on average, with the main production being exported. In 2000/2001, sunflower oil exports from Ukraine were 550,000 mt, but by 2012/2013 this value had risen to 3.3 million mt. Ukraine supplies sunflower oil to 88 countries, including India (27% of total exports), the EU (22%), Turkey (12%), Egypt (8%) and Russia (6%) (Maslak, 2012).

Fertilizer consumption in sunflower cultivation

Between 2003 and 2012 an enormous increase in mineral fertilizer use in sunflower cultivation took place rising from 35,000 mt of mineral fertilizers in 2003 to 169,200 mt of NPK by 2012 (Table 2). Before 2006, however, fertilizer utilization per ha did not change significantly, varying between 6-8 kg nitrogen (N), 4-6 kg of P_2O_5

Table 1. Production, consumption and export of sunflower oil in Ukraine (‘000 mt).

Description	1995/96	2000/01	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
					mt					
Oil production	740	970	1,750	2,010	1,756	2,500	3,035	3,327	4,347	3,730
Oil export	219	550	1,200	1,826	1,326	2,098	2,645	2,652	3,263	3,300
Oil domestic consumption	426	417	540	375	395	365	395	470	540	585

Source: USDA, The State Statistics Service of Ukraine.

Table 2. The application of fertilizers in sunflower in Ukraine.

Year	Nutrient consumption						
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	Total NPK
	---------------- *'000 mt* ----------------			------------------------ *kg ha⁻¹* ------------------------			
2003	18.7	11.4	4.9	6	4	2	11
2004	14.5	11.0	5.4	6	4	2	12
2005	20.2	16.5	8.6	8	6	3	17
2006	23.6	18.1	9.9	8	6	3	18
2007	30.6	22.5	14.0	12	9	5	26
2008	46.9	27.3	18.4	15	9	6	29
2009	42.8	18.6	12.8	14	6	4	24
2010	63.3	30.2	19.5	18	9	6	33
2011	80.5	40.0	26.3	22	11	7	41
2012	95.4	44.7	29.1	24	11	7	42

Table 3. The effectiveness of K in the northern steppe.

Treatment	Yield	Increment		Agronomic efficiency	Oil yield
	mt ha⁻¹	*mt ha⁻¹*	*%*	*kg seeds per kg K_2O applied*	*mt ha⁻¹*
$N_{45}P_{45}$	2.65	-	-	-	1.29
$N_{45}P_{45}+K_{60}$	2.85	0.20	7.5	3.3	1.40
$N_{45}P_{45}+K_{90}$	3.02	0.37	13.9	4.1	1.49
$N_{45}P_{45}+K_{120}$	3.07	0.42	15.8	3.5	1.52
$N_{45}P_{45}$	2.65	-	-	-	1.29

and 2-3 kg K_2O. But, between 2007 and 2012, consumption of mineral fertilizer in sunflower production doubled, increasing from 12 to 24 kg per ha for N, from 6 to 11 kg per ha for P_2O_5, and from 3 to 7 kg for K_2O (Rybczynski 2013; State Statistics Service of Ukraine).

This level of fertilizer consumption, however, is not enough to obtain high yields of sunflower seeds. Sunflower takes up to 120 kg N, 50 kg P_2O_5 and 250 kg K_2O to produce 20 mt ha^{-1} of seeds together with the above ground biomass. Although sunflower has a poorer response to mineral fertilizer than cereals, it is necessary to provide enough N, phosphorus (P) and K fertilizer in sunflower production. The estimated rates of fertilizers are 60 kg N, 60 kg P_2O_5 and 40-60 kg K_2O per ha (Marchuk *et al.*, 2002).

Sunflower has large requirements for mineral nutrients and especially for K, compared to other nutrients. However, the effectiveness of K fertilization depends largely on the agro-ecological zone in which the crop is grown. Steppe soils, where the main cropping areas of sunflower are located, are heavy and have a high content of K, leading to low efficiency of fertilization with this nutrient. However, in some soils in the steppe zone in which there is a negative balance for K, the use of K fertilization for sunflower is recommended. In the forest-steppe zone, soils are poor in K and the benefit of K application increases by applying a complete mineral fertilizer at rates of N between 40 to 90, P_2O_5 between 40 to 60 and K_2O between 40 to 90 kg ha^{-1}.

In an experiment carried out under the northern forest-steppe zone conditions, the highest sunflower seed yield increase (0.42 mt ha^{-1} or 15.8% compared to $N_{45}P_{60}$ treatment) was obtained with 120 kg K_2O (Table 3), but the highest agronomic efficiency per kg K_2O resulted from 90 kg K_2O combined with N and P (Gorodniy, 1990).

Potassium applied together with N and P increased not only seed yield, but also oil yield. Sunflower oil yield from this Chernozem (black dirt) at $N_{45}P_{45}$ was 1.29 mt ha^{-1}. However, by additional application of K at 120 kg K_2O ha^{-1}, the highest oil yield of 1.52 mt ha^{-1} was obtained, representing a yield increment of 0.23 mt ha^{-1}, as compared to the N and P treatment only.

Summary

1. The failure of crop rotation in many regions leads to depletion in soil fertility and the spread of diseases. Sunflower already makes up about 20 percent of the land cultivated in Ukraine. As sunflower is a very profitable crop in Ukraine, the total current area of sunflower cultivation is predicted to be maintained, but its distribution is expected to change, falling in the south and increasing in the northern regions.

2. To improve sunflower yield, it is necessary to increase the use of modern high-yielding hybrids, plant protection products and fertilizers, including potash.

3. Increasing Ukrainian sunflower yield could lead to increased oil production and exports, helping meet the needs of the continuously increasing global demand for vegetable oil.

4. One of the possible limitations to increasing sunflower yield in the coming years is the cost of the growth of fertilizer consumption including K, particularly in the forest-steppe zone.

References

Andrienko, A., I. Semenyaka, and O. Andrienko. 2011. Sunflower in Ukraine: Myths and Sensation. Zerno, Number 4. (In Russian).

Gorodniy, M. 1990. Oilseed and Essential Oil Crops. Urozhay. 125 p. (In Ukrainian).

Denisenko, L. 2013. The Analysis of World Dynamics of Sunflower Market. The Journal of National Scientific Center "Kharkov Institute of Physics and Technology". Edition 137, Kharkov. 308 p. (In Ukrainian).

Kirichenko, V., V. Kolomatska, K. Maklyak, and V. Sivenko. 2010. Sunflower Production in Ukraine: State and Prospects. The Journal of the Research Center for Agricultural Supply of Kharkov Region, Number 7. p. 281-287. (In Ukrainian).

Kirichenko, V., V. Kolomatska, and J. Rudnik-Ivashchenko. 2013. Plant Breeding and Seed Farming – A Significant Factor of Increasing Oil Crops Productivity. Variety Investigation and Protection of Plant Variety Rights, Number 1. p. 4-8. (In Ukrainian).

Marchuk, I., V. Makarenko, V. Rozstalniy, and A. Savchuk. 2002. Fertilizers and their Usage. Handbook, Kiev. 245 p. (In Ukrainian).

Maslak, O. 2012. Sunflower Forecasting. Agribusiness' Today, Number 17. (In Ukrainian).

Perepyatko I. 2013. Economic Effectiveness of Sunflower Production in Agricultural Enterprises in Ukraine. The Journal of National Science Center "Kharkov Institute of Physics and Technology" Number 2. p. 175-179. (In Ukrainian).

Rybchinsky, R. 2013. Materials of Yalta Agrochemical Forum, Yalta.

The official website of the State Statistics Service of Ukraine: http://www.ukrstat.gov.ua.

The official website of national agro portal Latifundist.com: http://latifundist.com.

USDA; the official website of the United States Department of Agriculture: http://gain.fas.usda.gov.

The paper "Sunflower Cultivation in Ukraine: Role of Fertilizers in Sunflower Seed Production" also appears on the IPI website at:

Regional activities/Eastern Europe

Research Findings

Photo 1. View of the experimental field. Photo by the authors.

Use of Different Potassium and Magnesium Treatments in Watermelon Production by Fertigation

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Abstract

Fertigation experiments were conducted in 2009 and 2011 in Hungary on watermelon plants to measure the effects on yield and quality of increasing doses of potassium (K). Potassium was supplied by fertigation together with all other major nutrients, apart from magnesium (Mg) which was applied as a foliar spray with sulphur (S) and some other micronutrients (5% EpsoMicrotop). In 2009, both grafted and non-grafted (cultivar *Crisby*) were used. Two grafted combinations with the following rootstocks: *Strongtosa* (interspecific squash hybrid) and *Nun 3001* (*Lagenaria* type) were investigated. A further experiment was carried out in 2011 using only the non-grafted (cultivar *Crisby*). Plants were grown under low tunnel conditions using intensive technology (soil covering, drip irrigation). Four fertilization treatments supplying different rates of K application were compared. In every treatment half of the plants received foliar Mg fertilizer (5% EpsoMicrotop). Measurement of the yield and

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fruit weight (kg, average mass) was made in the field. Laboratory analyses of fruit quality included: dry matter content, soluble solid content (Brix %), and sugar content - the most important characteristics of a good-quality watermelon. The results of the 2009 experiments showed that *Strongtosa* interspecific rootstock gave higher yield with higher rates of K application without any loss in fruit quality. In 2011 with only non-grafted plants, yield and total soluble solids (TSS) content ran parallel with the increasing rates of K supply.

Introduction

Watermelon is an important crop for growers in Hungary. It accounts for the third largest horticulture production area, about 6,000 ha, with a significant amount of the crop being exported. In recent years there has been a growing interest in the use of grafted plants and, over the last five years, the size of the grafted watermelon area has expanded considerably from 200-300 ha to 1,000-1,500 ha.

The watermelon crop requires considerable amounts of nitrogen (N), phosphorus (P) and potassium (K). For crops to which 40-50 mt ha^{-1} of manure are applied, an additional 90-110 kg of N ha^{-1}, 50-60 kg of P ha^{-1} and 120-140 kg ha^{-1} of K in some form of inorganic fertilizer is also required. Without manure the quantity suggested is 20 percent greater. Fertilization practice in cultivating watermelon in Hungary varies considerably from conventional mineral fertilizer application to highly controlled sophisticated methods of fertigation. The professional growers use plastic mulch with drip tubing to supply the nutrients. In order to reduce expense, preplant fertilizer can be placed under the mulch in narrow beds during spring. Specialized water soluble fertilizers may also be used, which are specifically formulated for different stages of plant development. A starter fertilizer with an NPK formulation of 15:15:15 is commonly used. Recommendations are different for self-rooted and grafted plants. From what is currently known, it appears that for grafted watermelon lower rates of N should be supplied but higher rates of K.

In order to obtain high yield and good quality watermelon, there is a need to augment the nutrient status of the soil to meet crop demand as well as maintaining soil fertility. Potassium is of particular interest since an adequate supply of this nutrient is associated with increased yields and improved quality features of various vegetable and horticultural crops, including watermelon. These features comprise fruit size, increased soluble solids and ascorbic acid concentrations, better fruit colour, increased shelf life, and shipping quality.

Many changes have occurred in watermelon production practices in the last few years, including new cultural systems such as polyethylene mulch and drip irrigation, changes in cultivars and the use of grafted plants. Seed companies are currently experimenting with grafted plants under Hungarian conditions.

It has been well documented that certain rootstocks show stronger resistance to soil pathogens, greater tolerance of low soil temperatures, as well as to salt stress (Davis *et al*., 2008; Hoyos, 2001; Oda, 2007). Thus, the selection of rootstocks is rarely based on characteristics related to nutrient utilization but rather almost always on resistance to environmental stress (Ruiz *et al*., 1997). Knowledge of the rootstock/scion nutritional relationship could be decisive in choosing rootstocks tolerant or resistant to soils that are deficient or toxic in one or more nutrients, as well as in preparing fertilization programmes after the grafted plant is transplanted (Chaplin and Westwood, 1980). Some researchers reported that quality (Brix, firmness, rind thickness etc.) of watermelon is greatly affected by rootstock, but it can also be influenced by nutrient dosage (Gao and Liao, 2006; Lee and Oda, 2003; Masuda *et al*., 1986; Yamasaki *et al*., 1994). Watermelon is sensitive to deficiencies of Mg, Boron (B), Iron (Fe) and Zinc (Zn). Foliar sprays of these nutrients in some cases, have proved useful in enhancing the sugar content of the fruit. Since watermelon yield and quality are so greatly influenced by production practices, it is important that watermelon varieties should be tested under conditions of adequate nutrition.

The paper presented here summarizes the findings of field experiments carried out with watermelon over two growing seasons, grafted and non-grafted in 2009 and non-grafted in 2011; yield and quality of the fruits were investigated in fertigation experiments with increasing levels of K together with addition of all the other major mineral nutrients, with the exception of Mg (and micronutrients) which were applied as a Mg-S micronutrient containing foliar spray (5% EpsoMicrotop).

Material and methods

Plant material and culture conditions

In both experimental years (2009 and 2011) the cultivar used was *Crisby* (seed source: Nunhems). In 2009, besides the non-grafted plants, two grafted combinations were used with the following rootstocks: *Cucurbita maxima* x *Cucurbita moschata* interspecific (squash) hybrid: *Strongtosa* (seed source: Syngenta), and a *Lagenaria* type (bottle gourd): *Nun 3001* (seed source: Nunhems).

In 2009, the experiment was carried out in Békés County in Dombegyház (Hungary 46º20'29.7"N; 21º8'3.3"E; site A), while in 2011 the experiment was set up in Kunágota (Hungary 46º25'24.2"N; 21º2'48.3"E; site B). In both areas the soil type is chernozem (black dirt). Before planting, soil analysis was carried out (Table 1). These results showed that both areas were very well provided in K and Mg. Carbonate and organic matter content were also very high.

Table 1. Results of soil tests from the two sites.

Properties	Site A (2009)	Site B (2011)
	---------------%---------------	
pH (KCl)	7.19	6.98
Soluble salt content	0.02	0.04
Total carbonate content in $CaCO_3$	4.63	4.02
Organic matter	3.17	3.12
	-------------*mg kg^{-1}*-------------	
(NO_2+NO_3)-N (M KCl soluble)	5.55	7.02
Phosphorus content as P_2O_5 (ammonium lactate extractant)	222.5	222.3
Potassium content as K_2O (ammonium lactate extractant)	318.7	305.0
Magnesium (M KCl soluble)	192	162
Sodium (ammonium lactate extractant)	23.5	19.8
Zinc (EDTA soluble)	1.25	1.08
Copper (EDTA soluble)	1.63	1.32
Manganese (EDTA soluble)	57.4	47.5
Sulphate (M KCl soluble)	<1.5	<1.5

The experiment was conducted on a grower's farm using intensive technology (drip irrigation, plastic soil cover, low plastic tunnel covering). Seedlings were used as propagating material each year. In 2009, the grafting was performed using the one-cotyledon grafting technique. In preparing a field, the land was disked, and rows laid out by the farmer. Beds were then fully shaped, treated for weeds and soil-borne pests, drip irrigation lines run, and plastic placed on top with the edges buried under the soil to hold it in place. Color plastic mulch was laid over each raised bed. Each row was irrigated with one drip tube with drippers spaced on-center 20 cm apart. Irrigation and fertigation was scheduled on visual inspection. Immediately after transplanting, the plants were grown under low tunnels fashioned using wire hoops covered with mono-layer polyethylene (Photo 2). These covers remained on the plants continuously until the first perfect female flower was observed. The watermelons were harvested by hand, beginning in June and continuing through July and into August.

Optimum plant density is an important factor in maximizing yields in many crops. Currently, commercial watermelon spacing is commonly around 80 cm by 100 cm or approximately 7,000-8,000 cm^2 per plant. Reduction in costs per ha might be achieved using grafted plants if it were possible to reduce plant populations yet attain similar yields compared to non-grafted watermelon seedlings using a traditional planting density. For grafted plants, the recommended density is 3,500-4,000 cm^2 per plant. In 2009, plants were transplanted to the field at 100 cm spacing within the row and 320 cm between rows (3,125 per ha) (Photo 1; see page 8). This density is adequate for grafted plants but, because of the arrangement of the irrigation system, equal spacing of the non-grafted plants was used. The experiment was set up with 448 plants in total. In 2011, non-grafted plants (*Crisby*) were used with a spacing of only 60 cm within the row and 170 cm between the rows (9,804 plant ha^{-1}). In this year 1,800 plants were planted. In both years, the planting took place on the 15th April.

Photo 2. Layout of the experiment (30-05-2009). Photo by the authors.

Some of the most important chemical characteristics of the soils are given in Table 1 as determined by methods of soil testing and advisory practice generally used in Hungary. The methods for these determinations are described in the Hungarian standards (MSZ-08-0206-2:1978; MSZ-08-0205:1978; MSZ-08-0210-2:1977, MSZ-20135:1999).

Treatments

In 2009, both grafted and non-grafted plants were studied and the applied fertilizer dose was calculated on the basis of an average yield of 90 mt ha^{-1}. In 2011, when the experiment included non-grafted plants only, this value was calculated as an average yield of 50 mt ha^{-1}. For each year there were four treatments with increasing rates of K and a control treatment without K as shown in Table 2.

Nutrient application was divided into different development phases (root development, intensive growth, first female flowers, small melons, half size crops). The treatments in 2009 are given in Table 3. Similarly, the nutrient applications for 2011 with grafted plants are given in Table 4.

Table 2. Fertigation treatments and foliar applications of the experiments in 2009 and 2011.

Treatment	Site A† (2009)			Site B‡ (2011)			Number of foliar applications	
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	2009	2011
	kg ha^{-1}						*5% of EpsoMicrotop§*	
Control	0	0	0	90	28	50	0	3
T_1	145	65	0	80	36	0	4	3
T_2	145	65	160	80	36	90	3	3
T_3	145	65	325	80	36	180	2	3
T_4	145	65	485	80	36	270	1	3

†Grafted and non-grafted plants; ‡Non-grafted plants only; §At 1,000 liters per ha.

Table 3. Application of nutrients (kg ha^{-1}) during growth stages (site A, 2009).

Growth stage	Treatment: T_1, T_2, T_3, T_4			T_1		T_2		T_3		T_4	
	N	P_2O_5	CaO	K_2O	MgO†	K_2O	MgO†	K_2O	MgO†	K_2O	MgO†
	kg ha^{-1}										
Root development	20	25	0	0	0	15	0	25	0	45	0
Intensive growth	25	0	0	0	0	25	0	35	0	65	0
First female flowers	25	25	0	0	0	35	0	45	0	85	0
Small melons	35	15	6	0	0/18	35	0/12	65	0/6	125	0
Half size crop	40	0	6	0	0/18	50	0/12	155	0/6	165	0/6
Total	145	65	12	0	0/36	160	0/24	325	0/12	485	0/6

†0 means control treatment without foliar fertilization.
Note: The quantities of the nutrients applied were based on yield target of 90 mt ha^{-1}.

Applied fertilizers

All fertilizer treatments were in the form of fertigation or foliar application. The soils on the experimental sites used had been treated neither with mineral nor organic fertilizer for the past 10 years. The fertilizers used were all fertigation or fully soluble grade: calcium nitrate (15.5% N + 25% CaO), ammonium nitrate (34% N), NPK 15:30:15 (Ferticare Starter) and potassium sulfate (50% K_2O + 18% S). EpsoMicrotop (15% MgO + 12% S + 1% B + 1% Mn) was used as Mg foliar spray (plus micronutrients).

Foliar application

In every treatment half of the plants received foliar Mg fertilizer (EpsoMicrotop 15% MgO; 12% S; 1% B; 1% Mn). The foliar fertilizer mixtures were diluted with water and applied at 5% concentration.

In 2009, the number of applications varied with the treatments. T_1 was sprayed four times (total 36 kg ha^{-1} of MgO), T_2 three times (total 24 kg ha^{-1}), T_3 twice (total 12 kg ha^{-1}) and T_4 once (total 6 kg ha^{-1}). In 2011, the plants were treated with foliar fertilizer (5% EpsoMicrotop) three times in each treatment (MgO 8 kg ha^{-1}), starting with initial fruit set. All foliar applications were made with a backpack sprayer and hand boom equipped with flat fan nozzles.

Table 4. Application of nutrients (kg ha^{-1}) during growth stages (site B, 2011).

Growth stage	Treatment: N					P_2O_5					CaO					K_2O					MgO†				
	C	T_1	T_2	T_3	T_4	C	T_1	T_2	T_3	T_4	C	T_1	T_2	T_3	T_4	C	T_1	T_2	T_3	T_4	C	T_1	T_2	T_3	T_4
	kg ha^{-1}																								
Root development	12	10	10	10	10	10	14	14	14	14	0	0	0	0	0	5	0	8	16	24	0	0	0	0	0
Intensive growth	15	12	12	12	12	0	0	0	0	0	0	0	0	0	0	8	0	14	28	42	0	0	0	0	0
First female flower	15	12	12	12	12	10	14	14	14	14	0	0	0	0	0	10	0	19	38	57	0	0	0	0	0
Small melons	20	18	18	18	18	8	8	8	8	8	5	5	5	5	5	10	0	19	38	57	0/12	0/12	0/12	0/12	0/12
Half size crop	28	28	28	28	28	0	0	0	0	0	5	5	5	5	5	17	0	30	60	90	0/12	0/12	0/12	0/12	0/12
Total	90	80	80	80	80	28	36	36	36	36	10	10	10	10	10	50	0	90	180	270	0/24	0/24	0/24	0/24	0/24

†0 means control treatment without foliar fertilization.
Note: The quantities of the nutrients were based on 50 mt ha^{-1}.

Irrigation and fertigation

Each treatment was set along one irrigation line. The drip lines for each row were equipped with a valve at the head line. This allowed water/fertilizer to be directed to selected rows during application.

Fungicides and insecticides were applied separately, but in a similar manner as needed throughout the season. For evaluation of the treatments the fruits were collected in every row in four replications.

Measurements

Measurement of yield and fruit weight (kg, average mass) was carried out in the field. Laboratory measurements of fruit quality included:

1. Fruit dry matter (%) (whole fruit (husk+fruit flesh) after drying at 105°C);
2. soluble solid content (Brix %) (from fruit flesh was measured by a manual digital refractometer (Hannah HI96801));
3. sugar content (%) (from fruit flesh by Luff-Schroorl method; Egan et *al.*, 1981):
   a) total sugar content (%),
   b) glucose+fructose content (%),
   c) sucrose content (%).

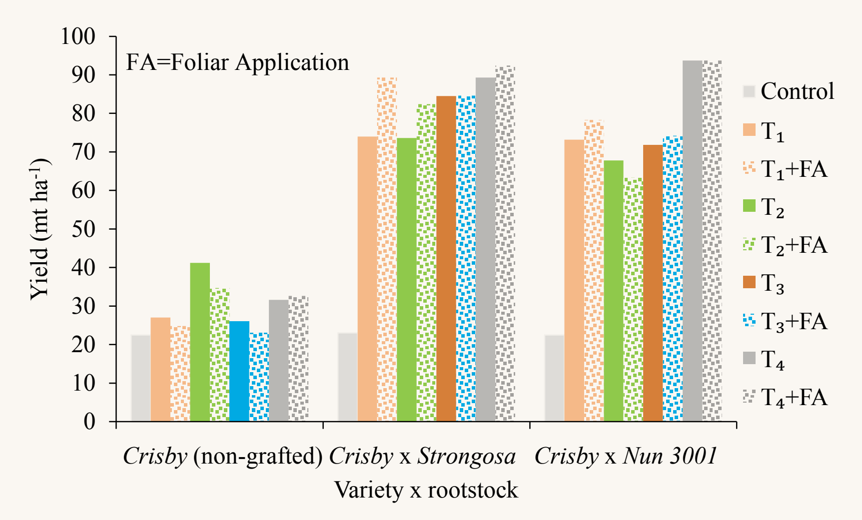

Fig. 1. The effect of K doses and Mg foliar fertilizer on the yield of non-grafted and grafted watermelon plants (site A, 2009).

The mineral content of the fruits were measured using dried plant material. Total N was determined using the Kjeldhal method (Gaspar *et al.*, 1975). Samples of plant material were wet oxidized and P and K determined in soluble form. P was measured colorimetrically using spectrophotometry (Thamm *et al.*, 1968). K was measured by flame photometry (Lasztify and Törley, 1994).

Results

Yields

In 2009, fruit were obtained from multiple harvests, which started with the non-grafted plants in the second half of June and the last harvest date taking place on 15th July. Harvesting the grafted plants of *Crisby* took place over a longer period starting at the beginning of July and continuing until the 15th August. In 2011, when only non-grafted plants were used, the harvest started in mid-June and continued until early August. The harvested fruit were counted and measured in the field as described above.

In 2009, the grafted and the non-grafted plants were planted with equal spacing because of the arrangement of the irrigation system. It thus follows that some parameters are not comparable between grafted and non-grafted plants. A very big difference in yields between the grafted and non-grafted plants (2009) was observed in favour of the grafted plants (Fig. 1). This resulted from the use of the same plant density for both types of plants, a much higher density being required by the non-grafted plants to produce the same yield.

While N and P, as well as N, P and K application to non-grafted plants contributed to yield, the effect on the grafted plants was far greater (Fig. 1). For the grafted plants, yield was positively correlated with the high K dose (T_4). The effects of foliar fertilization on yield of this grafted rootstock were greater for the lower K treatments and especially at the lowest (T_1) K dose. Of the two types of rootstock used, the interspecific squash (*Strongtosa*) generally produced a higher yield.

In 2011, the highest yield was obtained from the higher K dose (180 and 270 kg K_2O ha^{-1}; T_3 and T_4, respectively; Fig. 2). The applied doses gave higher values compared to the control (the grower's technology; 50 kg ha^{-1}). In all treatments, the addition of foliar spray (FA) slightly increased both yield and fruit weight (Fig. 2). Omission of K (T_1) resulted in a steep decline in yield. The overall benefit from applying K (as compared to T_1, K=0) was approximately 50 percent. The evaluation of fruit weight result shows the same tendency as with fruit yield.

Quality parameters

In general, lower fruit quality reported for watermelon due to grafting includes reduced soluble solids content, insipid taste, and poor texture (Traka-Mavronaet *et al.*, 2000). Our results confirm these findings: in all treatments, the non-grafted plants had higher soluble solid, dry matter, total sugar, glucose, fructose and sucrose concentrations (Table 5). Increasing levels of applied

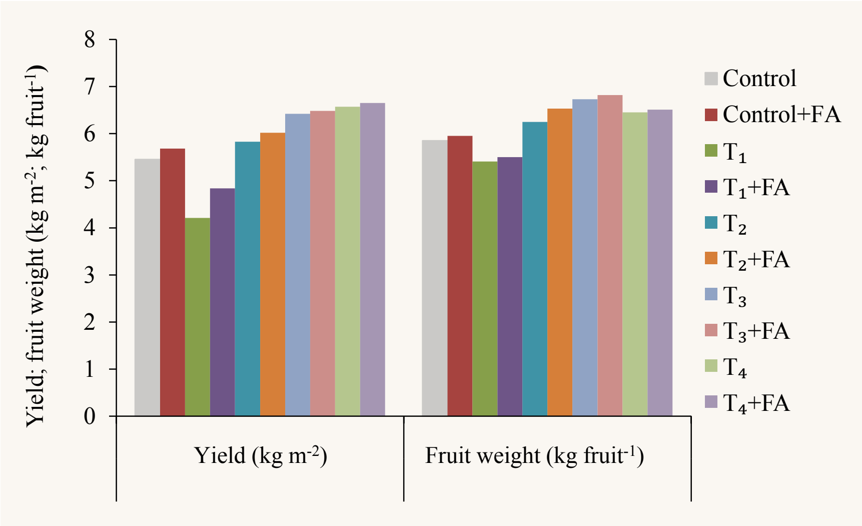

Fig. 2. The effect of K doses and Mg foliar fertilizer on yield and fruit weight of *Crisby* (non-grafted) watermelon plants (site B, 2011).

K improved these in non-grafted and grafted plants, but the effect of FA was small (Table 5).

In 2009, differences were observed between the two different rootstock types. The mature fruit from the *Crisby/Nun 3001* combination had significantly lower soluble solid content compared to that from the *Crisby/Strongtosa* combination (Table 5.). The higher K dose resulted in higher TSS content, and EpsoMicrotop treatments raised this even more.

There are conflicting reports on changes of fruit quality due to grafting. Reports vary on whether grafting effects are advantageous or deleterious, but most agree that the rootstock/scion combination must be carefully chosen for optimal fruit quality. If the effects of rootstocks on fruit quality are detrimental, recommendations are aimed at minimizing these effects.

Table 5. The effect of K doses and Mg foliar fertilizer on total soluble solid (TSS), dry matter (DM), and sugar content of grafted and non-grafted *Crisby* (site A, 2009).

Treatment	Total Soluble Solid (Brix)			Dry Matter			Total Sugar			Glucose+Fructose			Sucrose (%)		
	NG	ST	NU	NG	ST	NU	NG	ST	NU	NG	ST	NU	NG	ST	NU
	%														
Control	10.60			8.02			8.02			3.89			4.13		
T_1	10.90	11.18	5.10	8.22	7.48	4.47	8.54	9.06	3.68	4.74	5.58	3.48	3.80	3.48	0.20
T_1+FA	12.50	11.33	11.28	9.90	8.64	7.76	10.83	10.00	7.24	4.14	4.04	3.08	6.69	5.96	4.16
T_2	11.30	10.15	6.80	8.85	7.64	6.04	9.69	8.54	4.63	3.84	5.78	4.18	5.85	2.76	0.45
T_2+FA	11.25	10.73	7.30	9.70	8.35	5.83	10.10	8.86	4.88	4.98	4.24	4.38	5.12	4.61	0.50
T_3	11.68	10.38	9.00	9.21	7.61	6.83	9.27	8.96	5.13	4.24	5.08	3.78	5.03	3.88	1.35
T_3+FA	12.45	10.68	8.08	10.87	8.14	6.84	11.47	8.96	5.93	5.38	3.94	3.78	6.09	5.02	2.15
T_4	12.50	11.45	9.85	10.56	8.25	8.01	10.62	9.58	6.88	5.88	4.88	3.98	4.74	4.70	2.90
T_4+FA	12.50	11.30	10.13	10.68	8.82	8.95	10.94	9.27	8.08	4.54	4.14	3.78	6.40	5.13	4.30

Note: NG = non-grafted; ST = grafted on '*Strongtosa*' rootstock; NU = grafted on '*Nun 3001*' rootstock.

Table 6. The effect of K doses and Mg foliar fertilizer on TSS, DM and sugar content of non-grafted *Crisby* watermelon (site B, 2011).

Treatment	Total Soluble Solid (Brix)	Dry matter	Total Sugar	Glucose+Fructose	Sucrose
	%				
Control	10.20	8.50	8.90	4.77	4.13
T_1	10.35	8.60	9.30	4.85	4.45
T_1+FA	8.90	8.02	8.20	4.30	3.90
T_2	9.50	8.90	8.45	4.20	4.25
T_2+FA	11.30	8.85	9.69	4.07	5.62
T_3	11.55	9.70	10.15	4.30	5.85
T_3+FA	11.68	9.21	10.20	3.99	6.21
T_4	12.25	10.87	10.78	4.46	6.32
T_4+FA	12.50	10.56	10.62	4.20	6.42
Control	12.70	10.68	11.30	4.55	6.75

Watermelons respond well to fertilizer: ususally, inreasing rates of supply of K and Mg speed up fruit ripening and increase sugar content. In 2011, measuring the total sugar content (%) and the different sugar fractions, we found that the increased K doses, and also application of Mg, increased sugar content of fruits (Table 6). K rate and the Mg raised sucrose content, but there was no effect on glucose+fructose content. Nutrient removal from the experimental plots in 2009 was calculated by N, P and K content in fruit (Table 7) multiplied by yield and presented as nutrient removed per ha (Table 8). Nutrient content did not change much between the different types of plants and with different treatments (Table 7). Hence, nutrient removal increased as a function of yield (Table 8 and 9), so that the much higher yields of grafted plants removed more than twice the N, P and K compared to non-grafted plants. This obviously has a significant implication on soil fertility and the consequent nutrient management of these plants.

Table 7. N, P and K content in grafted and non-grafted *Crisby* fruit (site A, 2009).

Treatment	N			P			K		
	NG	ST	NU	NG	ST	NU	NG	ST	NU
	mg g^{-1}								
Control	23.2	23.2	23.2	2.1	2.1	2.1	26.0	26.0	26.0
T_1	31.9	34.3	35.7	4.6	4.1	3.8	43.0	32.0	31.0
T_1+FA	34.6	32.9	35.0	5.0	4.3	4.0	34.0	29.0	45.0
T_2	31.9	28.7	38.5	5.1	3.1	4.6	46.0	29.0	34.0
T_2+FA	28.4	29.8	34.6	3.4	3.6	2.9	32.0	31.0	35.0
T_3	29.1	31.9	32.6	3.8	3.9	3.3	38.0	31.0	32.0
T_3+FA	31.2	35.0	35.3	4.4	4.6	3.3	35.0	38.0	29.0
T_4	33.6	29.6	24.6	3.4	3.4	2.9	30.0	35.0	27.0
T_4+FA	35.3	30.5	33.2	4.2	3.4	3.7	35.0	35.0	38.0

Note: NG = non-grafted; ST = grafted on '*Strongtosa*' rootstock; NU = grafted on '*Nun 3001*' rootstock.

Table 8. N, P and K removal by grafted and non-grafted *Crisby* fruit (site A, 2009).

Treatment	N			P			K		
	NG	ST	NU	NG	ST	NU	NG	ST	NU
	kg ha^{-1}								
Control	52.2	52.2	52.2	4.8	4.8	4.8	58.5	58.5	58.5
T_1	86.1	253.8	261.2	12.3	30.0	27.8	116.1	236.8	226.9
T_1+FA	85.9	293.9	274.0	12.2	38.2	31.4	84.3	258.9	352.3
T_2	82.9	243.0	276.1	13.4	26.5	33.2	119.6	245.0	244.1
T_2+FA	65.6	252.1	257.1	7.9	30.3	21.4	73.9	262.3	259.7
T_3	119.9	234.6	220.8	15.6	29.2	22.5	156.6	228.2	216.9
T_3+FA	108.2	288.4	223.7	15.4	38.1	20.9	121.4	313.1	183.6
T_4	106.0	274.7	171.5	10.7	31.5	20.0	94.8	324.8	188.2
T_4+FA	115.2	281.7	311.6	13.6	31.8	34.3	114.1	323.4	356.1

Note: NG = non-grafted; ST = grafted on '*Strongtosa*' rootstock; NU = grafted on '*Nun 3001*' rootstock.

Table 9. N, P and K content and removal by grafted and non-grafted *Crisby* fruit (Site B, 2011).

Treatment	Nutrient content			Nutrient removal		
	N	P	K	N	P	K
	mg g^{-1}			*kg ha^{-1}*		
Control	30.8	2.1	31.0	167.9	11.6	168.9
Control+FA	31.1	2.2	32.0	176.6	12.8	181.8
T_1	29.8	4.6	24.0	125.4	19.3	101.0
T_1+FA	28.7	4.9	27.0	138.9	23.9	130.7
T_2	29.5	5.1	35.0	171.9	30.0	204.1
T_2+FA	29.7	4.9	36.0	178.8	29.5	216.7
T_3	29.1	4.9	38.0	186.9	31.3	243.9
T_3+FA	30.1	4.4	38.0	195.0	28.8	246.2
T_4	30.4	4.6	40.0	199.7	29.9	262.8
T_4+EpsoTop	30.5	4.2	38.0	202.8	27.9	252.7

Conclusions

The main aim of this experiment was to investigate the effects on fertigated grafted and self-rooted watermelon of KCl application at various levels, with or without a Mg containing foliar fertigation. The results of this study are in agreement with some earlier findings that K in the fertigation solution enhances fruit appearance and improves fruit quality.

In our study the beneficial effect of K in raising yield was more conspicuous in the interspecific squash rootstock (*Strongtosa*). In 2009, with only non-grafted *Crisby* plants, the lowest K dose (T_2; 160 kg ha^{-1}) resulted the highest yield, whereas in the 2011 experiment, yield increased with increasing K application. The highest K dose enhanced the yield by 20 percent compared to the control (grower's technology). The benefits of K on watermelon growth have been documented by numerous previous investigators, such as Okur and Yagmur (2004) who found that 240 kg ha^{-1} of K_2O produced the highest yield of watermelon at 54,320 kg ha^{-1}. In order to obtain high yields with grafted watermelon a high K dose is specifically required.

Based on the results of 2009 with grafted and non-grafted plants, application of the Mg foliar fertilizer (EpsoMicrotop) enhanced yields especially at lower rates of K. Knowledge of this relationship may be very useful to the growers who may be able to compensate lower rates of K application by additional foliar Mg fertilization to increase yield.

Both yield and fruit quality are important parameters in watermelon. For grafted plants, the question of fruit quality is of particular interest. Sugar content appears to be one of the most important characteristics of a good-quality watermelon, based on the fruit quality indices routinely measured by scientists. Some previous research has generally shown that grafting has a negative effect on TSS content in watermelon fruit when grafting watermelon onto *C. maxima* x *C. moschata*, or *L. siceraria* rootstocks (Ioannouet *et al*., 2002). In our experiment we obtained similar results, but higher rates of K application could to some extent offset this decrease. For the non-grafted plants, increasing K dose resulted in higher sugar content in both experimental years.

Considering the opportunities for growers of the many plant mineral nutrients, K and Mg stand out as having a very strong influence on quality attributes that determine fruit marketability. As for effect of K, it was clear that the medium and high levels of application raised the number of fruits/plant, fruit weight, total yield and TSS (%) compared with low level treatment. In most cases for the two seasons the best gains financially were recorded with the medium K level with Mg and micronutrient supplement.

The findings of this study help to improve the quality of watermelon fruits as well as the quantity. However, this study also indicates the need for further investigation concerning the interaction between K-Mg in watermelon fertigation, especially using grafted plants. It also has to be taken into account in these field experiments that supplying foliar Mg, in the form of EpsoMicrotop, provides the crop with additional S and micronutrients which may possibly influence the K/Mg interaction.

References

Chaplin, M.H., and M.N. Westwood. 1980. Nutritional Status of ‘Barlett’ Pear on Sydonia and Pyrus Species Rootstock. Journal of the American Society for Horticultural Science Number 105. p. 60-63.

Davis, A.R., P. Perkins-Veazie, Y. Sakata, S. López-Galarza, J.V. Maroto, S.G. Lee, Y.C. Huh, Z. Sun, A. Miguel, S.R. King, R. Cohen, and J.M. Lee. 2008. Cucurbit Grafting Critical Reviews. Plant Sciences.

Egan, H., R. Kirk, and R. Sawyer. 1981): The Luff Schoorl Method. Sugars and Preserves. *In:* Pearson’s chemical analysis of foods. 8th edition, Longman Scientific and Technical: Harlow, UK. p. 152-153.

Gao, J.H., and H.J. Liao. 2006. Effect of Grafting on Watermelon Quality. China. Cucurbits and Vegetables Number 5. p. 12-14.

Gáspár, L., H. Kalász, I. Kerese, Ö. Takács, and E. Tyihák. 1975. Fehérjevizsgálati módszerek. Műszaki Könyvkiadó, Budapest.

Hoyos Echebarria, P. 2001. Influence of Different Rootstocks on the Yield and Quality of Greenhouses Grown Cucumbers. ActaHorticulturae Number 559. p. 139-144.

Ioannou, N., M. Ioannou, and K. Hadjiparaskevas. 2002. Evaluation of Watermelon Rootstocks for Off-Season Production in Heated Greenhouses. ActaHorticulturae, Number 579. p. 501-506.

Lásztify, R., and D. Törley. 1994. Élelmiszerkémiai és Technológiai Gyakorlatok. Műegyetem Kiadó, Budapest. 129 p.

Lee, J.M., and M. Oda. 2003. Grafting of Herbaceous Vegetable and Ornamental Crops. Horticultural Reviews, Number 28. p. 61-124.

Masuda, M., T. Takamori, T. Tanaka, H. Takahashi, and M. Sugio. 1986. Studies of the Characteristics of Nutritional Uptake of the Rootstocks of Grafted Crop Fruits. Fruit Quality and Water and Mineral Absorption in Watermelon Grafted to Squash and to Bottle Gourd Interstock. Journal of the Japanese Society of Horticultural Science. Spring Meeting. p. 180-181.

Oda, M. 2007. Vegetable Seedling Grafting in Japan. ActaHorticulturae, Number 759. p. 175-180.

Okur, B., and B. Yagmur. 2004. Effects of Enhanced Potassium Doses on Yield, Quality and Nutrient Uptake of Watermelon. IPI Regional Workshop on Potassium and Fertigation Development in West Asia and North Africa; Rabat, Morocco, 24-28 Nov. 2004. p. 36-43.

Ruiz, J.M., A. Belakbir, I. López-Cantarero, and L. Romero. 1997. Leaf-Macronutrient content and yield in Grafted Melon Plants. A model to evaluate the influence of rootstock genotype. ScientiaHorticulturae, Number 71. p. 227-234.

Thamm, F.NÉ., M. Krámer, and J. Sarkadi. 1968. Növények és Trágyaanyagok Foszfortartalmának Maghatározása Ammonium-Molibdo-Vanadátos Módszerrel. Agrokémia és Talajtan Tankönyv. 17. p. 1-2.

Traka-Mavrona, E., M. Koutsika-Sotiriou, and T. Pritsa. 2000. Response of Squash (*Cucurbita spp.*) as Rootstock for Melon (*Cucumis melo* L.). Scientia Hort., Number 83. p. 353-362.

Yamasaki, A., M. Yamashita, and S. Furuya. 1994. Mineral Concentrations and Cytokinine Activity in the Xylem Exudate of Grafted Watermelons as Affected by Rootstocks and Crop Load. Journal of the Japanese Society of Horticultural Science, Number 62. p. 817-826.

The paper “Use of Different Potassium and Magnesium Treatments in Watermelon Production by Fertigation” also appears on the IPI website at:

Regional activities/Central Europe

Research Findings

Photo by S.K. Bansal.

Potassium Nutrition for Improving Yield and Quality of Onion

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Abstract

Field experiments were conducted at the Post Graduate Institute Farm of the Department of Soil Science and Agricultural Chemistry, Mahatma Phule Agricultural University, Rahuri (Maharashtra) during three consecutive Rabi seasons from 2007-2008 to 2009-2010 to study the effect of increasing rates of potassium (K) fertilizer application on yield, quality and nutrient uptake of onion (Cv. N-2-4-1). All treatments including a yield targeted treatment and one based on a soil test significantly increased bulb yield compared to the control without K. Application of 100 kg K_2O ha^{-1} recorded statistically superior bulb yield of (52 mt ha^{-1}); but further improvement on yield was not detected with the two higher rates of up to 150 kg K_2O ha^{-1}. Total sugar, reducing sugar and non-reducing sugar percentage contents of the

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bulbs increased significantly as a consequence of application of K_2O (100 kg ha^{-1}) along with the recommended dose of N and P fertilizers. The yield contributing characters viz., polar diameter and equatorial diameter were significantly increased by 100 kg K_2O ha^{-1}. Application of graded levels of K raised the quality of the crop by increasing the total soluble solids, non-reducing sugars and chlorophyll (45 days after transplanting) content up to 100 kg K_2O ha^{-1}. This beneficial influence of K most probably largely relates to its stimulating effect on photosynthesis and the translocation of photosynthetic products to the bulbs.

Nutrient balance (fertilizer input vs. crop offtake) was influenced by the various K treatments. Offtake of nutrients increased with increased yields but also with higher N and K tissue concentrations. At zero or low levels of applied K fertilizer, a positive nitrogen (N) balance (unused N fertilizer by the crop) was induced in accordance with the low yield. A zero N balance between crop offtake and fertilizer input was observed with an application of 75 kg K_2O ha^{-1}. With further increase in K fertilizer input, yield increased up to 100 kg K_2O ha^{-1}, but at higher levels of K fertilization a negative balance of N to the extent of 70-80 kg N ha^{-1} was evident. These results suggest that the stagnation in yield increase beyond the application of 100 kg K_2O ha^{-1} was largely due to a lack of N. The results obtained in the present investigation indicate that the economic analysis is not sensitive to the cost of K fertilizer, and on this particular site the application of 150 kg K_2O ha^{-1} resulted in the highest economic yield.

Introduction

Onion is one of the most widely grown vegetable crops on a commercial scale. It is extensively cultivated all over the world, especially in Australia, Bangladesh, China, India, The Netherlands and Pakistan. As the second largest onion growing country in the world, India accounts for about 16% of world production, but has an average yield of only 10.38 mt ha^{-1}, considerably lower than the global average of 18.08 mt ha^{-1} (www.fao.org, 2005). Imbalanced fertilization with excess N and too little phosphorus (P) and K, inducing low nutrient efficiency, is a common cause of low yield and poor quality in vegetables, including onion (Kanwar and Sekhon, 1998).

The essential role of K in numerous physiological and biochemical processes in the plant - including photosynthesis, enhancing the translocation of assimilates, protein synthesis, maintenance of water balance, and promoting enzyme activities - are well established (Marschner, 2012). In practical terms the importance of K in relation to onion yield and quality has been reported (Yadav *et al.*, 2002; Masalkar *et al.*, 2000). An adequate K content of the bulb is also important for storage quality of the crop. K deficiency in onion is expressed by the appearance of brown tips in older leaves and poor bulb formation. The application of an appropriate quantity and source of K to onion at critical growth stages is thus essential for maintenance of growth and quality (Subba Rao and Brar, 2002). The onion crop removes large quantities of nutrients from the soil, which must be replenished to maintain soil fertility. For a 40 mt ha^{-1} bulb yield this amounts to 120 kg N, 50 kg P and 160 kg K per ha^{-1} (Tandon and Tiwari, 2008), whereas lower nutrient rates of 100 kg N, 50 kg P_2O_5 (30 kg P) and 50 kg K_2O (41 kg K) per ha^{-1} are commonly applied, especially for K.

The present work was therefore undertaken to study the effect of soil applied graded levels of K as muriate of potash (MOP) on yield, quality and nutrient uptake by onion (Cv. N-2-4-1).

Materials and methods

Field experiments using onion (Cv. N-2-4-1) were conducted during three consecutive Rabi seasons from 2007-2008 to 2009-2010 at the same site of the Post Graduate Institute Farm of the Department of Soil Science and Agricultural Chemistry, Mahatma Phule Agricultural University, Rahuri (Maharashtra). Experiments were laid out in a randomized block design comprising eight potash treatments, each replicated four times. These included five increasing potash rates (50, 75, 100, 125, 150 kg K_2O ha^{-1}) and three other treatments viz. an absolute control, a treatment as per soil test and a treatment as per yield targeted 40 mt ha^{-1} (Table 1). A fertilizer dose of 100 kg N as urea and 50 kg P_2O_5 as single super phosphate was uniformly given to all treatments, except T_2 and T_5, in accordance with the soil test (higher N) and yield target calculation (higher N and P). K_2O was applied in the form of muriate of potash (KCl). The gross plot size was 5 m x 3 m while the net plot size was 4.40 m x 2.60 m using the recommended spacing of onion at 15 x 10 cm. The soil used in the experiment was an Inceptisol (Vertic Haplustepts) with the following chemical properties: pH 8.5, electrical conductivity (EC) 0.16 dS m^{-1}, organic carbon (6.2 g kg^{-1}), calcium carbonate (106.2 g kg^{-1}), available N (75 ppm), available (Olsen-P) P (8.5 ppm) and available (NH_4OAc-K) K (130 ppm). Farmyard manure (FYM) @ 10 mt ha^{-1} was applied to all the treatments every year.

Table 1. Treatments with applied nutrients.

Treatment		Applied nutrients		
		N	P_2O_5	K_2O
			kg ha^{-1}	
T_1	NP	100	50	0
T_2	$NPK^{(1)}$	125	50	33
T_3	NPK_{50}	100	50	50
T_4	NPK_{75}	100	50	75
T_5	$NPK^{(2)}$	125	78	86
T_6	NPK_{100}	100	50	100
T_7	NPK_{125}	100	50	125
T_8	NPK_{150}	100	50	150

(1)According to soil test; (2)yield target 40 mt ha^{-1}

Note: Values of P and K are for P_2O and K_2O.

A yield targeted treatment of 40 mt ha^{-1} was established using the equations below:

$FN = 5.40 \times T - 0.54 \times SN$
$FP_2O_5 = 4.0 \times T - 4.32 \times SP$
$FK_2O = 3.10 \times T - 0.13 \times SK$

where FN, FP_2O_5 and FK_2O represent fertilizer N, P_2O_5 and K_2O (kg ha^{-1}), and T the targeted yield finalized on the basis of maximum achievable yield by progressive onion growers for the productive capacity of the variety (mt ha^{-1}). SN, SP and SK indicate soil available N, P and K (kg ha^{-1}), respectively (Kadam and Sonar, 2006). The treatment of the soil test was based on measurement of available K.

Farmers currently use a fertilizer dose of $N_{100}P_{50}K_{50}$. However, the introduction of high yielding onion varieties, with assured irrigation facilities, while increasing productivity and helping to enhance farmers' income has placed a higher nutrient demand that cannot be met by current rates of fertilizer application, especially of K.

Soil samples were collected before planting and after harvesting the crop. Dry and processed soil samples (<2 mm) were used to determine chemical properties using standard procedures. Measurements were made as follows: pH and electrical conductivity in 1:2 soil suspension (Jackson, 1973), organic carbon (C) by the methods of Nelson and Sommer (1982); available N by the alkaline permanganate method (Subbiah and Asija, 1956); available P by extracting the soil with $NaHCO_3$ at pH 8 followed by spectrophotometeric determination (Olsen *et al.*, 1954) and available K by soil extraction with 1N neutral NH_4OAc followed by estimation using a flame photometer (Knudsen *et al.*, 1982).

Plant samples were dried to a constant weight, then ground and analyzed. Total N was determined using the micro-kjeldahl digestion method with H_2SO_4:H_2O_2 (1:1) followed by ammonia estimation. Total P and K were both determined following wet digestion of the dried plant material with H_2SO_4:$HClO_4$:HNO_3 (1:4:10) as described above. Total soluble solids (TSS) were determined using a hand refractometer. Reducing and non-reducing sugars were estimated by the Fehling reagent method as per procedures given by A.O.A.C. (1990). Chlorophyll content of the fresh leaves was determined at 45 days after transplanting. Fresh leaf tissue was crushed in acetone by use of a pestle and mortar then filtered. The color intensity of the filtrate was then measured spectrophotometrically at 645 and 663 nm wavelengths as per the method outlined by Arnon (1949).

Size of onion plants with increasing levels of K application. Photo by S.K. Bansal.

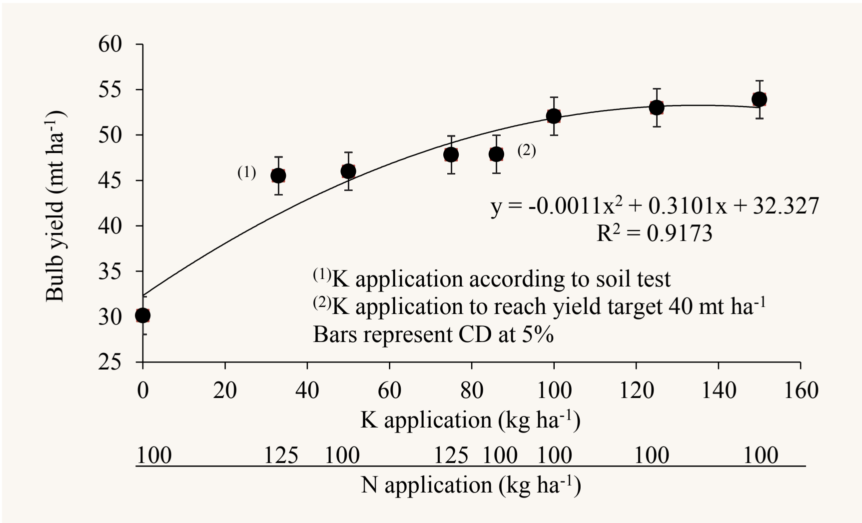


Fig. 1. Response of onion (bulb yield) to K and N application.

Results and discussion

Yield of onion

Yield data is presented in Fig. 1 and yield contributing characters are given in Table 2. As evident from Fig. 1, application of KCl at various levels and treatments all significantly increased bulb yield over the control without K (NP, T_1). Application of K_2O of 150 kg ha^{-1} (T_8) recorded the highest bulb yield of 53.90 mt ha^{-1}, however, there was no statistical difference between this treatment and the maximum achieved with the application of 100 kg K_2O ha^{-1} (T_6) (52.06 mt ha^{-1}). The yields of all three treatments (T_6, T_7, T_8) were significantly higher than the yield of T_1 - the absolute control with no K (30.11 mt ha^{-1}) - and the yields of the four other treatments with K levels lower than 100 kg K_2O ha^{-1}, including the dose calculated from soil test (T_2) and that calculated for yield target (T_5).

These findings show that the treatment as per soil test (T_2; point 1 in Fig. 1) overestimated N requirement and underestimated K_2O requirement, clearly indicating the need for a complete reappraisal of the interpretation of this soil testing method in relation to K fertilizer recommendations for the onion crop. In the targeted yield treatment (T_5; point 2 in Fig. 1), it appears that despite the 25% additional N and 56% additional P_2O_5 applications (Table 1), the yield was restricted by sub-optimal K_2O application. The addition of more K than the recommended dose, at levels greater than 100 kg K_2O ha^{-1}, resulted in vigorous plant growth and higher bulb yield. This may possibly be due to higher concentrations of K in promoting photosynthesis, enhancing the translocation of assimilates as well as enzyme activity, and protein synthesis (Shaheen *et al.*, 2011; Shusheel Kumar *et al.*, 2006).

Chlorophyll content and yield contributing characters

The application of potash significantly increased the chlorophyll content of onion leaves (Table 2). The chlorophyll leaf content at 45 days after transplanting (DAT) was significantly higher with 100 kg K_2O ha^{-1} (0.627 mg g^{-1} of fresh weight) than all other treatments tested. To our knowledge there is no evidence that K plays a direct role in chlorophyll synthesis. However, it seems very plausible that a high K status should facilitate essential processes of growth and development, thereby, inducing an indirect effect to increase chlorophyll concentration. Evidence in support of this concept comes from the findings of Varpe (2005) who reported an increased chlorophyll content in onion leaves at 45 days after transplanting in response to raised supply of all three nutrients N, P and K, presented individually compared to the control.

Table 2. Effect of potash levels on chlorophyll content (45 DAT) and yield contributing characters of onion.

Treatment	Chlorophyll content in leaves	Polar diameter	Equatorial diameter	Neck thickness
	mg g⁻¹ fresh wt	----------------------*cm*----------------------		
$N_{100}P_{50}$	0.542	4.43	4.83	0.28
$N_{125}P_{50}K_{33}$ (1)	0.596	5.48	5.63	0.61
$N_{100}P_{50}K_{50}$	0.547	5.40	5.63	0.63
$N_{100}P_{50}K_{75}$	0.595	5.75	5.73	0.62
$N_{125}P_{78}K_{86}$ (2)	0.549	5.70	5.74	0.55
$N_{100}P_{50}K_{100}$	0.627	6.88	7.00	0.56
$N_{100}P_{50}K_{125}$	0.583	5.54	5.78	0.56
$N_{100}P_{50}K_{150}$	0.558	5.53	5.73	0.57
SE ±	0.003	0.149	0.164	0.026
CD at 5%	0.009	0.439	0.482	0.077

(1)According to soil test; (2)yield target 40 mt ha^{-1}

Significant effects of treatment combinations on the size of the onion bulb (viz. polar diameter, equatorial diameter and neck thickness) were recorded (Table 2). The highest polar diameter and equatorial diameters were found in treatment T_6 i.e. application of 100 kg K_2O ha^{-1} (6.88 and 7.00 cm, respectively). Neck thickness was also affected by K application, ranging between 0.55 to 0.61 cm, compared to the control (only 0.28 cm). Similar results have been reported by others (Mohanty and Das, 2001; Yadav *et al.*, 2003; Kumar *et al.*, 2001; Nandi *et al.*, 2002).

Quality parameters of onions

Potash levels significantly increased bulb contents of total soluble solids (TSS),

Table 3. Effect of potash levels on quality parameters of onion.

Treatment	TSS	Reducing sugar	Non-reducing sugar	Total sugar
	°brix	----------------------%----------------------		
$N_{100}P_{50}$	7.19	2.01	3.88	5.89
$N_{125}P_{50}K_{33}$ (1)	7.94	2.16	4.43	6.59
$N_{100}P_{50}K_{50}$	7.56	2.18	4.25	6.43
$N_{100}P_{50}K_{75}$	7.83	2.66	4.44	7.10
$N_{125}P_{78}K_{86}$ (2)	7.87	2.68	3.92	6.60
$N_{100}P_{50}K_{100}$	8.34	2.56	4.76	7.32
$N_{100}P_{50}K_{125}$	8.25	2.74	3.77	6.51
$N_{100}P_{50}K_{150}$	7.87	2.60	4.45	7.05
SE ±	0.030	0.026	0.108	0.097
CD at 5%	0.088	0.075	0.319	0.286

(1)According to soil test; (2)yield target 40 mt ha^{-1}

reducing and non-reducing sugars and thereby total sugar (Table 3). The highest TSS (8.34° brix) was achieved with the application of 100 kg K_2O ha^{-1}, significantly higher than 7.19° brix obtained with K=0 (absolute control). Many workers have reported increased TSS content in onion in response to raised K status which has been ascribed to enhanced carbohydrate production during photosynthesis (Singh and Singh, 2000; Vacchani and Patel, 1993). Additionally from evidence of other crops, such as sugar cane, higher concentrations of K in the phloem enables more rapid translocation of photosynthates including both sucrose and amino N compounds from leaves to other plant parts i.e. source to sink (Hartt, 1969).

Similarly, for total sugar percentage content, increase in potash levels from the absolute control to 100 kg K_2O ha^{-1} significantly increased values from 5.89% (T_1) to 7.32% (T_6). With a further increase in potash levels, for the two higher treatments, T_7 and T_8, a decrease in content of total sugar in the bulb was observed at 6.51 and 7.05%, respectively. The maximum non-reducing sugar content of bulbs was 4.76% in T_6 (100 kg K_2O ha^{-1}). The maximum reducing sugars content of bulbs was recorded at 2.74% in T_7 (125 kg K_2O ha^{-1}) and an increasing trend was found from T_1 to T_5 treatments. The higher sugar contents of the onion bulbs with increasing K application may be explained by the direct stimulating effect of K on photosynthesis in the onion leaves and enhancing transport of the resulting photosynthates to the bulbs which act as a very strong sink.

Nutrient offtake and input/output balance

Offtakes of N, P and K by bulbs and leaves of onion (kg ha^{-1}) are presented in Fig. 2, and as a function of the yield in Fig. 3A and 3B. We found that offtake of nutrients in bulbs is more than three times higher than that of leaves, and hence, bulb yield and offtake are the critical components for nutrient balance calculations. A good yielding onion field with yields of 50-55 mt ha^{-1} removes 300-350 kg of nutrients (Fig. 2) per season.

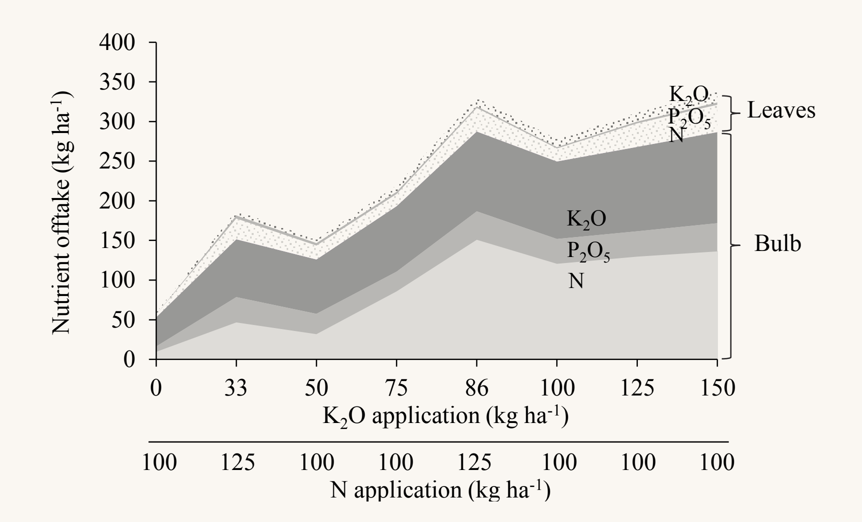


Fig. 2. Nutrient offtake in bulbs and leaves of onion.

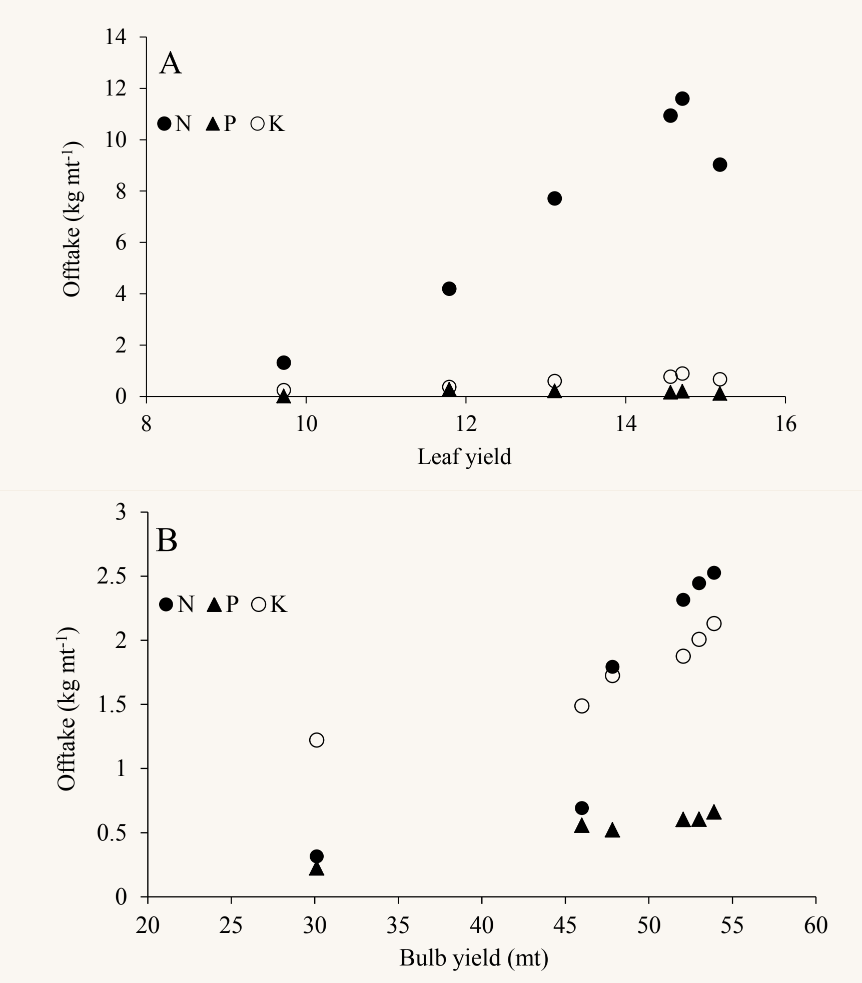


Fig. 3. Concentration of N, P and K in leaves (A) and bulbs (B) of onion, at harvest in relation to bulb yield levels obtained in the experiment.

N offtake in bulbs increased tenfold as K application increased, from approximately 10 kg ha^{-1} with K=0 to 136 kg N when K=150 kg ha^{-1} (Fig. 2). At the same time, yield doubled (Fig. 1 and 3A), so that N concentration in bulb tissue increased as yield increased from 0.3 to 2.5 kg N mt^{-1} of bulbs (Fig. 3B). The N concentration in leaves also increased markedly (10 fold) as leaf yield of onion increased (Fig. 3A). K offtake in bulbs increased from 37 to 115 kg K_2O ha^{-1}, as K increased from zero to 150 kg K_2O ha^{-1}, or three times more, and its concentration in the bulbs doubled as yield doubled, from 1.2 to 2.1 kg K_2O mt of bulbs (Fig. 3B). K offtake in leaves, however, hardly changed as yield increased (Fig. 3A). These findings thus show that the application of K greatly influence N and K offtake in bulbs and leaves, by both increasing the yield, and, no less significantly, by increasing N and K levels in the bulbs, and leading to higher N in the leaf tissue with increasing yield. P offtake in bulbs increased from 7 to 36 kg P_2O_5 ha^{-1}, mostly accountable by increased yield (Fig. 1) and to a small extent by increased P levels in bulb tissue as yields increased (Fig. 3B).

The peak nutrient offtake at T_5, associated with higher N offtake in bulbs, was probably due to the higher N application rate (125 kg ha^{-1}), although it did not induce a yield increase. In T_8, N offtake was lower than that of T_5, probably due to lower N application (100 kg ha^{-1}), but had a higher K offtake, potentially due to higher rates of K application (150 kg K_2O ha^{-1}). Hence, increased K application can induce higher N offtake in both bulbs and leaves (Fig. 2).

These findings indicate that nutrient removal calculations for onion bulbs must take into account the bulb yield, as uptake levels per mt of bulbs can double when yields increase. The higher uptake of nutrients may possibly be attributed to a more expansive root system resulting from increased supply of photosynthetic productions as observed by Watson (1963) in the potato crop.

Partial nutrient balance (PNB; fertilizer input minus crop offtake) in the various treatments is presented in Fig. 4. Zero or low levels of applied K fertilizer (0, 33 and 50 kg K_2O ha^{-1}) induced a positive N balance of at least 50 kg N ha^{-1}, due to low yield and offtake. N was balanced when 75 kg K_2O ha^{-1} was applied (bulb yield of 48 mt ha^{-1}), but with increased K input and yields N became deficient to the extent of 70-80 kg N ha^{-1} (Fig. 4). With PNB calculations, P was slightly to medium over fertilized, and a surplus of 11-43 kg P_2O_5 prevailed through all treatments.

In contrast to N and P, K PNB was negative in almost all treatments, and became positive only with application of at least 125 kg K_2O ha^{-1} (Fig. 4). These results suggest that the stagnation in yield increase beyond the application of 100 kg K_2O ha^{-1} (Fig. 1) is due to the lack of N, as presented by the severe deficits of N in T_7 and T_8.

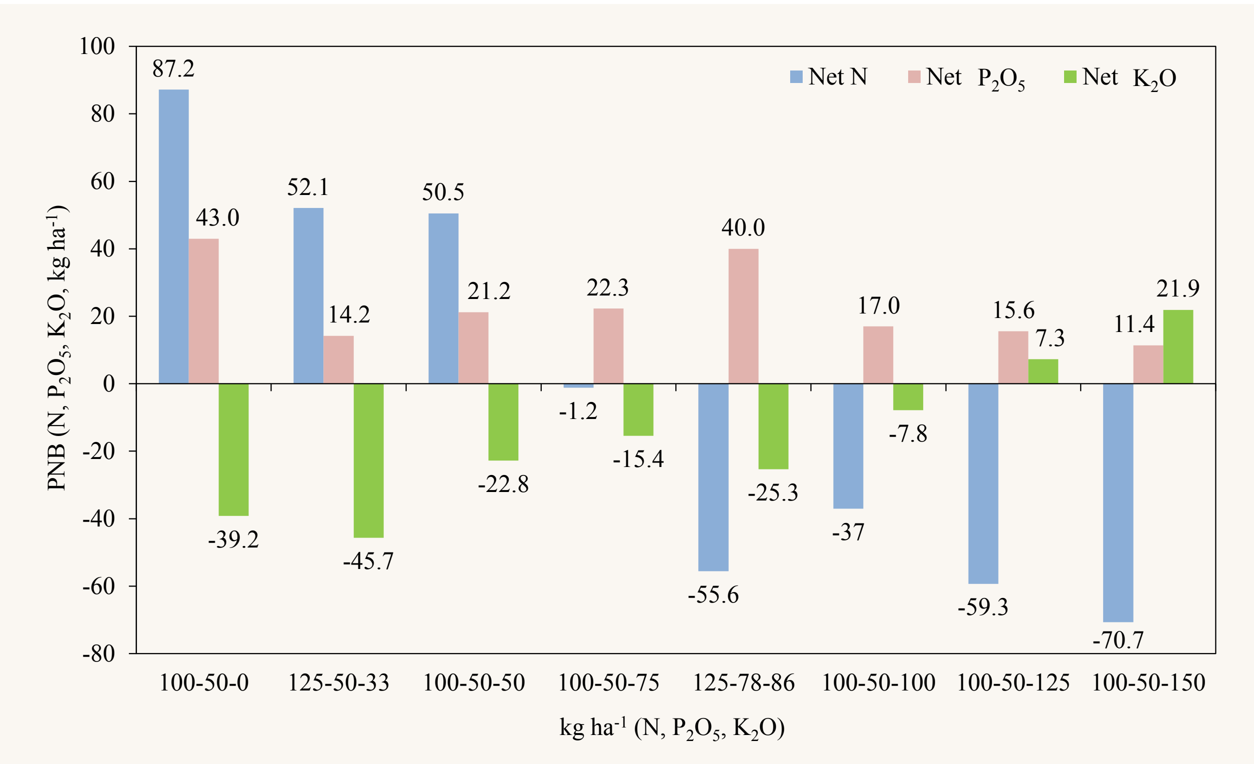


Fig. 4. Net PNB (fertilizer input minus crop offtake) of N, P_2O_5 and K_2O in onion (bulbs and leaves) in the different experimental treatments.

Economics

The highest gross income and net profit of Rs. 258,720 and Rs. 183,386 ha^{-1}, respectively, was obtained with the highest K application (T_8; 150 kg K_2O ha^{-1}; Fig. 5). With the cost of cultivation insensitive to the cost of additional K application, the higher the yield, the higher the net profit. Profits increased substantially (+50%) over the control for the first K application (T_2; 33 kg K_2O ha^{-1}), but made a further increase when applied K was greater than 86 kg K_2O ha^{-1}. From this data, it can be concluded that K application proved profitable up to the highest level of applied K (150 kg K_2O ha^{-1}). While yield increase over 100 kg K_2O ha^{-1} was not statistically different, the increase in income and net profit suggests that farmers can be generous with K application, as financial return is stable.

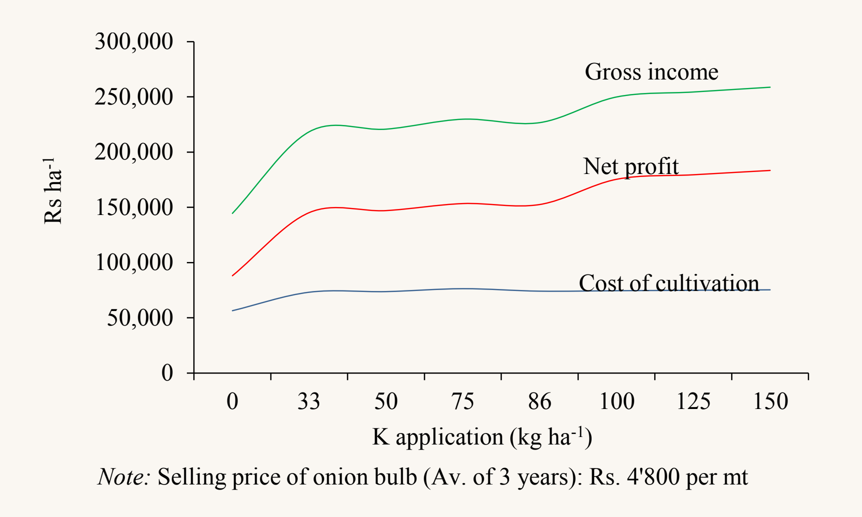


Fig. 5. Economics of applied K to onion crop (cost of MOP Rs. 11.80 kg^{-1}).

Conclusions

Application of all levels of K significantly increased bulb yield and quality of onion over no K treatment. The application of 100 kg K_2O ha^{-1} was found to be significantly greater than the recommended dose calculated from the soil test (33 kg K_2O ha^{-1} in soil with 130 ppm exchangeable K) and the calculated dose from target yield (86 kg K_2O ha^{-1}). These results suggest that both indicators (soil test and target yield calculation) need additional improvements.

The nutrient balance of onion is sensitive to bulb yield, and the application of at least 300 kg N, P and K is required to compensate for the removal of 55 mt onion bulbs per ha. Positive K PNB is achieved only when K application levels exceed 125 kg K_2O ha^{-1}.

The application of high levels of K fertilizer improves yield, but our findings point to the fact that at such high yield levels, N becomes the limiting nutrient. We propose to further investigate the response of onion (Cv. N-2-4-1) with NPK formulas ranging from 100-200 kg ha^{-1} for N and K_2O, while retaining the P level at 50 kg P_2O_5 ha^{-1}.

From the present study, it can be concluded that K application proved profitable up to the highest level of applied K (150 kg K_2O ha^{-1}). Moreover, with current income from onion, additional yield more than compensates for any incremental expenditure of nutrients. Our profit results also support the assumption that higher N and K application levels should be further investigated.

Acknowledgement

The study was funded by the International Potash Institute and the financial help is gratefully acknowledged. The MPKV, Rahuri is also thanked for all facilities provided.

References

A.O.A.C. 1990. Official Methods of Analysis of the Association of Analytical Chemists, 12th Edition. AOAC, Washington D.C.

Arnon, D.I. 1949. Copper Enzymes in Isolated Chloroplasts Polyphenol-oxidase in *Beta vulgaris*. Plant Physiology 24(1):1-15.

Edmond, J.B., T.L. Senn, F.S. Znderw, and R.G. Halfacre. 1981. Fundamentals of Horticulture. Tata McGrow-Hill Publishing Company Limited, New Delhi, India.

Jackson, M.L. 1973. Soil Chemical Analysis. Prentice Hall, New Delhi, India.

Kadam, B.S. and K.R. Sonar. 2006. Targeting Yield Approach for Assessing the Fertiliser Requitrements of Onion in Vertisols. Journal of the Indian Society of Soil Science 54(4):513-515.

Kanwar, J.S. and G.S. Sekhon. 1998. Nutrient Management for Sustainable Intensive Agriculture. Fert. News. 43:33-40.

Knudsen, D., G.A. Peterson, and P.F. Pratt. 1982. Lithium, Sodium and Potassium. *In:* Weaver, R.W., J.S. Angle, and P.S. Bottomley (eds.) Methods of Soil Analysis Part 2: Chemical and Microbiological Properties. Am. Soc. Agron., Madison, Wisconsin. p. 225-238.

Kumar, A., R. Singh, and R.K. Chhillar. 2001. Influence of Nitrogen and Potassium Application on Growth, Yield and Nutrient Uptake in Onion (*Allium cepa*). Indian J. Agron. 46(4):742-746.

Marschner, P. 2012. Marschner's Mineral Nutrition of Higher Plants. Third Edition. Academic Press, Elsevier.

Masalkar S.D., K.W. Lawande, R.S. Patil, and V.K. Garande. 2000. Effect of Potash Levels and Season on Physiochemical Composition of White Onion Phule Safed. Acta Hort. 688. p. 17-18.

Mohanty, B.K. and J.N. Das. 2001. Response of Rabi Onion cv. Nashik Red to Nitrogen and Potassium Fertilization. Veg. Sci. 28(1):40-42.

Nandi, R.K., M. Deb, T.K. Maity, and G. Sounda. 2002. Response of Onion to Different Levels of Irrigation and Fertiliser. Crop Research 23(2):317-320.

Nelson, D.W. and L.E. Sommer. 1982. Total Carbon and Organic Matter. *In:* Weaver, R.W., J.S. Angle, and P.S. Bottomley (eds.) Methods of Soil Analysis Part 2: Chemical and Microbiological Properties. American Society of Agronomy, Madison, Wisconsin. p. 539-579.

Olsen, S.R., C.V. Coles, F.S. Watanabe, and L.N. Dean. 1954. Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. USDA Circular 939.

Raut, D.B. 2007. Effect of Mulches and Potash Levels on Growth, Yield and Quality of Rabi Onion (*Allium cepa* L.). M.Sc. (Agri) Thesis, MPKV, Rahuri.

Shaheen, A.M., F.A. Rizk, A.M.M. El-Tanahy, and E.H. Abd El-Samad. 2011. Vegetative Growth and Chemical Parameters of Onion as Influenced by Potassium as Major and Stimufol as Minor Fertilizers. Australian Journal of Basic and Applied Sciences 5(11):518-525.

Singh, R.B. and S.B. Singh. 2000. Significance of Nitrogen, Phosphorus and Potassium on Onion (*Allium cepa* L.) Raised from Onion Sets (Bulblets).Veg. Sci. 27(1):88-89.

Subba Rao, A. A.O.A.C. 1990. Official Methods of Analysis of the Association of Analytical Chemists, 12th edition. AOAC, Washington, D.C.

Subbiah, B.V. and G.L Asija. 1956. A Rapid Procedure for the Estimation of Available Nitrogen in Soils. Current Science 25(8):259-260.

Susheel Kumar, Sushant, Tiwari, C.P., and Singh, Vinay. 2006. Bulb Yield and Quality of Onion (*Allium cepa* L.) as Affected by Application Rates of Nitrogen and Potassium Fertilisers. Agric. Sci. Digest 26(1):11-14.

Tandon, H.L.S. and K.N. Tiwari. 2008. Nutrient Management in Horticultural Crops. FDCO Publishers, New Delhi.

Vacchani, M.V. and Z.G. Patel. 1993. Effect of Nitrogen, Phosphorus and Potash on Bulb Yield and Quality of Onion (*Allium cepa*). Indian J. Agron. 38(2):333-334.

Varpe, A.S. 2005. Effect of Graded Levels of Sulphur and Zinc on Growth, Yield and Quality of Onion in Inceptisols. MSc. (Agri.) Thesis, MPKV, Rahuri.

Watson, D.J. 1963. In the Growth of Potato. Ivins, J. D. and F.L. Mithorpe (eds.). Butterworths, London. p. 233-247.

Yadav, R.L. N.L. Sen, and B.L. Yadav. 2003. Response of Onion to Nitrogen and Potassium Fertilisation under Semi-Arid Condition of Rajasthan. Indian J. Hort. 60(2):176-178.

Yadav, R.L., N.L. Sen, M.S. Frageria, and R.S. Dhaka. 2002. Effect of Nitrogen and Potassium Fertilisation on Quality Bulb Production of Onion. Haryana J. Hort. Sci. 31(3+4):297-298.

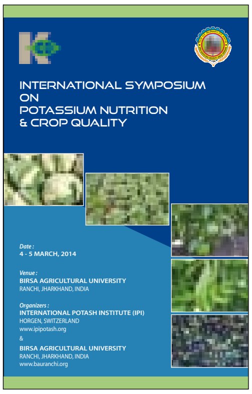
The paper "Potassium Nutrition for Improving Yield and Quality of Onion" also appears on the IPI website at:

Regional activities/India

Events

IPI Events

March 2014



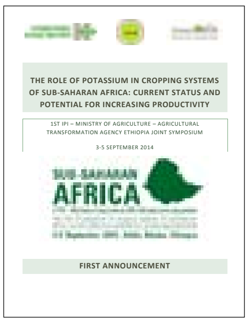
IPI-BAU International Symposium on "Potassium Nutrition and Crop Quality", BAU, Ranchi, Jharkhand, India, 4-5 March 2014. Two day symposium is organized jointly by IPI East India, Bangladesh & Sri Lanka region and Birsa Agriculture University (BAU), Kanke, Ranchi, Jharkhand, India. The Symposium is planned to address the present scenario on potassium nutrition, identify the emerging issues and discuss the ways and means for their mitigation. Thrust will be on the issue of balanced nutrition of crops in relation to yield & quality of crops, biotic and abiotic stress and to sustain soil & plant environment.

Themes:

- Potassium Nutrition on Yield and Quality of Crops
- Nutrient Use Efficiency and K-Balance
- Potassium on Stress and Disease-Pest Management
- Impacts on Soil Microbes and Environment
- Food Quality and Human Health
- Marketing and Policy Issues for K-Fertilizers
- Research - Industry Interfaces and Technology Dissemination

For more information please contact Mr. Neeraj Kumar Awasthi, IPI Coordinator East India, Bangladesh & Sri Lanka or see more on the IPI website/Events.

September 2014



1st IPI-Ministry of Agriculture-Agricultural Transformation Agency Ethiopia joint symposium in East Africa on "the Role of Potassium in Cropping Systems of sub-Saharan Africa: Current Status and Potential for Increasing Productivity", Addis Ababa, Ethiopia, 3-5 September 2014.

Themes:

- Potassium Fertilizer Management in Major Cropping Systems of sub-Saharan Africa
- Current Advances made in the Determination of Potassium Status in Soils and Plants
- Evaluation of Soil Potassium Fertility in Ethiopia and East Africa
- Evidence of the Effect of Potassium Fertilization on Nutrient and Water Use Efficiency
- The Beneficial Role of Potassium in Tackling Biotic and Abiotic Stresses in Cropping Systems
- Nutrient Mining and Stagnation of Agricultural Productivity in sub-Saharan Africa
- Potash Production in Ethiopia: Prospects and Challenges
- Public-Private Partnerships: The Role of NGOs in Scientific Information Generation and Transfer

For more details contact Mr. Eldad Sokolowski, IPI Coordinator sub-Saharan Africa or see updates and information on the IPI website/Events.

International Symposia and Conferences

September 2013

The 4th GFRAS Annual Meeting took place from 24-26 September 2013 in Berlin, Germany. It discussed the role of producer organisations and private sector in RAS. You can find reports, presentations, photos, and more on the GFRAS website. Many of the sessions and side events were recorded on video and can be viewed on the same website.

February 2014

World Congress on Agroforestry: Trees for Life: Accelerating the Impacts of Agroforestry, New Delhi, India, 10-14 February 2014. See more details on the congress website.

March 2014

"Transforming Cassava in Africa - Enhancing Food Security to Agro-Industrial Products" takes center-stage at CMT's first **Cassava World Africa** coming to **Lusaka, Zambia, 20-21 March 2014** at the Radisson Blu Hotel Lusaka. See more details on the event website.

The 12th New Ag International Conference and Exhibition, Warsaw, Poland, 26-28 March 2014 at the Hilton Warsaw Hotel & Convention Centre. See more details on the conference website.

June/July 2014

20th World Congress of Soil Science, ICC Jeju, Jeju, Korea, 8-13 June 2014. For more details see congress website.

New Ag International 2014 China Conference and Exhibition, Fertigation and Foliar Feeding, Beijing, China, 30 June - 2 July 2014. For more details see the conference announcement.

August 2014

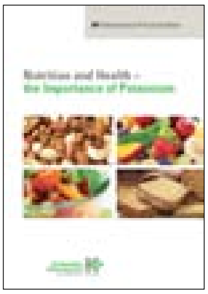
29th International Horticulture Congress, Brisbane, Australia, 17-22 August 2014. See more details on the congress website.

September 2014

2014 African Green Revolution Forum, Addis Ababa, Ethiopia, 2-4 September 2014. For details go to the forum website.

Publications

IPI Publications



Nutrition and Health - the Importance of Potassium

Compiled by S. Anavi; edited by P. Imas. 17 p. 2013.

Minerals are present in all body tissues and fluids. Their presence is required to maintain certain physical and chemical processes which are essential to life. For humans, potassium (K) is an essential macronutrient, and its importance to human health has been well recognized, with new studies continuing to emphasize its positive effects and its potential use in public health. For example, a high dietary intake of K has been shown to protect people from a number of conditions that affect the cardiovascular system, kidneys, and bones.

Topics covered in this nutrition and health booklet include blood pressure, cardiovascular disease, bone and kidney health, type 2 diabetes, dietary recommendations and safe intake considerations.

This leaflet can be downloaded from the IPI website. For hardcopies, please contact IPI head office at ipi@ipipotash.org.

IPI Bulletin No. 21: Fertilizing for High Yield and Quality - Sugarcane

Ridge, R. 117 p. with color plates. 2013.

Sugarcane is one of the world's most widely grown crops. In 2010, FAO estimated sugarcane was cultivated on around 23.8 million ha across more than 90 countries, with a worldwide harvest of 1.69 billion tonnes. Brazil is the largest producer of sugarcane in the world with China, India and Thailand as the next three major producers. As a replacement for fossil fuel, there is increasing diversion of sugarcane towards ethanol production, most notably in Brazil where around 50% of the crop is used for ethanol production. There is also increasing co-generation of power from sugarcane bagasse.

The latest IPI Bulletin provides comprehensive coverage of plant development of sugarcane including mineral nutrition and fertilization for high yield and quality. Of interest to all sugarcane growing regions, this evidence-based publication is written by Ross Ridge who, for 33 years, was a research agronomist and soil scientist with BSES Limited, the principal research, development and extension organisation for the sugar industry in Australia. Since retiring from BSES as Principal Research Officer in 1999, Ross Ridge has undertaken a range of sugar industry consultancies and has visited sugarcane production areas in Brazil, Colombia, Fiji, Hawaii, Indonesia, Mauritius, Reunion, Swaziland, Taiwan, Thailand and USA where he has observed agronomic research and practices.

The bulletin can be downloaded from the IPI website. For hardcopies, please contact IPI head office at ipi@ipipotash.org.

Kalijum u Ishrani Biljaka - Kalijum i Povrće Potassium in Plant Nutrition - Potassium and Vegetables

Kastori, R., Ž. Ilin, I. Maksimović, and M. Putnik-Delić. 325 p. In Serbian.

Potassium demands of individual plant species and genotypes are different. Vegetables are mostly regarded as potassium-loving plant species, which is why their optimal supply is very important.

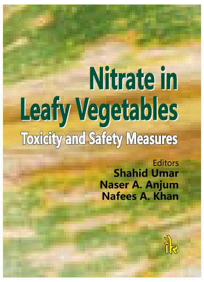
The large number of species with specific demands for mineral nutrition, combined with many different production systems, is what makes vegetable production so specific.

Additionally, vegetable production is one of the most intensive branches of plant production. Vegetables are used for different processed products, and with high contents of nutrients and protective agents they are very important for human nutrition.

All this combined means vegetables very important in the total food production, and are of great economic value, prompting the decision to publish this book looking at vegetable nutrition with potassium.

This book can be downloaded from the IPI website. For hardcopies, please contact Prof. Dr. Rudolf Kastori at kastori@polj.uns.ac.rs.

Other Publications



Nitrate in Leafy Vegetables Toxicity and Safety Measures

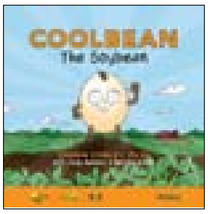
Editors Shahid Umar, Naser A. Anjum, Nafees A. Khan. 2013. ISBN 978-93-82332-21-3. Published by I.K. International Publishing House Pvt. Ltd., New Delhi, India. E-mail: info@ikinternational.com. Website: www.ikbooks.com.

Proceedings of the 1st World Congress on the Use of Biostimulants in Agriculture

The 1st World Congress on the Use of Biostimulants in Agriculture was held in Strasbourg, France in November 2012. This congress was organized by New Ag International. The papers contained in a special volume of the world famous Acta Horticulturae publication of ISHS, report the peer reviewed Proceedings. The papers which have been judged suitable for publication by the Editors and members of the Editorial Board have now been published in this special volume of Acta Horticulturae.

New Ag International has decided to fully open the access to the PDF versions of the abstracts of all oral and poster presentations. The abstracts are available for download at:
http://www.biostimulants2012.com/programme/programme.html

For details on how to purchase the PDF version of the conference proceedings contact:
biostimulants@newaginternational.com



Coolbean the Soybean

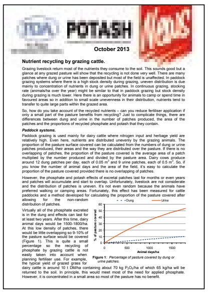
Conley, S. 28 p. 2013. ISBN: 978-0-89118-617-5

A new ASA, CSSA, and SSSA children's book written by Shawn Conley, University of Wisconsin-Madison. With colorful graphics and peer-reviewed content, this book is published with support from the Wisconsin Soybean Marketing Board. portal.sciencesocieties.org.

Publication by the PDA

Nutrient Recycling by Grazing Cattle

POTASH News, Autumn 2013.



Grazing livestock return most of the nutrients they consume to the soil. This sounds good but a glance at any grazed pasture will show that the recycling is not done very well. There are many patches where dung or urine has been deposited but most of the field is unaffected. Read more on the PDA website.

Potash Development Association (PDA) 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.

K in the Literature

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Managing Agricultural Nutrients for Food Security in China: Past, Present, and Future

Zhenling Cui, Zhengxia Dou, Xinping Chen, Xiaotang Ju, and Fusuo Zhang. 2013. Agron. J. 106(1):191-198, doi:10.2134/agronj2013.0381.

Abstract: Over the past 2000 yr, agriculture in China has transformed from a low-input, low-output organic-based system to an intensive production system that relies heavily on inorganic inputs. The modern high-input, high-output system has provided the nation with basic food self-sufficiency, although at escalating environmental costs. Meanwhile, crop production has been nearly stagnant since the mid-1990s, despite continued increases in production inputs, such as chemical fertilizers. In the future, China must increase agricultural output by 50% to meet its growing food demand. New advances to increase agricultural productivity and improve resource (e.g., N and P) use efficiency will be critical in China for sustainable agriculture and ecosystem services. Here, we discuss an integrated soil-crop system management (ISSM) paradigm that may help achieve the sustainable intensification goal. This paradigm features (i) improving soil quality, (ii) enhancing the use of various nutrient resources, (iii) closing the yield gap, and (iv) effectively reducing N losses. Recent on-farm trials based on ISSM principles almost doubled corn yield, while fertilizer N amounts were similar to current farming methods. This ISSM in China is a novel agricultural paradigm that can improve food security and environmental quality worldwide, especially in regions of high input with low-efficiency systems.

Application of Kinetic Models in Describing Soil Potassium Release Characteristics and their Correlations with Potassium Extracted by Chemical Methods

Hosseinpur, A.R., and H.R. Motaghian. 2013. Pedosphere 23(4): 482-492, ISSN 1002-0160/CN 32-1315/P.

Abstract: Potassium (K) release characteristics in soil play a significant role in supplying available K. Information on K-release characteristics in soils of central Iran is limited. The objectives of this study were to determine K release characteristics and correlations of K release rate constants with K extracted by different chemical methods in surface soils of ten calcareous soils of central Iran. The kinetics of K release in the soils was determined by successive extraction with 0.01 mol L^{-1} $CaCl_2$ in a period of 2-2 017 h at 25±1 °C. Soil K was extracted by distilled water, 0.5 mol L-1 $MgNO_3$, 0.002 mol L^{-1} $SrCl_2$, 0.1 mol L^{-1} $BaCl_2$, 0.01 mol L^{-1} $CaCl_2$, 1 mol L^{-1} NaCl, 1 mol L^{-1} boiling HNO_3, 1 mol L^{-1} NH_4OAC, Mehlich 1, 0.002 mol L^{-1} $SrCl_2$ 0.05 mol L^{-1} citric acid, and ammonium bicarbonate-diethylenetriamine pentaacetic acid (AB-DTPA). A plot of cumulative amounts of K released showed a discontinuity in slope at 168 h. Thus, two equations were applied to two segments of the total reaction time (2-168 and 168-2017 h). Cumulative amounts of K released ranged from 55 to 299 mg kg^{-1} in 2-168 h and from 44 to 119 mg kg^{-1} in 168-2 017 h. Release kinetics of K in the two time segments conformed fairly well to parabolic diffusion, simplified Elovich, and power function models. There was a wide variation in the K release rate constants. Increasingly higher average concentrations of soil K were extracted by distilled water, Mehlich 1, $SrCl_2$, $CaCl_2$, $SrCl_2$ + citric acid, AB-DTPA, $MgNO_3$, NaCl, NH_4OAc, $BaCl_2$ and HNO_3. Potassium release rate constants were significantly correlated with K extracted. The results of this study showed that information obtained from mathematical modeling in two reaction time segments can help to estimate the K-supplying power of soils.

Read on

Iowa State: Research Proves Moist K Soil Test Results More Reliable

October 10, 2013. CropLife.

Farmers Dig into Soil Quality

Schiermeier, Q. 2013. Nature 502:607.

Sustainable Management: Recycle Waste for Nourishing Soils

Lehmann, J. 2013. Nature 504:33.

From Fertiliser to Zyklon B: 100 Years of the Scientific Discovery that brought Life and Death

Read about Haber Bosch process: The Guardian, 3 November 2013.

The Social, Economic and Environmental Value of Agricultural Productivity in the EU

2013. The Humboldt Forum for Food and Agriculture (HFFA).

Effects of N and K Fertilizers on Durum Wheat Quality in Different Environments

Olfa Daaloul Bouacha, Sadok Nouaigui, and Salah Rezgui. ScienceDirect: J. of Cereal Science 59(1):9-14.

How do Phosphorus, Potassium and Sulphur Affect Plant Growth and Biological Nitrogen Fixation in Crop and Pasture Legumes? A Meta-Analysis

Guillermo A. Divito, and Victor O. Sadras. ScienceDirect: Field Crops Research 156:161-171.

Project Tests New Ways to Deliver Climate Messages to Farmers' Cell Phones

Surabhi Mittal, and Dharini Parthasarathy. 2013. CGIAR.

App Could Transform Farming and Address Food Shortages

2013. BBC News.

Clipboard

In memory of Volker Römheld

We are deeply saddened by the loss of Prof. Dr. Volker Römheld who died, at his home in Stuttgart on the 27th November 2013.

Volker Römheld was a German agricultural scientist, plant physiologist and soil biologist. As Professor of Plant Nutrition at Hohenheim University, Germany he was recognized internationally as an outstanding contributor to the subject. He published approx. 300 papers in peer review journals and was invited to attend many conferences and symposia and supervised numerous students for their masters and PhD theses. For almost the last twenty years he held a visiting Professorship at the China Agricultural University (CAU), Beijing, China, where he cooperated in the university research program as well as supporting many young Chinese researchers in their first steps in science.

Over the years Volker helped the International Potash Institute (IPI) in many and varied ways. He was always glad to do so, whether it is to join a field visit to a project in a rural area, or to deliver a paper at our symposia, or to conduct a lively debate with young researchers and colleagues covering a wide range of topics. He loved science and appreciated those people who wanted to apply their scientific knowledge to help farmers grow more and better crops. Volker was always ready to help with good advice and a scientific contribution. His presentations were invariably of a very high standard and made in the most logical manner using the tables, figures and pictures that his wife Haoyan had prepared (and which he kept in his electronic notebook). His approach to discussion and indeed to his research was always to maintain an open mind, which was one of his great strengths.

Some years back we traveled together in the Brazilian Cerrado. Volker was typically curious to find out the new wonders of Brazilian agriculture. Very soon afterwards we were told, not unexpectedly, that he was involved in research projects to solve some of the issues that had emerged from this visit. A few years later, in India, we came to learn from him that much work was still needed to investigate the importance of plant nutrients to mitigate biotic and abiotic stresses of plants on crop growth. Volker felt that through proper cooperation and scientific work one could "push" (as he liked to put it) for focused research. In 2012, Volker joined us at a symposium in China, where he felt so very much at home. As always, he was pointing out urgent issues where further research was needed or where some particular fact should be noted or the results of research findings to be passed on to farmers.

Volker is succeeded by his wife Haoyan and daughter Ida.

We will miss Volker greatly for his wholehearted enthusiasm, endless dedication, his vast knowledge and experience, as well as of course for the loss of a dear friend and colleague.

In memory of Volker Römheld, we have compiled a collection of photographs on Flickr from some of the occasions when Volker helped the International Potash Institute by sharing his time with us.

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