POTASSIUM NITRATE

Book of abstracts

-

2021

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Introduction

This SQM Potassium Nitrate Book of Abstracts 2021 brings together the most relevant scientific literature references on agronomic applications of potassium nitrate in an easy-to-read abstract format. The target audiences include the scientific community, agronomists and technicians in crop nutrition management.

The SQM Potassium Nitrate Book of Abstracts 2021 will be updated on a regular base with the latest studies on potassium nitrate in order to stay relevant.

In order to facilitate searching for a specific item, the SQM Potassium Nitrate Book of Abstracts 2021 contains three handy indices on crop and title (page i), full literature reference (page vii) or key words (page xvi). Additionally, the normal available electronic document search function can be used.

The SQM Potassium Nitrate Book of Abstracts 2021 includes scientific publications on the importance of selecting the right nutrient source. Various studies compare nitrate with ammonium and/or ureic nitrogen based fertilization programmes from which it can be concluded that best results are obtained when nitrate is the predominant nitrogen source in the fertilization programme. With respect to K-source selection, it was shown that fertilization programs need to tune the amount of sulphate application to the crop's sulphate demand and exclude chloride containing fertilizers in order to prevent excess sulphate and chloride salinity build up in soils. All this makes potassium nitrate the best choice as source of N and K.

At SQM's Specialty Plant Nutrition division, we value the scientific approach. Our agronomists translate the latest scientific insights on the main applications of potassium nitrate into practice. This makes them knowledgeable problem solvers in plant nutrition. Their solutions deliver results in terms of higher crop yield, improved produce quality and reduced crop losses. To them, potassium nitrate is an indispensable part in their plant nutrition tool kit for the preparation of well-balanced plant nutrition programmes, targeted at a wide variety of crops and applications. In our opinion, better fertilization programmes are not be considered as a cost, but as an investment with an excellent return!

For more information, contact the local SQM office or SQM distributor

Table of contents

A CLICK ON THE TITLE WILL BRING YOU TO THE PAGE

List of references

A CLICK ON THE TITLE WILL BRING YOU TO THE PAGE

Serraj, R. and J. Drevon. 1998. Effects of salinity and nitrogen source on growth and nitrogen fixation in alfalfa. Journal of Plant Nutrition, 21 (9): 1805-1818 ..2

Sing, J. L. and R.J. McNeil. 1992. The effectiveness of foliar potassium nitrate sprays on the 'Hass' avocado (Persea americana Mill.). In: World Avocado..............4

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Sotiropoulos,T., I. Therios and N. Voulgarakis. 2010. Effect of various foliar sprays on some fruit quality attributes and leaf nutritional status of the peach cultivar 'Andross'. Journal of Plant Nutrition, 33(4): 471-484...147

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Southwick, S.M., W. Olson, J. Yeager and K.G. Weis. 1996. Optimum timing of potassium nitrate spray applications to 'French' prune trees. Journal of the American Society for Horticultural Science 121(2): 326-333...148

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Index of application

APPLICATION METHOD AND BENEFITS OF POTASSIUM NITRATE

Dormancy breaking

14, 109, 119, 145, 146, 150, 154, 155, 156

Fertigation

2, 7, 11, 16, 17, 18, 21, 26, 35, 36, 37, 73, 81, 106, 128, 138, 149, 152, 153, 161, 163, 164, 167, 169, 171, 172, 173, 176, 177, 178, 179, 181, 187, 189, 191

Flowering induction

76, 83, 85, 86, 88, 89, 90, 91, 95, 96, 97, 99, 100, 103

Foliar

4, 5, 8, 14, 20, 23, 24, 27, 28, 29, 30, 31, 32, 34, 38, 39, 40, 43, 44, 45, 46, 47, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 60, 61, 62, 63, 65, 67, 69, 70, 71, 73, 76, 77, 80, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 103, 108, 109, 111, 112, 113, 115, 122, 124, 126, 128, 129, 132, 134, 135, 139, 140, 145, 146, 147, 148, 150, 154, 155, 156, 158, 159, 166, 172, 175, 183, 184, 191

K-sources

28, 35, 36, 50, 80, 128, 149, 176, 187, 191

N-sources

16, 18, 26, 80, 128, 138, 153, 161, 163, 167, 169, 171, 173, 179, 181

Pest & disease reduction

8, 11, 30, 58, 62, 63, 108, 140, 164, 166

Salinity relief

2, 7, 11, 17, 21, 24, 37, 67, 73, 81, 106, 152, 158, 159, 172, 177, 178, 184, 187, 189

Seed priming

20, 105, 116, 119, 120, 143, 167

Soil applied

117

Yield & Quality

4, 5, 20, 23, 27, 28, 29, 31, 32, 33, 34, 38, 39, 40, 43, 44, 45, 46, 47, 49, 50, 51, 52, 53, 54, 55, 56, 57, 60, 61, 65, 69, 71, 77, 84, 87, 89, 92, 93, 94, 98, 108, 111, 112, 113, 115, 117, 122, 124, 126, 129, 132, 134, 135, 139, 145, 147, 148, 175, 183, 191

Alfalfa

Alfalfa

Potassium nitrate-fed alfalfa plants were more salt tolerant, when grown under NaCl imposed salinity conditions.

Fertigation *Salinity relief*

The interaction between the effects of nitrate (NO_3) and sodium chloride (NaCl) concentration on growth, water relations, nitrogen (N) contents and N fixation were investigated in alfalfa (Medicago sativa L. cv. Magali).

The plants were grown hydroponically in a growth chamber, in the presence or absence of 3 mM potassium nitrate (KNO_3) and exposed to various concentrations of NaCl. During the first 20 days, i.e., before nodule emergence, the nutrient solution was complemented with 2 mM urea. After this period, the plants were transferred to a new nutrient solution either without N or with 3 mM potassium nitrate (KNO_3), a concentration that inhibits completely nodulation (Serraj et al., 1992. J. Plant Physiol.140: 366-371). At this stage, the plants were exposed to salinity by adding NaCl to the growth medium (final concentration 0, 25, 50, or 100 mM).

Increased salinity resulted in a significant decrease in shoot (Figure 1) and root biomass, relative water content and water potential. N_2-fixing alfalfa plants are more salt sensitive than NO_3-fed plants, as with KNO_3. Nitrogenase activity measured by acetylene reduction activity was substantially inhibited by NaCl, and this inhibition was significantly correlated to the inhibition of shoot growth and total N contents.

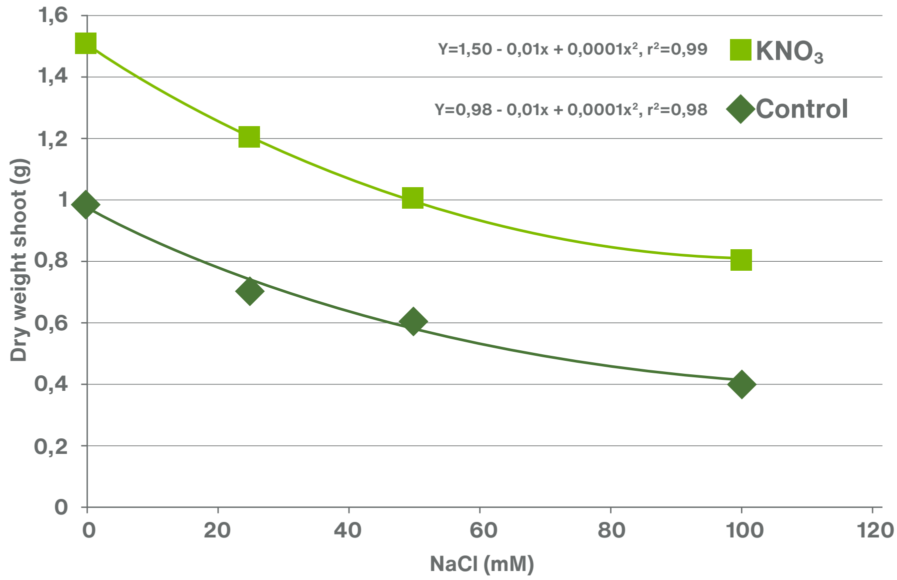

Figure 1. Effect of NaCl concentration on alfalfa shoot growth in the presence (KNO_3) or absence (control) of 3 mM KNO_3.

Serraj, R. and J. Drevon. 1998. Effects of salinity and nitrogen source on growth and nitrogen fixation in alfalfa. Journal of Plant Nutrition, 21 (9): 1805-1818.

Avocado

Avocado

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Foliar applied potassium nitrate effectively increased the K content of 'Hass' avocado leaves.

Foliar *Yield & Quality*

The effect of foliar applied potassium nitrate on four-year-old bearing 'Hass' avocado (Persea Americana Mill.) trees was studied. KNO_3 was sprayed on the leaves at a rate of 3,6 kg per 100 liters of water. A single spray was applied at half leaf expansion, full leaf expansion or one month after full expansion. A combination of two and three of these spray treatment times was also done. The leaves were wetted to a point where the spray solution started dripping from the leaves. Approximately 11,35 liters of spray solution per tree was applied.

Foliar applications of KNO_3 were effective in increasing the K level in the leaves of 'Hass' avocado trees. Two or three sprays were most effective in increasing the K content. Results indicated that spraying one month after full leaf expansion was the most effective moment to increase the K content of avocado trees. Several interactions appeared to exist among the macro- and micronutrient content of the leaves as induced by the K applications. All treatments significantly increased the leaf Zn level compared to the control. The three spray treatments increased the Mn level above the control.

Sing, J. L. and R.J. McNeil. 1992. The effectiveness of foliar potassium nitrate sprays on the 'Hass' avocado (Persea americana Mill.). In: World Avocado Congress II, Proceedings: "The Shape of Things to Come" (Lovatt, CJ ed.), Vol. 1: 337-342.

Combination of foliar applied potassium nitrate and paclobutrazol increased fruit retention and average fruit weight in avocado.

Foliar *Yield & Quality*

The effect of spray application of paclobutrazol (PBZ) + KNO_3, and the addition of paclobutrazol to the soil, during inflorescence development and flowering on new shoot vigour, fruit set and retention, and fruit size and yield at harvest were assessed in Mendez avocado. 90, three-year-old Mendez avocado trees (on "Criollo" seedling rootstock) of uniform size and approximately 2 m in height were selected in an irrigated, commercial orchard in the Guadalajara region (Mexico) in early September 2012. In mid-September, when inflorescence development was occurring, 10 inflorescence bearing terminal branches were labeled per tree.

Bearing Mendez avocado trees were sprayed with paclobutrazol (1 or 2%) or paclobutrazol (1 or 2%) + KNO_3 (2%) during inflorescence development and flowering. In addition, soil applications of paclobutrazol were made (3 or 6 ml Austar applied around the trunk). Austar is an Australian paclobutrazol formulation containing 250 g of active ingredient per litre. Spray and soil applications were made on October 1, 2012, when the trees were flowering and the inflorescences were developing. Knapsack sprayers were used in spraying, and full-cover sprays were applied. There were 10 single tree replications of 9 treatments (incl. control) in a Complete Randomized Blocks design.

Paclobutrazol (spray and/or soil application) + KNO_3 spray treatments were effective in reducing new shoot vigour, as determined by total shoot length at harvest on Sep. 5, 2013 (Table 1). These treatments did not reduce the number of fruits present on Jan 5, 2013, or the number of fruits retained at harvest. Individual fruit weight was increased by 46% (Table 1), this consequently increasing fruit yield. The results indicate that paclobutrazol application at flowering is effective in increasing fruit size but not fruit retention. Spray application was apparently sufficient for this response, as no added benefit was noted in additionally applying PBZ to the soil. Combining PBZ with 2% KNO_3 resulted in an increase in the number of fruits retained until harvest by 32% - when a comparison was drawn with the application of PBZ alone. This contributed to an increase in yield.

Table 1. Least squares means of number of fruits present and total new shoot length on Jan. 5, 2013 and Sep. 5, 2013, and average "individual" fruit weight at harvest on Sep. 5, for each of the comparisons of relevance.

Treatments used for comparison	Number of fruits on Jan. 5, 2013.	Number of fruits retained	Total length new shoots on Sep. 5 (cm)	Average fruit weight at harvest (g)
Control	2,09	0,70	34,6	120
PBZ spray, soil + KNO_3 (2%)	2,04	0,61	23,3	175
Significance level	0,8926	0,4137	0,0001	0,0002
Spray PBZ at 1 or 2%	2,14	0,57	23,6	171
Spray PBZ at 1 or 2% + KNO_3 (2%)	1,98	0,75	24,2	173
Significance level	0,6071	0,0621	0,8152	0,8908

Oosthuyse, S.A. and M. Berrios. 2014. Effect of spray and/or soil application of paclobutrazol, and spray application of potassium nitrate during flowering on new shoot growth and cropping of "Mendez" avocado. International Society for Horticultural Science (IHC Brisbane 2014): 1-6.

Barley

Barley

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Improved drought and salinity tolerance in barley by root application of potassium nitrate.

Fertigation *Salinity and drought stress relief*

This study was conducted to evaluate if KNO_3 or salicylic acid (SA) can alleviate the negative effects of stress caused by salinity or water deficit in barley (Hordeum vulgare L. cv. Gustoe). Grains were sown in plastic pots containing 2 kg of soil. Substrate was composed of soil, sand and peat moss at 2:1:1 v/v ratio. The soil mixture had a pH of 7,2, an EC of 1,65 ds/m and available K^+ of 55 ppm. Three week old plants were subjected to various treatments for two weeks. Different levels of NaCl (50, 100 and 150 mM), or drought stress (80%, 70% and 50% of soil water content (SWC)) were applied. Only at the highest salinity and drought stress levels the effect of treatment with SA or KNO_3 was investigated. SA (50 µM) was spray-applied or KNO_3 (10 mM) was added to the nutrient solution.

Increasing the salt or water deficit stress reduced shoot fresh weight, shoot height, leaf photosynthetic pigments (Chl A, Chl B and carotenoids), K^+ content, and provoked oxidative stress in leaves. This was confirmed by measurement of considerable changes in soluble carbohydrate, proline, malondialdehyde (MDA), total phenolic compounds, antioxidant activity and Na^+ contents. The Na^+/K^+ ratio increased with increasing salt and water deficit treated plants. Addition of KNO_3 showed significant alleviation of both salinity and drought stress, in the same order of magnitude compared to the SA spray treatments. The addition of KNO_3 prevented leaf chlorosis, increased the shoot growth and leaf photosynthetic capacity measured by content of chlorophyll and carotenoid pigments (Table 1).

The level of oxidative damage of lipids was measured as increase in MDA content. In plants grown under the highest salinity (150 mM NaCl) and water deficit (50% SWC) stress, without the addition of KNO_3 to the nutrient solution, MDA content increased to 140% and 158% of the control. However, addition of KNO_3 to medium of plants under these highest stress conditions, resulted in similar MDA levels as found in plants under the lowest salt-stress (50 mM) or lowest water deficit stress (80% SWC).

Moreover, addition of KNO_3 in the nutrient solution has proven to be effective in decreasing the Na^+/K^+ ratio in leaves of plants under salinity and drought stress. It is suggested that this is due to prevention of osmotic stress related leakage of K^+ from the cell through the plasma membrane. It can be concluded that the addition of KNO_3 alleviated the oxidative stress in barley plants caused by either salinity or drought.

Table 1. Effect of salt stress, water deficit stress and 10 mM KNO_3 treatments on shoot height, pigment content (Chl A, Chl B and carotenoids), Na^+ and K^+ content of barley plants.

Treatments	Shoot height (cm)	Pigment content (mg/g FW)	Na^+ content (mg/g DW)	K^+ content (mg/g DW)	Na^+/K^+ Ratio
Control	23,9	2,6 (100%)	11,1	35,8	0,3
150 mM NaCl	15,2	1,1 (43%)	19,8	19,8	1,0
150 mM NaCl + 10 mM KNO_3	17,9	1,9 (73%)	15,8	37,3	0,4
50% SWC	17,8	1,3 (49%)	13,7	28,2	0,5
50% SWC + 10 mM KNO_3	21,5	2,0 (78%)	12,5	40,2	0,3

Fayez, K. A. and S.A. Bazaid. 2014. Improving drought and salinity tolerance in barley by application of salicylic acid and potassium nitrate. Journal of the Saudi Society of Agricultural Sciences, 13(1): 45-55.

Potassium nitrate application is effective in decreasing growth rate of the aphid Schizaphis graminum in barley.

Foliar *Pest & disease reduction*

The purpose of this study was to determine the effect of KNO_3 fertilization on the resistance of barley (Hordeum distichum) to the greenbug Schizaphis graminum. Eighteen-day-old seedlings of two barley cultivars (cv F. Unión, a cultivar without gramine and cv MCU-34 with natural gramine) were irrigated with nutrient solutions differing in KNO_3 concentrations. These seedlings were infested with adult aphids and placed in a growth chamber. Five days later the aphids were counted. In both cultivars the infestation levels reached were inversely proportional to KNO_3 supply. The population growth rate of the greenbug Schizaphis graminum decreased in barley seedlings watered with nutrient solutions containing 30 mM or more nitrate.

Nitrate accumulated more in the first leaf than in the second of these seedlings as a function of nitrate fertilization. The concentration of gramine, an insect resistance factor in barley, increased in the second leaf (youngest), and decreased in the first one (oldest) with increasing NO_3^- in the nutrient solution. The feeding behaviour of aphids was negatively affected by KNO_3 in artificial diets and in the plants. The survival of aphid nymphs of S. graminum fed with potassium nitrate decreased with increasing KNO_3 concentrations (Figure 1) after 24 hours (LD50 = 200 mM). It is suggested that nitrate fertilization may affect aphid performance on barley seedlings because it causes changes in gramine concentration in the leaves.

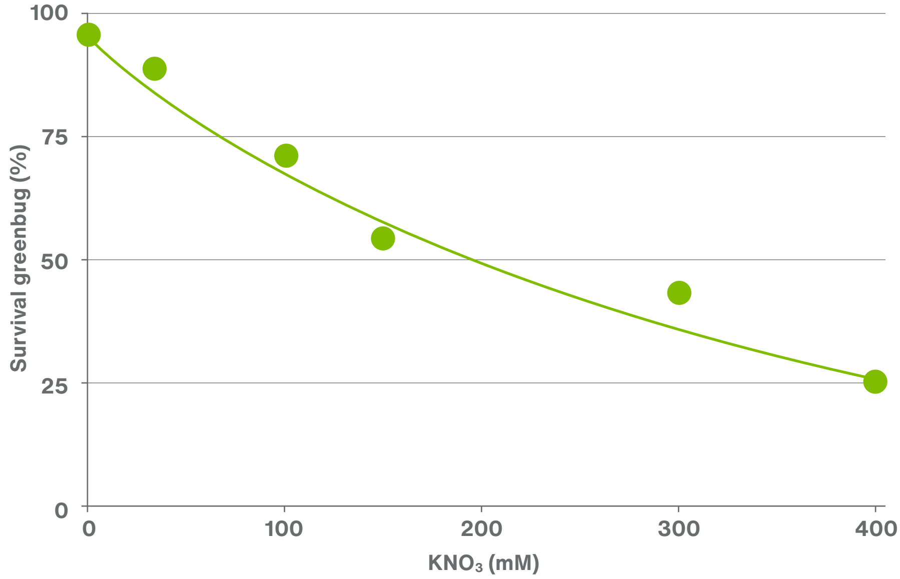

Figure 1. Effect of KNO_3 on survival rate of the aphid Schizaphis graminum fed with artificial diets. Each point is the mean of five samples of 10 nymphs each.

Salas, M. L., L.J. Corcuera and V.H. Argandona. 1990. Effect of potassium nitrate on gramine content and resistance of barley against the aphid Schizaphis graminum. Phytochemistry 29(12): 3789-3791.

Bean

Bean

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Potassium nitrate outperformed potassium acetate in growth parameters of broad beans, grown under salinity stress.

Fertigation *Salinity relief*

The objective of the study was to determine the influence of two salinity levels [50 and 100 mM sodium chloride (NaCl)], counterbalanced at equal concentrations of 50 mM and 100 mM of two potassium salts, potassium nitrate (KNO_3) or potassium acetate (CH_3CO_2K), applied in combination with the NaCl, on the development of seedlings of two cultivars of broad bean (Vicia faba L), grown in pots of perlite under controlled greenhouse conditions in Turkey.

At harvesting time, plant height, number of leaves, number of internodes, internodal length, leaf fresh weight, leaf dry weight, stem fresh weight, and stem dry weight of the seedlings were recorded and measured. The plant growth parameters studied, were not statistically significantly affected by increasing NaCl concentrations in the nutrient solution, when fed with potassium nitrate. This was explained by the finding that potassium nitrate had less effect on Na^+ accumulation in broad bean cultivars. Contrary, the addition of potassium acetate had further pronounced negative effects on the growth parameters studied and caused significant reduction of growth in both NaCl concentrations. This reduction was related to increasing Na^+ concentration in bean cultivars for the potassium acetate treatment.

Bulut,F., Ş. Akıncı and A. Eroğlu. 2011. Growth and uptake of sodium and potassium in broad bean (Vicia faba L.) under salinity stress. Communications in Soil Science and Plant Analysis, 42 (8): 945-961.

Potassium nitrate improved yield of Meloidogyne incognita infected bean plants.

Fertigation *Pest & disease reduction*

In this study one-week-old bean (Phaseolus vulgaris) plants were inoculated with 4000 second stage Meloidogyne incognita nematode juveniles and fertilized with Hoagland solution containing none (Nem 0 K), normal (Nem 1 K), double (Nem 2 K) or quadruple (Nem 4 K) strength KNO_3 and compared with uninfected controls that received normal strength Hoagland solution. The aim was to determine if increasing the levels of KNO_3 in normal strength Hoagland solution could alleviate the detrimental effect of M. incognita infection in beans. Bean seedlings were grown in plastic pots filled with steam sterilized soil (1:1 sand:silt mix).

The stem, shoot and total plant dry weight of the uninfected plants was significantly higher than all infected treatments, except the Nem 4 K treatment (Table 1). At 28 days after inoculation, the number of pods and seeds for the infected plants was significantly decreased compared to the uninfected control plants, except the Nem 4 K treatment (Table 1). Four times the normal dose of KNO_3 applied to a nematode infected plant resulted in the same yield level as an uninfected plant receiving normal KNO_3 dose. From 21 days after infestation onwards the photosynthetic rate of all nematode infected plants generally increased with increasing potassium nitrate level, but not higher than in the uninfected controls. The results showed that the growth response of M. incognita infected beans can be improved by applying KNO_3 to the soil. Increasing the potassium nitrate dose applied to nematode infected plants delayed chlorosis, prolonged the photosynthetic period and rate, and so increased productivity of the infected plants.

Table 1. The effect of Meloidogyne incognita nematodes on plant dry weight and yield of bean plants at 28 days after inoculation. Means followed by the same letters are not significantly different from others in the same column at P=0,05 (n=4).

Treatments	Plant dry weight (g)	Yield (number/plant)	
		Pods	Seeds
Uninfected control	1,85 a	6,00 a	28,50 a
Nem 0 K	1,00 b	3,00 c	11,25 c
Nem 1 K	1,02 b	4,00 bc	14,50 bc
Nem 2 K	1,22 b	4,00 bc	16,25 b
Nem 4 K	1,43 ab	5,25 ab	23,25 ab

Note: Plants fertilized with Hoagland solution containing none (Nem 0 K), normal (Nem 1 K), double (Nem 2 K) or quadruple (Nem 4 K) strength KNO_3.

Melakeberhan, H., J.M. Webster, R.C. Brooke and J.M. D'Auria. 1988. Effect of KNO_3 on CO_2 exchange rate, nutrient concentration and yield of Meloidogyne incognita infected beans. Revue Nématol., 11 (4): 391-397.

Berries

Berries

Potassium nitrate increased bud break and rooting of blackcurrant cuttings.

Foliar *Dormancy breaking*

In blackcurrant (Ribes nigrum L.) bud break is linked to rooting. Different treatments to break bud dormancy were applied to evaluate their influence on rooting. One-year-old shoots of cv Wellington were collected from 8 year old field grown bushes. Single bud cuttings, 25-30 mm long, were prepared from the middle region of each shoot. The cuttings were soaked in KNO_3 at three different concentrations of 0, 1 and 5% for one hour. The 5% KNO_3 treatment gave a more advanced stage of bud development and highest number of roots per cutting (Table 1). A one hour KNO_3 soaking period, when compared with two, four and eight hours gave an equal or a more advanced stage of bud development and a greater number of roots. In a comparison experiment between the effect of different nitrate salts (KNO_3, $Ca(NO_3)_2$, $Mg(NO_3)_2$, NH_4NO_3, $NaNO_3$ and $Zn(NO_3)_2$), KNO_3 gave results similar to the most advanced bud break and largest number of roots.

Table 1. Effect of soaking single bud cutting of blackcurrants in KNO_3 solutions. Assessments were made 40 days after treatment application.

Treatments	Stage of bud development*	Root number per cutting
0% KNO_3	0,47	0,22
1% KNO_3	1,10	2,38
5% KNO_3	2,20	4,30
* Bud development stages:		
0 - bud dormant, no growth 2 - one fully expanded leaf visible		
1 - leaves beginning to emerge 3 - two fully expanded leaves visible		

Wainwright, H., S.F. Todd and D.J. Price. 1985. Forcing and rooting dormant single node cuttings of blackcurrant. In: IV International Rubus and Ribes Symposium, Acta Horticulturae 183: 331-338.

Capsicum

Capsicum

Supplementary potassium improved fruit yield in bell pepper at low ammonium:nitrate ratios up to 1:1 in the nutrient solution.

Fertigation N-source

Nitrogen (N) is a key component of most organic compounds found in plants. Plant requirements for nitrogen are species-dependent and may vary within plant parts and developmental phase. However, suboptimal or excess N levels may result in reduced growth, and toxicity may develop in plants that receive high proportions of NH_4^+ as opposed to NO_3^- as a source of nitrogen.

Potassium (K) is highly abundant in plants, and has a significant effect on nitrogen nutrition. It affects NO_3^- uptake by being a counter-ion for NO_3^- translocation from root to shoot. Potassium is reported to have an antagonistic effect on NH_4^+ uptake in high concentrations, and both are cations, have a similar diameter of hydrated ion, and have a similar effect on the electrical potential of the cell membrane.

A study in bell pepper cv. Dársena was performed in a greenhouse in north México in 2009-2010 to delineate the response to varying ratios of NO_3^-:NH_4^+, and increasing concentrations of K in the nutrient solution. Thirty-three-day old bell pepper plants were transplanted to pots filled with 12L sphagnum peat moss, drip irrigated as regulated by seasonal plant demand, with a constant leaching fraction of ~30%. Nutrient solutions with 13 mM total N were prepared with varying percentage of NO_3^-:NH_3^+ (100:0 (control), 75:25, 50:50 and 25:75) and three concentrations of K (6 (control), 9 and 12 mM). Other nutrients were supplied at Hoagland's nutrient solution concentration.

The bell pepper plants were tolerant to moderate proportions of ammonium (NH_4^+ content 50%, 25% or lower). Higher proportion of ammonium resulted in vegetative growth reduction and drop in fruit production at 6 mM K in the nutrient solution. This negative effect is attributed to substrate acidification, as a result of NH_4^+ uptake though a proton-cation antiport, resulting in H^+ extrusion.

A linear decrease for all growth parameters was detected regardless of K concentration when substrate pH became less than 5,1.

Increasing K in the nutrient solution did not ameliorate the growth of vegetative parts, but did compensate for reduction of yield when K was increased to 9 mM (Figure 1). At this concentration of K, yield was enhanced at 25% NH_4^+ in the nutrient solution: this greater yield when both N forms are supplemented has been attributed to lower energy cost of NH_4^+ assimilation opposed to NO_3^- assimilation, when provided at a proportion not yet high enough to impose toxic effects on plant growth.

Calcium and magnesium content in the leaves was decreased in all treatments when ammonium was present in the nutrient solution, and calcium content of the leaves was lower with higher supply of potassium in the nutrient solution. Although cation-cation competition between between these cations and ammonium cannot be ruled out, in this study the decrease was associated with the acidification of the substrate at higher ammonium proportions.

In general, leaf K was increased with increased supply of potassium, and decreased with increasing proportion of ammonium. The authors suggest that increased K ameliorated the response in yield of bell peppers by competing with NH_4^+, a reasoning supported by the finding of the highest leaf and root K concentrations when only nitrate was used as source of N. Increased K was also found to enhance photosynthesis rate at the optimal nutrient composition of 9 mM K and 25% NH_4^+ in the nutrient solution. Additionally, potassium supplementation may have alleviated stress resulting from excess ammonium through maintenance of water relations by optimal K content of the plant tissues, and modification of carbohydrate allocation to the fruit.

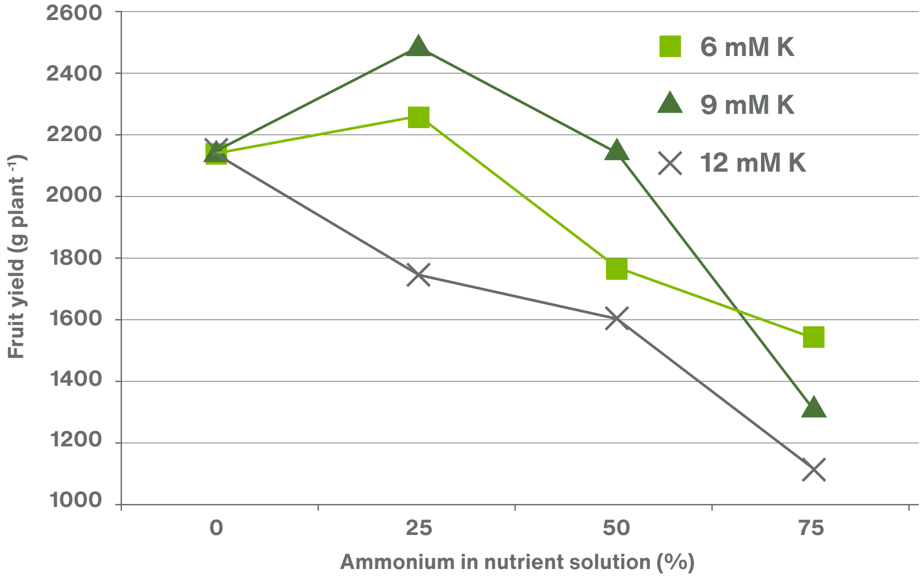

Figure 1. Fruit yield of bell pepper in response to increasing proportion of ammonium (NH_4^+) and potassium (K) concentration in the nutrient solution. Total nitrogen in the nutrient solution was maintained at 13 mM and completed with nitrogen as nitrate (NO_3^-). Each point represents the average of four replications with three plants each.

Hernández-Gómez, E., L.A. Valdez-Aquilar, A.M. Castillo-González, M. T. Colinas-Léon, D.L. Cartmill, A.D. Cartmill, R. H. Lira-Saldívar, 2013. Supplementary Potassium Sustains Fruit Yield in Bell Pepper under High Ammonium Nutrition. HortScience 48(12): 1530-1536.

Supplementary potassium nitrate improved salt tolerance in bell pepper plants.

Fertigation *Salinity relief*

In Turkey, the effect of supplementary KNO_3 on growth and yield of bell pepper plants, grown under high salinity in pots, filled with loamy clay soil, was studied. The untreated control and NaCl salt treatments were combined with different potassium nitrate additions to the soil. Supplemental KNO_3 was applied in three equal parts: banded into the soil prior to planting, top-dressed at flowering and at fruit set.

Plants, grown at high NaCl concentrations, had significantly less dry matter, plant height, chlorophyll and fruit yield than those in the untreated control treatment (Table 1). Membrane permeability increased significantly with high NaCl application, but less so when supplementary KNO_3 was applied (Table 2). High NaCl resulted in plants with very leaky root systems as measured by high K efflux; rate of leakage was reduced by supplementary KNO_3. These data suggest that NaCl status affect root membrane integrity. Concentrations of K and N in leaves were significantly lower in the high salt treatment than in the control. For the high salt treatment, supplementing the soil with KNO_3 at 1 g per kg resulted in K and N levels similar to those of the control. These results support the view that supplementary KNO_3 can overcome the effects of high salinity on fruit yield and whole plant biomass in pepper plants.

Table 1. Effects of NaCl salinity and potassium nitrate treatments on bell pepper plants.

NaCl treatments (g/kg soil)	KNO_3 treatments (g/kg soil)	Whole plant DW (g/plant)	Plant height (cm)	Total chlorophyll (mg/kg DW)	Fruit yield (g/plant)
0	0	37,4 b	68,1 a	1775 c	1680 a
0	0,5	38,8 ab	69,7 a	1845 b	1720 a
0	1,0	40,8 a	71,3 a	1930 a	1760 a
3,5	0	22,7 c	51,3 d	1251 e	810 d
3,5	0,5	27,3 b	57,6 c	1538 d	1020 c
3,5	1	34,4 b	65,7 b	1595 d	1320 b

Table 2. Effects of NaCl salinity and potassium nitrate treatments on membrane permeability of bell pepper roots.

NaCl treatments (g/kg soil)	KNO_3 treatments (g/kg soil)	Cum. K release from roots after 48 hours (μmol/g/root dm)
0	0	44 c
0	0,5	47 c
0	1,0	51 c
3,5	0	208 a
3,5	0,5	127 b
3,5	1,0	69 c

Kaya, C. and D. Higgs. 2003. Supplementary potassium nitrate improves salt tolerance in bell pepper plants. Journal of plant nutrition, 26 (7): 1367-1382.

Nitrate corrected the negative effects of ammonium and urea nutrition on the growth of Capsicum plants.

Fertigation *N-source*

The aim of this study was to compare the effects on plant growth of the main mixed N forms containing urea with that of nitrate and nitrate-ammonium as an N source for two plant species, wheat (tolerant to ammonium) and Capsicum (sensitive to ammonium). The experiment was performed in a growth chamber and plants were grown in siliceous sand pots. Capsicum plants received only one level of N: 8,5 mmol/L, whereas wheat plants received three levels of N: 2, 8,5 and 15 mmol/L. Treatment compositions for 8,5 mmol/L are described in Table 1.

Table 1. Composition of treatment solutions for a N level of 8,5 mmol/L. All concentrations are in mmol/L.

Treatments	NO_3^-	NH_4^+	U	NA	NU	AU	NAU
$Ca(NO_3)_2$	2,0						
KNO_3	4,5				4,25		
$(NH_4)_2SO_4$		4,3				2,13	
Urea			4,25		2,13	2,13	1,4
NH_4NO_3				4,25			2,85
K_2SO_4	0,3	2,5	2,5	2,5	0,38	2,5	2,5
KH_2PO_4	1,0	1,0	1,0	1,0	1,0	1,0	1,0
$MgSO_4$	2,0	2,0	2,0	2,0	2,0	2,0	2,0

Note: U=urea, NA=nitrate/ammonium, NU=nitrate/urea, AU=ammonium/urea, NAU=nitrate/ammonium/urea

Results showed that for both wheat and Capsicum the growth of plants, fed with mixed nitrogen forms containing urea, was similar to that of plants receiving nitrate and nitrate/ammonium. Only for Capsicum, fed with ammonium/urea a significant decrease in plant growth was found (Table 2). The presence of nitrate (as for example supplied with KNO_3) corrected the negative effects of ammonium and urea nutrition on the growth parameters of Capsicum plants.

Table 2. Effects of different nitrogen forms on growth parameters of Capsicum plants.

Treatments	Height (cm)	Number of leaves	Leaf dry weight (g per plant)	Root dry weight (g per plant)
NO_3^-	19,0 cd	40,8 ab	4,85 b	2,72 bc
NH_4^+	13,0 ab	26,7 a	2,16 a	1,52 a
U	15,3 abc	55,0 b	3,92 ab	1,85 ab
NA	16,5 abc	43,5 ab	4,80 b	2,17 ab
NU	20,8 d	44,5 ab	4,97 b	3,29 c
AU	12,8 a	26,0 a	2,38 a	1,64 a
NAU	17,3 bcd	45,0 ab	4,72 b	2,16 ab

Note: U=urea, NA=nitrate/ammonium, NU=nitrate/urea, AU=ammonium/urea, NAU=nitrate/ammonium/urea

Houdusse, F., M. Garnica and J.M. García-Mina. 2007. Nitrogen fertiliser source effects on the growth and mineral nutrition of pepper (Capsicum annuum L.) and wheat (Triticum aestivum L.). Journal of the Science of Food and Agriculture, 87(11): 2099-2105.

Foliar applied potassium nitrate improved Capsicum yield.

Foliar *Yield & Quality*

This study evaluates the effects of foliar potassium nitrate applied to bell peppers (Capsicum ssp.) at a rate of 5,6 kg KNO_3/ha at two week intervals from bloom to harvest. Foliar applications were made at bloom, 2 weeks later, 4 weeks later and 6 weeks later. Another treatment received applications at all four times, and an untreated check received no potassium nitrate. The test was conducted as a randomized complete block and replicated five times. Total yields were highest in the treatment that received potassium nitrate every 2 weeks for eight weeks. The untreated check produced lowest yields.

Weir, B.L. and B. Giampaoli. 2012. Effect of Foliar Applied Potassium Nitrate on Yield and Quality of Capsicum spp. 21st international pepper proceedings: 50.

Potassium nitrate outperformed other priming agents on seed vigour of hot pepper (Capsicum annuum).

Seed priming

The influence of seed priming using different priming agents on seed vigour of hot pepper (Capsicum annuum) cv. 'Hot Queen' was examined. The seeds were surface sterilized by dipping in sodium hypochlorite (5%) solution for five minutes and dried on filter paper. These sterilized seeds were primed in distilled water (dH_2O), NaCl (1%), salicylic acid (SA, 50 ppm), acetyl salicylic acid (ASA, 50 ppm), ascorbic acid (AsA, 50 ppm), PEG-8000 (PEG, -1,25 MPa) and KNO_3 (3%) in darkness for 48 hours. All priming treatments significantly improved final germination percentage (FGP) of pepper seeds over the control. Seeds primed in KNO_3, AsA, SA and ASA showed maximum value of FGP i.e. 100% in each. KNO_3 primed seeds outperformed all other priming agents in terms of decreased time taken to 50% germination, increased root and shoot length and seedling fresh weight (Figure 1).

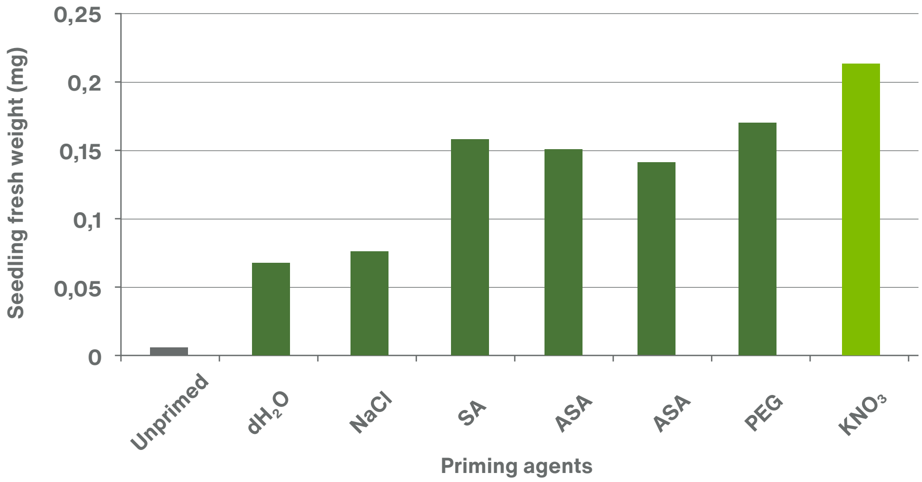

Figure 1. Effect of priming on fresh weight of pepper seedlings. Priming agents: distilled water (dH_2O), NaCl (1%), salicylic acid (SA, 50 ppm), acetyl salicylic acid (ASA, 50 ppm), ascorbic acid (AsA, 50 ppm), PEG-8000 (PEG, -1,25 MPa) and KNO_3 (3%).

Amjad, M., K. Ziaf, Q. Iqbal, I. Ahmad, M.A. Riaz and Z.A. Saqib. 2007. Effect of seed priming on seed vigour and salt tolerance in hot pepper. Pak. J. Agric. Sci, 44(3): 408-416.

Yield of Capsicum increased with increased nitrate fertilization under salinity.

Fertigation *Salinity relief*

The effects of salinity due to sodium chloride (NaCl) and nitrogen concentration in the nutrient solution were studied with sweet pepper plants (Capsicum annum cv. Largo de Reus). Capsicum plants were cultivated under greenhouse conditions in containers of 18 liters using crushed volcanic rock as inert media for cultivation. In the nutrient solution four levels of salinity were achieved by addition of 0, 25, 50 and 100 meq/l of NaCl and two levels of N fertilization by addition of 2 and 15 meq/l of nitrate (calcium nitrate and potassium nitrate). The nitrate fertilization had a positive effect on the content of N and K in leaves and decreased the concentration of Na in leaves. The highest N treatments with potassium nitrate and calcium nitrate resulted in increased yield levels.

Gómez, I., J. Navarro Pedreño, R. Moral, M.R. Iborra, G. Palacios and J. Mataix. 1996. Salinity and nitrogen fertilization affecting the macronutrient content and yield of sweet pepper plants. Journal of Plant Nutrition, 19(2): 353-359.

Citrus

Citrus

Foliar sprays with potassium nitrate outperformed potassium sulphate in terms of increasing fruit size and yield of clementine.

Foliar *Yield & Quality*

The effects of various rates and frequencies of foliar potassium nitrate and potassium sulphate on fruit production and quality parameters of citrus clementine were studied. The experiment was located in the Gharb plain of Morocco. The soil type was clay and the citrus clementine variety used was Cadoux, grafted on citrange Carizzo, trees were 23 years old. Application rates of tested foliar fertilizers were 5% and 8% KNO_3, and 2,5% and 4% K_2SO_4, applied either two or three times during fruit growth on orchards of three planting densities (D1: 6 m x 6 m, D2: 5 m x 6 m and D3: 6 m x 3,5 m tree spacing). The control was sprayed with water alone. The dates of foliar applications were as follows: July 16, August 3 and August 21, 2007. At a given application date, each tree was sprayed with ten liters of the foliar K fertilizer.

The high K concentration treatments in three sprays were most effective in increasing fruit size of clementine fruit. At low density (D1), 8% KNO_3 in two or three foliar applications, proved most effective in improving average fruit weight compared to the control. The treatment 8% KNO_3 in 3 applications gave the highest percentage of fruit in the extra-large sized class in all planting densities (table 1). Trees sprayed with only two foliar sprays were markedly less effective in improving fruit size compared with three applications.

Potassium nitrate applications were more effective than potassium sulphate in terms of improving fruit color and total soluble sugar (TSS) content of the fruit. Concerning the effect of foliar K fertilisation, the results clearly demonstrated that raising the K concentration and the number of foliar sprays increased tree fruit yield. 8% KNO_3 and 4% K_2SO_4 treatments were most effective in improving fruit yield. The largest gain in production of 12-13 MT/ha over the control was found with 3 sprays of 8% potassium nitrate (Figure 1). Spraying 8% KNO_3 resulted in the highest yield for all three planting densities compared to other K treatments with three applications.

Table 1. Distribution of fruit number (%) of clementine in the largest size class in response to foliar K fertilization for the low (D1), medium (D2) and high (D3) planting density.

Treatments	Cal 1-3: 57 to 63 mm					
	D1	D2	D3	D1	D2	D3
Control	8	9	8			
	2 sprays			3 sprays		
5% KNO_3	22	17	14	63	61	54
8% KNO_3	21	16	13	73	63	57
2,5% K_2SO_4	20	22	16	62	55	49
4% K_2SO_4	24	19	15	63	56	48

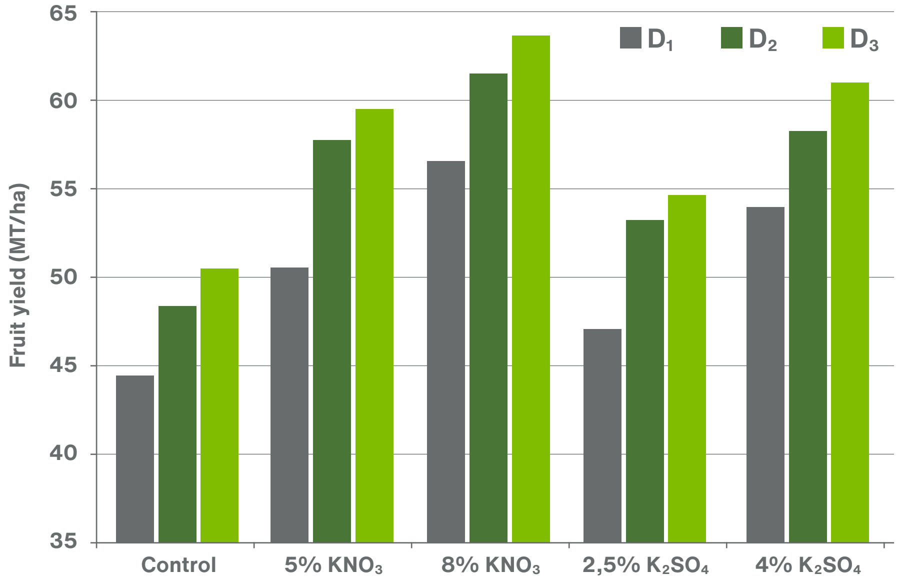

Figure 1. The effect of three foliar applications on clementine fruit yield for the low (D1), medium (D2) and high (D3) planting density.

Hamza, A., A. Bamouh, M. El Guilli and R. Bouabid. 2012. Response of clementine citrus var. Cadoux to foliar potassium fertilization; Effects on fruit production and quality. Research findings: e-ifc No. 31: 8-15.

Foliar potassium nitrate application improved the tolerance of Citrus macrophylla L. seedlings to drought conditions.

Foliar *Salinity and drought stress relief*

A pot experiment in climate chambers was conducted to explore if additional N supply (NH_4NO_3 or KNO_3) via foliar application could improve the drought tolerance of Citrus macrophylla L. seedlings under dry conditions. Two-month-old seedlings were transplanted into 1L plastic pots containing a universal substrate consisting of Canadian blond peat moss blended with coconut fibre and perlite (Compost Reciclable S.L. Spain). The seedlings were watered daily with Hoagland's nutrient solution. Water-stress treatments were imposed for four weeks, starting two weeks after transplanting. The amount of water applied was decreased by 25% of the daily water lost due to evapotranspiration every week, ending with one week of complete water withdrawal. The well-watered controls were maintained at field capacity. The foliar treatments consisted of applying N (2% in spray solution) weekly either as NH_4NO_3 or KNO_3 to drought-stressed (DS) plants. Unsprayed drought stressed plants were also included in the trial design.

Biomass measured as leaf and stem dry weight decreased significantly in all plants under drought stress compared to the well-watered control plants. DS+KNO_3 showed the least reduction in biomass, compared to the DS and DS+NH_4NO_3 treatments (Figure 1). Total biomass was reduced 25% for the treatment DS+KNO_3. It was reduced about 46% in the other two treatments (DS and DS + NH_4NO_3).

The leaf-water potential was decreased by drought stress in all the treatments, and it was the lowest in DS+KNO_3. Additionally, plants treated with KNO_3 retained the highest rate of net CO_2 assimilation of the treatments with drought stress, explaining the higher biomass at the end of the trial.

Foliar application of NH_4NO_3 enhanced leaf proline concentration. In contrast, after foliar application with KNO_3, proline accumulation was lower, and K^+ content of leaves higher, compared to DS+NH_4NO_3. This could explain the retention of CO_2 assimilation capacity by plants under drought stress treated with KNO_3. Accumulation of potassium ions to decrease leaf-water potential does not require extra energetic costs, whereas conversion of starch to proline after NH_4NO_3 treatment does require extra energy.

This indicates the importance of potassium in the adaptive mechanism of citrus plants to drought stress. The authors conclude that foliar application of nitrogen at 2% in the spray solution, in the form of KNO_3, could be a good. agronomical strategy to mitigate the negative effects caused by drought in C. macrophylla seedlings grown in Mediterranean nurseries.

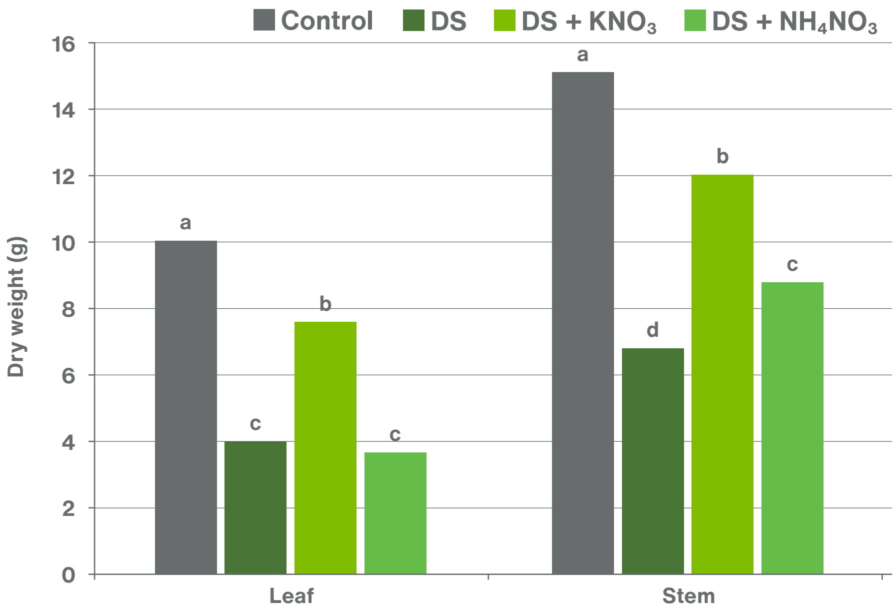

Figure 1. Leaf and stem dry weight in Citrus macrophylla L. seedlings at 28 days after starting the water stress treatment among the following four treatments: control (well-watered plants), drought -stressed plants (DS), and drought-stressed plants supplied with 2% foliar-N applications as KNO_3 (DS+KNO_3) or NH_4NO_3 (DS+NH_4NO_3). The means followed by different letters are significantly different (P<0,05, Tukey).

Gimeno, V., L. Díaz-López, S. Simón-Grao, V. Martínez, J.J. Martínez-Nicolás and F. García-Sánchez. 2014. Foliar potassium nitrate application improves the tolerance of Citrus macrophylla L. seedlings to drought conditions. Plant Physiology and Biochemistry, 83: 308-315.

Fertigation *N-sources*

Citrus is a major crop in the Valencia province in Spain. The crop requires a large quantity of nitrogen fertilizers and irrigation water. When not managed properly leaching of nitrates to the drain water can cause contamination of the aquifers. Growers need to implement a more efficient nitrogen application method to decrease the contamination rate in the citrus area. Research work has been conducted to address this objective. The nitrogen absorption efficiency was determined, in relation to the type of fertilizer (potassium nitrate or ammonium sulphate), moment of application and soil characteristics.

In a first study, fertilizers enriched with a labeled isotope (15N) were applied to sandy and loam soils, both calcareous, in spring and summer. It was observed during the whole trial period, that percentage of absorbed nitrogen of the total amount supplied, was higher on sandy soils and when N was applied with potassium nitrate (Figure 1). Lower nitrogen absorption efficiency was observed on loam soil when N was applied as ammonium sulphate (Figure 2).

The second study in a clementine orchard (cv. Nules), focused on nitrate (NO_3^-) and ammonium (NH_4^+) mobility in the soil, both applied through drip irrigation. It was observed that the nitrate ions moved easily to a lower depth, in contrast to the ammonium ions which showed a more restricted mobility in the wet bulb. Ammonium was found to be subject to rapid nitrification, thus the restricted mobility did not cause problems in availability of nitrogen. Nitrate concentration was higher in the wet bulb when the drip irrigation line was buried in (at 30 cm soil depth), compared to superficially placed drip lines. This observation indicates that the nitrification process of ammonium is more efficient when drip lines are buried in.

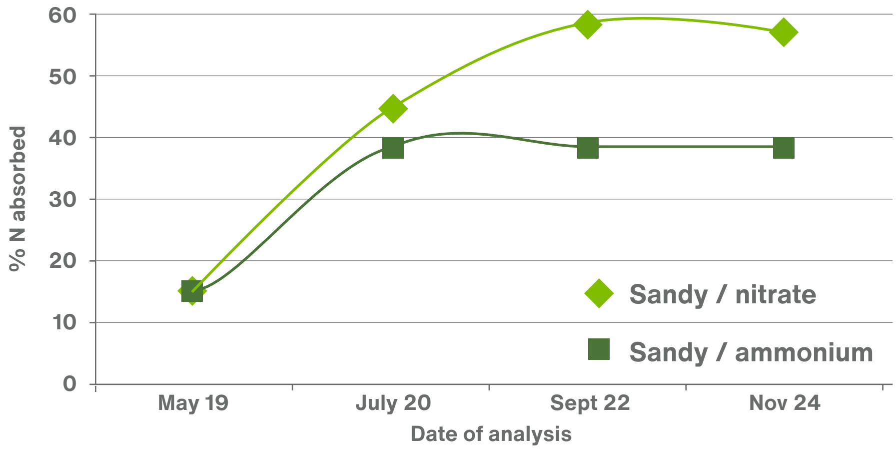

Figure 1. Efficiency in N absorption (percentage of labeled 15N recovered) during the trial period when supplied with potassium nitrate or ammonium sulphate on a sandy soil.

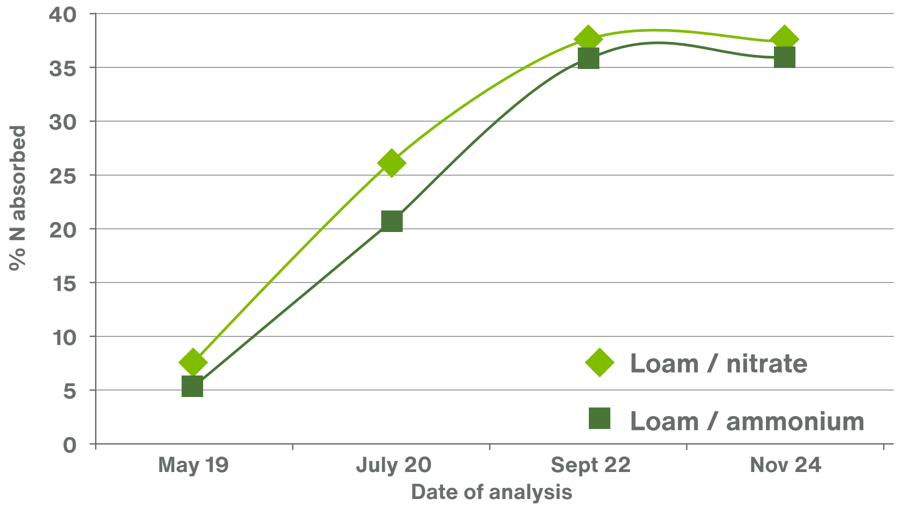

Figure 2. Efficiency in N absorption (percentage of labeled 15N recovered) during the trial period when supplied with potassium nitrate or ammonium sulphate on a loam soil.

Legaz Paredes, F., B.M. Olmo, M.D.S. Guirao and N.M. Enrique. 1996. Dinámica de nutrientes y mejora de las técnicas de fertilizacion en cítricos. Instituto Valenciano de Investigación Agrária (IVIA). Valencia, 233-239.

Potassium nitrate sprays resulted in more and larger-sized 'Valencia' orange fruits per tree.

Foliar *Yield & Quality*

A three years study of foliar nutrient sprays in "Valencia" orange was performed to investigate the effects of foliar application on the number of fruits per tree, total soluble solids production and fruit yield. Three sprays with 23 kg KNO_3/ha/ spray (1% conc.) were applied at the following stages: pre-bloom (Febr.), post-bloom (April) and during fruit fill (mid-July to mid-August). KNO_3 sprays increased the number of fruits per tree, the total soluble solids content, fruit yield and consequently the gross income of the farmer, compared to the untreated control treatment (Figure 1).

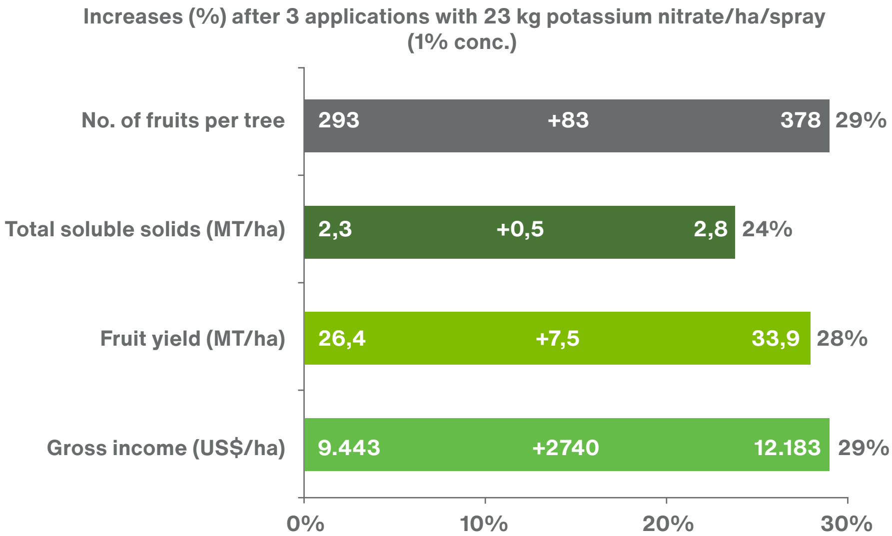

Figure 1. Increases (%) of yield parameters and gross income after 3 applications with 23 kg KNO_3/ ha/spray (1% concentration).

Boman, B.J. 2001. Foliar nutrient sprays influence yield and size of 'Valencia' orange. Proc Fla State Hort Soc. 114: 83-88.

Sprays with potassium nitrate outperformed potassium sulphate in increasing fruit size of ‘Valencia’ and ‘Shamouti’ orange.

Foliar *Yield & Quality*

One foliar spray in “Valencia” and “Shamouti” orange was conducted respectively 6 and 8 weeks after flowering. Spraying 20 ppm 2,4-D (auxin) + 5% KNO_3 increased fruit size by 8-20% for “Shamouti” and 8-25% for “Valencia” compared to the control.

Potassium nitrate also increased significantly the juice acid level in “Shamouti” orange by 15%. Spraying with KNO_3 was more efficient than spraying K_2SO_4 in increasing fruit size per 1000 distributed fruits (Figure 1).

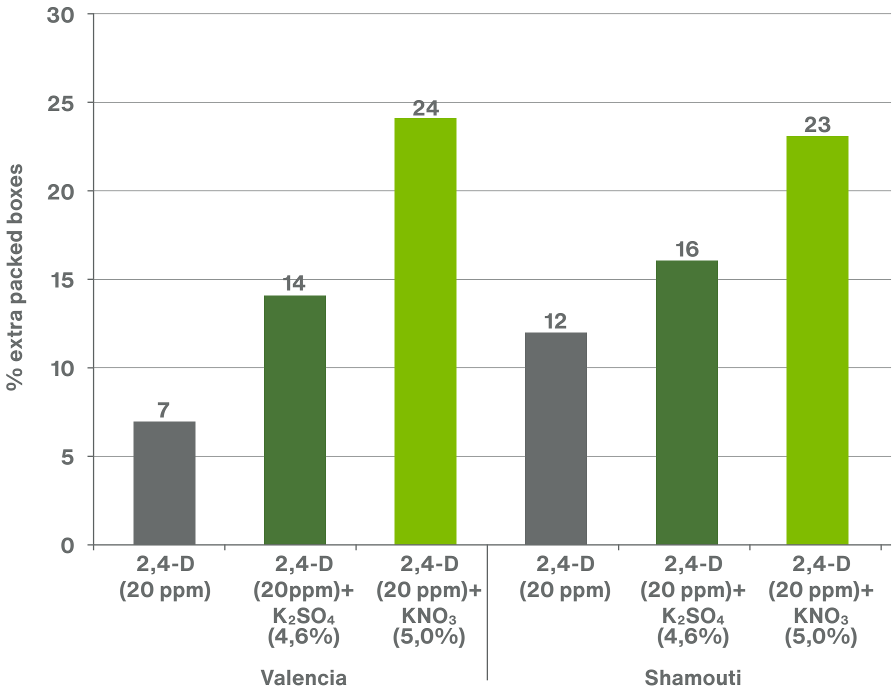

Figure 1. Effect of foliar sprays on % extra packed boxes (untreated control=0%).

Erner, Y., Y. Kaplan, B. Artzi, and M. Hamou. 1993. Increasing citrus fruit size using Auxins and potassium. Acta Horticulturae 329: 112-119.

Review paper: Potassium nitrate found to be the preferred K-source with respect to citrus tree performance.

K-sources

Erner et al (2001) published a review paper about the most significant effects of potassium (nitrate) on citrus tree growth and productivity. The paper discusses K requirement and K effects on growth and yield, external and internal fruit quality, when applied to the soil or in a foliar spray. Growers should take into account that the differences in crop performance are related to the counter ion of the main K-sources used (i.e. nitrate, sulphate and chloride ions). For citrus trees grown in arid zones, potassium nitrate was found to be the preferred K-source. Most of the articles, referred to in the review paper by Erner et al (2001), can be found in this book of abstracts as well.

Erner, Y., Y. Kaplan, B. Artzi, and M. Hamou. 2001. Potassium Affects Citrus Tree Performance. The Volcani Center, Institute of Horticulture, Department of Fruit Trees, PO Box, 6.

Phenology model: Timing of potassium nitrate sprays to increase citrus fruit size and fruit retention.

Foliar *Yield & Quality*

The goal of this research was to identify the role essential nutrients play in the physiology of tree crops, and then to apply the nutrient as a foliar fertilizer to stimulate a specific metabolic process at phenological stages when nutrient demand is high.

During fruit set, when flower and fruit abscission take place, greatest gain in fruit retention and yield can be made (Figure 1). At low soil temperatures, root activity is limited, which results in less nutrient uptake. Early pre-bloom and post-bloom sprays with nitrogen containing fertilizer source, such as urea or KNO_3, can help to overcome this limited root activity related problem. Foliar absorbed N will be broken down to ammonia, which will be metabolically transformed to arginine and arginine to polyamines. Polyamines play a well-established role in promoting growth by cell division. More cells means usually larger fruit. 70% of final fruit size is related to the number of cells in the fruit. Cell division typically stops by late April (Florida); size change throughout the rest of the year comes from cell enlargement.

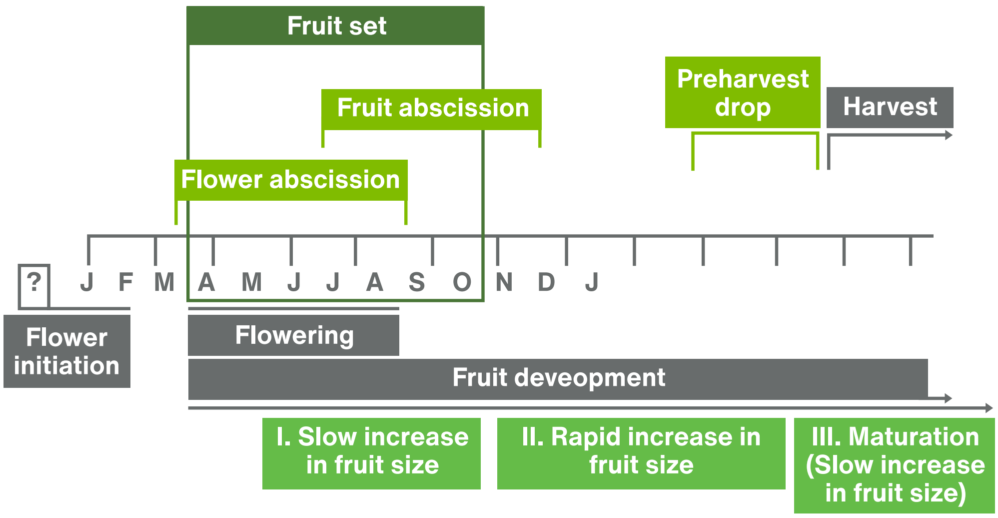

Figure 1. Phenology model of the Navel orange based on 25-year-old ‘Washington’ Navel orange (Citrus sinensis L. Osbeck) trees on ‘Troyer’ citrange [Poncirus trifoliate (L. Raf) x C. sinensis] rootstock at Riverside, CA.

Lovatt, C.J. 1999. Timing Citrus and Avocado Foliar Nutrient Applications to Increase Fruit Set and Size. HortTechnology. October–December 9(4): 607-612.

Thinning populations of the Florida Wax Scale in citrus by use of potassium nitrate and surfactant.

Foliar *Pest & disease reduction*

The purpose of the study was to test the control of Florida Wax Scale (FWS) in citrus by potassium nitrate in comparison with broad-spectrum insecticides. The trial included the following treatments: organophosphate (13L in 3500L water/ha), KNO_3 (4%) + surfactant (Triton B-1956) 0,05% sprayed in 3500 L/ha and the control. These treatments were carried out on a 34 ha, 20 years old, citrus grove in the southern coastal plain of Israel. Control of FWS by potassium nitrate + surfactant was nearly as good as organophosphate pesticides and statistically significantly better than the untreated control (Figure 1).

In addition, in a citrus grove at Yesodot (southern coastal plain) in Israel, thinning the invading generation of FWS larvae at low population densities by a combination of a nutritional spray of 4% potassium nitrate with 2% spray oil, once a year, obviated the necessity to control the pest by any other means during 7 years.

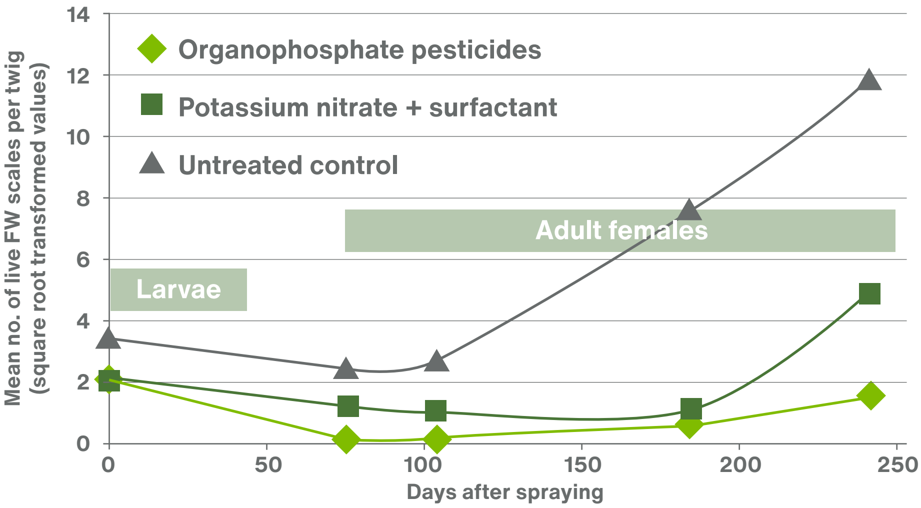

Figure 1. Effect of treatments on the mean number of live Florida Wax Scale per twig (square root transformed values) in days after spraying.

Yardeni, A., E. Shapira, K. Ascher and Y. Ben-Dov. 1995. Thinning populations of the Florida wax scale, Ceroplastes floridensis Comstock (Coccidae), by use of potassium nitrate and spray oil, as an option in IPM of citrus groves in Israel. Israel Journal of Entomology, 29: 271-276.

Post bloom foliar potassium nitrate applications increased grapefruit size.

Foliar *Yield & Quality*

In the Indian River area of Florida (USA), the effect of potassium sprays during the post-bloom and summer periods was studied, to determine if the size of grapefruit could be increased. 'Marsh' grapefruit trees were used in a randomized complete block design with 4 replications of each treatment. Equal ratios of K_2O of 12 kg K_2O/ha and 24 kg K_2O/ha were applied with 28 and 56 kg/ha KNO_3, and with 38 and 76 kg/ha MKP, respectively. Two rates of MKP and two rates of KNO_3 were used in block A, whereas in block B single rates of MKP (76 kg/ha) and KNO_3 (56 kg/ha) were applied and compared with the non-sprayed control plots. Foliar sprays were applied post bloom on April 21 and May 19, and later on August 9 and September 14. Post-bloom foliar K applications to Florida grapefruit were shown to be effective in increasing average size of grapefruit. Both MKP and KNO_3 treatments statistically significantly increased the mean diameter of grapefruit compared to the control in both blocks, except the MKP-38 treatment in block A (Figure 1). Both the MKP-76 and KNO_3-56 treatments in Block B had increased fruit enlargement compared to the control treatment at each measurement date. The fruit on trees sprayed with MKP and KNO_3 had increased 1.9-2.4 mm more than fruit from control trees by the time the November 28 MKP-76 measurements were taken. Around 40% of the foliar K-treated fruit increased 20 mm or more from August 4 to November 28, compared to 20% of the control treatment fruit.

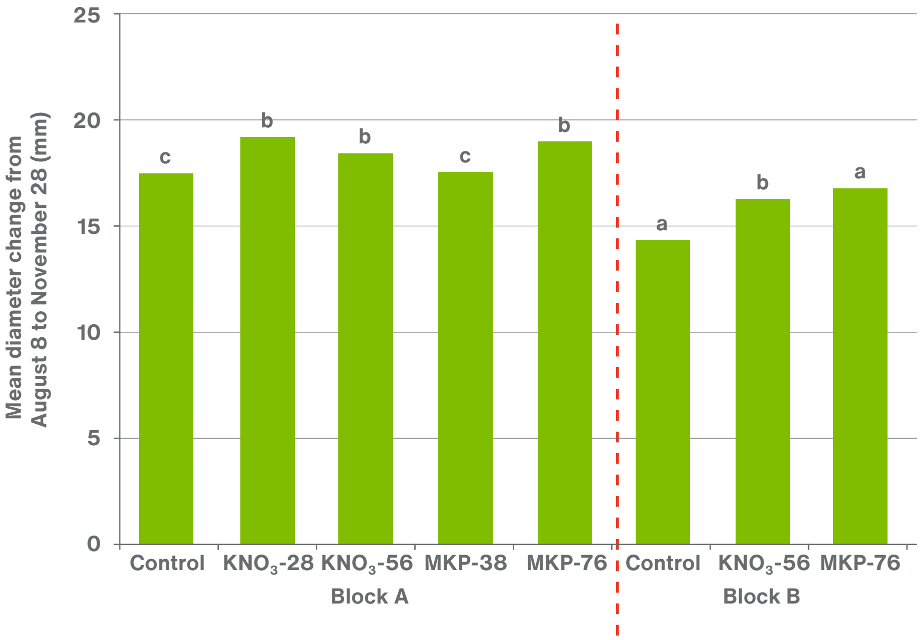

Figure 1. Effect of foliar sprays on the grapefruit size.

Boman, B. J. and J.W. Hebb. 1998. Post bloom and summer foliar K effects on grapefruit size. In Proceedings-Florida State Horticultural Society, Vol. 111: 128-134.

Fall foliar potassium nitrate applications increased grapefruit size.

Foliar *Yield & Quality*

In Florida (USA) a three years study was conducted to determine if potassium applications during late summer and early fall could increase the size of grapefruit. In 1994, foliar sprays were made on 9 September, 6 October and 27 October with an application rate of 22,4 kg KNO_3/ha in 2350 L water. The fruits which received the foliar potassium nitrate application statistically significant increased 11,4% in diameter from September 10 to 23 November as compared to 8,0% for the untreated control. In total, 61% of the fruits sprayed with KNO_3 enlarged 2 sizes or more (Table 1). As larger sized fruits are better priced, the enlargement of these fruit sizes is very beneficial. Fall applications of KNO_3 significantly increased the average grapefruit diameter compared to non-sprayed control fruit in 1994. For the other two years the fruit size was increased, although statistically non-significant. Although average fruit diameter growth was only increased 0,6 to 2,4 mm for treated fruit as compared to control fruit, the greater growth in the smaller fruit sizes is likely to be economically significant in many years.

Table 1. The change in size class from 10 September to 23 November for grapefruit.

Size change	% of fruit	
	Control	KNO_3
0-1	13	1
1-2	61	38
2-3	20	46
>3	6	15

Boman, B. 1997. Effectiveness of fall potassium sprays on enhancing grapefruit size. In Proceedings of the annual meeting of the Florida State Horticultural Society, 110: 1-7.

Girdling plus potassium nitrate sprays outperformed girdling plus di-potassium hydrogen phosphate sprays in mandarin.

Foliar *Yield & Quality*

Ten years old 'Balady' mandarin trees, grown under sandy soil conditions in Egypt, were sprayed with 1% or 2% potassium nitrate or di-potassium hydrogen phosphate twice at the beginning of April and ten weeks later (mid June) and treated with girdling before blossoming (late Dec.). The experiment was arranged in a complete randomized design with three replicates, each consisted of three trees. Results concluded that girdling plus potassium sprays specially potassium nitrate at any concentration had a positive effect on nitrogen and potassium percentages, total carbohydrate, total chlorophyll and chlorophyll (a) content in the leaves, which reflected on increasing fruit weight, number of fruits per tree and finally yield weight per tree. In this 2-years trial, spraying trees with potassium nitrate either at 1% or 2% increased yield per tree on average with 23% and 26%, respectively, compared to girdling only (Table 1 and 2). The potassium treatments also enhanced fruit volume, soluble solids content and SSC/acid ratio. Results showed that at any concentration KNO_3 outperformed K_2HPO_4 in terms of yield and number of fruits per tree in both seasons.

Table 1. Effect of girdling and different potassium sprays on yield and fruit characteristics of Balady mandarin trees during 2002.

Treatments	Yield (kg/tree)	Number of fruits/tree	Fruit weight (g)	Fruit volume (cm^3)
Control	40,2	348	115	136
Girdling	51,6	380	133	140
Girdling + 1% KNO_3	63,3	405	156	172
Girdling + 2% KNO_3	65,0	412	157	173
Girdling + 1% K_2HPO_4	57,4	390	147	158
Girdling + 2% K_2HPO_4	62,1	400	155	177
LSD at 5%	3,7	8,2	3,6	1,1

Table 2. Effect of girdling and different potassium sprays on yield and fruit characteristics of Balady mandarin trees during 2003.

Treatments	Yield (kg/tree)	Number of fruits/tree	Fruit weight (g)	Fruit volume (cm^3)
Control	39,9	350	114	135
Girdling	51,4	378	136	140
Girdling + 1% KNO_3	63,9	410	155	176
Girdling + 2% KNO_3	64,7	425	155	173
Girdling + 1% K_2HPO_4	57,8	385	150	159
Girdling + 2% K_2HPO_4	62,8	396	158	177
LSD at 5%	1,1	12,8	3,1	3,5

Mostafa, E. A. M. and M. M. S.Saleh. 2006. Response of Balady mandarin trees to girdling and potassium sprays under sandy soil conditions. Research Journal of Agriculture and Biological Sciences, 2(3): 137-141.

Foliar potassium nitrate applications increased income of tangerine growers.

Foliar *Yield & Quality*

A study conducted during the 1997-98 through 2001-02 seasons in 'Sunburst' tangerine (Citrus reticulata Blanco x C. paradisi Macf.), located in Indian River County, Florida (USA) investigated the effect of foliar potassium nitrate sprays on fruit size and yield. Trees were grown on a Riviera fine sand soil and trees were either untreated or had 3 foliar applications of 28 kg KNO_3 per hectare per spray, in a randomized block design with four replications. Sprays were applied during the dormant (February), post bloom (April) and summer (July) stage. In each of the seasons the KNO_3 treatment resulted in 30% or more fruit of size 120 and larger during the first spot pick. In the two years when all the fruit from each tree was harvested, the potassium nitrate treatment averaged 23% more total fruit of size 120 and larger for the entire season. In this experiment, three 28 kg/ha KNO_3 foliar applications per year were effective in increasing fruit size, and thus Gross Packed Value (GPV) for 'Sunburst' tangerines (Figure 1). Average season total increase in GPV for the KNO_3 treatment was US$ 13,52 per tree (US$ 6047/ha) compared to the control. These applications, which added only minimally to production costs, were able to increase returns of growers due to increased numbers of larger-sized fruit with no apparent detrimental effects on fruit shape or internal quality.

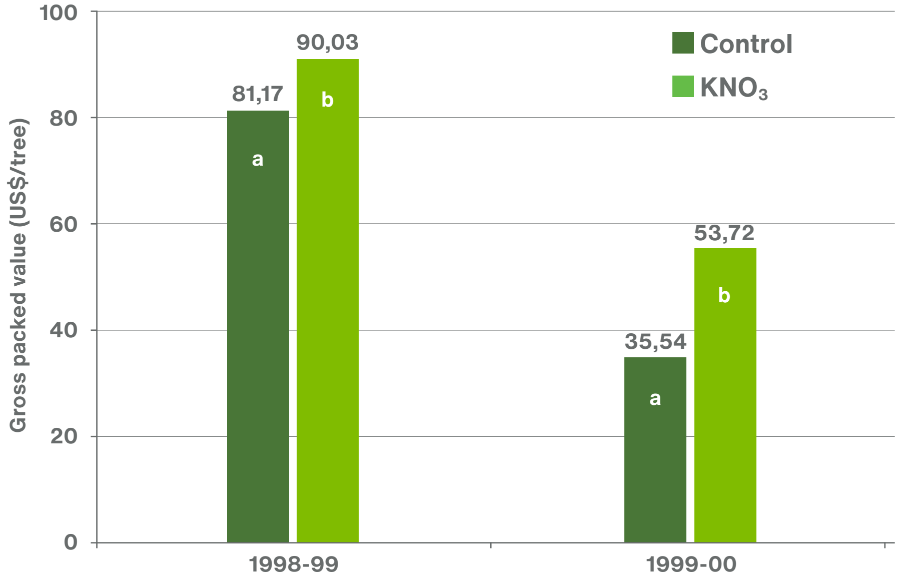

Figure 1. Gross Packed Value (GPV) for 1998-99 and 1999-00 season for control and KNO_3 treatment.

Boman, B. J. 2002. KNO_3 foliar application to 'Sunburst' tangerine. In Proceedings of the Florida State Horticultural Society, Vol. 115: 6-9.

Potassium nitrate sprays improved leaf K content, fruit size and peel thickness of clementines.

Foliar *Yield & Quality*

This study was carried out in mature Clementine trees "Nules" (Citrus Clementine Hort. Ex. Tan) grafted on Troyer citrange (Citrus sinensis x Poncirus trifoliata) rootstock in Puzol, Spain. The experiment was laid out in a randomized complete block design with 4 replicates per treatment, conducted over 3 years (1998-1999-2000) on an alkaline sandy loam soil.

Three doses of foliar potassium nitrate sprays (0,5% equals 25 kg KNO_3/ha, 1,0% equals 50 kg KNO_3/ha and 1,5 % equals 75 kg KNO_3/ha) were used in different stages of the growth cycle. Three sprays were applied: May-June-July (M-J-J), June-July-August (J-J-A) or July-August-September (J-A-S).

The three doses increased the leaf K concentration with regard to the control. In particular those at 1,5% were effective in increasing leaf K concentrations, mainly when applied at the earlier moments of applications (M-J-J) and (J-J-A), whereas leaves were less responsive to late applications (J-A-S).

The yield was scarcely affected by the treatments, and this value was kept almost constant during the three years. The individual fruit weight was improved by any treatment times and doses, but mainly with the dose of 1,5%. The peel thickness increased with the treatments, and the highest values were found with the higher dose. Varieties that produce small fruits and thin peel, will benefit from KNO_3 sprays, preferably at 1,5% concentration. However, the peel and juice percentages were slightly affected, the total soluble solids and acidity percentages always increased with any dose applied, but the higher values were reached with 1,5 %. The colour index (orange colour intensity) at the harvest time was favoured with the potassium nitrate treatments when compared with the control trees.

Bañuls, J., A. Quiñones, B. Martín, E. Primo-Millo and F. Legaz. 2001. Efecto complementario de la aplicación foliar de nitrato potásico sobre la nutrición del potasio y la calidad del fruto en Clementina de Nules. Levante Agrícola: Revista internacional de cítricos: 368-377.

Potassium nitrate, an effective foliar K-source in 'Valencia' orange.

Fertigation K-sources

The objective of this study was to evaluate different potassium fertilizers: KCl, KNO_3, K_2SO_4 and K-$MgSO_4$ (double potassium and magnesium salt) and to determine their effects on the fruit quality and yield of 'Valencia' orange (Citrus sinensis (L.) Osbeck) after three years of applications. Eighteen-year-old orange trees grown on La Rosa series soil, classed as Mollisol, were used. Fertilizers were manually applied at the beginning of the spring season each year (1990, 1991, 1992) in two furrows, one each side of the tree's projection canopy, at 25 cm depth. Each year an equivalent dose of 3 kg of K_2O per tree was used. The experiment consisted of a randomized complete block design with five treatments and six replicates. The initial average concentration of potassium in the leaf was 5,7 g K/kg, which was indicated to be low. The available potassium level in the soil was medium with 0,5 cmol/kg exchangeable K in the first 20 cm and low with 0,25 cmol/kg exchangeable K at 20-40 cm depth. The potassium content in the leaves was incremented already in the second year in the KNO_3 and K_2SO_4 treatments and in the third year in all treatments in relation to the control treatment. The higher potassium concentration was obtained for KNO_3 (6,8 g K/kg), compared to 6,0 g K/kg for the other K-sources.Fruit yield increment was not present, but there was an increase in fruit size. Potassium nitrate and potassium chloride statistically significantly increased the average individual fruit weight compared to the other K-sources (Table 1). All K-treatments produced an increase in the juice acidity.

Table 1. Effect of different potassium sources on yield characteristics of 'Valencia' orange.

Treatments	Yield (kg/tree)	Number of fruits per tree	Av. fruit weight (g)
Control	187 a	1722 a	109 a
KNO_3	231 a	1780 a	135 b
KCl	201 a	1487 a	145 b
K_2SO_4	245 a	2073 a	124 ab
K-$MgSO_4$	200 a	1603 a	125 ab

Opazo Aguila, J.D. and B. Razeto M. 2001. Effects of different potassium fertilizers on foliar content of nutrients, yield and fruit quality in orange trees cv. Valencia. Agricultura Técnica (Chile), Vol. 61, No. 4: 470 – 478.

Foliar potassium nitrate applications in citrus were beneficial in terms of fruit yield, number of fruits and reducing fruit splitting.

Fertigation *K-sources*

Three levels of potassium nitrate 2%, 4% and 6% were tested as foliar sprays at different times i.e. first time application was at full bloom stage, the second time application at fruit diameter from 1,5-2,0 cm and at both times of application. The aim was to investigate the effects of these foliar sprays on fruit set, yield, fruit quality and fruit splitting of 40-years-old Washington navel orange (Citrus sinensis) trees in Egypt during the 2008 and 2009 growing seasons. Trees were planted in a clay soil at 5x5 m spacing in a randomized block design with 4 single-tree replicates. KNO_3 treatments, especially at higher concentrations, increased fruit size, peel thickness and juice acidity compared to the control. Moreover, it was noticed that trees sprayed at first application or first and second time of application gave the best results, while the second time application showed the best performance for reducing fruit splitting. This reduction in fruit splitting was only observed for the KNO_3 sprays at 4% and 6%. The highest yield (+53%) compared to the control was obtained with one spray during full bloom at 4% potassium nitrate (Figure 1). The increase in yield was explained by the increase in number of fruits per tree harvested.

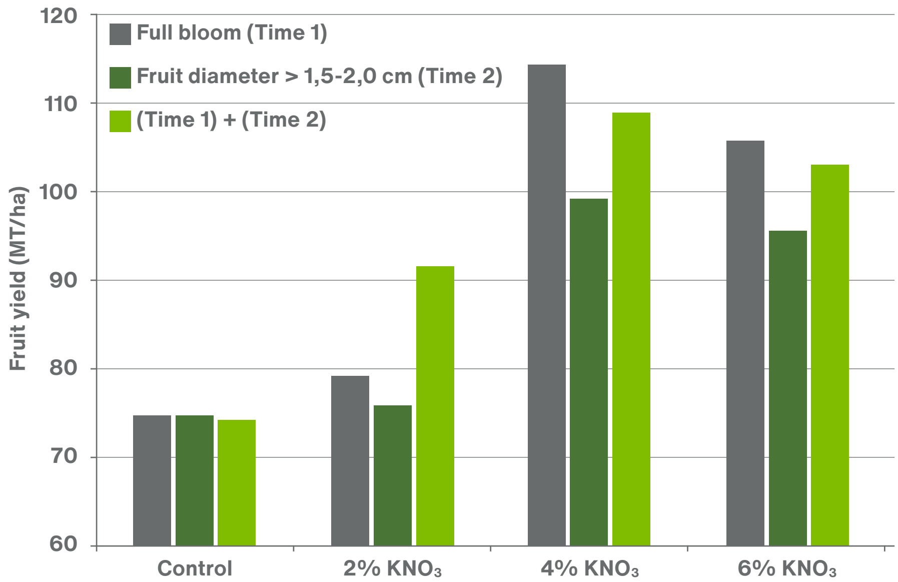

Figure 1. Two-seasons average yield (kg/tree) of Washington navel orange trees as affected by potassium nitrate.

Abd El-Rahman, G.F., M.M. Hoda and A.H.T. Ensherah. 2012. Effect of GA_3 and potassium nitrate in different dates on fruit set, yield and splitting of Washington navel orange. Nature and Science, 10(1): 148-157.

Potassium nitrate improves growth in salt-stressed citrus seedlings.

Fertigation *Salinity relief*

A greenhouse experiment was conducted with 1-year-old Navelina Citrus sinensis (L.) Osbeck scions grafted onto either Carrizo citrange (Citrus sinensis (L.) Osbeck x Poncirus trifoliata (L.) Raf.), Citrus macrophylla Wester or Cleopatra mandarin (Citrus reshni Hort. Ex Tanaka) rootstocks. Plants were grown for 60 days in pots with a mixture of sand and turf (85:15). All plants were irrigated three times per week. The control treatment was irrigated with water, the salinity treatment with water containing 25 mM $NaCl:CaCl_2$ (15:1) and the salinity + nitrate supplementation treatment with water containing 25 mM $NaCl:CaCl_2$ plus 10 mM KNO_3. Salt stress reduced total plant biomass by 27-38%, whereas potassium nitrate supplementation partially counteracted this effect by increasing total dry matter of the plant.

Potassium nitrate supplementation increased for all three rootstocks the total plant biomass of salinity-treated seedlings by 22-36% (Figure 1). Salt-stressed plants had lower photosynthesis rates than the control. Addition of KNO_3 increased photosynthetic rates of salt-treated Navelina orange by 25-30% in scions grafted on Carrizo citrange or C. macrophylla and by 66% in scions grafted on Cleopatra mandarin. The supplementation of KNO_3 also reduced leaf abscission for all three rootstocks under salinity conditions (Table 1). Next to that, potassium nitrate-induced increase in leaf biomass resulted in chloride dilution in the leaves and roots, leading to a reduction in chloride concentration, the critical parameter for salt damage.

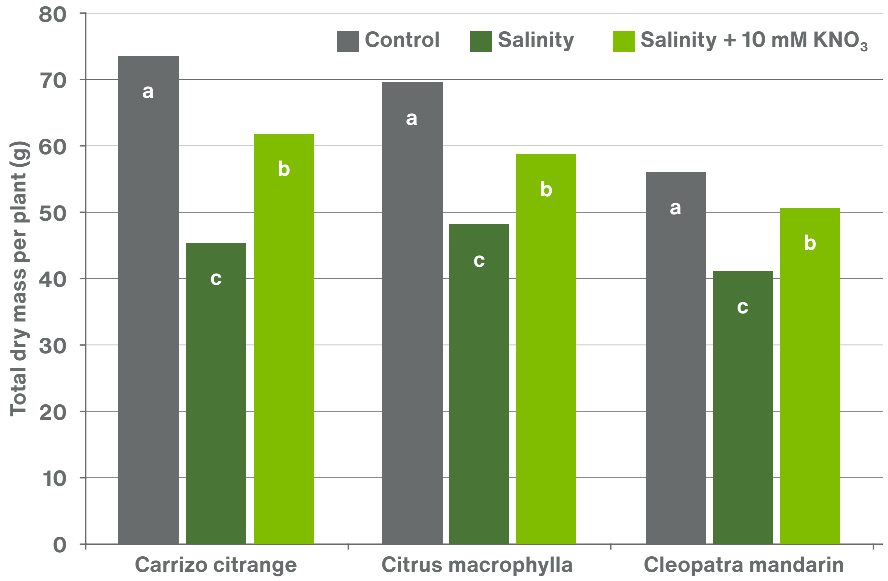

Figure 1. Treatment effect on the total dry mass (g) for Navelina citrus grafted on three different citrus rootstocks.

Table 1. Treatment effect on the leaf abscission (%) for Navelina citrus grafted on three different citrus rootstocks.

Treatments	Leaf abscission (%)		
	Carrizo citrange	Citrus macrophylla	Cleopatra mandarin
Control	0	0	0
Salinity	32,4	21,0	28,2
Salinity + 10 mM KNO_3	20,2	15,1	12,6

Iglesias, D. J., Y. Levy, A. Gòmez-Cadenas, F.R. Tadeo, E. Primo-Millo and M. Talon. 2004. Nitrate improves growth in salt-stressed citrus seedlings through effects on photosynthetic activity and chloride accumulation. Tree physiology, 24: 1027-1034.

Potassium nitrate sprays in 'Nova' tangerine reduced fruit splitting and increased fruit weight.

Foliar *Yield & Quality*

The effects of nutritional and hormonal sprays on decreasing fruit splitting was investigated. A citrus Florida hybrid (Clementine X Orlando) named 'Nova' was used. It was found that two to three sprays of KNO_3 at 5% in combination with auxins (2,4-D, NAA, Maxim) at a concentration of 20 ppm, mainly used to increase fruit size, increased leaf K level and fruit weight, reduced the percentage of split fruit and increased yield per tree (Table 1). There was an indication that this treatment reduced the percentage of creased fruits. In some cases fruit splitting might be the result of creasing, a serious peel disorder of 'Valencia' orange, 'Nova' mandarin and others.

Table 1. The effects of foliar spray treatments on leaf K, fruit weight, split fruit and yield of Nova tangerines.

Spray treatments*	Leaf K (% dry weight)	Fruit weight (g)	Split fruit (%)	Yield (kg/tree)
Control	0,50 d**	117 c	27,5 a	47,4 c
KNO_3 (1 spray)	0,50 d	123 abc	18,0 b	54,7 bc
2,4-D (1 spray)	0,69 c	123 abc	15,0 bc	65,4 ab
KNO_3 + 2,4-D (2 sprays)	0,79 b	130 ab	15,0 bc	64,2 ab
KNO_3 + 2,4-D (3 sprays)	1,00 a	134 a	11,0 c	68,8 a

* The concentrations of KNO_3 and 2,4-D were 5% and 20 ppm, respectively, in all treatments.
** Mean separation within columns by Duncan's multiple range test at P = 0.05.

Lavon, R., S. Shapchiski, E. Mohel and N. Zur. 1992. Nutritional and hormonal sprays decreased fruit splitting and fruit creasing of "Nova". Hasade 72: 1252-1257.

Correction of potassium deficiency of citrus with potassium nitrate sprays.

Foliar *Yield & Quality*

Already in 1972 benefits of spraying potassium nitrate were observed. This review was a result of developments during those days in spraying potassium nitrate to correct potassium deficiencies. On calcareous soils it was difficult to raise the K content of citrus leaves beyond very minimal amounts by extensive soil applications of K fertilizers. Citrus leaves analyzing 0,5 to 0,8% K were not uncommon in groves on calcareous soils, although maximum yield of citrus on these soils were associated with leaf K levels of over 1,0%. Accumulation of calcium in the citrus leaves apparently resulted in a physiological deficiency of K when grown on these soils. KNO_3 was compatible as a neutral constituent with both fungicides and pesticides commonly used in regular spray programs. Trees with adequate leaf K produced larger oranges, stronger peels, and greater yields, resulting in improved packing and keeping quality for fresh fruit markets. Citrus creasing, particularly present in years of heavy fruit set and nutritional stress, was significantly reduced by foliar application of KNO_3.

Calvert, D. V. and R.C. Smith. 1972. Correction of potassium deficiency of citrus with KNO_3 sprays. Journal of Agricultural and Food Chemistry, 20(3), 659-661.

Foliar applied potassium nitrate increased individual fruit size and thus grower revenues in citrus.

Foliar *Yield & Quality*

The paper described the effects of a single high concentration spray of potassium nitrate enriched with soluble phosphates (13-2-44, N-P-K) and a special adjuvant on citrus yields, fruit quality and grower's profitability. All experiments were conducted in mature (>15 year old) citrus orchards in central Israel.

Foliar feeding with this enriched potassium nitrate product has achieved the following results in citrus crops:

- In 'Shamouti' ("Jaffa") oranges a single application of 9-10% (w/v), when fruits were 18-22 mm in diameter, increased percentage of fruit size above 75 mm (diameter) by 75%, consequently, total yield increased by 14 ton/ha. Shelf life of stored fruit was also significantly enhanced due to a marked increase in potassium content of the rind by 0,44% (in dry matter).
- In 'Newhol' navel orange (Citrus sinensis Osb.), a single application of a 10% solution, when fruits were 15-20 mm in diameter, significantly increased total yield by 19% and fruit share above 75 mm increased by 28% (Figure 1).
- In Nova tangerine (Citrus reticulata Bla.), a single application of a 10% solution, when fruits were 12-20 mm in diameter, significantly increased total yield by 30%, mean fruit weight by 38,3 g and reduced the incidence of rind creasing by 20%.

The described experiments showed that foliar application of potassium nitrate is recommended for high production and fruit quality in citrus. The applications resulted in agronomical and economic benefits compared to the unsprayed control in terms of nutrient contents in the leaves, fruit rind, total yield, fruit-size distribution and grower revenues. The shift towards bigger sizes in fruit-size distribution is the major factor in producing higher revenues due to the higher market prices received for the bigger sized fruits.

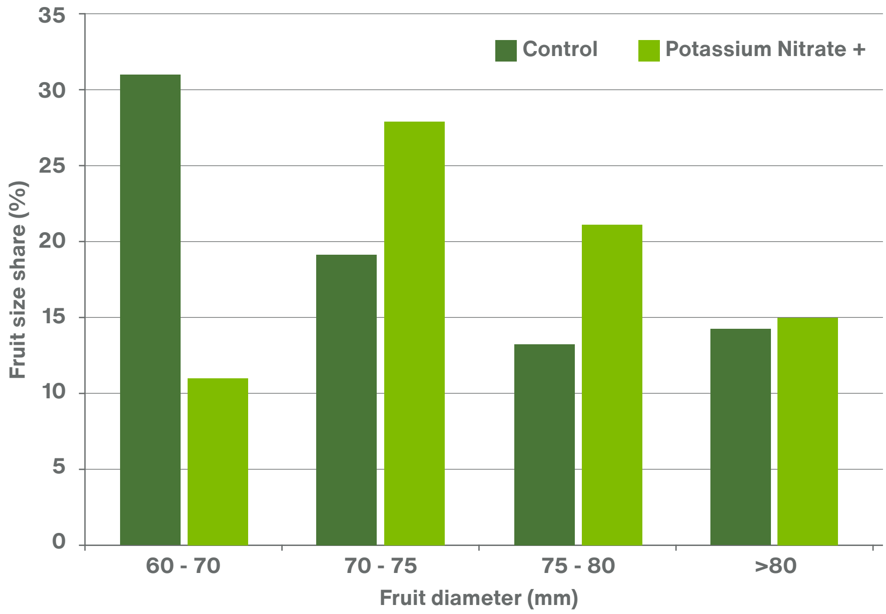

Figure 1. The effect of foliar application of potassium nitrate enriched with soluble phosphate and a special adjuvant on size distribution in 'Newhol' navel orange.

Achilea, O., Y. Soffer, D. Raber and M. Tamim. 2001. "Bonus-NPK" - Highly concentrated, enriched potassium nitrate, an optimal booster for yield and quality of citrus fruits. In: International Symposium on Foliar Nutrition of Perennial Fruit Plants 594: 461-466.

Foliar application of potassium nitrate outperformed potassium phosphate and potassium thiosulphate in mandarin in terms of number of fruits produced per tree.

Foliar *Yield & Quality*

Different potassium forms (potassium nitrate, mono potassium phosphate and potassium thiosulphate (PTS)) and their effect as foliar sprays on "Balady" mandarin trees were studied for two growing seasons. The experiment was done with 13 years old trees budded on sour orange rootstock and spaced at 4x4 meters apart. Trees were grown in sandy soil at Giza, Governorate, Egypt. All K treatments were supported with chelated zinc at 0,5% and sprays were applied on the trees either pre bloom (late May) or post bloom (late July). Treatments were: control (water sprays), KNO_3 at 1%, KNO_3 at 1,5%, MKP at 1%, MKP at 1,5%, PTS at 1% and PTS at 1,5%. The experiment was arranged in a randomized complete block design with three replications.

The obtained results showed that all potassium forms supported with Zn induced a remarked promotion in leaf mineral status. Regarding to the number of fruits, the highest number in both seasons was found with the 1,5% KNO_3 sprays (436 and 441 fruits/tree) this was significantly higher compared with the other treatments. Control treatments recorded on average the lowest number of fruits per tree (380 fruits/tree). In the first season spraying KNO_3 and PTS at 1,5% concentrations significantly increased the yield to 60,6 and 61,3 kg/tree. In the second season only KNO_3 sprays at 1,5% significantly increased the yield to 64,2 kg per tree compared to all other treatments. Lowest yields were observed for the control treatment with 44,0 kg/tree in the first season and 46,5 kg/tree in the second season. All fruit physical characteristics (fruit length, diameter, weight, volume and specific gravity) and fruit chemical characteristics (TSS, acidity, TSS/acidity ratio and vitamin C content) were significantly increased for all treatments compared to the control. Foliar K applications were beneficial for fruit yield and quality of mandarin trees with the highest yields obtained for the 1,5% KNO_3 treatment.

Sarrwy, S. M. A., M.H. El-Sheikh, S.S. Kabeil and A. Shamseldin. 2012. Effect of foliar application of different potassium forms supported by zinc on leaf mineral contents, yield and fruit quality of “Balady” mandrine trees. Middle-East Journal of Scientific Research, 12(4): 490-498.

Cotton

Cotton

Foliar applied potassium nitrate stimulated square development in cotton.

Foliar Yield & Quality

Although the application of foliar KNO_3 has been shown to increase the number of squares, it was uncertain whether this effect was due to the K^+ or the NO_3^-. Therefore a study was conducted in the USA to evaluate the influence of different foliar-applied salts on square development of two cotton varieties that differ in maturity and root morphology. Plants were transferred to a K-free nutrient solution 21 days after planting and one of the following salts, KNO_3, K_2SO_4 or NH_4NO_3 was foliar applied at an equivalent rate of 11,2 kg/ha KNO_3. Control plants were applied with an equivalent volume of water without nutrients. The experiment was conducted in a randomized complete block design with three replications. The foliar treatment of KNO_3 increased the number of squares by 31% compared to the control, 29% compared to K_2SO_4 and 49% compared to NH_4NO_3 (Figure 1). This finding suggests that K^+, not NO_3^- is responsible for the improved square development with foliar-applied KNO_3. Application of KNO_3 several days before square development resulted in increased square number if K is limiting. Potassium nitrate outperformed other salts in foliar application where a response to K is desired.

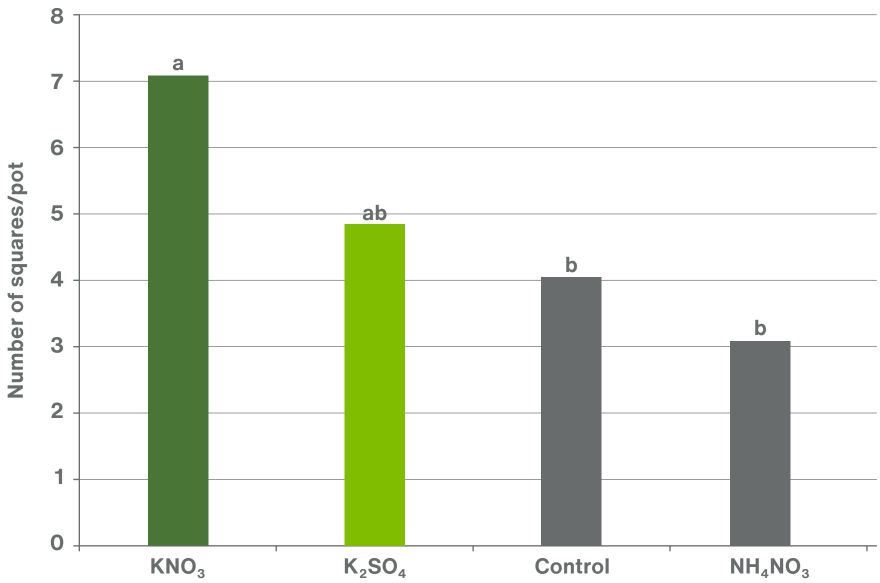

Figure 1. Effect of foliar treatments on square formation in cotton. Means followed by the same letter are not significantly different at P=0,05 using protected LSD.

Keino, J. K., C.A. Beyrouty, E.E. Gbur, and D.M. Oosterhuis. 1997. Effect of foliar-applied nutrients on square development of cotton. Special Reports-University of Arkansas Agricultural Experiment Station, 183: 108-111.

Potassium nitrate sprays gave the highest net return in cotton compared to urea and potassium chloride.

Foliar *Yield & Quality*

In India a field experiment was conducted with upland cotton (Gossypium hirsutum L.) at Ludhiana for 4 years to study the effect of foliar nutrition as a supplement to soil-applied nutrients on cotton. The study was performed on a course loamy, non-calcareous soil, low in organic carbon and medium in available P and K. Treatments consisted of the control (soil-applied fertilizer) and 4 supplemental sprays each of 2% potassium nitrate, 2% urea and 2% potassium chloride at weekly intervals, starting from flower initiation. Average data of 4 years showed that seed-cotton yield increased with 36,3% for potassium nitrate, 27,2% for urea and 22,4% for potassium chloride compared to the untreated control (Table 1). Also the number of flowers and bolls/plant increased the most for potassium nitrate. With respect to net return potassium nitrate was most profitable and outperformed urea and potassium chloride (Figure 1).

Table 1. The effect of foliar sprays compared to the untreated control.

Treatments	No. of sprays and conc. (%)	Increase in no. of flowers/plant	Increase in no. of bolls/plant	Seed cotton yield (kg/ha)
Control				1.443
KNO_3	4 * 2%	43%	39%	1.967
Urea	4 * 2%	38%	33%	1.836
KCl	4 * 2%	42%	19%	1.766

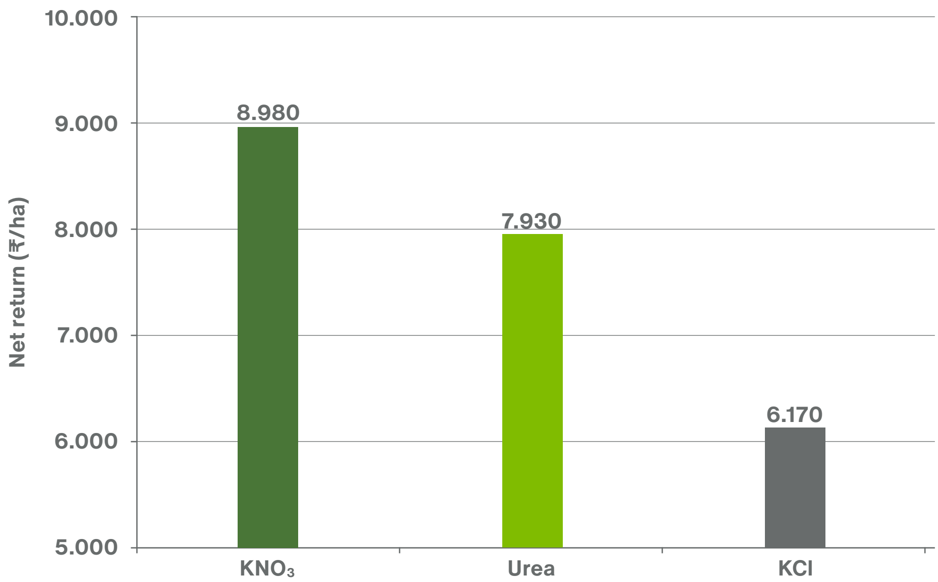

Figure 1. The effect of foliar applications on the net return (₹/ha) for cotton.

Brar, M.S. and A.S. Brar. 2004. Foliar nutrition as a supplement to soil fertilizer application to increase the yield of upland cotton. Indian J agric Sci 74: 472-475

Increased yield levels with foliar-applied potassium nitrate in cotton.

Foliar *Yield & Quality*

The study was initiated to evaluate cotton (Gossypium hirsutum L.) responses to soil- and foliar-applied K for conventional-tillage (CT) and no tillage (NT) production systems in Tennessee, USA. The soil was described as a Memphis silt loam soil, low in Mehlich-1 extractable K. Potassium rates of 0, 34, 67 and 134 kg K_2O/ha were soil applied to the plots each year. Foliar treatments included: no-foliar K, KNO_3, and $Ca(NO_3)_2$. Potassium nitrate was applied at 4,9 kg K_2O/ha/application and $Ca(NO_3)_2$ was applied at 1,6 kg N/ha per application, equivalent to N from KNO_3. Foliar treatments were applied at bloom or 2 weeks after bloom and on either a 9 or 14 days interval for a total of four applications. All foliar treatments were applied in 93,5 L water/ha. A split plot arrangement of treatments in a randomized complete block design was used with five replications per treatment.

Regression equations expressing yield as a function of K_2O rate were developed for KNO_3 and no-foliar K treatments each year for both tillage systems. Yields in both tillage systems were increased by soil and foliar applied K. In 1991 and 1992, the foliar KNO_3 treatment increased yields at all soil K_2O rates. In 1993, foliar KNO_3 increased yields at soil K_2O rates up to 105 kg K_2O/ha in CT and up to 115 kg K_2O/ha in NT. In addition, foliar KNO_3 increased yields at soil K_2O rates up to 121 kg K_2O/ha for the 1994 NT cotton. Based on the results foliar K may be expected to increase yields on medium and low testing soils, even if fertilized with 134 kg K_2O/ha.

Howard, D. D., C.O. Gwathmey, R.K. Roberts and G.M. Lessman. 1998. Potassium fertilization of cotton produced on a low K soil with contrasting tillage systems. Journal of production agriculture, 11(1), 74-79.

Foliar -applied potassium nitrate on cotton is a profitable supplement to soil-applied K on low K testing soils.

Foliar *Yield & Quality*

The study was initiated to evaluate cotton (Gossypium hirsutum L.) responses to soil- and foliar-applied K for conventional-tillage (CT) and no tillage (NT) production systems in Tennessee, USA. The soil was described as a Memphis silt loam soil, low in Mehlich-1 extractable K. Potassium chloride was soil applied at potassium rates of 0, 34, 67 and 134 kg K_2O/ha to the plots each year. Foliar fertilization provided 44,8 kg/ha KNO_3 in four applications of 11,2 kg/ha each. Foliar treatments were applied shortly after bloom on either a 9 or 14 days interval. Similarly, the foliar calcium nitrate treatment provided 40,3 kg/ha $Ca(NO_3)_2$ in four applications of 10 kg/ha, each applied at a rate equal to nitrogen in the foliar KNO_3 treatment. All foliar treatments were applied in 93,5 L water/ha.

Regression equations expressing yield as a function of K_2O rate were developed for KNO_3 and no-foliar K treatments each year for both tillage systems. Both for conventional and no-tillage cotton lint yield response models the KNO_3 foliar treatment had increased yield levels compared to the $Ca(NO_3)_2$ and the control treatments at all five K levels applied to the soil. Economic analysis suggested that foliar KNO_3 on this low K soil in Tennessee provided higher net revenues per hectare than the control, even when relatively high rates of K were applied to the soil for up to two years.

Roberts, R.K., D.C. Gerloff and D.D. Howard. 1997. Foliar Potassium on Cotton – A Profitable Supplement to Broadcast Potassium Application on Low Testing Soils. Better Crops/Vol. 81 (No. 1): 20-23.

Late season potassium deficiency in cotton prevented by foliar-applied potassium nitrate.

Foliar *Yield & Quality*

In some cotton fields in Brazil and abroad potassium deficiencies developing late in the season have been observed. Therefore two years experiments were conducted to study the effects of timing and rates of KNO_3 sprays on leaf K content, yields and fiber quality in sites with different yield potentials for cotton (Gossypium hirsutum L.). The experiments were developed in Pederneiras and Boracéia, SP, Brazil. In the first two experiments 16 or 32 kg KNO_3 per hectare was applied at a dose rate of 8 kg/ha per spray. So 16 kg equals 2 sprays and 32 kg equals 4 sprays, spraying started at different moments after start of flowering but always repeated at weekly intervals. In the other experiment KNO_3 was applied at 32 kg/ha and split in four equal sprays of 8 kg/ha at weekly intervals starting moment different from the first to the fourth week after the beginning of flowering. The decrease observed in K contents of cotton leaves was considered a natural process and was not reversed by K application. Foliar fertilization with KNO_3 increased the K contents in the leaves in some conditions, as in cotton plants deficient in K. However, this did not affect K contents in the cotton fruits, cotton yields and fiber quality.

Rosolem, C. A. and J.P.T. Witacker. 2007. Adubação foliar com nitrato de potássio em algodoeiro. Bragantia, 66(1): 147-155.

Increased cotton lint yield with foliar potassium nitrate applications.

Foliar *Yield & Quality*

This experiment in cotton cv. DPL-50 was conducted at the Tidewater Agricultural Research and Extension Center, Virginia, USA on a coarse-loamy soil for 3 years. In one experiment the effect of foliar K applications on cotton yield was investigated. Foliar sprays were applied every two/three weeks or weekly starting from first bloom. KNO_3 was the K source for foliar treatments and KCl was applied to the soil at the recommended rate of 56 kg K_2O/ha. KNO_3 was sprayed at 2,24, 4,48 and 6,72 kg/ha with a carbon dioxide hand-driven sprayer at a rate of 15,3 L/ha. Even though foliar treatments at two to three weeks interval did not increase yield significantly, a slight increase was observed. Foliar KNO_3 applied at five to seven days interval resulted in significant lint yield increase compared to the untreated plots. A 20% increase in lint yield was observed (196 kg/ha). The higher lint yield for a combination of soil and foliar applied K indicates the importance of plant available K during cotton boll development. As the author explained, the KNO_3 rates applied were lower than in previous trials with foliar-applied potassium nitrate at a rate of 11,2 kg/ha. This can explain a lack of consistent response to foliar treatments in this trial.

Abaye, A.O. 1998. Effect of method and time of potassium application on cotton lint yield. Better crops, 82: 25-27.

Potassium nitrate sprays gave the highest seed cotton yield increase of 36% compared to urea and potassium chloride.

Foliar *Yield & Quality*

In India the benefits of foliar-applied K and N-sources were examined in 4 years of field experimentation. The foliar K and N-sources were applied in addition to the recommended rates of basal N and P of 75 kg N plus 30 kg P_2O_5/ha (and 0 kg K_2O/ha). Three mid-season foliar KNO_3 applications, spaced at weekly intervals, were applied. The experimental plots were unable to meet the high daily N and K requirements during flowering and boll development, the foliar products were all effective but KNO_3 gave the highest yield increase of 36% (Table 1).

Table 1. The effect of foliar sprays on the average seed cotton yield in 4 years compared to control treatment.

Treatments	No. of sprays and conc. (%)	Yield (kg/ha)	Av. seed cotton yield increase
Control		1470	
KNO_3	3 * 2%	2000	530 kg/ha (+36%)
Urea	3 * 2%	1867	397 kg/ha (+27%)
KCl	3 * 2%	1793	323 kg/ha (+22%)

Brar, M.S. and K.N. Tiwari. 2004. Boosting Seed Cotton Yields in Punjab with Potassium: A Review. Better Crops/Vol. 88 (No. 3): 28-31.

Four potassium nitrate sprays at 2% concentration increased seed cotton yield with 11%.

Foliar *Yield & Quality*

Bt cotton hybrids may require additional supply of fertilizers, due to increased fruit retention in these crops. In 2006, field experiments with various soil applied N, P and K fertilizer combinations, applied according to local practices, were tested in combination with 4 foliar sprays of 2% potassium nitrate, on 18 locations, in 5 districts in Punjab, northern India. Foliar sprays were applied at weekly intervals, starting from flower initiation.

This study showed cotton yield increases of 11% with foliar potassium nitrate sprays (Figure 1), which resulted in a net increased farmer's income. This yield increase was found to be irrespective of the soil K status and addition of K fertilizer through soil application. Deducting the costs of the foliar fertilizer product from the gross income, resulted in a benefit to cost (B:C) ratio of over 10,4 to 1.

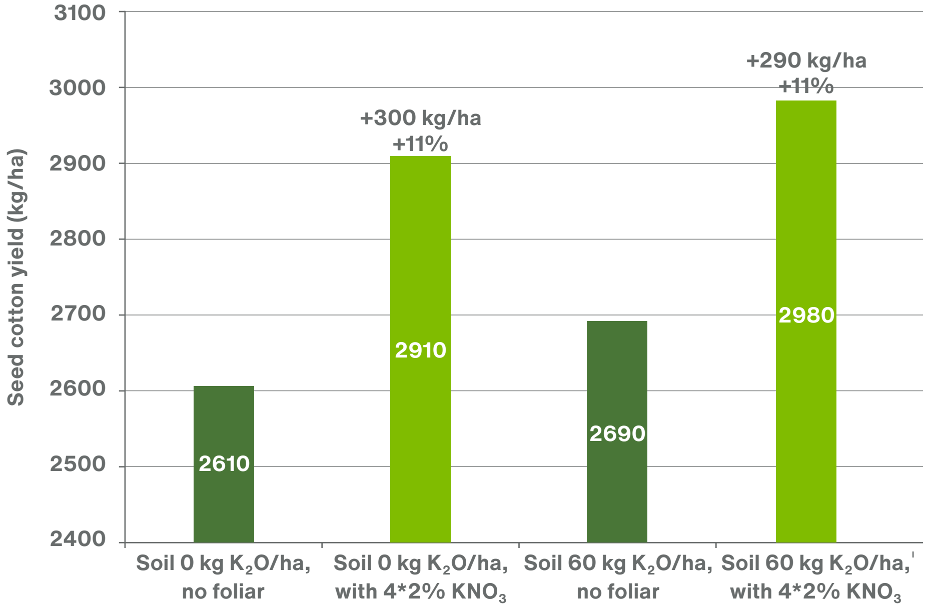

Figure 1. Average effect of soil K and foliar K application in cotton.

Brar, M.S., M.S. Gill, K.S. Sekhon, B.S. Sidhu, P. Sharma and A. Singh. 2008. Effect of soil and foliar application of nutrients on yield and nutrient concentration in BT cotton. J. Res. Punjab Agric Univ 45 (3&4): 126-131.

Four sprays of 8 kg potassium nitrate per hectare resulted in maximum seed cotton yield.

Foliar *Yield & Quality*

The aim of the study was to evaluate the effect of combined soil and foliar spray potassium doses on seed cotton yield and quality of cotton fiber, in southeastern Goiás State, Brazil. Seed cotton yield gains were observed for potassium applied both through soil (as KCl) and foliar spraying (as KNO_3), without interactions between modes of application. With four foliar potassium nitrate sprays at 10 days interval, a maximum of 5% (200 kg yield per ha) seed cotton yield increase was reached with 8 kg KNO_3 per spray (Figure 1). There were no effects of doses and mode of application on cotton fiber quality, in the cultivar Delta Opal tested.

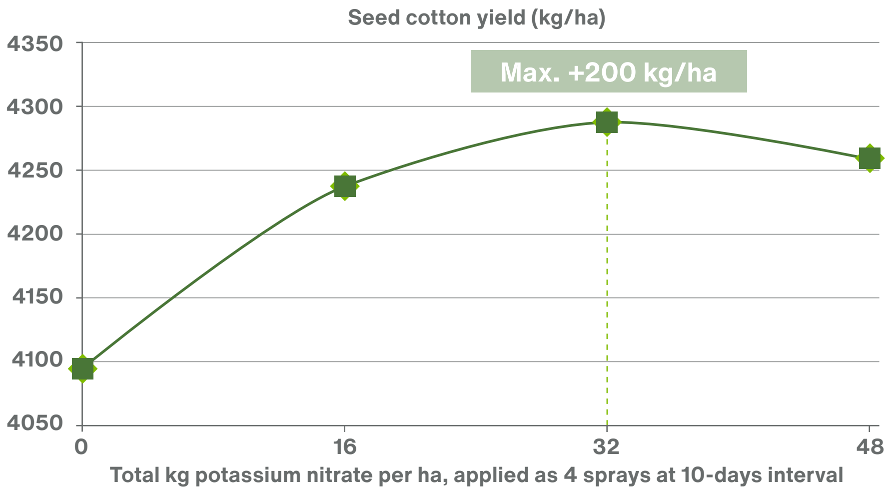

Figure 1. The effect of increasing potassium nitrate dose rates on seed cotton yield.

De Freitas, R.J., W. M. Leandro and M.C.S. Carvalho. 2007. Efeito da adubação potássica via solo e foliar sobre a produção e a qualidade da fibra em algodoeiro (Gossypium hirsutum l.). (Effect of soil and foliar potassium application on yield and fiber quality in cotton (Gossypium hirsutum L.). Pesq Agropec Trop 37 (2): 106-112.

Combined spray of potassium nitrate and boron in cotton gave the greatest yield increase with 13%.

Foliar *Yield & Quality*

The yield response in cotton to foliar K was obtained in three experiments which included various K sources, pH buffering of the K solution, and the addition of boron to the soil or the foliar K sprays. Out of the four K sources tested, KNO_3 gave the greatest yield increase with 13% compared to the control, while other K sources showed yield increases of 8 to 9% with four applications of 4,1 kg K/ha.

All boron treatments improved lint yield, but best result was found for the foliar applied B plus K application (Table 1). Foliar B and KNO_3 were applied in 93,5 liter of water/hectare at early flower or 2 weeks after, and repeated at 9-14 day interval between the four applications.

Table 1. Effect of boron applied to the soil and via foliar (average of 3 years) on the lint yield in cotton.

Treatments	Dose per application kg B/ha	Total applied kg B/ha	Lint yield kg/ha	Relative yield %
Control	-	-	1093	100
B foliar	0,11	0,45	1176	108
B foliar	0,22	0,90	1110	102
B soil	0,56	0,56	1164	106
B Foliar + 11,2 kg KNO_3/ha	0,11	0,45	1237	113

Howard, D.D., C.O. Gwathmey, and C.E. Sams. 1998. Foliar feeding of cotton: Evaluating potassium sources, potassium solution buffering, and boron. Agron. J. 90: 740-746.

Potassium nitrate proved to be the preferred foliar K-source in cotton.

Foliar *K-sources*

Five sources of potassium for foliar fertilization were compared in this study. Dose rates of N and K applied were equivalent to 11,2 kg KNO_3/ha in 93 liters of solution/ha. For the control and other treatments than KNO_3 1,5 kg N/ha as urea was applied to equal the N rate supplied by the KNO_3 treatment. In total 5 sprays were applied at 2, 4, 6, 7 and 8 weeks after the start of flowering. The KNO_3 treatment resulted in the greatest lint yield (Figure 1).

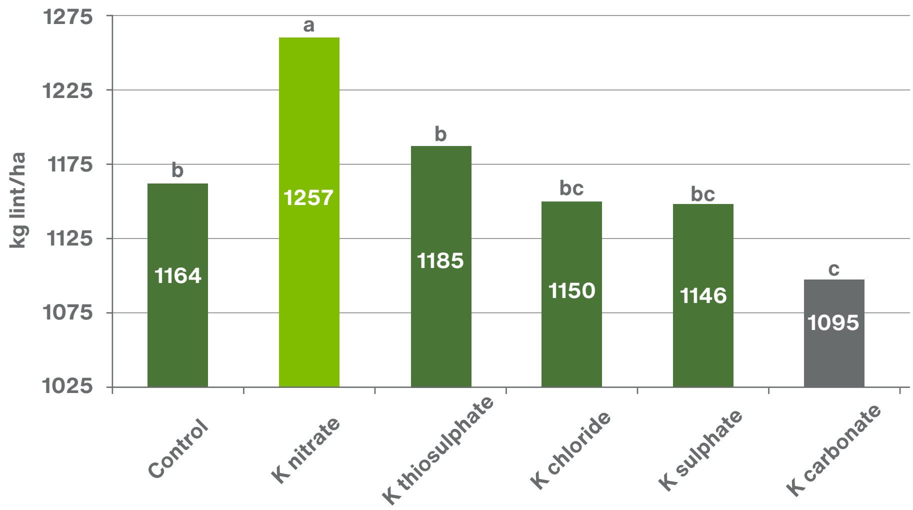

Figure 1. Effect of foliar applications of five K sources on cotton yield (kg lint/ha).

Miley, W.N., D.M. Oosterhuis, and L.D. Janes. 1994. Effects of foliar application of five potassium fertilizers on cotton yield and quality. Arkansas Soil Fertility Studies 1993. Arkansas Agri. Exp. Sta. Research Series 436: 62-66.

Potassium nitrate + adjuvant sprays enhanced cotton yield and farmers net income.

Foliar *Yield & Quality*

The objective of this study was to determine if applying an adjuvant with foliar potassium nitrate on medium-to-high-K soils is economically beneficial to cotton producers. Experiments were conducted on no-tillage cotton produced on a high-K silt loam soil at Jackson (TN), USA, and on conventional- and no-tillage cotton produced on a medium-K silt loam soil at Milan (TN), USA. Treatments for each experiment were a non-foliar check (control), a foliar KNO_3 treatment, and a foliar KNO_3 plus adjuvant treatment. The use of adjuvants may promote absorption of foliar-applied nutrients into leaves compared with solutions without adjuvants, reducing nutrient loss and enhancing yield. KNO_3 foliar treatments were applied four times at 11,2 kg/ha in 94 litres/ha of water starting at flowering to 14 days after flowering on a 9-to-14-day interval. The adjuvant ‘Penetrator Plus’ was added to the foliar solutions at 1,25% (v/v). ‘Penetrator Plus’ is a light to mid-range paraffin oil, polyol fatty acid esters, polyethoxylated esters of polyol fatty acids, and ethoxylated allkylarly phosphate ester, buffering crop oil concentrate, manufactured by Helena Chemical Co. of Memphis (TN), USA.

The mean cotton lint yield statistically significantly increased on the medium-to-high K soils in Milan and Jackson for the foliar KNO_3 plus adjuvant treatment (Figure 1). The results suggest that farmers producing cotton on these medium-to-high-K soils who are already applying foliar KNO_3 can increase their net revenue substantially by adding the adjuvant ‘Penetrator Plus’ to this foliar fertilizer. On the other hand, comparing the foliar KNO_3 treatment with the check on these medium-to-high-K soils was not beneficial. The unprofitability of foliar KNO_3 compared with the control was not surprising given the medium-to-high levels of extractable K in the soils for this experiment.

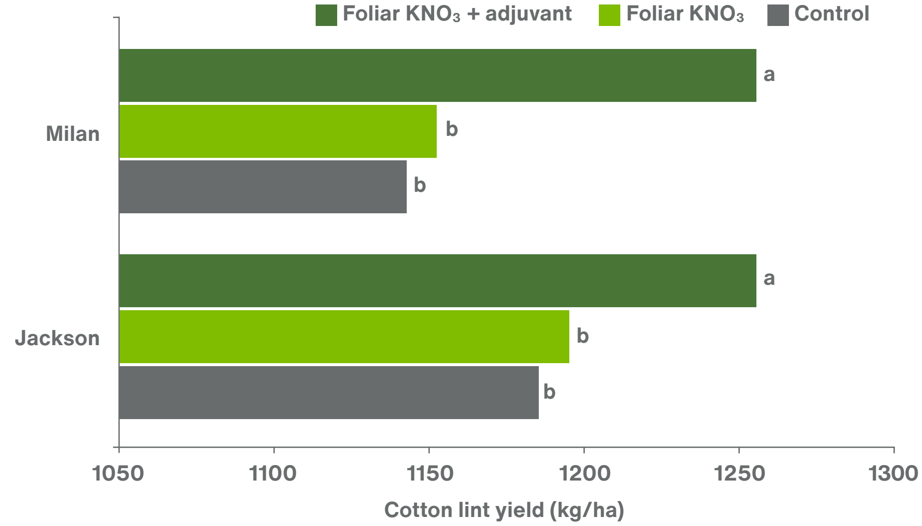

Figure 1. The overall mean for no tillage cotton lint yield at Milan and Jackson.

Roberts, R.K., J.M. Gersman and D.D. Howard. 1999. Economics of using an adjuvant with foliar potassium nitrate (KNO_3) on cotton. The Journal of Cotton Science, 3: 116-121.

Foliar applied potassium nitrate beneficial in terms of cotton seed yield and lint yield.

Foliar *Yield & Quality*

This study was performed to evaluate the response of cotton (Gossypium hirsutum L.) yield and yield characteristics to foliar K at three silty loam field locations in Arkansas (USA) from 1999 through 2002. The Mehlich-3 extractable (1:7) soil test values for these three locations ranged from 270 to 376 kg K ha^{-1}, which is considered to be in the high range for cotton production in Arkanses. Foliar KNO_3 was applied at 11,2 kg KNO_3 ha^{-1} for four consecutive weeks starting one week after first flowering with a pressurized CO_2 backpack sprayer calibrated to deliver 93,5 L ha^{-1}. The foliar potassium nitrate treatment had a statistically significant effect on the number of seeds per hectare. Foliar KNO_3 increased the number of seeds ha^{-1} by 13% compared to the untreated control. Across the five site years, foliar K numerically increased lint yield by only 4% (1285 vs. 1337 kg/ha), with a majority (171 kg) of this increase occurring at one site year (Table 1). Foliar KNO_3 applications did not increase yields when sufficient K is available to the plant in the root zone. The authors recommend further study of interactive effects of water-deficit stress and foliar-applied K on the yield of cotton grown where soil residual K levels range from low to medium.

Table 1. Effect of foliar applied potassium nitrate on cotton lint yield.

Treatments	Cotton lint yield (kg/ha)					
	1999	2000	2000	2001	2002	Mean
Control	1261	1238	1027	1482	1413	1285
Foliar KNO_3	1280	1225	1086	1512	1584 a	1337 b

a: significant at P<0,05 for the paired treatments.
b: denotes treatment interaction significant at P<0,05.

Coker, D. L., D.M. Oosterhuis, and R. S. Brown. 2009. Cotton yield response to soil-and foliar-applied potassium as influenced by irrigation. Journal of Cotton Science, 13: 1-10.

Spraying surfactants in combination with potassium nitrate enhanced cotton lint yield.

Foliar *Yield & Quality*

A trial was conducted at West Tennessee (USA) in 1991 to evaluate the effects of foliar applied potassium nitrate with and without surfactants on cotton (Gossypium hirsutum L.) lint yield and K concentrations in the leaf and petiole. Cotton plants were grown on a silty loam soil and plots received a base dressing according to recommended farm practices. The experiment was set up as a randomized complete block design. Foliar treatments included an untreated control, 10,8 kg KNO_3/ha + water, 10,8 kg KNO_3/ha + 'Penetrator Plus', 10,8 kg KNO_3/ha + 'X-77', 5,3 kg KNO_3/ha + 'Penetrator Plus', and 5,3 kg KNO_3/ha + 'X-77'. Foliar sprays were supplied at 94 L/ha and the surfactants were added to the solutions at: 1,25% (v/v) for Penetrator Plus and 0,5% (v/v) for X-77. The foliar sprays were applied 4 times: at two, four, six and eight weeks after mid-bloom in the first three years. In the fourth year (1994) the first spray was applied at mid-bloom, the second 2 weeks later and the third and fourth spray were applied 9 and 18 days after the second spray.

Increases in leaf and petioles K concentrations mostly occurred from the 10,8 kg KNO_3 treatments applied with a surfactant. Seven days after foliar applications the K concentrations of the leaves and petioles were increased by respectively 11% and 6% compared to the untreated control. First harvest lint yields were generally unaffected by foliar treatments. Second harvest and total yields were increased by applying the 10,8 kg KNO_3/ha with Penetrator Plus relative to the other treatments. Total cotton lint yield for the 10,8 kg KNO_3/ha with Penetrator Plus treatment statistically significantly increased by 10% compared to the untreated control (Figure 1). No additional yield increase was observed when 'X-77' was added. These results suggest that spraying surfactants in combination with KNO_3 may enhance K uptake and cotton yield.

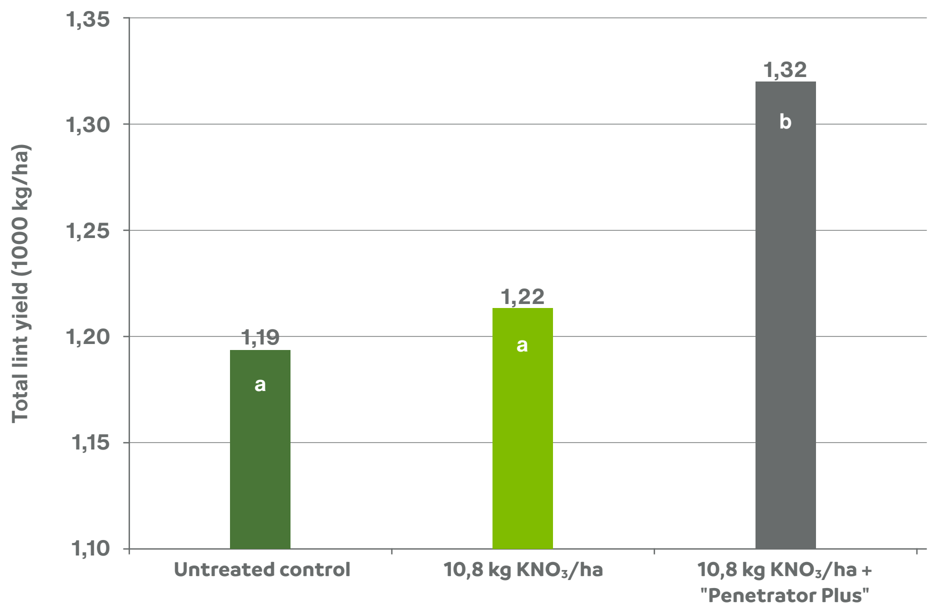

Figure 1. Total lint yield (two harvests per year; four-year averages).

Howard, D. D. and C.O. Gwathmey. 1995. Influence of surfactants on potassium uptake and yield response of cotton to foliar potassium nitrate. Journal of plant nutrition, 18(12): 2669-2680.

Foliar potassium nitrate application increased yield, yield components and lint quality of cotton.

Foliar *Yield & Quality*

A field experiment was conducted to evaluate the effect of potassium nitrate on yield and fiber quality of cotton (Gossypium hirsutum L.). The experiment was laid out in a randomized complete block design with split plot arrangement and three replications at the University of Agriculture in Faisalabad, Pakistan. In one block, only one KNO_3 spray at 0,5%, 1,0%, 1,5% or 2,0% was applied during flowering and in the other block three foliar sprays were applied: first at flowering, second and third at 14 days interval. Together with the four different levels of potassium nitrate (0,5%, 1,0%, 1,5%, 2,0%) a control (no spray) and a water spray were used as treatments.

The treatment with three potassium nitrate sprays showed a statistically significant higher number of bolls (61,2) compared to one KNO_3 spray (54,1). The maximum number of bolls and yield per plant was obtained when 2% potassium nitrate was sprayed, followed by 1,5% potassium nitrate (Table 1). Maximum values of fibre length, fibre strength and fibre uniformity were observed when 2% KNO_3 was sprayed. The effect of time of sprays was non-significant in its effect on fibre quality parameters. The 2% KNO_3 spray statistically significantly outperformed all the other treatments in terms of fibre length (Figure 1).

Table 1. The average effect of number of sprays and concentrations of foliar potassium nitrate application on seed cotton yield and its components.

Treatments	Number of bolls	Boll weight (g)	Yield /plant (g)
Number of sprays			
1	54,1 b	3,31	168
3	61,2 a	3,24	201
Concentrations of KNO_3 sprayed			
Control	42,0 f	2,97 d	124 e
Water	50,0 e	3,02 d	151 d
0,5% KNO_3	56,5 d	3,21 c	181 c
1,0% KNO_3	61,8 c	3,37 b	208 b
1,5% KNO_3	66,1 b	3,57 a	235 a
2,0% KNO_3	69,6 a	3,53 ab	246 a
Interaction			
CxN	Significant	NS	Significant
Data within columns followed by different letters are significantly different at P<0,05.			

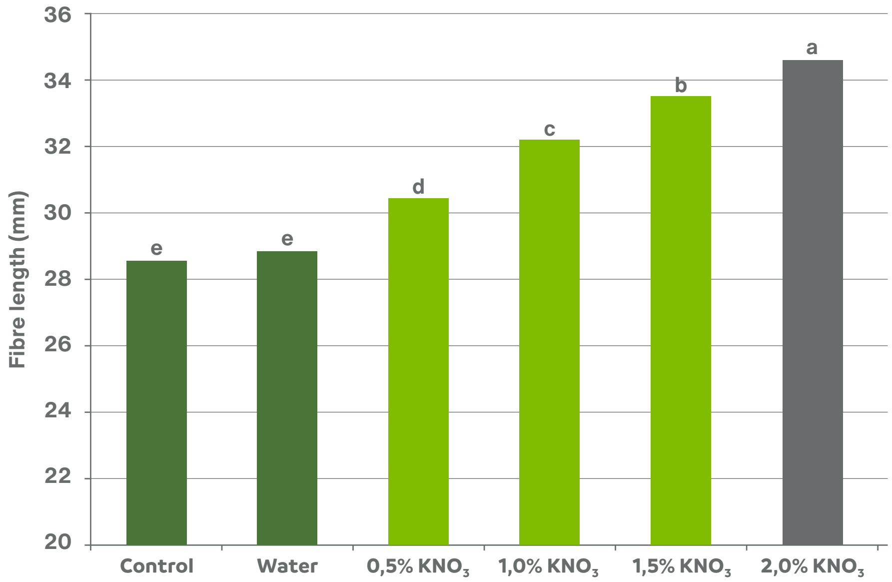

Figure 1. The effect of foliar treatments on fibre length of cotton.

Waraich, E.A., R. Ahmad, R.G.M. Hur, Ehsanulluh, A. Ahmad and N. Mahmood. 2011. Response of foliar application of KNO_3 on yield, yield components and lint quality of cotton (Gossypium hirsutum L.). African Journal of Agricultural Research, 6(24): 5457-5463.

Foliar potassium nitrate application increased cotton yield and quality parameters.

Foliar *Yield & Quality*

In a study in Argentina 9 kg KNO_3/ha/spray was applied two or three times, at a weekly interval, starting at first flower appearance. Both foliar treatments increased significantly lint yield, lint percentage, micronaire and fibre length (Tables 1 and 2), when compared to the untreated control plot. On the parameters tested, there was no statistically significant difference between the numbers of KNO_3 sprays (i.e. 2 or 3 sprays) applied.

Table 1. The effect of foliar applied potassium nitrate dose rates on lint yield, fertilizer use efficiency, % lint and the seed index.

Treatments	Lint yield	Lint yield increase	Fertilizer use efficiency	Lint	Seed index
	kg/ha	kg/ha (%)	kg yield/ kg foliar	%	g/100 seeds
Control	1122 b	0	-	37,4 b	10,2 a
2*9 kg KNO_3/ha	1451 a	329 (+29%)	18,3	38,6 a	10,4 a
3*9 kg KNO_3/ha	1483 a	361 (+32%)	13,4	38,8 a	10,5 a
LSD (0,05)	218,2			0,7	0,7
CV(%)	5,74			4,1	4

Table 2. The effect of foliar applied potassium nitrate dose rates on micronaire, fibre length, length uniformity and fibre strength.

Treatments	Micronaire	Fibre length	Length uniformity	Fibre strength
		mm	%	g per tex*
Control	4,3 b	28,1 b	82,6 a	27,4 a
2*9 kg KNO_3/ha	4,7 a	28,5 a	82,4 a	27,7 a
3*9 kg KNO_3/ha	4,7 a	28,5 a	82,5 a	27,7 a
LSD (0,05)	0,3	0,3	0,5	1
CV(%)	4,72	1,15	0,34	2,09

* a tex unit is equal to the weight in grams of 1000 meters of fibre

Mondino, M. and L. Araujo. 2011. Fertilización foliar con nitrato de potasio para mejorar la cantidad y calidad de fibra del algodón en surcos estrechos a 0,52 m. CONGRESSO BRASILEIRO DE ALGODÃO, 8.; COTTON EXPO, 1., 2011, São Paulo. Evolução da cadeia para construção de um setor forte: Anais. Campina Grande, PB: Embrapa Algodão, 2011. p.1863-1871. (CD-ROM)

Foliar applied potassium nitrate supported cotton boll development, even in K-sufficient soils.

Foliar *Yield & Quality*

Earlier-maturing, faster-fruiting, higher-yielding, modern cotton varieties have a relatively high need for potassium in a relatively short period from flower initiation to boll maturation. During this peak demand, the limited root system is not capable of absorbing the required amount of potassium for boll development, not even in soils well-fed with potassium. Foliar -applied K, as with potassium nitrate, offers the opportunity of correcting K-deficiency more quickly and efficiently.

Oosterhuis, D., K. Hake and C. Burmester. 1991. Foliar feeding cotton. Physiology Today (2): 1-8.

Foliar fertilisation of potassium nitrate increased cotton lint yield.

Foliar *Yield & Quality*

The effect of foliar applied KNO_3, compared to soil applied KCl, on cotton yield was evaluated in a three year Beltwide study. The yields were averaged over sites for foliar potassium studies in 12 Cotton Belt states in the USA. In the low soil K treatments potassium was applied as KCl according to preplant soil tests and for the high soil K treatments this recommended dose was doubled. Foliar rate was 11,2 kg/ha/spray of KNO_3 applied four times at 10 to 14 days interval after first flower. All treatments showed yield increases compared to the control (Figure 1).

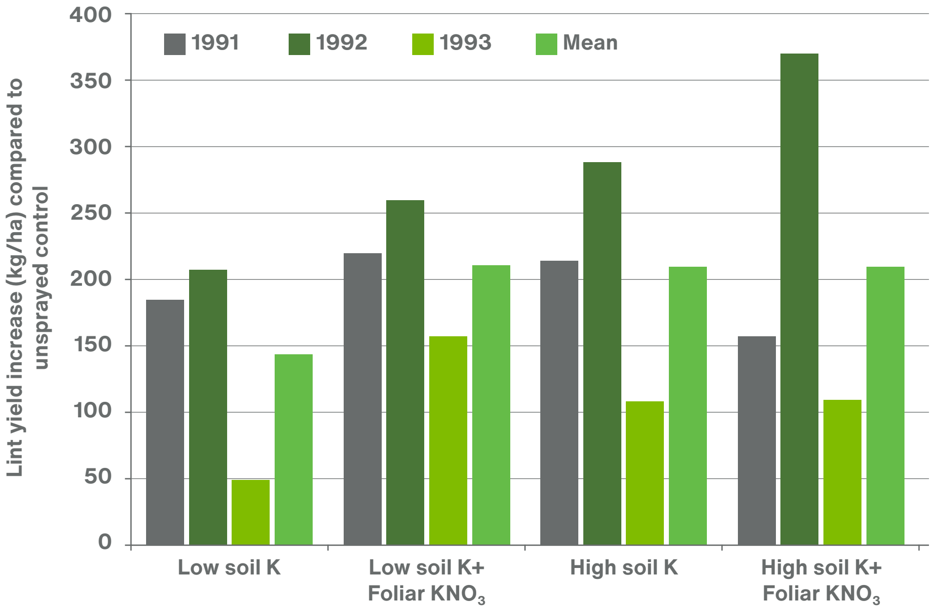

Figure 1. Mean cotton yield increases averaged over 12 Cotton Belt states.

Oosterhuis, D.M. 1994. Foliar fertilization of K on cotton shows potential. Fluid Journal. Summer 1994. P. 1-2.

Foliar applied potassium nitrate increased cotton lint yield.

Foliar *Yield & Quality*

Over a period of 5 years, the cotton lint yield increased by foliar applied potassium in California, USA. Greatest increases in lint yield were observed from applications beginning two weeks after first bloom. A typical lint yield response curve of K foliar materials (such as potassium nitrate) is found in Figure 1, applied in a single spray of 5 kg K_2O/ha (11 kg potassium nitrate/ha), to cotton after first bloom, grown in the San Joaquin Valley, California, USA. Up to 135 kg extra cotton lint yield per hectare (+11%) can be observed.

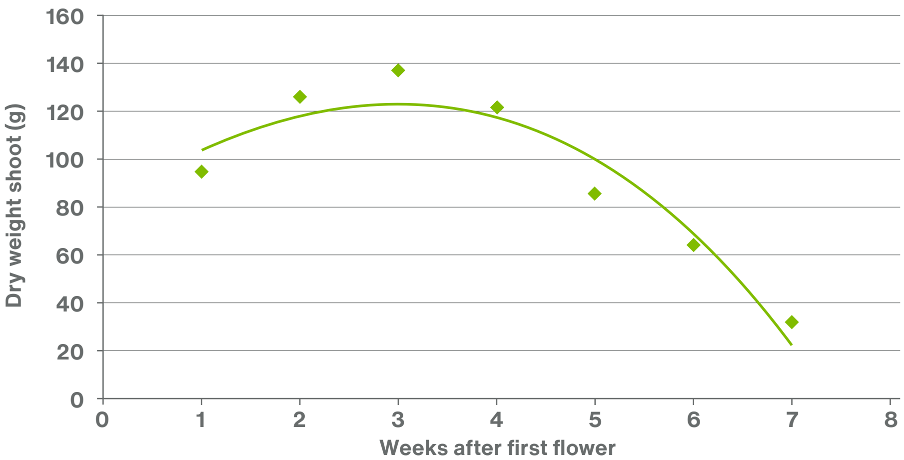

Figure 1. Typical response curve of K foliar materials applied to cotton after first bloom, Weir, University of California.

Weir, B. 1998. Foliar potassium bumps cotton yields. Fluid Journal. Fall 1998. p. 1-2.

Foliar applied potassium nitrate suppressed alternaria leaf blight in cotton.

Foliar *Pest & disease reduction*

In a trial in Australia, 13 kg KNO_3 per ha per spray was applied four times in a cotton crop and compared with the control. The first application was 7 days before flowering and the three applications after flowering were carried out at two-weekly intervals. The sprays significantly ($P<0,05$) reduced the mean disease incidence, disease severity and leaf shedding assessed (Table 1). Foliar application of KNO_3 may be effective in reducing the effect of Alternaria leaf blight of cotton (Gossypium hirsutum) in north Australia.

Table 1. Mean incidence, severity and number of leaves shed due to Alternaria leaf blight of cotton at Katharine Res. Station 2004.

Treatments	Incidence (%)	Severity (0-20)	No. of leaves shed from main stem
KNO_3	90,94	9,13	2,39
Control	92,34	9,84	2,72
Prob. (n=145)	P=0,048	P<0,001	P<0,001

Bhuiyan, S.A., M. C. Boyd, A. J. Dougall, C. Martin and M. Hearnden. 2007. Effects of foliar application of potassium nitrate on suppression of Alternaria leaf blight of cotton (Gossypium hirsutum) in northern Australia. Australasian Plant Pathology 36: 462–465.

Cucumber

Cucumber

Foliar application of potassium nitrate outperformed calcium nitrate with higher increase in fruit weight and cucumber yield.

Foliar *Yield & Quality*

A field trial was conducted in a plastic greenhouse at the National Research Centre in North Egypt, and repeated during two successive seasons in 2011 and 2012. The study aimed to determine the effect of supplemental foliar application with either potassium nitrate or calcium nitrate on growth, yield and quality of cucumber. Transplants of the cucumber hybrid cultivar 'Pracodo' were transplanted to a sandy soil with pH of 8,2 in the third week of December in both seasons and watered by drip irrigation. Five foliar treatments were tested: control (distilled water spray), 10 and 15 mM calcium nitrate, and 10 and 15 mM potassium nitrate. Foliar sprays were applied three times with a hand-held sprayer, starting 20 days after transplant and repeated on a 15 days interval. Plants were sprayed till the point of complete wetting at each application.

All treatments increased vegetative growth expressed as plant length, number of leaves per plant and leaf area compared to the control. However, only the foliar applications with higher concentrations (15 mM) of both compounds resulted in statistically significant differences (LSD at 5% level). Foliar application with 15 mM KNO_3 increased the number of flowers per plant (55,8) and percentage fruit set (46,6%) compared to the control (47,9 flowers/plant and 40,8% fruit set). Also the highest and statistically significant amounts of N, P, K and Ca were found in the tissues of cucumber plants treated with three foliar applications of 15 mM KNO_3 followed in descending order by spray of 10 mM KNO_3 and both concentrations of calcium nitrate. All foliar treatments significantly enhanced cucumber productivity measured in number of fruits per plant, average fruit weight and total yield of fruits per plant (Table 1). Foliar spray with potassium nitrate at both concentrations was more effective than foliar spray with calcium nitrate. Additionally, KNO_3 sprayed at both concentrations resulted in the highest increase of percent total soluble sugars (TSS) and percentage dry matter of cucumber fruits. The highest fruit yield and best growth vigor of the cucumber plants treated with 15 mM KNO_3 foliar spray may be explained by the observed highest uptake of the elements N, P, K and Ca by these plants.

Table 1. Effect of calcium nitrate and potassium nitrate sprays on number of fruits, average fruit weight and total yield of cucumber plants. Means followed by the same letter are not significantly different (LSD, 5%)

Treatments	Number of fruits/plant	Average fruit weight (g)	Total yield (kg/plant)
Control	17,6 a	101,6 a	1,9 a
10 mM $Ca(NO_3)_2$	19,3 ab	104,1 a	2,0 a
15 mM $Ca(NO_3)_2$	21,0 bc	104,5 a	2,1 ab
10 mM KNO_3	21,9 bc	116,9 b	2,5 bc
15 mM KNO_3	23,3 c	118,4 b	2,6 c
LSD at 5% level	3,2	6,4	0,4

Shafeek, M. R., Y.I. Helmy, W.A. El-Tohamy and H.M. El-Abagy. 2013. Changes in growth, yield and fruit quality of cucumber (Cucumis sativus L.) in response to foliar application of calcium and potassium nitrate under plastic house conditions. Research Journal of Agriculture and Biological Sciences, 9(3): 114-118.

Potassium nitrate sprays improved plant growth, yield and fruit storability of cucumber.

Foliar Yield & Quality

The objective of this study was to evaluate the effects of sprays with calcium nitrate, potassium nitrate and Anfaton growth stimulator on plant growth, yield and fruit storability of soil grown cucumber cv. Al-Hytham in Iraq. Three concentrations of Anfaton; 0, 600 and 1000 mg/L and five concentrations of spray solutions; 0 mM (control), 10 and 15 mM of calcium nitrate and 10 and 15 mM of potassium nitrate in addition to the combination of Anfaton and the two nutrients were used. The experiment was set up in a silt clay soil in a Complete Randomized Block Design (CRBD) with three replications. Spraying was conducted three times; first spray was applied 20 days after transplanting and repeated every 15 days for the second and third spray. With respect to only potassium nitrate sprays, the foliar sprays with 15 mM KNO_3 (1,5 g KNO_3/L) resulted in statistically significantly higher values for plant height, leaf area, chlorophyll content, average fruit weight, total number of fruits and the total yield compared to the control (Table 1 & 2). KNO_3 sprays were also beneficial in controlling fruit weight loss and maintaining total soluble solids at higher level during storage.

Table 1. Effect of sprays with potassium nitrate on plant characteristics of cucumber cv. Al-Hytham.

Treatments	Plant height (cm)	Leaf area ($dm^2 plant^{-1}$)	Chlorophyll content ($mg\ g^{-1}$ fw)
Control	161	70	0,432
10 mM KNO_3	170	77	0,552
15 mM KNO_3	170	78	0,592
LSD (P=0,05)	6,1	3,3	0,120

Table 2. Effect of sprays with potassium nitrate on yield characteristics of cucumber cv. Al-Hytham.

Treatments	Av. Fruit weight (g)	Total no. of fruits $plant^{-1}$	Total yield (kg $plant^{-1}$)
Control	103,2	14,9	1,5
10 mM KNO_3	111,0	16,0	1,8
15 mM KNO_3	114,5	20,1	2,3
LSD (P=0,05)	6,5	3,3	0,4

Al-Hamzawi, M. K. A. 2010. Effect of calcium nitrate, potassium nitrate and Anfaton on growth and storability of plastic houses cucumber (Cucumis sativus L. cv. Al-Hytham). American Journal of Plant Physiology, 5(5): 278-290.

Foliar potassium nitrate application effectively suppressed and controlled powdery mildew development on cucumber plants.

Foliar *Pest & disease reduction*

The effect of foliar sprays with aqueous solutions containing various phosphates and potassium salts to control powdery mildew, caused by Sphaerotheca fuliginea, was studied. Cucumber plants (Cucumis sativus cv. Delilla) were grown in a greenhouse in plastic pots containing a mixture of peat, vermiculite and soil (1:1:1, v/v). Twice per week, plants were watered to saturation with a 0,1% 20-20-20 (N-P-K) fertilizer solution. The plants were inoculated with a powdery mildew conidial suspension and number of colonies was counted (8-12 days later) before treatment applications. The upper surface of each leaf was sprayed with 1-2 ml of aqueous solutions (25 mM) of KNO_3, K_2HPO_4, KH_2PO_4, KH_2PO_4 + KOH or KCl.

The data presented in Figure 1 clearly demonstrate a high fungicidal activity of phosphate and potassium salt solutions up to 12 days after application. Efficiency of control, as expressed by the disappearance of 99% of pustules, was recorded 1 or 2 days after application of single sprays of the salts (Figure 1). Treatments also markedly reduced (> 99%) the production of conidia from colonies. A further application of these salts to the same plants resulted in the elimination of about 50% of mildew colonies present prior to the application. Further spray application inhibited disease development compared with water-sprayed plants, but did not reduce the number of existing lesions. This study demonstrated that phosphate and potassium salts effectively suppressed and controlled powdery mildew development on cucumber plants.

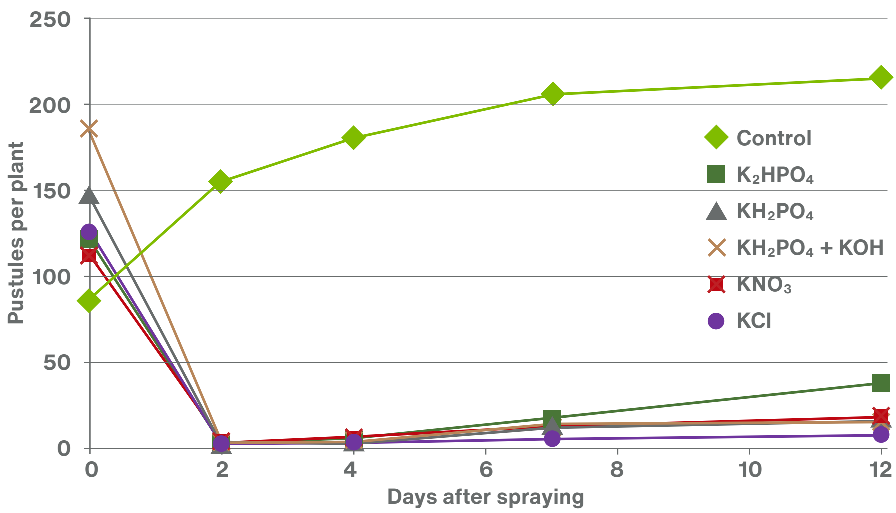

Figure 1. Effect of single foliar sprays with 1-2 ml of aqueous salt solutions (25 mM) on suppression of powdery mildew pustules on cucumber plants. The number of pustules on each leaf was counted before application (day 0) and at various days after application.

Reuveni, M., V. Agapov and R. Reuveni. 1995. Suppression of cucumber powdery mildew (Sphaerotheca fuliginea) by foliar sprays of phosphate and potassium salts. Plant Pathology, 44: 31-39.

Controlling powdery mildew caused by Sphaerotheca fuliginea in cucumber by foliar applied potassium nitrate.

Foliar *Pest & disease reduction*

The study was performed to evaluate the efficacy of foliar sprays in controlling powdery mildew (Sphaerotheca fuliginea) in greenhouse-grown cucumber (Cucumis sativus L. cv. Delilla) plants. The cucumber plants were grown in a greenhouse in plastic pots containing a mixture of peat, vermiculite and soil (1:1:1, v/v). Twice per week, plants were watered to saturation with a 0,1% 20-20-20 (N-P-K) fertilizer solution. Sprays of KNO_3 (20 mM), KH_2PO_4 + KOH (20 mM) and the fungicide Pyrifenox (Dorado, 0,01% 480 EC, Ciba Geigy, Switzerland) were applied to the upper leaf surface of greenhouse-grown cucumber plants at the five-leaf stage 4 days before inoculation with a conidial suspension of S. fuliginea. These foliar sprays reduced powdery mildew colonies (87%) by 9 days after the inoculation (Figure 1).

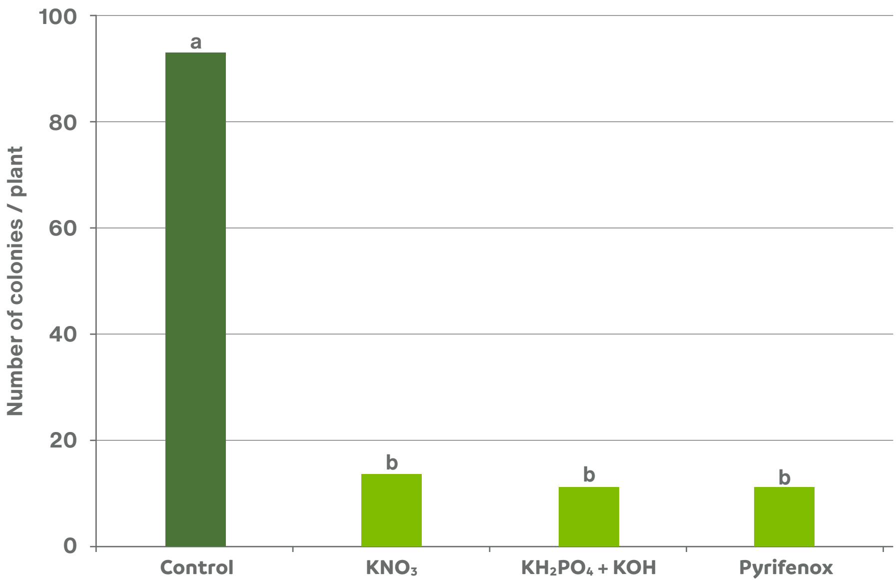

Figure 1. Effect of pre-inoculation foliar treatments on control of powdery mildew on cucumber plants. The number of powdery mildew colonies was counted 9 days after inoculation.

In another experiment plants, naturally infected, were transplanted to 10 liter containers. Foliar sprays with 25 mM solutions of KNO_3, K_2HPO_4, KH_2PO_4 + KOH and the fungicide Pyrifenox were applied at 7 and 14 day intervals, starting seven days after transplanting. Treatments were repeated at 7 and 14 day intervals to give a total of eight and four foliar sprays, respectively. Overall, regardless of 7 or 14 days intervals between applications, KNO_3, K_2HPO_4, KH_2PO_4 + KOH and Pyrifenox significantly inhibited disease development for all treatments compared to the control (sprayed with water).

The present study clearly demonstrated that simple compounds such as KNO_3, K_2HPO_4 and KH_2PO_4 + KOH can control powdery mildew on leaves of greenhouse-grown cucumbers as effectively as the systemic fungicide Pyrifenox.

Reuveni, M., V. Agapov and R. Reuveni. 1996. Controlling powdery mildew caused by Sphaerotheca fuliginea in cucumber by foliar sprays of phosphate and potassium salts. Crop Protection, 15(1): 49-53.

Fig

Fig

sqmnutrition.com

Potassium nitrate sprays enhanced fresh and dried fig quality.

Foliar *Yield & Quality*

The effect of foliar applied potassium nitrate and calcium nitrate on fruit quality of Sarilop figs was studied in a 15 years old orchard in Aydin province in Turkey. Treatments consisted of various spray applications, among which a control, 3% KNO_3 and a mix of 2% KNO_3 + 2% $Ca(NO_3)_2$. Foliar sprays were conducted twice on July 10 and July 25. The trial was set up as a randomized block design with three replicates and three trees per replicate. The fruit size of fig fruits was highly affected by the foliar applications (Table 1). Lowest average fresh fruit weight was found for the control, all foliar treatments increased the fresh fruit weight compared to the control. Neck length was increased for the foliar treatments, this is important in terms of harvesting since longer necks may ease hand picking. Another benefit of the foliar sprays was a closed or narrower opening compared to the control, because the ostiole opening is the entrance for pathogens and their vectors. Smaller openings together with bigger fruit sizes are beneficial effects of foliar sprays on fresh figs. KNO_3 sprays also enhanced dried fig quality through its positive effects on colour, texture, total sugar and fructose contents.

Treatments	Width (mm)	Weight (g)	Neck length (mm)	Ostiole width (mm)
Control	47,8 b	92,1	7,91	8,44 a
3% KNO_3	53,7 a	99,4	9,92	7,14 b
2% KNO_3 + 2% $Ca(NO_3)_2$	53,9 a	97,5	10,45	7,35 b
LSD (5%)	3,82	ns	ns	0,871

Table 1. Effect of KNO_3 and $Ca(NO_3)_2$ applications on fresh fruit quality parameters of fig.

Irget, M. E., Ş. Aydın, M. Oktay, M. Tutam, U. Aksoy and M. Nalbant. 1999. Effects of foliar potassium nitrate and calcium nitrate application on nutrient content and fruit quality of fig. Springer Netherlands - Improved Crop Quality by Nutrient Management: 81-84.

Gourd

Gourd

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Foliar applied potassium nitrate induced salt tolerance in bottle gourd, grown under saline conditions.

Foliar Salinity relief

Salinity limits crop growth and development. Therefore a moderately salt tolerant crop Lagenaria siceraria (bottle gourd) was used to study the effect of foliar sprays on leaf area and fruit weight per plant. A foliar spray of 250 ppm KNO_3 increased the leaf area under non saline conditions by 16% and under 0,2% sea-salt dilution by 12% compared to the control (Table 1).

The plants sprayed with 250 ppm KNO_3 under saline conditions of 0,2% sea-salt dilution not only inhibited toxic effects of salt on fruit formation, but also increased the fruit weight per plant by 77%, whereas a foliar spray of 500 ppm KNO_3 increased the fruit weight per plant by 18% (Figure 1).

Table 1. The effect of a 250 ppm KNO_3 foliar spray on the total leaf area (cm^2) per plant compared to non-spray and non-saline conditions.

Saline condition	Non-spray	Foliar spray of 250 ppm KNO_3
Non-saline		+16%
0,2% sea-salt dilution	-1%	+12%

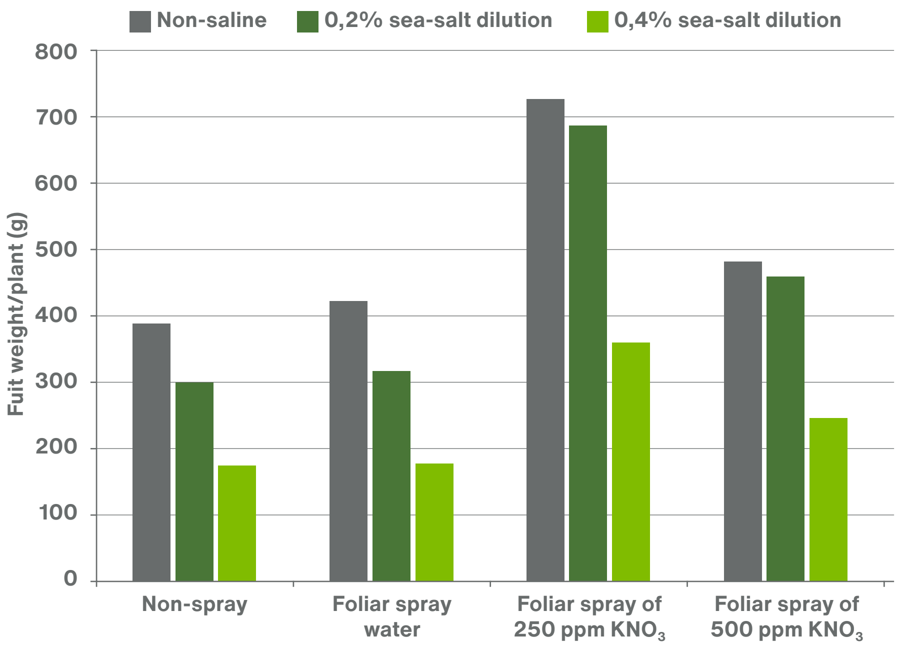


Figure 1. Effect of foliar spray of KNO_3 on fruit weight per plant (g) of Lagenaria Siceraria grown under various levels of saline water irrigation.

Ahmad, R. and R. Jabeen, 2005. Foliar spray of mineral elements antagonistic to sodium-a technique to induce salt tolerance in plants growing under saline conditions. Pakistan Journal of Botany, 37(4): 913-920.

Grape

Grape

Potassium nitrate sprays increased yields of Colombard and Carignane wine grapes.

Foliar *Yield & Quality*

A scientific study in Turkey revealed that two foliar KNO_3 sprays at 1% or 2% statistically significantly increased yield and hundred berry weight compared to the control. The trial was designed in randomized blocks with 4 replications in a 10 year old vineyard with two varieties; Colombard and Carignane. Soil analysis results showed a sandy-loam texture, high pH, low organic matter content and 130 mg/kg available K in the soil. Best result was observed with two sprays of 2% KNO_3, which increased the yield of Colombard grapes with 24% and Carignane with 43% compared to the control (Figure 1). Furthermore, foliar potassium nitrate sprays both at 1% and 2% increased total soluble solids (TSS) and improved leaf N and K contents, although not statistically significant. It was concluded that the doses of 1% and 2% can be suggested for agricultural practice.

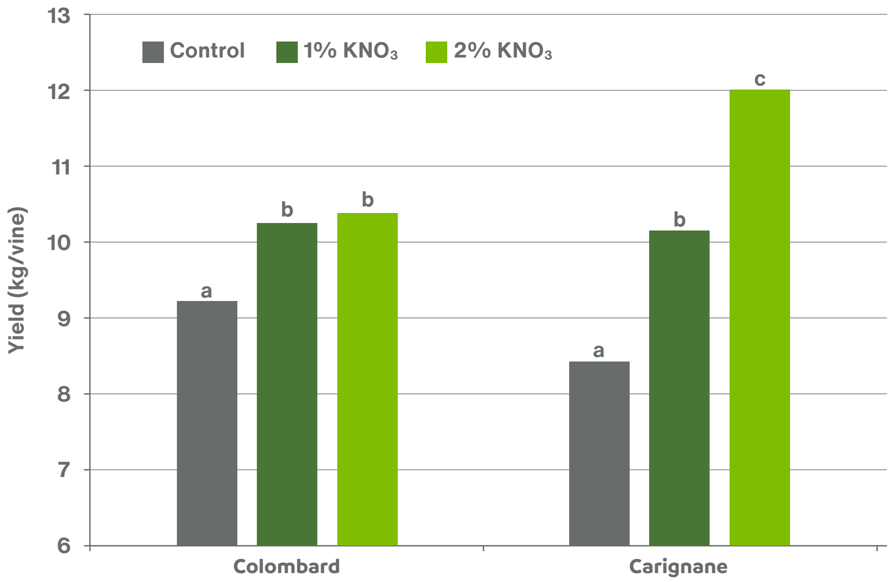


Figure 1. The effect of KNO_3 sprays on the yield of Colombard and Carignane grape varieties.

Altındişli, A., M.E. İrget, H. Kalkan, S. Kara and M. Oktay. 1999. Effect of foliar applied KNO_3 on yield, quality and leaf nutrients of Carignane and Colombard wine grapes. Springer Netherlands - Improved Crop Quality by Nutrient Management, 103-106.

Highest grape yield obtained with foliar potassium nitrate applications at 3%.

Foliar *Yield & Quality*

This study was performed in Izmir, Turkey, in two consecutive years to determine the effects of KNO_3 foliar applications on yield and leaf contents in Sultani seedless grapes. The soil texture was sandy-loam with a pH of 6,3. Treatments were control, 1%, 2% and 3% KNO_3 and 1% $KH_2PO_4 + NH_4H_2PO_4$, all applied as successive foliar sprays every week in June. KNO_3 foliar applications increased yields in 1996 and 1997 (Figure 1). Highest yield was obtained for the 3% KNO_3 treatment, the yield increased by 35% in 1996 and 17% in 1997 compared to the control. The results showed that potassium nitrate foliar applications lead to considerable increases in yield of Sultani seedless grapes.

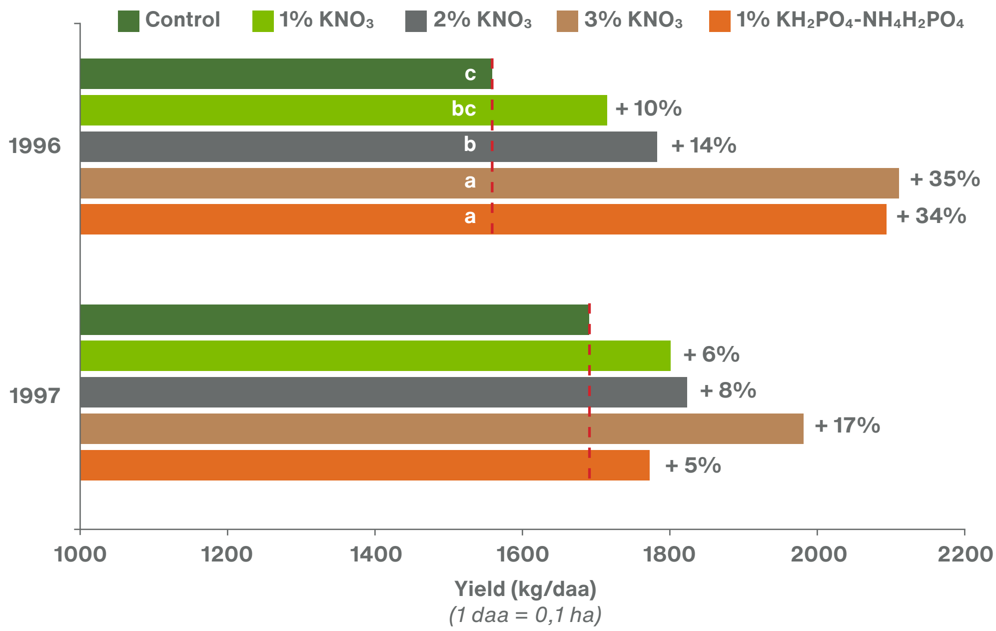


Figure 1. Effect of foliar applications on grape yield in 1996 and 1997.

Ceylan, Ş. and I.Z. Atalay.1999. Effect of KNO_3 applications on fruit yield and N, P, K content of leaves in Vitis Vinifera grapes. Springer Netherlands - Improved Crop Quality by Nutrient Management: 27-29.

Increased quality of dry wines with foliar potassium nitrate applications.

Foliar Yield & Quality

The effect of potassium nitrate sprays on the wine quality of two grape varieties was studied. Ten year old Carignane (red wine) and Colombard grape (white wine) varieties were sprayed with KNO_3 at 0%, 1%, 2% and 3% concentrations on June 21 and July 5 in 1996. The experiment was performed in randomized complete block design with 3 replicates in a vineyard in the Izmir area, Turkey. Must and chemical analysis were performed to check the quality of both grape varieties. For complete evaluation of wine quality, density (aerometrically), total soluble solids (TSS), pH, total acidity of must, total bound and free SO_2, alcohol content, volatile acidity, total acidity were performed. Organoleptical analyses were conducted according to OIV (Office International du Vin) tests.

The highest value of density was reached in the musts of grapes treated with 2% KNO_3; 1,078 g/cm³ for Carignane variety and 1,079 g/cm³ for Colombard variety. The density of the controls was significantly lower (1,071 g/cm³). The TSS (Total Soluble Solids) values in the musts of both varieties sprayed with KNO_3 were significantly higher than controls, excluding the 3% KNO_3 sprays. The highest value of TSS was reached in the 2% KNO_3 treatment. For all chemical and organoleptical results, it could be evaluated that up to 2% KNO_3 application for Colombard and up to 1% for Carignane have positive effects on wine quality.

Kalkan, H., M.E. İrget, A. Altındişli, S. Kara and M. Oktay. 1999. The effect of foliar fertilization with KNO_3 on quality of dry wines. Springer Netherlands - Improved Crop Quality by Nutrient Management: 99-102.

Grass

Grass

Foliar applied potassium nitrate is more effective on canopy quality than soil application in saline conditions.

Fertigation *Foliar* *Salinity relief*

Two experiments were conducted to determine the effect of KNO_3 application on ryegrass (Lolium perenne L.) salinity tolerance. Pots of 50 cm in diameter were filled with a mix of perlite and sand (1:1), after sowing pots were placed into a glasshouse. Two NaCl levels (0 and 60 mM) were combined with four KNO_3 levels (0, 5, 10 and 15 mM) as treatments. Potassium nitrate was applied either to the soil or foliar sprayed. The pots were arranged in a randomized complete block design with four replicates.

The increased KNO_3 level up to 5 and 10 mM promoted the leaf growth at NaCl0 and NaCl60, respectively. In NaCl60 treatment, plants supplied with KNO_3, however, showed less reduction of leaf area, fresh and dry weight compared with plants growing without KNO_3.The 15 mM KNO_3 treatment significantly inhibited both the fresh weight and leaf growth. The percentage of survival plants under salinity conditions was higher for the foliar KNO_3 treatments compared to the soil applications (Figure 1 and 2).

The results of the experiments clearly indicated the ameliorating effect of potassium nitrate application on the growth, mineral nutrients (K and N) concentration and chlorophyll content of plants grown in saline conditions. Foliar application of KNO_3 was proven to be more effective compared to soil application to improve perennial ryegrass growth in saline conditions. The possible explanation was that supplying of NaCl along with KNO_3 to the salt-treated perennial ryegrass increased both osmotic potential and ion toxicity while, the adverse effects of salinity on the increased osmotic potential should be lower when KNO_3 is supplied by foliar application.

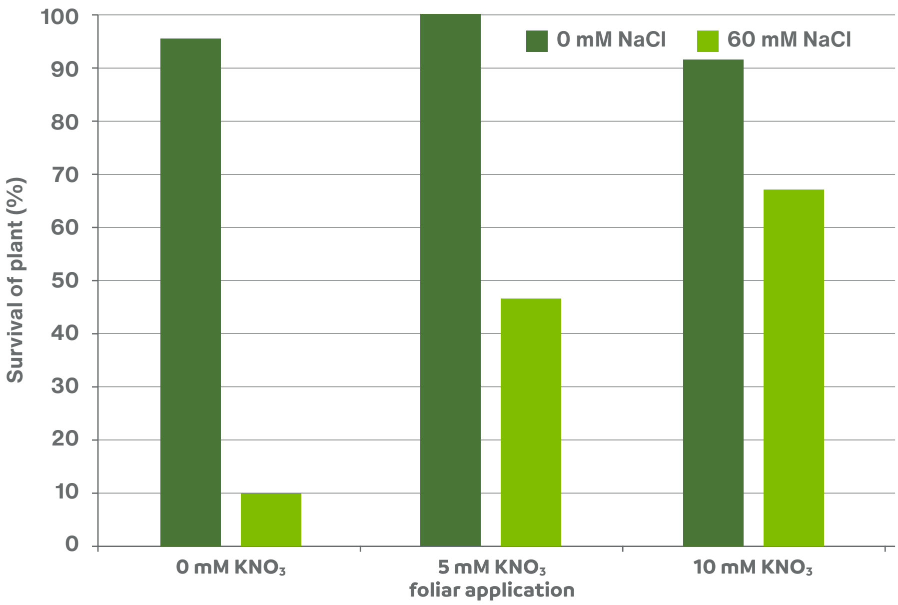


Figure 1. Effect of salinity and foliar application of potassium nitrate on canopy quality, as percentage of survival plants.

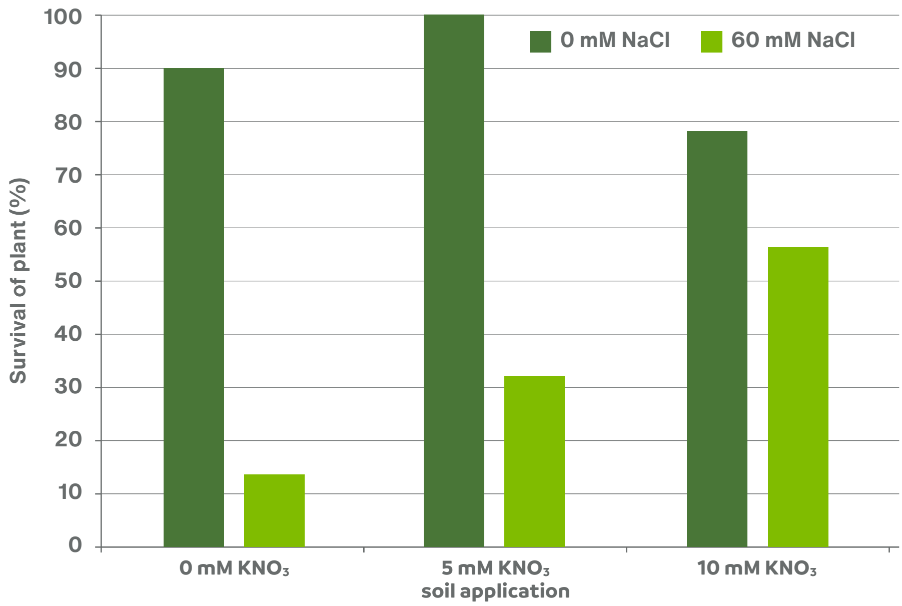


Figure 2. Effect of salinity and soil application of potassium nitrate on canopy quality, as percentage of survival plants.

Tabatabaei, S. J. and F. Fakhrzad. 2008. Foliar and soil application of potassium nitrate affects the tolerance of salinity and canopy growth of perennial ryegrass (Lolium perenne var Boulevard). American Journal of Agricultural and Biological Sciences, 3(3): 544-550.

Litchi

Litchi

sqmnutrition.com

Flowering induction with potassium nitrate in litchi in India.

Foliar *Flowering induction*

In litchi yields are often irregular and suffer from alternate bearing. Productivity in off-years is unacceptably low. Therefore the effects of Ethephon (0.4 ml/L), Potassium nitrate 1% and TIBA (tri-iodobenzoic acid) 0.1% on flowering and fruiting in India were studied over 4 years. Treatments were applied by 4 sprayings at 30-days intervals, in the months September to December.

Potassium nitrate could replace the need for vegetative dormancy period, and induced higher flowering rates than plant growth regulators (Figure 1). The higher flowering resulted in higher yields, mainly in “off” years and thus produced highest yields also on 4-years basis, 52% higher than the control (Figure 2).

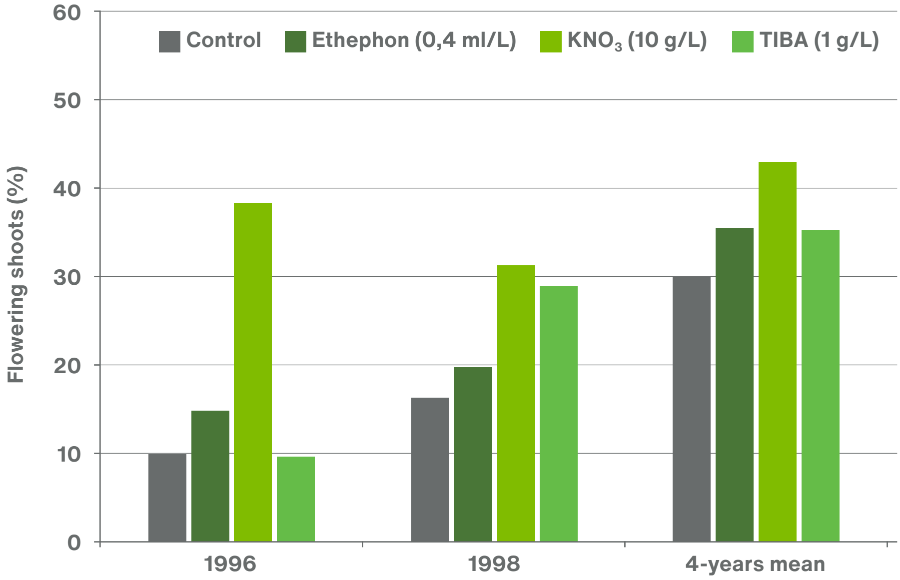


Figure 1. Effect of flower induction treatments on flowering shoots (%) in litchi trees in ‘off’-years.

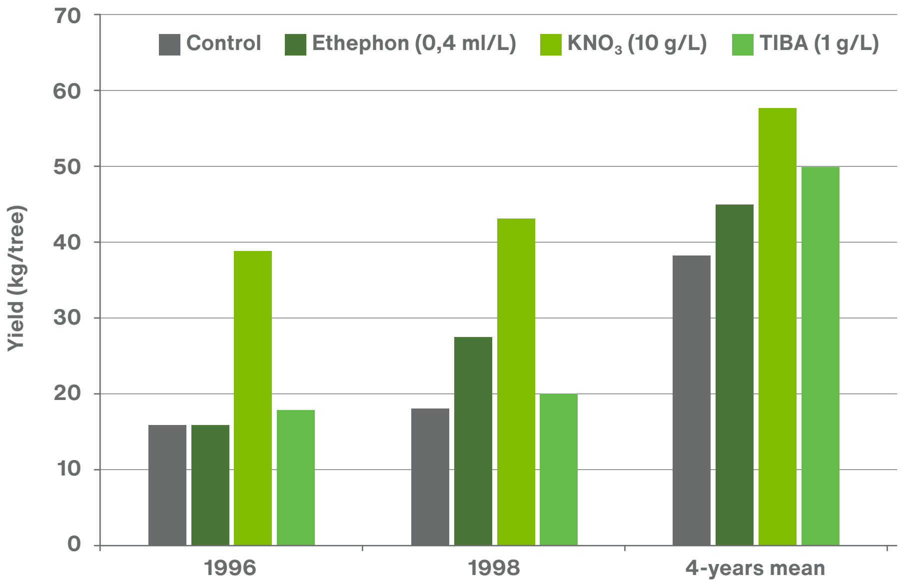


Figure 2. Effect of flower induction treatment on the yield of litchi trees in ‘off’-years.

Mitra, S. K., and D. Sanyal. 2000. Effect of cincturing and chemicals on flowering of litchi. Acta Horticulturae I International Symposium on Litchi and Longan 558: 243-246.

Preharvest treatments including potassium nitrate improved yields and quality of litchi.

Foliar Yield & Quality

In this study in South Africa preharvest treatments were tested with commercial practice to improve yield, fruit size, weight and quality attributes of litchi cv. 'Maritius'. The experiment was conducted in two growing seasons in a 20 year old litchi orchard on a sandy Hutton soil. The basic orchard program (control treatment) was compared with five foliar treatments. Four out of five treatments consisted of one or more KNO_3 foliar sprays during flowering and/or fruitlet stage. All treatments produced statistically significantly higher yields than the control plot in both seasons, even as the fruit weight and fruit size. The fruit K content and the SSC/TA ratio showed significant changes in all the treatments compared to the control.

Cronje, R. B., D. Sivakumar, P.G. Mostert and L. Korsten. 2009. Effect of different preharvest treatment regimes on fruit quality of litchi cultivar 'Maritius'. Journal of Plant Nutrition, 32(1): 19-29.

Three potassium nitrate sprays increased yield, fruit quality and income of litchi.

Foliar Yield & Quality

This study was conducted to test the efficacy of potassium nitrate foliar application on quality attributes and yield of litchi (Litchi chinensis Sonn.) cv. Rose Scented in Pantnagar, India. Foliar KNO_3 spray(s) at 1% concentration were applied on 14 year old fruit bearing litchi plants. Treatments consisted of an unsprayed control, a single spray at 15 or 30 or 45 days after fruit setting, two sprays at 15 and 30 days, 15 and 45 days or 30 and 45 days after fruit setting and 3 sprays at 15, 30 and 45 days after fruit setting as final treatment. The experiment was laid out in a randomized block design with 8 treatments and 3 replications per treatment. Total soluble solids increased with 3 foliar sprays to 18,0% compared to 16,5% for the control (Table 1). Three KNO_3 sprays resulted also in less fruit cracking (up to 40% reduction over control) and maximum accumulation edible portion (65%) in the fruits weighing 18,3 g. The maximum yield was obtained with 3 sprays and was statistically significantly higher (+21%) compared to the control (Table 2). This yield increase was caused by reduced fruit drop of 11% and increased fruit weight of 14%. The bigger sized fruits have a higher market price, which resulted in a higher net income for two and three KNO_3 sprays applications compared to the control and one spray applications, which resulted in smaller sized fruits.

Table 1. Effect of foliar potassium nitrate applications at 1% concentration on quality attributes of litchi.

Treatments	Foliar timing (days)[1]			TSS	Fruit cracking	Fruit drop	Fruit weight
	15	30	45	(%)	(%)	(%)	(g)
T1 (control)				16,5	12,1	90,8	16,0
T2	x			16,8	10,6	89,2	17,3
T3		x		16,3	9,9	86,2	17,5
T4			x	17,0	8,0	84,4	17,5
T5	x	x		17,6	8,0	83,6	17,5
T6	x		x	17,6	7,5	82,6	17,8
T7		x	x	18,1	7,4	81,1	18,1
T8	x	x	x	18,0	7,2	81,3	18,3
CD at 5%				0,9	4,2	4,9	1,9
CV				3,9	10,3	7,1	6,2

[1] Days after fruit set.

Table 2. Effect of foliar potassium nitrate applications at 1% concentration on yield and profit of litchi.

Treatments	Foliar timing (days)[1]			Fruit yield/tree	Profit over control[2]
	15	30	45	(kg)	(₹/ha)
T1 (control)				23,1	-
T2	x			24,0	35.600
T3		x		24,7	36.695
T4			x	24,5	36.320
T5	x	x		27,0	53.260
T6	x		x	27,1	53.460
T7		x	x	27,7	54.520
T8	x	x	x	28,0	54.800
CD at 5%				2,0	
CV				8,3	

[1] Days after fruit set.
[2] After deducting fertilizer product cost.

Kumar, A. and G. Kumar. 2004. Effect of foliar applications of water soluble fertilizer 'Multi-K' on yield and quality of litchi (Litchi chinensis Sonn.) cv. Rose Scented. Advances in Plant Sciences 17(II): 519-523 .

Maize

Maize

Foliar applied potassium nitrate outperformed other K sources in terms of maize grain yield.

Foliar K K-source

A pot experiment in Thailand was conducted to find the most effective K-source for foliar K-fertilization of maize plants (Zea mays L.) grown with sufficient K-supply to the soil. Glazed clay pots were filled with 23-25 kg soil (air dry), that had been classified as Pakchong series. Different treatment ratios were used to apply equal K concentration of 0,52%. Treatments were: control (no foliar), 1% KCl, 1,4% KNO_3, 1,2% K_2SO_4, 1,8% KH_2PO_4 and 1,2% K_2HPO_4. Sprays were applied on the third day after 50% tasselling (50% of tassels, male flowers, visible). Results showed that only the potassium nitrate spray caused a statistically significant increase in grain yield of 47% compared to the control.

In another pot experiment, maize was sprayed with different potassium nitrate concentrations, ranging from 0,5% to 5% KNO_3. Maximum maize grain yield was obtained with 2,5% KNO_3 spray concentration, which resulted in 36% grain yield increase in comparison to the untreated control plot.

Suwanarit, A. and M. Sestapukdee. 1989. Stimulating effects of foliar K-fertilizer applied at the appropriate stage of development of maize: A new way to increase yield and improve quality. Plant and soil, 120(1): 111-124.

Nitrate nitrogen the preferred N-source for maize.

Foliar N N-sources

The nitrogen utilization of two maize hybrids (Pioneer 3732 and Volga) of similar yield potential was studied under greenhouse conditions. In a three-year model experiment, plants were grown in pots filled with 40 kg dry clay soil. 150 mg N/kg soil was applied as NH_4Cl or KNO_3, besides PK base fertilisation. In the first two experimental years, ^{15}N-labeled N-sources (5 atom.% ^{15}N) were also applied to study the utilization of different N-forms. Volga showed a more favorable response to nitrate-fertilization in terms of grain yield production. The N-uptake of both hybrids was considerably higher from the NO_3-N source than from the NH_4-N source. The ^{15}N-fertilizer utilization was higher with the application the NO_3-N source. On average, it amounted to 48-62%, while only 32-54% was measured with the application of the NH_4-N source.

Debreczeni, K. 2000. Applications in sustainable production: Response of two maize hybrids to different fertilizer-N forms (NH_4-N and NO_3-N). Communications in Soil Science & Plant Analysis, 31(11-14): 2251-2264.

Salinity is alleviated by application of potassium nitrate in sweet corn.

Fertigation *Salinity relief*

The effect of salinity and KNO_3 levels in sweet corn (Zea mays cv Jubilee) was investigated in two experiments. The experiments were carried out in an unheated greenhouse in Bet Dagan, Israel, using an aero-hydroponic system. This system consisted of a 130-L covered container for the nutrient solution, a pump for its circulation, and boxes in which plants were grown. The roots were continuously sprayed with the nutrient solution. In each experiment, 15 treatments were tested: three KNO_3 levels (2, 7 and 13 mM in autumn and 2, 8 and 14 mM in spring), and five salinity levels (EC of 2, 5, 7, 10 and 12 dS/m).

Fresh ear yield at any KNO_3 level decreased linearly as the EC (dS/m) was elevated beyond a certain threshold value. In spring the interaction between EC and KNO_3 was significant, resulting in a stronger reduction in yield due to increase in EC as KNO_3 increased from 2 to 8 to 14 mM. In both experiments, increasing KNO_3 concentration from 2 to 14 mM increased dry matter production and ear yield, while increasing salinity reduced them. According to the researchers this result indicated that at appropriate KNO_3 nutrition the detrimental effect of salinity on ear yield is delayed.

Imas, P. and A. Feigin. 1995. Yield and water use efficiency of sweet corn grown in solution culture as affected by KNO_3 and salinity levels. Acta Hort. 401: 301 - 308.

Mango

Mango

Foliar applied potassium nitrate at 2% and 5% induced flowering and improved yield in five year old 'Chok Anan' mango trees.

Foliar *Flower initiation*

The aim of the study was to determine the influence of foliar application of potassium nitrate, on stimulation of flowering to improve fruit production in mango clone 'Chok Anan'. This field experiment was conducted in Selangor, Malaysia, on one and five year old trees to study the difference in response to potassium nitrate between trees of different ages. Treatments were started early May 2011 and were repeated at two week intervals until flower initiation. Mango shoots were sprayed three times with KNO_3 in three dose rates: 1%, 2% and 5% in the spray solution, with Sapol added as a wetting agent. The experiment was arranged in a randomized complete block design.

The results differed between young and older trees. One year old mango trees did not produce inflorescences in the control treatment nor on terminal buds of shoots sprayed with 2% and 5% KNO_3. Foliar application of 1 % KNO_3 in the spray solution did result in 14,5% flowering shoots in the canopy 5 weeks after the treatment. Flowering induction was observed on new leaf flush produced 2 months after the foliar application of KNO_3 in the higher concentrations (2% and 5%).

In contrast, a high degree of flowering induction was observed for the five year old mango trees sprayed with 2% and 5% KNO_3, resulting in 80% and 70% inflorescence bearing shoots (Figure 1). More flowers resulted in a higher number of fruits produced per tree, and ultimately, increased fruit yield. Best results were observed with 2% KNO_3 in the spray solution, applied on the shoots of five year old trees (Figure 1).

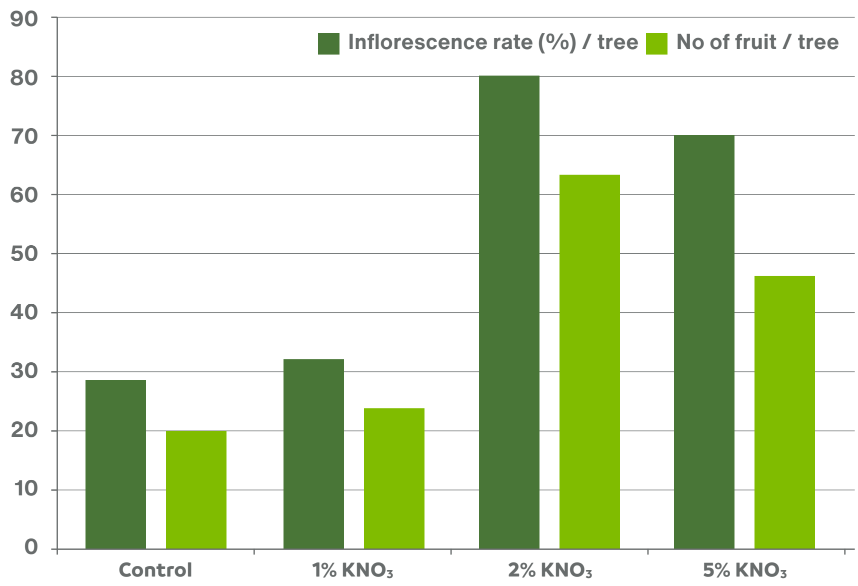


Figure 1. Effect of increasing rates of potassium nitrate applied with two week intervals in three foliar sprays on average flowering intensity and number of fruits produced by five year old mango trees 'Chok Anan' in Malaysia.

Afiqah, A. N., R. Nulit, Z.E.J. Hawa and M. Kusnan. 2014. Improving the yield of Chok Anan (MA 224) mango with potassium nitrate foliar sprays. International Journal of Fruit Science, 14: 416-423.

Increased yield and quality in mango by foliar application of potassium nitrate.

Foliar *Yield & Quality*

To improve local mango (Mangifera inidica L.) production, the Bangladesh Agricultural University conducted a field trial during the period from September 2006 to July 2007. Aim was to study the effect of KNO_3 and urea on regulation of flowering and harvesting time, and increasing yield and quality of the fruits. Nine year old plants of the cultivar 'Amrapali' were grown with a plant spacing of 5 m x 5 m. The experiment was laid out in a Randomized Complete Block Design with 3 replications. The six treatments included a control (water spray), potassium nitrate at three rates (4%, 6% and 8% in the foliar spray solution) and urea at two rates (2% and 4% in the foliar spray solution). Tween 80 was added as a surfactant (3 drops/L spray solution). All foliar sprays were applied once, on 15 November 2006, one month before the appearance of the first panicle.

A great number of parameters regarding vegetative and generative development, yield and fruit quality were recorded.

Observations on the leaf, shoot and panicle development, showed that foliar application of both urea and KNO_3 at 4% in foliar spray increased growth compared to the control. At this dose, urea mostly increased the vegetative development, with the most profound effect on leaf area, whereas KNO_3 (4% in foliar spray) was most effective in increasing the size of the panicle and number of secondary branches on the panicle.

Potassium nitrate advanced flowering: Panicles on trees sprayed with 4% KNO_3 appeared 17 days earlier, compared to the control treatment. Potassium nitrate also increased the panicle number: At 4% KNO_3 in the foliar spray, the highest number of panicles per plant (220,7) was counted, more than double the count on control trees (107,7). Maximum initial fruit set per panicle was recorded for the 6% KNO_3 foliar treatment (19,9 fruit/panicle) followed by 4% KNO_3 (17,3 fruit/panicle) and 4% urea (17,3 fruit/panicle). This was again an improvement on the control, with an average initial fruit set of 6,5 fruits per panicle. The number of fruits retained per panicle at harvest was highest after foliar application of 4% KNO_3 (1,6 fruit/panicle) or 4% urea (1,4 fruit/panicle) compared to 0,7 in the control.

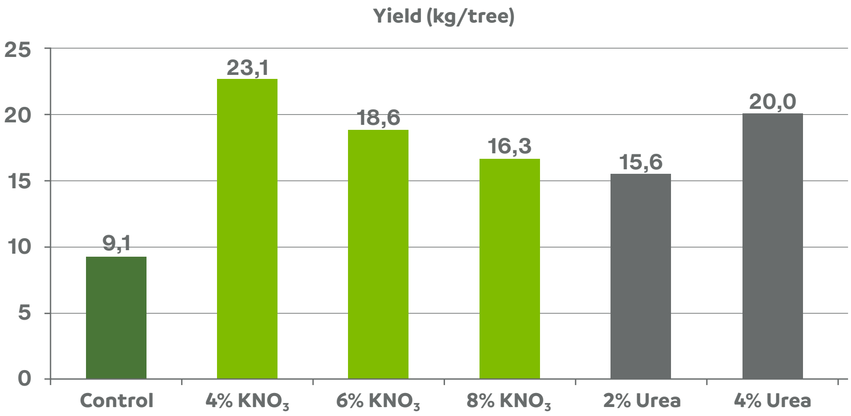


Figure 1. Effect of foliar treatments with different concentrations of KNO_3 and urea on the yield of mango.

Harvest was advanced not more than 5 days on trees sprayed with potassium nitrate or urea at all rates, compared to the control. The higher number of panicles and fruit set observed earlier in the season, had developed at harvest time to the highest number of harvested fruits per plant on trees sprayed with 4% KNO_3 (136,7 fruits/plant) compared to the control (62,7 fruits /plant) or the second highest (108,3 fruits /plant) after spray with 4% urea. Weight per fruit and dry matter content of the fruit was highest after the 4% KNO_3 and 4% urea sprays, and all KNO_3 and urea foliar treatments resulted in higher vitamin C and total sugar content of the fruits compared to the water spray treatment. Moreover, the average shelf life of the mango fruits from trees sprayed with either urea or KNO_3 at 4% in foliar spray was increased by more than two days compared to the control.

Spraying potassium nitrate at 4% also led to the highest yield (23,1 kg fruit/plant). All the foliar treatments improved the yield compared to the minimal yield of 9,1 kg fruit/plant in the water sprayed control (Figure 1).

The authors conclude that foliar application of KNO_3 and urea at 4% in the foliar application both improved yield as well as quality of mango fruit. Sprays had little effect on the manipulation of harvesting time.

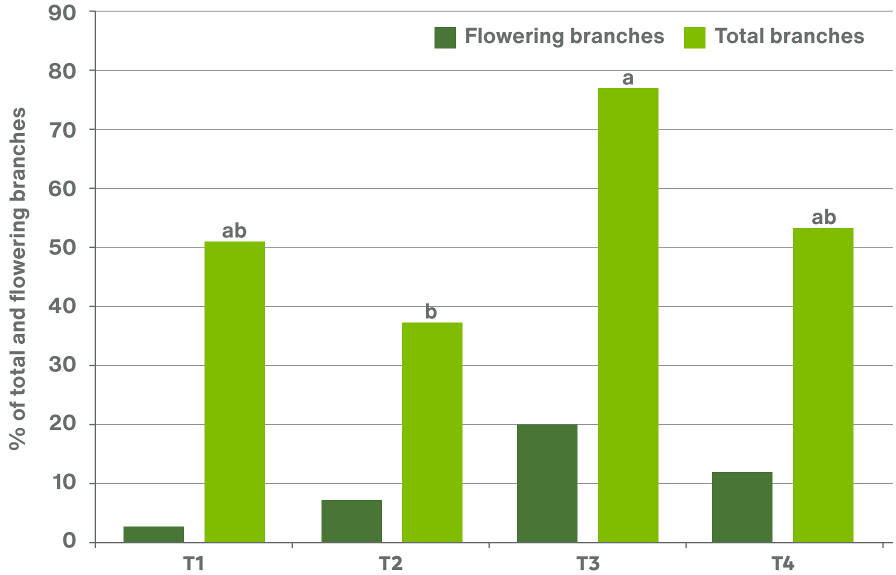
Sarker, B. C. and M.A. Rahim. 2013. Yield and quality of mango (Mangifera indica L.) as influenced by foliar application of potassium nitrate and urea. Bangladesh Journal of Agricultural Research, 38(1): 145-154.

Foliar potassium nitrate applications strengthened the flowering induction in mango.

Foliar Flower induction

Three different foliar treatments were tested in an eight years old 'Haden' mango orchard. The trees were planted on a sandy loam soil with a neutral pH at 4 m x 4 m in an orchard located at the Central University of Venezuela in Maracay, Venezuela. The effect of two urea sprays (0,5%) combined with two KNO_3 sprays (60 g/L) (T2), two potassium thiosulphate (4% PTS) sprays combined with two KNO_3 sprays (60 g/L) (T3) and three KNO_3 sprays (T4) on the vegetative and floral growth as studied (Figure 1).

At 130 days after the first application the first flowering branches were observed after treatment T4. This treatment included one more foliar application with potassium nitrate compared to T2 and T3. Flowering is associated to ethylene production, coming from a large synthesis of methionine, due to a larger nitrate-reductase enzyme activity. KNO_3 can contribute to this effect. In general all foliar applications of potassium nitrate strengthened the flowering induction compared to the untreated control T1 (Figure 1). At 210 days after the first application a higher percentage of flowering branches (not statistically significant) and more total branches (significant at $p<0,05$) were recorded for treatment T3: alternating foliar sprays with PTS or KNO_3. The authors recommend treatment T3 for mango orchard management in Venezuela, because of the improved balance between flowering and vegetative growth.



Treatment	T1	T2	T3	T4
1st spray - Jul. 1997	-	0,5% Urea	4% PTS	KNO_3 (60 g/L)
2nd spray - Oct. 1997	-	KNO_3 (60 g/L)	KNO_3 (60 g/L)	KNO_3 (60 g/L)
3rd spray - Nov. 1997	-	0,5% Urea	4% PTS	-
4th spray - Dec. 1997	-	KNO_3 (60 g/L)	KNO_3 (60 g/L)	KNO_3 (60 g/L)

Figure 1. Treatment effects on the percentage of flowering branches and the total percentage of developed (flowering+vegetative) branches, 210 days after the first nutrient spray application.

Sergent, E., F. Leal and M. Anez. 2000. Potassium thiosulphate, urea and potassium nitrate applications on vegetative and floral growth in mango Haden. In: VI International Symposium on Mango , Acta Hort. 509: 653-659.

Review paper: potassium nitrate application as floral induction method in mango.

Foliar *Flower induction*

Ramirez et al. (2012) published a review paper about mango flowering physiology. Mango flowering is a complex process. Low temperatures are important for mango floral induction under subtropical conditions. But also tip pruning and the use of potassium nitrate are effective methodologies to induce mango flowering, especially in Colombia. Different research papers prove the effectiveness of foliar application of potassium nitrate. Potassium nitrate was more effective in stimulating of vigorous flowering in mature shoots than in younger ones. Additionally, an increase in the number of panicles was observed. The beneficial effect of KNO_3 sprays on flowering induction seems to be mediated by its dormancy-breaking property. It is especially used to induce off-season flowering. Potassium nitrate has been used to enhance flowering but also to increase the mango fruit retention (Oosthuyse, 1996).

Ramírez, F. and T.L. Davenport. 2010. Review: Mango (Mangifera indica L.) flowering physiology. Scientia Horticulturae, 126(2): 65-72.

Increased mango fruit yield with foliar potassium nitrate application.

Foliar *Yield & Quality*

A field trial was conducted from 2005 to 2009 to study the effects of pruning and foliar sprays on flowering and fruit yield in 'Alphonso' mango at the Indian Institute of Horticultural Research in Bangalore. Trees were 16-years old and raised on the rootstock 'Peach'. Trees were spaced at 10 m x 5 m under rain-fed condition on a red loamy soil with pH 7,2 and available nutrient contents of 249 kg N/ha, 14 kg P/ha and 149 kg K/ha. Seven treatments (Table 1) were applied and the trial was laid out in RBD design with four replications. Pruning treatments were imposed after harvesting in August, K_2HPO_4 and KH_2PO_4 sprays were applied in October and KNO_3 and thiourea sprays at the time of bud-break in December. A spray volume of 4 liters/tree was used for the foliar applications. All treatments increased the number of fruits per tree and the fruit yield compared to the control. The highest increase was observed when pruning was combined with 1% K_2HPO_4 + 1% KNO_3. This resulted in almost doubled fruit yield (64 kg/tree) compared to the control (33 kg/tree) (Table 1). Both treatments with potassium nitrate gave the highest gross and net returns, and consequently also the maximum cost:benefit ratio.

Table 1. Effect of pruning and foliar nutrient sprays on number of fruits, fruit yield and cost:benefit ratio in mango cv. Alphonso.

Treatments	No. of fruits /tree	Fruit yield (kg/tree)	Cost: benefit ratio
Pruning + 1% K_2HPO_4	200	41	1:2,3
Pruning + 1% KH_2PO_4	216	44	1:2,5
Pruning + 1% K_2HPO_4 + 1% KNO_3	309	64	1:3,8
Pruning + 1% KH_2PO_4 + 1% KNO_3	244	52	1:2,7
Pruning + 1% K_2HPO_4 + 1% Thiourea	245	50	1:2,5
Pruning + 1% KH_2PO_4 + 1% Thiourea	238	51	1:2,6
Control (no pruning or chemical spray)	159	33	1:1,5

Reddy, Y.T.N. and R.M. Kurian. 2012. Effect of pruning and chemicals on flowering and fruit yield in mango cv. Alphonso. Journal Hortl. Sci, volume 7(1): 85-87.

Foliar potassium nitrate sprays induced flowering in 'Haden' mango.

Foliar Flowering induction

The objective of the study was to evaluate the effect of potassium nitrate and paclobutrazol (PBZ) on flowering induction and yield of 'Haden' mango. The experiment was conducted with 5-year-old 'Haden' trees grown in a sandy loam soil with pH 7 at the Central University Research Station in Maracay, Venezuela. The trees were laid out in a Randomized Complete Block Design with 3 replications, 8 treatments and 3 trees per experimental plot. The KNO_3 sprays were applied at 24, 36 or 48 g/L and divided in 3 applications in September, October and November during the seasons 1993-1994 and 1994-1995. Paclobutrazol was soil applied with different concentrations (2,5, 5, 10 and 15 g a.i./tree).

The number of fruits significantly increased with the potassium nitrate sprays at 36 and 48 g/L and high PBZ concentration (15 g a.i./tree) during 1994 compared to the control and other treatments. PBZ and KNO_3 treated trees at high concentrations were harvested earlier and produced more kg fruit per tree as compared to the control and the PBZ treatments at low concentrations. Concluded was that high KNO_3 doses (3,6 and 4,8%) induced earlier flowering and harvesting (30-45 days sooner) compared to control trees. Also yields were increased and apparently the alternate bearing was reduced (Figure 1).

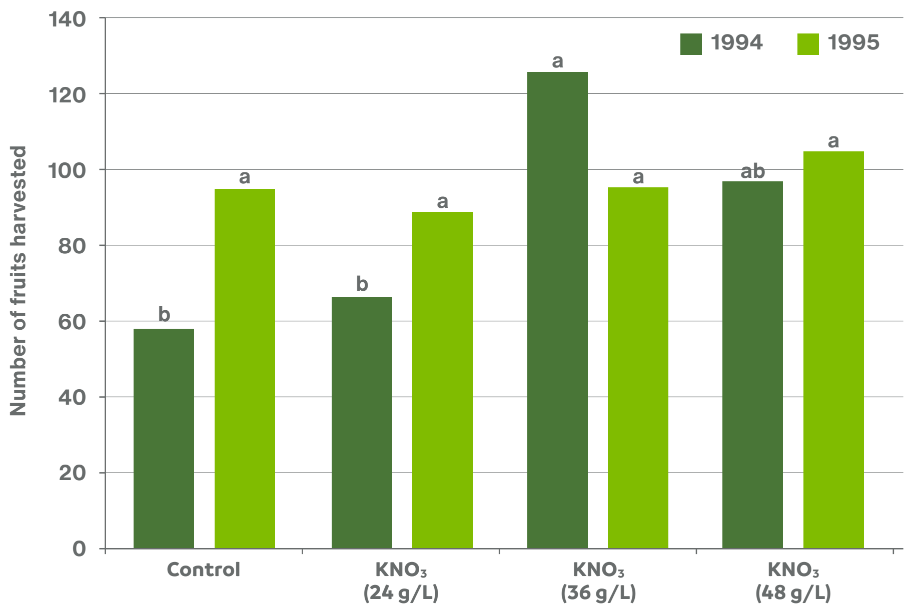


Figure 1. Effect of KNO_3 sprays on the number of mango fruits harvested in two consecutive seasons. Means followed by the same letter do not differ statistically (Duncan Multiple Range α=0,01).

Sergent, E., D. Ferrari and F. Leal. 1996. Effects of potassium nitrate and paclobutrazol on flowering induction and yield of mango (Mangifera indica L.) cv. Haden. In: V International Mango Symposium, Acta Hort. 455: 180-187.

Earlier and enhanced flowering in mango with potassium nitrate sprays.

Foliar *Flowering induction*

Paclobutrazol (PBZ) was applied to different mango cultivars to induce flowering, but cv. Khiewsawoey (KSW) was less responsive to PBZ and therefore potassium nitrate sprays were included in an experiment in Thailand. Three year old trees received soil applied PBZ at 6 g a.i./tree in July 1986, followed by 2,5% KNO_3 sprays 4, 6, 8 or 10 weeks after the PBZ treatment. The potassium nitrate sprays applied 8 or 10 weeks after PBZ application resulted in earlier and improved flowering during the off-season.

Tongumpai, P., N. Hongsbhanich and C.H. Voon. 1989. Cultar for flowering regulation of mango in Thailand. In: VI International Symposium on Growth Regulators in Fruit Production, Acta Hort. 239: 375-378.

Earlier flowering and more advanced panicles with soil applied paclobutrazol and foliar applied potassium nitrate in mango.

Foliar *Flowering induction*

In this study different doses of soil applied paclobutrazol (PBZ) combined with foliar applied potassium nitrate were evaluated in order to determine their effect on flowering and fruit quality of two mango clones. The experiment was carried out at an experimental station in Veracruz, Mexico. A 14-year old orchard of Manila Cotaxtla 1 and Manila Cotaxtla 2 clones spaced at 8 m x 8 m without irrigation was used. PBZ was distributed in four parts to the soil at the following rates: 0, 0,5, 1,0, 1,5 and 2,0 g PBZ per meter of canopy diameter. The foliar sprays of 20 g KNO_3/L or 40 g KNO_3/L were applied twice on October 22 and November 2. The application of PBZ and KNO_3 resulted in earlier flowering, 51 days sooner than the flowering of non-treated trees and the highest dose rates of PBZ and KNO_3 induced a higher number of advanced panicles compared to the control.

Rebolledo-Martínez, A., A. Lid del Angel-Pérez and J. Rey-Moreno. 2008. Effects of paclobutrazol and KNO_3 over flowering and fruit quality in two cultivars of mango Manila. Interciencia, 33(7): 518-522.

Positive effect of potassium nitrate and urea sprays on flowering and yield of mango.

Foliar *Yield & Quality*

In Ethiopia the effects of foliar applied potassium nitrate alone and in combination with urea at different concentrations were evaluated on flowering, fruit set and fruit quality of Tommy Atkins' mango. The sprays were conducted initially on the immature postharvest flushes and then repeated after the maturation of the flushes for dark green leaves. There were no significant differences found for the quality parameters. But for most of the flowering and yield parameters potassium nitrate in combination with urea (5 liter solution of 4% KNO_3 + 0,5 g urea tree^{-1} and 5 liters of 4% KNO_3 + 1 g urea tree^{-1}) produced better results.

Yeshitela, T., P. J. Robbertse, and P. J. C. Stassen. 2005. Potassium nitrate and urea sprays affect flowering and yields of 'Tommy Atkins' (Mangifera indica) mango in Ethiopia. South African Journal of Plant and Soil 22.1: 28-32.

Potassium nitrate found to be an effective flower inducer for 'Carabao' mango.

Foliar *Flowering induction*

Twenty-one years old trees cv. "Carabao", were fed and irrigated according to the commercial routine. To define the optimal treatment for increasing mango yield and quality, foliar treatments to induce flowering were conducted. A water-soluble NPK (12-2-44), with K fully derived from potassium nitrate (PN), was sprayed at various concentrations, and Boom and Super blum as local commercial products in the Philippines were sprayed, all as one single application. The control treatment (water) did not flower and the percentage of flowering in 'Carabao' mango increased with increasing concentration of PN up to 2,0 percent level. The highest yield was found for the 1,0% spray of 174 kg/tree, with a marketable yield of 150 kg/tree.

The wsNPK 12-2-44 is recommended as flower inducer for 'Carabao' compared to standard chemicals due to: high flowering rate at 14 and 21 days after induction, more hermaphrodite flowers, higher fruit-setting and better quality fruits. The recommended dose rate per season; December-April season: 1,0% and 1,5%, July-November season: 2,0% and 2,5%.

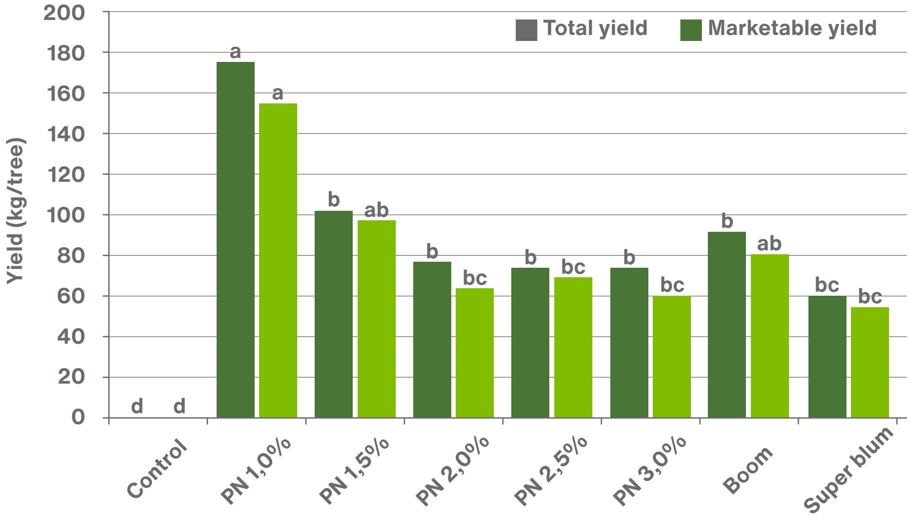


Figure 1. The total yield and marketable yield of 'Carabao' mango after one foliar application, PN is the wsNPK 12-2-44 based on potassium nitrate. Columns, means having the same matter(s) are not significant at 5% level using the multiple range test of Duncan.

Golez, H. G., and N. F. Zamora. 1996. The influence of Multi NPK 12-2-44 on the flowering capacity of 'Carabao' mango. Acta Horticulturae V International Mango Symposium 455: 108-115.

A model for potassium nitrate-induced flowering of 'Carabao' mango.

Foliar *Flowering induction*

It is generally accepted that nitrate salt application stimulates bud break. Presumably, there is a threshold for nitrogen concentration that, if exceeded, will allow the plant to flower.

Potassium nitrate probably acts by elevating nitrogen levels over a nitrogen threshold thereby synchronizing bud break from apices with existing floral initials. The signaling process is probably mediated by polyamines or ethylene.

In addition, the role of potassium nitrate is related to increased production and translocation of sugars to the bud.

General recommendation: 3 to 4 weekly sprays with potassium nitrate (3-4% w/v) to affect general terminal bud development, and to ensure intense and even flowering.

Protacio, C. M. 1999. A model for potassium nitrate-induced flowering in mango. Acta Horticulturae VI International Symposium on Mango 509: 545-552.

Foliar applied potassium nitrate found to induce bud break of quiescent pre-existing floral buds in mango.

Foliar *Flowering induction*

The exact mechanism of foliar applied potassium nitrate in mango on bud dormancy break is still not fully understood. A flower intensity index of 4 (flowers all over the canopy) and longer inflorescences in paclobutrazol (PBZ) treated trees was a result of induction of flower bud break by 2% KNO_3 sprays, while control trees (no PBZ) exhibited a flower intensity index of 2 (less than 25% of the canopy have flowers). PBZ treated trees showed 12,3% longer panicles and 67% higher fruit retention (Table 1).

Mango shoots must have low gibberellic acid (GA) content to allow total non-structural carbohydrates, primarily starch, to accumulate in the leaves and buds, leading to the early formation of floral initials. Potassium nitrate induces bud break of quiescent pre-existing floral buds and is not responsible for the transformation of vegetative buds to reproductive ones, because floral initials were present before KNO_3 application.

Table 1. Effect of paclobutrazol (at 1 g of PBZ per meter canopy diameter) treatment on the intensity of flowering and retention of fruits in KNO_3-sprayed 'Carabao' mango trees.

Treatments	Intensity	Description	Length of panicle (cm)	No. of fruits retained
KNO_3 2%	2	25-50% has flowers	14	1
PBZ + KNO_3 2%	4	numerous flowers all over canopy	15	2

Serrano, E. P., I.P. Marquez, F.M. Rodriguez, C.M. Protacio and J.E. Quinto. 2009. Unravelling the mechanism of mango flowering. Acta Horticulturae VIII International Mango Symposium 820: 259-270.

Foliar potassium nitrate application increased fruit retention and fruit yield in various mango cultivars.

Foliar *Yield & Quality*

The effect on fruit retention, fruit size, tree yield, and fruit quality of inflorescence applications of KNO_3 to mango trees was investigated during two experiments in South Africa. Sprays at 2% or 4% were applied once during full bloom or twice during the active development of the inflorescences and subsequently during full bloom. The first experiment was conducted with eight-year-old 'Tommy Atkins' trees in Constantia, South Africa. Linear increases in number of fruits retained and tree yield were apparently associated with the increase in concentration of KNO_3 applied (Table 1). Moreover, these increases were apparently associated with a linear reduction in average fruit weight.

Table 1. Effect of foliar potassium nitrate sprays on yield characteristics of 8-year-old mango trees ('Tommy Atkins').

Treatments	Number of fruits harvested	Average fruit weight (g)	Tree yield (kg)
Unsprayed	205	385	78
1 x 2% KNO_3	226	366	83
1 x 4% KNO_3	244	367	90

In the second experiment three mango ('Tommy Atkins', 'Heidi' and 'Kent') cultivars were studied. The two- to three-year-old mango trees of uniform size and stage of flowering were grown at Mariepskop Estate, South Africa. In 'Tommy Atkins', the greatest increase in fruit retention and consequently yield (+69%) occurred following one spray at 4% KNO_3 compared to the control. In 'Heidi', two sprays at 4% each gave rise to the greatest yield increase (+400%), and in 'Kent', two sprays at 2% each increased fruit retention and yield (+60%) the most compared to the untreated control (Figure 1).

Increases in fruit retention and tree yield occurred by foliar potassium nitrate application despite all the trees received adequate soil fertilizers. Spraying KNO_3 during flowering resulted not in a reduction in fruit size, although fruit retention and yield were increased. There was no apparent effect of the KNO_3 sprays on fruit quality (ground skin colouration, total soluble solids content, pH, or taste on ripening).

Oosthuyse, S. A. 1996. Effect of KNO_3 sprays to flowering mango trees on fruit retention, fruit size, tree yield, and fruit quality. In V International Mango Symposium 455: 359-366.

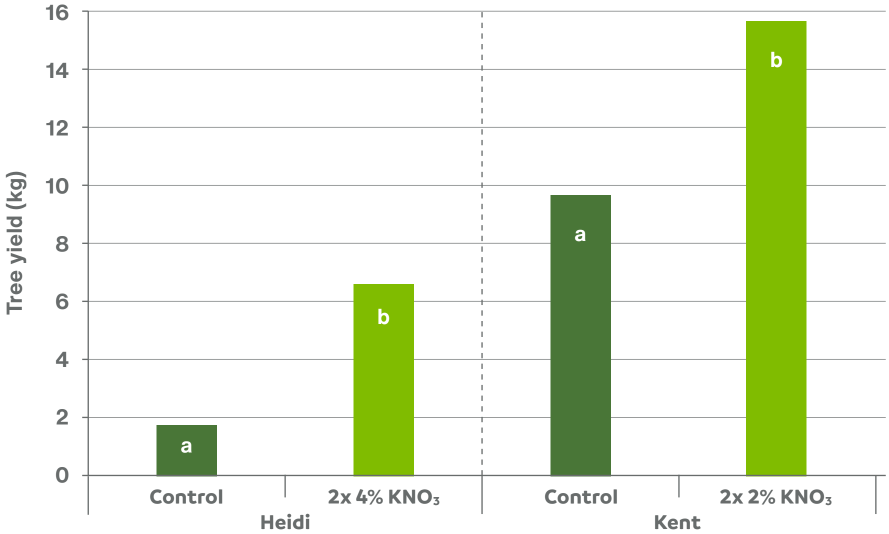


Figure 1. Effect of KNO_3 sprays on tree yield (kg) of two- to three-year-old 'Heidi' and 'Kent' mango trees.

Foliar applied potassium nitrate outperformed potassium thiosulphate in mango.

Foliar *Yield & Quality*

The effects of pruning in combination with potassium nitrate or potassium thiosulphate application on mango production were studied on the Maracaibo plain, Zulia State, Venezuela. A factorial design was used, with two treatments of pruning at two levels (without pruning and with pruning), two flowering inductor levels (potassium nitrate (KNO_3) at 6% and potassium thiosulphate at 1% (PTS)), and a control without pruning and without inductor (Figure 1). The treatments were located at random using two varieties: 'Irwin' and 'Tommy Atkins' with four plants per treatment. Two consecutive production seasons were studied considering early and late induction that means four essays over different plots.

The result compared to the untreated control showed 25 to 30 days earlier harvests for Irwin variety, and 15 to 20 days earlier harvest for Tommy Atkins variety, when potassium nitrate was applied. The application of the inductor shortened the total harvesting time. About 80% of production was concentrated in two initial months of harvesting when potassium nitrate was applied. For almost all treatments early induction resulted in higher yield levels compared to late induction. Results of this research showed that for the Irwin variety potassium nitrate combined with pruning resulted in the highest yield level, during both inductions, compared with other applied treatments (Figure 1). Pruning was more effective for Irwin variety, whereas no pruning gave better results in Tommy Atkins variety. It can be concluded that potassium nitrate seemed to be the preferred inductor compared to potassium thiosulphate.

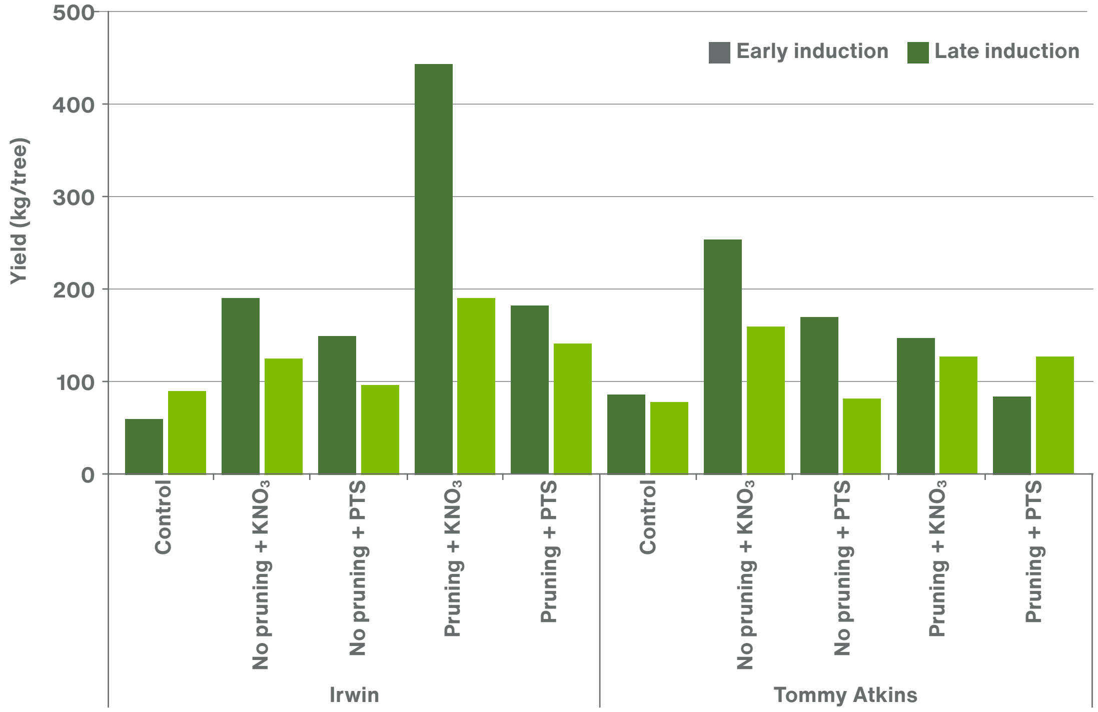


Figure 1. The effect of pruning and foliar application of potassium nitrate (KNO_3) and potassium thiosulphate (PTS) on the averaged yield (for two cropping seasons) of two mango varieties.

Quijada, R., V. Herrero, R. González, Á. Casanova and R. Camacho. 2009. Influence of pruning and potassium nitrate and potassium thiosulphate application on the production of mango (Magifera indica L.) varieties Irwin and Tommy Atkins in the Maracaibo plain, Venezuela. Revista UDO Agricola 9 (2): 312-321.

Foliar applied potassium nitrate increased number of fruits and fruit yield of mango.

Foliar *Yield & Quality*

An experiment with mango (Mangifera indica L.) cv. Tommy Atkins was carried out in Livramento de Nossa Senhora, Bahia state, Brazil. The objective was to evaluate the flowering, number of fruits produced and the yield of mango fruits. The plants were about six years old and planted with 10 x 10 m spacing. The plants were sprayed three times with 3% potassium nitrate at different timing intervals: one, three, five, seven, nine days of interval (and an untreated control). All plots treated with potassium nitrate produced a statistically significantly higher number of fruits per plant (ranging from 550 to 700 fruits) compared to the control (about 200 fruits). However, no significant differences among the different time intervals for the KNO_3 treated plants were observed. The yield of mango plants treated with foliar KNO_3 was increased due to the increase in number of fruits, as no statistical differences in average fruit weight were observed. Three applications with 3% potassium nitrate increased mango yield, and consequently grower's net income and profitability (Table 1).

Table 1. Yield and economic analysis related to the foliar application of potassium nitrate in mango.

Treatments	Yield (kg/ha)	Net income (US$/ha)	Extra income (US$/ha)	Extra fertilizer cost (US$/ha)	Profitability (%)
Control	10.620	8.358			
KNO_3	24.821	20.987	12.629	233	5,3

Ataide, E. M. and A. R. S. Jose. 1999. Effect of different intervals of potassium nitrate spraying on flowering and production of mango trees (Mangifera indica L.) cv. Tommy Atkins. Acta Horticulturae 509: 581-586.

Foliar potassium nitrate sprays at 2% and 5% induced mango flowering and number of fruits retained per tree.

Foliar *Flowering induction*

The aim of the study was to determine the influence of different application rates of the inducing substance, potassium nitrate, on enhancement of flowering in mango clone "Chok Anan" and ultimately, the fruit production. This field experiment was conducted in Selangor, Malaysia, with trees aged about twelve months and five-years-old. The plants were subjected to three treatments of spray application with 1% KNO_3, 2% KNO_3 and 5% KNO_3 onto mango shoots at two weeks interval until flower initiation. The experiment was arranged in a randomized complete block design. Twelve-months-old mango trees initiated only little flowering when sprayed with 1% KNO_3, while flowering induction was not observed for the control and on terminal bud treated with 2% and 5% KNO_3. Flowering induction was highly observed for the five-year-old mango trees treated with 2% and 5% KNO_3. More flowers generated a higher fruit set rate and thus increased the number of fruits produced (Table 1). It was concluded that the age of tree and shoot maturity may influence the flowering response to KNO_3 application. Best results were observed with 2% KNO_3 sprays to induce early flowering in five-year-old mango trees.

Table 1. Effect of potassium nitrate sprays on flowering intensity and fruit number of five-years-old mango trees.

Treatments	Inflorescence rate/tree	No. of fruits/tree
Control	29%	20
1% KNO_3	32%	25
2% KNO_3	80%	64
5% KNO_3	70%	47

Nur Afiqah, A., H.Z.E. Jaafar, N. Rosimah and K. Misri. 2012. Flowering enhancement of Chok Anan mango through application of potassium nitrate. Trans. Malaysian Soc. Plant Physiol. 20: 106-110.

Potassium nitrate and calcium nitrate used for flowering induction and fruit retention in mango.

Foliar | Flowering induction

The effects of paclobutrazol, potassium nitrate (KNO_3) and calcium nitrate ($Ca(NO_3)_2$) on the growth and development of mango cv. Tommy Atkins were studied in Venezuela. Four-year-old trees grafted on mango cv. Hilacha, spaced 8 m × 4 m, were used. Paclobutrazol was applied to the soil at 0 and 6 ml Cultar/m^2, while nitrate was given at the following levels: no nitrate, 8% KNO_3 or 8% $Ca(NO_3)_2$ sprayed in one application, and 3,5% KNO_3 or 3,5% $Ca(NO_3)_2$ sprayed in three applications at weekly intervals. Paclobutrazol inhibited vegetative growth and stimulated flower development. Flowering was initiated six weeks earlier than under normal conditions. In contrast, the nitrates had no effect on generative shoots, but 8% KNO_3 stimulated the burst of vegetative, mixed and total buds. Paclobutrazol produced a large number of fruits per inflorescence but had no effect on the percentage of retained fruits. The highest percentage of retained fruits was found for three sprays of 3,5% KNO_3 (Table 1).

Table 1. Effect of potassium nitrate and calcium nitrate on fruit retention of mango.

Treatments (Conc. % x no. of appl.)	Retained fruits (%)
No nitrates	17,8
KNO_3 (8% x 1)	15,9
KNO_3 (3,5% x 3)	21,3
$Ca(NO_3)_2$ (8% x 1)	15,7
$Ca(NO_3)_2$ (3,5% x 3)	17,2
C.V. (%)	8,6

Cárdenas, K. and E. Rojas. 2003. Efecto del paclobutrazol y los nitratos de potasio y calcio sobre el desarrollo del mango 'Tommy Atkins'. Bioagro 15(2): 83-90.

Foliar sprays of potassium nitrate for flower induction in 'Pahutan' mango shoots.

Foliar | Flowering induction

Already in 1978 Bondad et al. speculated that KNO_3 may play a role in the induction of floral differentiation in mango (Mangifera indica L. 'Pahutan'). In 7 out of 8 monthly trials in the Philippines, flowering of 4,75 to 12,75 months old mango shoots occurred one week after spraying 10 to 160 g/liter KNO_3. Induction was 33% to 100% in 7 to 14 days. First trial started in September and in all months flowering occurred. There was a general decrease in percentage flowering of treated shoots from January to April. In contrast, natural flowering which began in February tended to increase till May. No consistent trend was observed in bud and panicle growth, but those produced by KNO_3 spraying appeared longer than natural produced panicles.

Bondad, N. D., E.A. Blanco and E. L. Mercado. 1978. Foliar sprays of KNO_3 for flower induction in 'Pahutan' mango shoots. Philippine Journal of Crop Science, 3(4): 251-255.

Potassium nitrate acts to stimulate and concentrate terminal bud development in Nam Doc Mai terminal shoots induced to flower by soil paclobutrazol treatment.

Foliar *Flowering induction*

Bearing Nam Doc Mai Si Thong mango trees in a non-irrigated orchard in the Chachoengsao Province, Thailand, were either soil treated in mid-July, 2011, when new terminal shoot development was commencing, with paclobutrazol (PBZ) or were left untreated in this regard. The treated trees were either sprayed or not sprayed with potassium nitrate in October and November to effect terminal bud and inflorescence development. Potassium nitrate (KNO_3) was sprayed on October 10, 20 and 27, and on Nov. 3, 2011. In addition, some of the KNO_3 sprayed trees were also sprayed with Ethrel/SOP in early September (Sep. 1 and 8) as a measure to prevent early bud development from the new shoots arising after PPZ treatment. The last treatment - PBZ/Ethrel-SOP/KNO_3 - was carried out in two replications.

Ethrel/SOP treatment had no apparent effect on the flowering period or flowering intensity. Only one flush materialized after mid-July from which new shoots or inflorescences developed during October and November. The trees not treated with PBZ or KNO_3 generally produced new shoots, whereas those treated with PBZ only produced inflorescences during Nov. and Dec. Here, terminal bud break was not concentrated, occurring over the entire period, and had not occurred or occurred very little by Nov. 10. In the trees sprayed by KNO_3, 40 to 50% of the terminal shoots showed extending or flowering inflorescences on Nov. 10 (Figure 1). During the 12 days that followed, terminal shoots showing inflorescence development in the PBZ treated trees increased to 58%, the level of those sprayed with KNO_3. By Nov. 24, 55 to 65% of all the treated trees showed inflorescence development, this increasing to 70 to 80% by Dec. 22. New shoots developed from terminal shoots on the untreated trees in a similar pattern and in the same time period as the trees treated with PBZ only. The data clearly indicate that the PBZ induced inflorescence development, whereas the KNO_3 sprays acted to stimulate and concentrate terminal bud development.

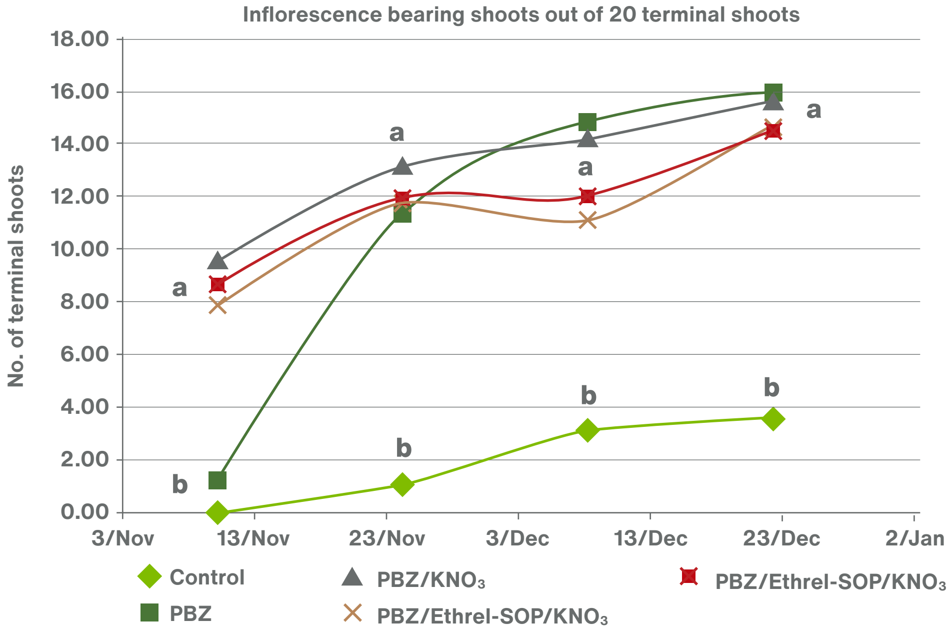


Figure 1. Marked terminal shoots showing inflorescences on Nov. 10 and 24 and Dec. 8 and 22, 2011. For specific dates, differing letters indicate significance according to the 5% LSD criterion.

Oosthuyse, S.A., B. Desmet and W. Wong. 2013. Potassium nitrate acts to stimulate and concentrate terminal bud development in Nam Doc Mai terminal shoots induced to flower by soil paclobutrazol treatment. X International Mango Symposium, 1-7.

Spray applications of potassium nitrate most effective in improving fruit retention, fruit weight, yield and return of mango trees.

Foliar Yield & Quality

The effects of foliar spray application of KNO_3, low biuret urea, GA_3 (a gibberellin), CPPU (a synthetic cytokinin) and NAA (a synthetic auxin) on fruit retention, average fruit weight and yield at harvest, and monetary return taking currently obtained prices in account were evaluated. For the experiment 10-year-old Tommy Atkins mango trees were selected in an orchard at Constantia in the north-eastern Transvaal, South Africa. Spray applications were made while the trees were in flower or subsequently, just prior to the commencement of fruit drop. Potassium nitrate was applied twice on August 28 (panicles in shoot: 3-15 cm) and on September 11 (panicles 50 to 100% anthesis) at a rate of 4 kg/100 liter water. LB urea was applied at 1% (w/v), GA_3 at 40 ppm, NAA at 40 ppm and CPPU at 10 ppm, and applications were made singly or in combination. Of all the treatments applied during flowering, KNO_3 application was the only treatment to noticeably increase fruit retention, average fruit mass, yield and monetary return (Figure 1). Spray applications of potassium nitrate can be employed to improve the yield of Tommy Atkins mango.

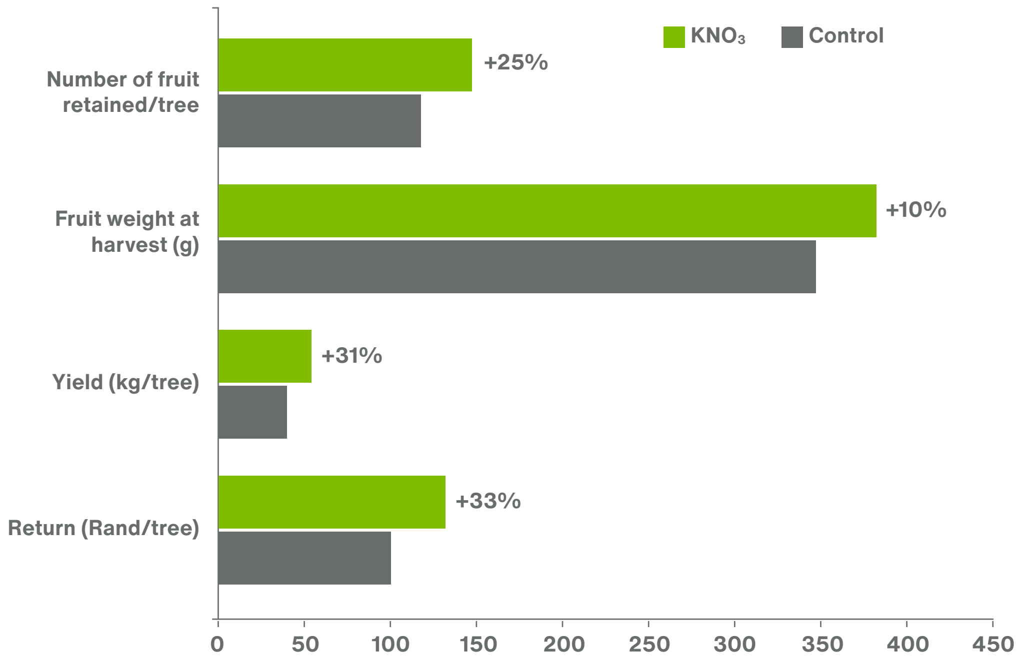


Figure 1. The effect of KNO_3 spray applications on Tommy Atkins mango trees.

Oosthuyse, S. A. 1993. Effect of spray application of KNO_3, urea and growth regulators on the yield of 'Tommy Atkins' mango. South African Mango Growers' Association Yearbook, 13: 58-62.

Potassium nitrate sprays during the inflorescence development period reduced post fruit set drop and increased tree yield in mango.

Foliar *Flowering induction*

In this study KNO_3 at 2 or 4% (w/v) was sprayed once or twice during the inflorescence development period on young Tommy Atkins, Heidi or Kent trees, to increase fruit retention and yield. In all instances, fruit retention and yield were increased by KNO_3 inflorescence spray application. In Tommy Atkins, one 4% application at full bloom appeared to be best, whereas in Kent two applications of 2% resulted in the greatest benefit (Table 1). In Heidi two applications of 4% KNO_3 resulted in highest retention and yield (Table 1). KNO_3 spray application during the inflorescence development period was considered the best option to reduce post fruit set drop and to increase tree yield in mango.

Table 1. Effect of various foliar sprays with potassium nitrate on fruit retention and fruit yield per tree in each of the varieties used.

Treatments	Tommy Atkins		Heidi		Kent	
	Fruits retained	Tree yield (kg)	Fruits retained	Tree yield (kg)	Fruits retained	Tree yield (kg)
Control	9,5 a	4,4 a	2,3 a	1,4 a	16,7 a	9,8 a
1 x 2% KNO_3	13,6 ab	5,9 ab	11,7 ab	6,5 a	21,9 ab	11,8 ab
1 x 4% KNO_3	18,1 b	7,8 b	5,3 ab	2,5 ab	14,2 a	7,4 a
2 x 2% KNO_3	13,7 ab	6,0 ab	10,2 ab	5,4 ab	30,6 b	15,6 b
2 x 4% KNO_3	15,9 b	7,4 ab	14,2 b	6,9 b	24,8 ab	12,0 ab

Oosthuyse, S. A. 2013. Spray application of KNO_3, low biuret urea and growth regulators and hormones during and after flowering on fruit retention, fruit size and yield of mango. Xth International Mango Symposium.

Potassium nitrate-induced flowering of 'Carabao' mango shoots at different stages of maturity.

Foliar *Flowering induction*

The purpose of this study was to check the effect of different potassium nitrate sprays on flowering induction of 'Carabao' mango shoots in the Philippines. Newly-emerging shoots on the trees were tagged, to get shoots of 4,5 to 8,5 months old. In August and at monthly interval thereafter up to December, randomly designated shoots were sprayed with 0, 10, 20 or 40 g/l KNO_3. The control shoots were sprayed with tap water. All potassium nitrate treatments at 10 to 40 g/l induced the flowering of 4,5 to 8,5 old 'Carabao' mango shoots. The oldest shoots of 8,5 months required only 10 g/l KNO_3 to produce the best flowering response. The best results were obtained with the younger shoots (4,5 to 7,5 months) and sprays of 20 g/l KNO_3. The high concentration treatment (40 g/l KNO_3) reduced percentage of flowering, panicle length and number of flowers at all stages of maturity for mango shoots. All control shoots did not flower.

Astudillo, E. O. and N.D. Bondad. 1978. Potassium nitrate-induced flowering of 'Carabao' mango shoots at different stages of maturity. Philippine Journal of Crop Science 3(3): 147-152.

Foliar applied potassium nitrate increased flowering, fruit retention and yield in mango.

Foliar *Flowering induction*

This experiment in mango (Mangifera indica L.) was conducted to study the flowering and fruiting behavior of 'Haden' and 'Manila' shoots in response to apical bud pruning (decapitation) and/or single KNO_3 spray. Trees used were 9-year-old, planted at 10 x 10 m and grown on a sandy and well-drained soil at Tecomán, Colima on the west coast of central Mexico. Treatments were: untreated control, shoot decapitation, single spray of 80 g KNO_3/liter of water and combined decapitation and KNO_3 spray. Sprays were applied with a hand sprayer to all leaves of corresponding shoots until run-off. Treatments were applied in mid-January during the natural flowering period in each cultivar. Percentage of flowering shoots was highest in both cultivars for the KNO_3 spray treatment, but spraying and decapitating combined produced triple and nearly double the number of panicles/shoot in Haden and Manila respectively, as compared with untreated controls. Highest fruit retention rates in both cultivars were found for KNO_3 sprayed shoots, although in Haden the rate was statistically equal to that of the untreated control (Figure 1). Spraying of Manila trees alone with KNO_3 produced the highest yield, 1,64 fruit/shoot, or about twice the yield in relation to the rest of treatments. Fruit size and quality were not affected by increased fruit set.

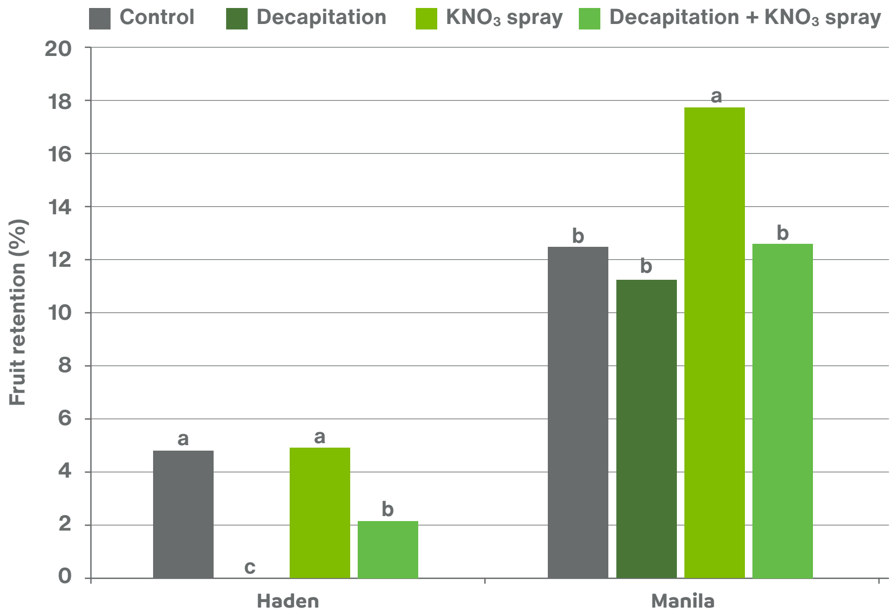


Figure 1. The effect of treatments on the fruit retention (%) of 'Haden' and 'Manila' mango cultivars.

Nuñez-Elisea, R. 1985. Flowering and fruit set of a monoembryonic and a polyembryonic mango as influenced by potassium nitrate sprays and shoot decapitation. In: Proceedings of the annual meeting of the Florida State Horticulture Society (USA), 98:179-183.

Mangosteen

Mangosteen

Foliar application of paclobutrazol in combination with potassium nitrate enhanced flowering and fruiting of mangosteen.

Foliar *Flowering induction*

A study was conducted to determine the effect of paclobutrazol (PBZ) application combined with potassium nitrate or Bicomine (a plant growth regulator) on flowering and fruiting of mangosteen (Garcinia mangostana L.). The trial was carried out during the 2003/2004 growing season at MARDI Research station, Bukit Tangga in the northern Peninsular of Malaysia. Fourteen-year-old mangosteen trees, uniform in vigour and canopy size were selected for this experiment and standard orchard management practices were applied. Treatments imposed were: 1) untreated control, 2) PBZ applied as soil drench at 2 g/tree followed by foliar application of Bicomine (at 1 mL in 6L of water) on 18 December followed by weekly applications during flowering and fruit development, 3) PBZ applied as foliar spray (at 1000 ppm) on 18 December followed by weekly foliar sprays with 2% KNO_3 until flowering and 4) PBZ applied as foliar spray (at 1000 ppm) on 18 December followed by weekly sprays with Bicomine (at 1 mL in 6L of water) during flowering and fruit development. Each treatment consisted of 10-single-tree replicates.

The results in Table 1 demonstrate that soil application of PBZ combined with Bicomine was not effective to enhance flowering or increase yield. Foliar application of paclobutrazol followed by foliar applications of potassium nitrate or Bicomine enhanced both flowering and fruiting of mangosteen, compared to the control. Total yield in weight of harvested fruits per tree did not show any significant differences between the treatments with foliar PBZ and KNO_3 or Bicomine ($p<0,05$). Both treatments increased yield compared to untreated control, even if trees sprayed with PBZ + KNO_3 produced less flowers and number of fruits per tree than those sprayed with PBZ + Bicomine (Table 1). The fruit size from foliar PBZ + Bicomine treated trees was significantly smaller than that from the other treatments. The increased number of fruits per tree may be the cause of this reduction in fruit weight. Other aspects of fruit quality were not affected regardless of the treatments imposed to the trees.

Table 1. Effect of treatments on flowering and yield of mangosteen. S= soil drench, F= foliar spray. The means with the same letter within the same column are not significantly different (LSD, P<0,05).

Treatments	Flowers/tree	Number of fruits/tree	Yield (kg/tree)	Fruit weight (g)
Control	830 c	328 c	22,9 b	80,7 a
PBZ (S) + Bicomine (F)	871 c	345 c	23,7 b	79,9 a
PBZ (F) + 2% KNO_3 (F)	1068 b	423 b	33,9 a	82,3 a
PBZ (F) + Bicomine (F)	1318 a	495 a	35,1 a	65,9 b

S = soil applied, F= Foliar applied

Omran, H. and R. Semiah. 2006. Effect of paclobutrazol application combined with potassium nitrate and Bicomine spray on flowering and fruiting of mangosteen (Garcinia mangostana L.). In: Xth International Symposium on Plant Bioregulators in Fruit Production, Acta Hort. 727: 151-154.

Melon

Melon

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Potassium nitrate turned out to be the preferred priming treatment for melon seedlings.

Seed priming

The aim of the work was to evaluate the response of melon seedling in order to reduce post-transplant stress and thus maximize biomass production as a strategy for managing melon crops. Priming was performed in 150 mM of different solutions: KNO_3, NH_4NO_3, $(NH_4)_2SO_4$ and NaCl. Fertigation with NH_4NO_3 did not eliminate the effect of previous priming treatments. Seedlings primed with KNO_3 showed the highest total fresh and dry biomass, mainly due to their higher metabolic activity and their greater leaf area (Table 1). Potassium nitrate outperformed the other priming treatments in this experiment.

Table 1. Effect of priming on seedlings fertigated with NH_4NO_3.

Treatments	Leaf area (cm^2)	Fresh weight (g)	Dry weight (g)
Control	56,6	3,71	0,53
KNO_3	80,2	5,74	0,81
$(NH_4)_2SO_4$	69,4	5,17	0,71
NaCl	73,4	4,98	0,70
NH_4NO_3	76,7	5,67	0,74
Significance	*	*	*

* Significant differences at P<0,05.

Guzmán, M. and J. Olave. 2006. Response of growth and biomass production of primed melon seed (Cucumis melo L. cv. Primal) to germination salinity level and N-forms in nursery. Journal of Food, Agriculture and Environment, 4(1): 163-165.

Improved salt tolerance of melon by the addition of potassium nitrate.

Fertigation *Salinity relief*

A pot experiment with melon (Cucumis melo) cv. "Tempo F1" was conducted under greenhouse conditions in Mugla-Ortaca (Turkey). The plants were grown in a mixture of peat, perlite and sand (1:1:1) to investigate the effects of potassium nitrate applications to salinity-treated plants with respect to fruit yield, plant growth, some physiological parameters and ion uptake. All treatments received a standard nutrient solution. The volume of the nutrient solution applied to the root zone of the plants ranged from 200 to 500 ml per application, depending on plant age, applied twice a week. Treatments were: 1) control (C), 2) salinity treatment by addition of 150 mM NaCl (C+S) and 3) plants receiving 150 mM NaCl plus supplementary 5 mM KNO_3 (C+S+PN). Each treatment was replicated three times and each replicate included 5 pots.

The salt treatment (150 mM NaCl) resulted in statistically significant decreases in plant growth, fruit yield and chlorophyll a content, accompanied by significant increases in electro leakage (membrane permeability). Supplementary KNO_3 treatments significantly ameliorated the adverse effects of salinity on plant growth, fruit yield and the physiological parameters examined (Table 1). This could be attributed to the effects of all the external supplements in maintaining membrane permeability, increasing relative water content, stomatal density and concentrations of Ca_2^+, N and K^+ in the leaves of plants subjected to salt stress. It can be concluded that potassium nitrate was effective in mitigating the adverse effects of salinity stress in melon plants.

Table 1: Effects of sodium chloride and potassium nitrate supplementation with a standard nutrient solution in melon.

Treatments	Plant DW (g/plant)	Fruit yield (kg/plant)	Chlorophyll a (mg/kg)	Electrolyte leakage (%)
C	27,6 a	6,3 a	890 b	11,5 c
C + S	21,7 b	4,1 c	660 c	42,7 a
C + S + PN	26,5 a	5,2 b	1030 a	25,3 b

Note: C, control: complete nutrient solution; S: 150 mM sodium chloride added to nutrient solution; PN: 5 mM KNO_3 supplemented in nutrient solution.

Kaya, C., A.L. Tuna, M. Ashraf and H. Altunlu. 2007. Improved salt tolerance of melon (Cucumis melo L.) by the addition of proline and potassium nitrate. Environmental and Experimental Botany, 60: 397-403.

Nuts

Nuts

Urea and potassium nitrate sprays for enhanced growth and quality of cashewnut.

Foliar *Yield & Quality*

In this research the effect of foliar application of 3% urea and 2% KNO_3 applied together with insecticides was studied. These foliar sprays had significant effect on growth, yield contributing characters, fruit set and fruit retention of cashewnut. The highest nut yield was obtained with 3% urea spray at new vegetative growth, flowering stage and at seed setting stage, but the highest average nut weight was observed with 2% KNO_3. The highest protein content in the nuts was found for a 2% foliar spray with KNO_3.

Palsande, V. N., D.J. Dabke, M.C. Kasture, N.H. Khobragade and S.D. Patil. 2013. Effect of urea, potassium nitrate and insecticides through foliar application on growth, yield and quality of cashewnut. BIOINFOLET-A Quarterly Journal of Life Sciences, 10(1b): 347-349.

Potassium nitrate plus surfactant sprays suppressed pecan aphid populations.

Foliar *Pest & disease reduction*

The aim of the study was to verify if early season spraying of pecan solely with potassium nitrate/surfactant (PN+S) would increase nut yield. The treatments did not influence yield components, foliar K nutrition or net photosynthesis, but they did suppress "yellow-type" aphid populations in pecan trees. Water sprays alone suppressed aphid populations and the addition of KNO_3 (0,5%) plus surfactant (0,15%) provided an additional level of suppression (Figure 1).

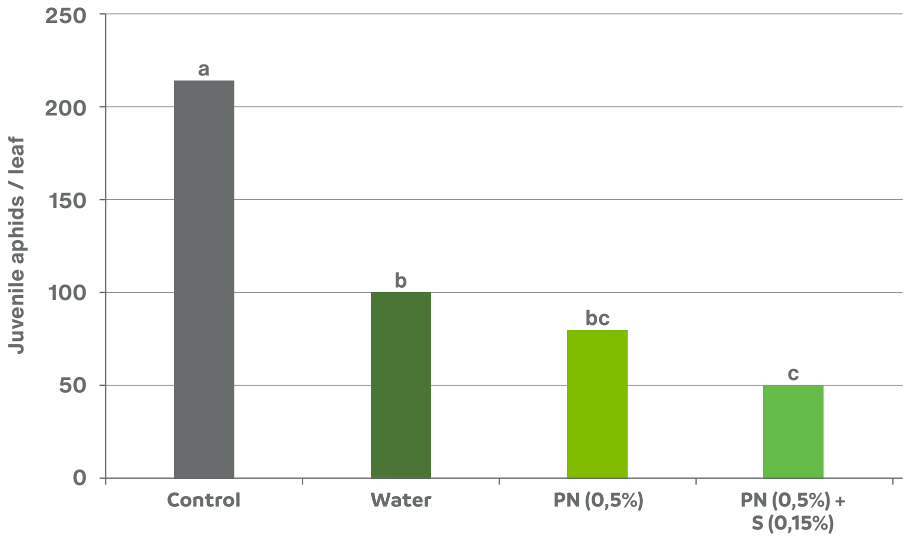

Figure 1. Influence of foliar sprays on juvenile yellow-type pecan aphid populations on pecan foliage 1 day after spraying. Treatments: control (unsprayed), water, PN (potassium nitrate) and S, surfactant, trisodium-phosphate-based Sears detergent.

Wood, B. W., J.A. Payne and M.T. Smith. 1995. Suppressing pecan aphid populations using potassium nitrate plus surfactant sprays. HortScience, 30 (3): 513-516.

Increased blooming of female and male flowers with foliar-applied potassium nitrate in pecan trees.

Foliar *Dormancy breaking*

The yield of pecan (Carya illionensis Koch) trees can be severely reduced in subtropical regions by inadequate chilling which may delay normal blooming. Therefore the effect of some chemical treatments on opening of different bud types, the date and percentage of full bloomed flowers (female and male) and fruit set was studied. The study was carried out on trees of five pecan cultivars (Cherokee, Desirable, Choctaw, Graking and Cape Fear) grown in the orchard of Kaha Research Station in Egypt. Potassium nitrate 5%, hydrogen cyanamide "Dormex" 3%, urea 10% and water (control) were applied to one-year-old shoots in 2006 and 2007, 4 weeks before normal bud break (1st February). Potassium nitrate and hydrogen cyanamide treatments resulted in the highest percentage of blooming flowers (Figure 1) and two weeks earlier opening of female flowers as compared to the control. Potassium nitrate was more effective in stimulating bloom of male flowers compared to all other treatments. Application of potassium nitrate or Dormex synchronized time of full bloom of male and female flowers within each cultivar in the two seasons. All treatments significantly stimulated the initial and final fruit set percentage compared to the control. Potassium nitrate and Dormex were greatly effective for increasing the initial and final fruit set percentage; meanwhile, application of urea had the least significant stimulative effect. The results of this study might be applicable to pecan growing regions with a mild winter.

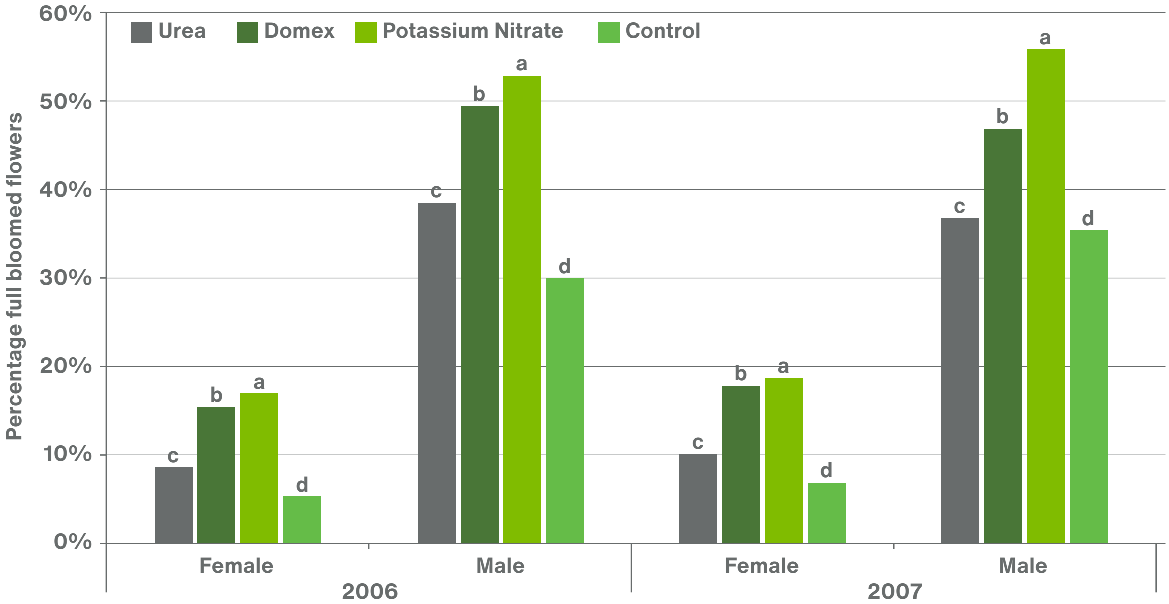

Figure 1. Average effect of different treatments on the percentage full bloomed female and male flowers of pecan. Means with different letters within each group of columns were significantly different at L.S.D. 0,05.

Fayek, M. A., T.A. Fayed, E.H. El-Said and E.E. Abd El-Hamed. 2008. Utilization of some chemicals for synchronizing time of male and female flowers in pecan (Carya illionensis Koch). Research Journal of Agriculture and Biological Sciences, 4(4): 310-320.

Olive

Olive

Improved fruit yield and quality in olive with foliar applied potassium nitrate.

Foliar *Yield & Quality*

This study was conducted in an orchard located at Cairo-Alexandria, Egypt, during two successive seasons in 2009 and 2010. The aim was to study the effect of foliar application with potassium nitrate at different concentrations and timing on vegetative growth, yield and fruit quality of Picual olive (Olea europaea L.). The trees were 15 years old and planted at 5 m x 8 m in a sandy soil with a high pH of 8,5 and poor in nutrients. Potassium nitrate was applied as foliar spray at two dosages: 2% and 4%. Both dosages were applied at two timings: 1) after final fruit set (mid-May) and 2) after pit hardening (first week of August). The control treatment was sprayed with water.

Potassium nitrate foliar sprays at 4% after final fruit set gave the highest number of new shoots per twig in both seasons. Yield was affected by potassium nitrate foliar applications in both seasons. The highest – statistically significant ($p<0,05$) - yield was observed in both seasons when 4% KNO_3 was applied as foliar spray after final fruit set, yield increased with 15% in 2009 and 35% in 2010 compared to the control (Figure 1). Foliar application of KNO_3 after pit hardening also increased the fruit length in both seasons. The highest fruit weight, flesh weight, flesh/fruit ratio and flesh oil content were obtained in both seasons with foliar application of 4% KNO_3 after pit hardening. The timing of application determines which beneficial effects were observed: 4% KNO_3 in foliar spray after final fruit set improved the vegetative growth and increased the yield. Foliar application of 4% KNO_3 after pit hardening increased fruit quality and the oil content.

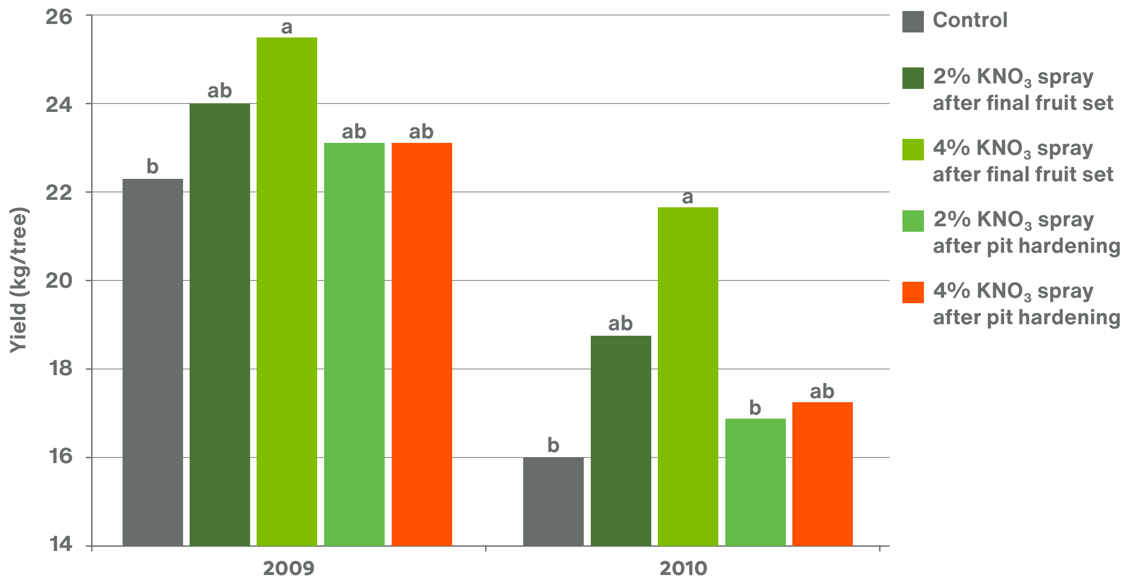

Figure 1. Effect of spraying potassium nitrate on fruit yield of Picual olive trees. Means with similar letters within each year are not significantly different at 5% level (Duncan).

Hegazi, E. S., S.M. Mohamed, M. R. El-Sonbaty, S. K. M. Abd El-Naby and T.F. El-Sharony. 2011. Effect of potassium nitrate on vegetative growth, nutritional status, yield and fruit quality of olive cv. Picual. Journal of Horticultural Science & Ornamental Plants, 3(3): 252-258.

Potassium nitrate sprays positively affected fruit growth and olive oil quality.

Foliar *Yield & Quality*

The experiment on olive trees was designed to evaluate the influence of foliar nutrition with N and K. Two potassium nitrate sprays at 3% during the second (II) and third (III) phase of development of the fruit increased fruit fresh weight, flesh to pit ratio, dry weight and oil content (Table 1). These foliar sprays also increased the important yield parameters: fruit yield, oil yield and fruit retention (Table 2).

Table 1. Average fruit characteristics of Olive cv. Carolea.

Treatments	Fresh weight (g)	Flesh to pit ratio	Dry weight (g)	Oil content (% DW)
Untreated	3,9	3,9	1,3	32,7
KNO_3 II + III	4,9	5,1	1,8	38,1
Difference (abs.)	1,0	1,2	0,5	5,4
Difference (%)	**26**	**31**	**38**	**17**

Table 2. Average yield characteristics of Olive cv. Carolea.

Treatments	Fruit yield (kg/tree)	Oil yield (kg/tree)	Increase of fruit retention (%)
Untreated	76,3	6,1	
KNO_3 II + III	86,9	10,1	
Difference (abs.)	10,6	4,0	
Difference (%)	**14**	**65**	**66**

Inglese, P., G. Gullo and L. S. Pace. 2002. Fruit growth and olive oil quality in relation to foliar nutrition and time of application. Acta Hort (ISHS) 586: 507-509.

Two foliar potassium nitrate sprays effectively increased K content in K-deficient olive plants.

Foliar *Yield & Quality*

The aim of this research was to study the effect of factors such as leaf age, salt type and concentration, number of foliar applications, and the nutritional status on the efficiency of foliar applications of potassium (K) in olive plants. The results obtained indicate that foliar applications of K effectively increased K content in K-deficient olive plants, and that foliar applications might be more effective on young leaves. Two foliar applications of KNO_3 or the equivalent of other salts are enough to increase leaf K concentration. The leaf K concentration for the KNO_3 treatment was 27 % higher than the control, an increase of 0,14% dry weight was found. The KNO_3 treatment showed also the greatest plant dry weight of 6,38 g, although this was not significantly different from the control treatment (6,02 g).

Restrepo-Díaz, H., M. Benlloch, and R. Fernández-Escobar. 2009. Leaf potassium accumulation in olive plants related to nutritional K status, leaf age, and foliar application of potassium salts. Journal of Plant Nutrition, 32(7): 1108-1121.

Foliar potassium nitrate applications increased fruit quality of table olives.

Foliar Yield & Quality

The effect of foliar applied potassium nitrate on some quality properties of olives was studied in Turkey. The 23-years old experimental trees (cv 'Memecik') were grown on a slightly alkaline loamy soil and severely affiliated to alternate bearing. Treatments in this study were: control + foliar water spray, control (untreated), NPK (soil application), NPK (soil) + 4% KNO_3 (foliar) and 4% KNO_3 (foliar). NPK fertilization consisted of 1,75 kg $(NH_4)_2SO_4$, 0,8 kg $(NH_4)_2HPO_4$ and 1,0 kg K_2SO_4 per tree. Foliar KNO_3 at 4% concentration was applied twice at 20 days of interval, first after fruit set and second after pit hardening. Experimental plots were arranged in randomized parcel design with 5 replicates per treatment.

The study was performed on two bearing years. The potassium nitrate treatment positively affected the fruit size, hundred fruit weight, fresh weight and pulp/pit ratio for table olives (Table 1). Especially during the pit hardening (August) and green ripeness (October) stages statistically significant increases for the potassium nitrate treatments were found on the parameters mentioned before. Although increases were observed at maturity stage (December), they were not statistically significant (Table 1). A slight increase was measured in oil percentage. No effect on yield was determined. Fruit K content increased by foliar KNO_3, compared to the control.

Table 1. The effect of foliar application of KNO_3 on some olive fruit quality characteristics averaged for two bearing years.

Treatments	Fruit width (cm)	Weight of 100 fruits (g)	Pulp/pit ratio
Control + water spray	13,2	210,3	3,0
Control (untreated)	13,1	206,6	3,0
NPK (S)	13,1	216,0	3,0
NPK (S) + 4% KNO_3 (F)	13,6	275,1	3,3
4 % KNO_3 (F)	14,0	261,2	3,6
Note: S = soil applied, F = foliar applied.			

Dikmelik, U., G. Püskülcü, M. Altuğ and M.E. Irget. 1999. The effect of KNO_3 application on the yield and fruit quality of olive. In: Improved Crop Quality by Nutrient Management, Sprinter Netherlands: 77-80.

Ornamentals
Ornamentals

Combination of foliar applied potassium nitrate and gibberellic acid increased tuberose yield.

Foliar *Yield & Quality*

An experiment was conducted to study the effect of 2 levels of gibberellic acid (100 and 200 ppm) and 2 levels of potassium nitrate (1 and 1,5%) alone and in combination on the growth and yield of tuberose (Polianthes tuberosa L.) during the wet season in 2010 and 2011. The experiment was carried out at the Farm of Horticulture section, College of Agriculture in Nagpur, India. Farm yard manure was applied at 20 MT/ha and in total 200 kg N, 300 kg P and 200 kg K was applied per hectare. The foliar sprays were applied 30 days and 60 days after planting, the control was sprayed with water only. The number of leaves per plant and total leaf area were the highest for the foliar application of 200 ppm GA_3 in combination with 1,5% KNO_3. Both GA_3 and KNO_3 had a significant effect on shortening the time to spike emergence as compared to the control. The combined sprays also increased the number of florets per spike. The higher concentration of GA_3 in combination with KNO_3 applied as foliar spray resulted in increased spike yields (Figure 1).

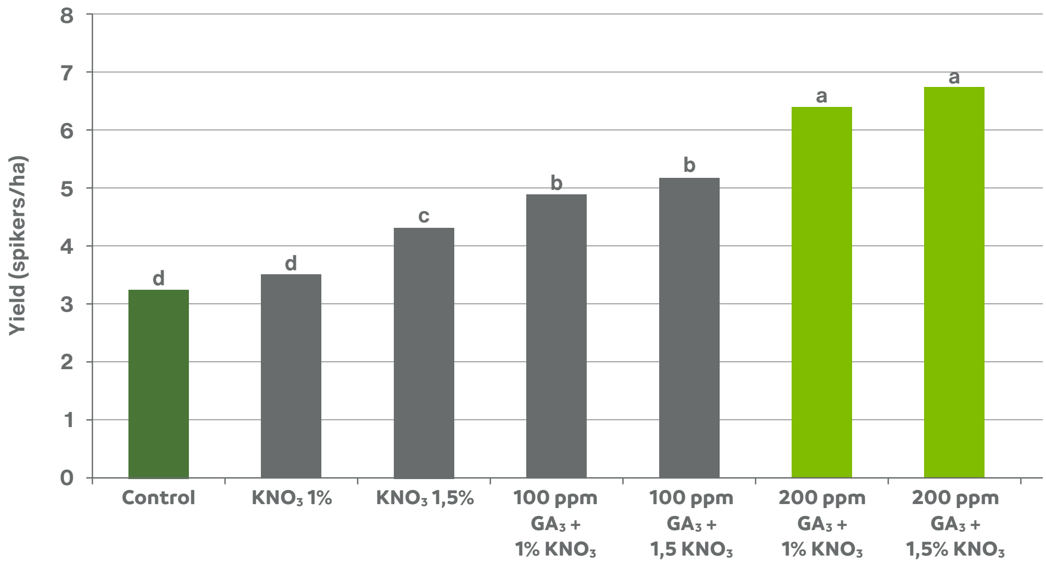

Figure 1. The effect of foliar applied KNO_3 and GA_3 on spike yield in tuberose.

Mahajan, Y. A., S.D. Khiratkar, D.M. Panchbhai, R.P. Gawali and P.S. Ghule. 2012. Effect of foliar application of GA_3 and KNO_3 on growth and yield of tuberose. Journal of Soils and Crops, 22(2): 358-361.

Priming with potassium nitrate positively influenced seedling development of gladiolus in terms of seedling length and bulb weight.

Seed priming

The effect of different priming concentrations of KNO_3 (1, 2, 3, 4, 5 and 0%) on seed germination and seedling development of gladiolus (Gladiolus alatus) was studied under controlled conditions in Pakistan. Seeds were either dipped in different concentrations (1 to 5%) of KNO_3 solution, placed in distilled water for duration of 48 hours or untreated (control). For each treatment 40 seeds were used. All seeds were placed in the growth chamber at a temperature of 20 ± 2°C for germination. Days taken for 50% germination increased with increase in KNO_3 concentration from 1% to 4%. Best germination rate of 92% was achieved in distilled water treatment followed by 80% for 1% KNO_3 and 70% for 2% KNO_3. Present results suggested that lower concentration of KNO_3 like 0,2% to 1% should be tested for priming studies of gladiolus. An effect of priming with KNO_3 on seedling development was found. Seedling length increased with increase in concentration from 1% to 3% KNO_3 solution. Tallest plants (14 cm) were observed with 3% potassium nitrate followed by 13,5 cm for 2% potassium nitrate. Analysis of variance revealed that there was a significant effect of different concentrations of KNO_3 on bulb weight of gladiolus seedlings. Maximum bulb weight of 0,64 g was found for 3% KNO_3 followed by 0,39 g for 4% KNO_3 and 0,21 g for 2% KNO_3. There was a positive correlation between seedling length and bulb weight as shown in figure 1.

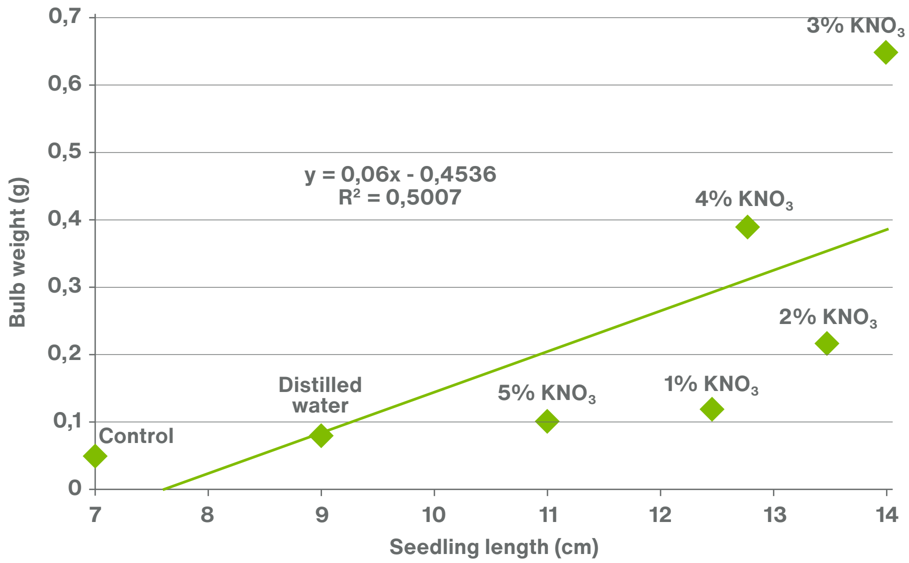

Figure 1. Relationship between seedling length and bulb weight in gladiolus as affected by seed priming treatments.

Ramzan, A., I.A. Hafiz, T. Ahmad and N.A. Abbasi. 2010. Effect of priming with potassium nitrate and dehusking on seed germination of gladiolus (Gladiolus alatus). Pak J Bot, 42(1): 247-258.

Additional potassium nitrate application improved flowering, flower quality and corm yield of Gladiolus grandiflorus.

Soil applied *Yield & Quality*

In the east Mediterranean region of Turkey an experiment was carried out to determine the combined effect of GA_3 with additional KNO_3 fertilisation on flowering and some quality characteristics of Gladiolus grandiflorus 'Eurovision' under plastic greenhouse conditions in late autumn planting. Corms were soaked in solutions of GA_3 at 0 (control), 50 and 100 mg/kg for one hour and were dried in shade for 5 days before planting. The soil had a sandy-loam texture and sulphur was applied to decrease the soil pH to 7,0. As a basal dressing 30 g/m^2 ammonium sulphate and 45 g/m^2 triple superphosphate were applied before planting. All experimental plots received KNO_3 at 25 g/m^2 at the three-four leaf stage (K1). Half of the plots (K2) received additional KNO_3 applications at weekly interval continued until two weeks before the corms were harvested.

The treatment with 100 ppm GA_3 and additional KNO_3 fertilisation had a significant shortening effect on the time from planting to harvest of approximately 10 days compared to the controls (Table 1). The flowering percentage of plants which were additionally fertilised with KNO_3 was higher than that of the plants fertilised only once with KNO_3 at three-four leaf stage. The same increase with additional potassium nitrate was found for the flower stem length, spike length and the stem diameter. The results indicated that additional potassium nitrate applications (K2) significantly increased the final weight of the corms compared to K1. Fertilising plants with 25 g/m^2 KNO_3 5 or 6 times in a weekly interval after three-four leaf stage was found to be effective to improve flowering, flower quality and corm yield.

Table 1. The effects of GA_3 and additional KNO_3 fertilisation on flowering and quality characteristics of Gladiolus grandiflorus 'Eurovision'. K1 treatment received only once KNO_3 and K2 treatment received additional KNO_3.

Treatments		Time to harvest	Flowering percentage	Flower stem length	Stem diameter	Corm weight
KNO_3	GA_3	(days)	(%)	(cm)	(mm)	(g/corm)
K1	Control	145 a	82 d	129 b	11,7 b	55 b
	50 ppm	143 ab	87 bc	129 b	12,0 b	59 b
	100 ppm	142 bc	90 ab	131 b	11,9 b	58 b
K2	Control	143 ab	85 c	135 a	12,7 a	68 a
	50 ppm	140 c	88 b	138 a	12,7 a	72 a
	100 ppm	135 d	92 a	139 a	12,9 a	71 a

Karagüzel, O., S. Altan, I. Doran and Z. Söğüt. 1999. The effects of GA_3 and additional KNO_3 fertilisation on flowering and quality characteristics of Gladiolus grandiflorus 'Eurovision'. Springer Netherlands - Improved Crop Quality by Nutrient Management: 259-262.

Papaya

Papaya

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Potassium nitrate enhanced dormancy breaking and seed germination of papaya seeds.

Seed priming *Dormancy breaking*

The objectives of this study were:

1) to investigate and enhance seed germination in two commercially grown papaya genotypes ("Solo" and "007") of importance in Queensland, Australia.
2) to study the effects of potassium nitrate on breaking dormancy and improving germination of fresh seed pre-storage.

Seeds were pre-soaked in aqueous solutions of potassium nitrate at a range of concentrations (0; 0,25; 0,5; 1,0; 1,5 M) for 0, 15, 30, 60 min, 2, 3, 6, 14 or 24 h prior to germination testing.

The mean percentage of germination increased above control levels for both varieties after pre-treatment in either 0,25M or 0,5M potassium nitrate. The highest mean percentage of germination was seen after pre-treatment at 0,25M potassium nitrate for 2 or 3 h (64% and 65% for "Solo", 58% and 64% for "007", Figure 1). Dormancy in fresh seeds of papaya cultivars when freshly harvested, could be broken to give acceptable levels of germination when potassium nitrate was used; potassium nitrate gave the highest levels of germination for "007" seeds and may be the preferred treatment for application in papaya.

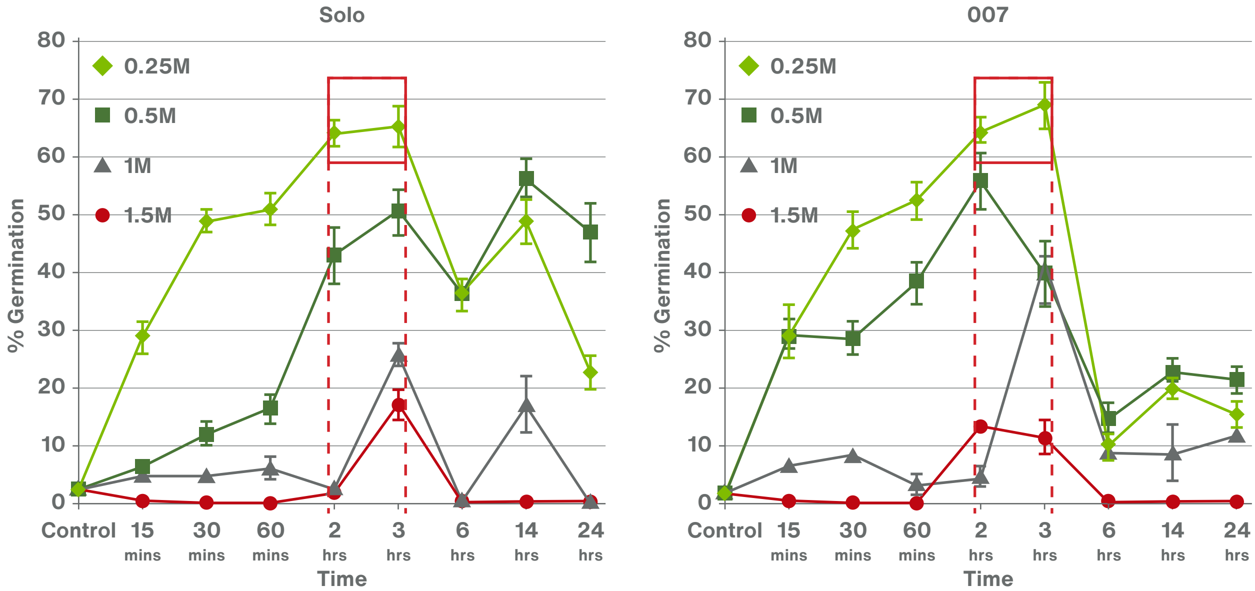

Figure 1. Mean percentages of germination of fresh seeds of Solo and 007 varieties of Carica papaya after pre-treatment for various times in a range of concentrations of KNO_3. Each data point is the mean of 10 replicates of 25 seeds. Error bars are standard errors of the means (SEM).

Ashmore, S. E., R.A. Drew, C. O'Brien, and A. Parisi. 2008. Cryopreservation of papaya (Carica papaya L.) seed: overcoming dormancy and optimizing seed desiccation and storage conditions. Acta Hort 839: 229-235.

Soaking seeds in potassium nitrate or gibberellic acid solutions were effective priming treatments.

Seed priming

The study consisted of three experiments and was conducted to evaluate the effect of elevated temperatures and varying concentrations of potassium nitrate (KNO_3) and gibberellic acid (GA_3) on germination of Papaya (Carica papaya L.) seeds. For all experiments, seeds of cultivar 'Kapoho Solo' were planted 0,5 cm deep in plastic pots containing moistened No. 2 grade vermiculite. All experiments were arranged as randomized complete block designs and consisted of 4 replications of 50 seeds/replication.

In the first experiment seeds were soaked in aqueous solutions of GA_3 at 0,0; 0,6; 1,2; or 1,8 mM, or in KNO_3 at 0, 0,5 or 1,0 M for 15 min prior to sowing. After priming the seeds were sown into pots and were placed either on heated (35 ± 5°C) or non-heated (25 ±5°C) benches in a fiberglass greenhouse. Seeds soaked in KNO_3 or GA_3 for 15 minutes exhibited an increased percentage emergence and a reduced time for 50% seedling emergence in comparison to seeds soaked in water. Increasing the KNO_3 concentration from 0 to 1,0 M increased percentage seedling emergence. Seeds treated with KNO_3 had a higher overall percentage seedling emergence than GA_3 treatments at both temperatures.

In the second experiment seeds were soaked in distilled water, in 1,0 M solutions of KNO_3, $CaNO_3$, KCl or $CaCl_2$ for 15 minutes. The seeds were planted and grown on non-heated (25 ±5°C) benches under greenhouse conditions. Potassium nitrate treatment had the highest percentage seedling emergence and shortest time to 50% seedling emergence (Table 1). Soaking seeds in KNO_3 or GA_3 before or after drying for 2 weeks in the third experiment did not alter the effects of KNO_3 or GA_3.

Table 1. The effect of soaking papaya seeds for 15 minutes in chemical solutions (treatments) on seedling emergence of papaya seeds.

Treatments	Seedling emergence (%)	Days to 50% emergence
1,0 M KNO_3	77	15,8
1,0 M $CaNO_3$	73	18,6
1,0 M KCl	34	23,4
1,0 M $CaCl_2$	10	39,0
Water (control)	7	28,4
LSD (P=0,05)	11	5,1

Furutani, S. C. and M.A. Nagao. 1987. Influence of temperature, KNO_3, GA_3 and seed drying on emergence of papaya seedlings. Scientia Horticulturae, 32: 67-72.

Pea

Pea

Potassium nitrate spray increased seed yield of grasspea, grown in rice fallows.

Foliar *Yield & Quality*

In India the effect of a foliar spray of potassium nitrate and calcium nitrate on a paira crop of grasspea (Lathyrus sativus L.), grown in rainfed lowland rice fallows, was studied. Entisol soil, having 0,72% organic carbon, 22 kg available P_2O_5/ha and 240 kg available K_2O/ha with pH 6,2 was used. The experiment was a randomized block design with three replications. The foliar sprays of potassium nitrate and calcium nitrate were given at 3 concentrations, supplied equal amounts of N (as nitrate) in the respective treatments. The single foliar sprays were applied during the 50% flowering stage of the crop. All foliar sprays increased the yield attributes of grasspea (Table 1). The foliar spray of KNO_3 at 0,50% increased the seed yield most, by 86% over the unsprayed control, averaged over two cropping seasons (Figure 1).

Table 1. Effect of foliar spray of KNO_3 and $Ca(NO_3)_2$ on yield attributes and average yield (1998-1999) of grasspea, grown as a paira crop.

Treatments	Pods /plant	Pod length (cm)	Seeds /pod	1000 seed weight (g)	Av. seed yield (t/ha)
Control	15,3	2,1	1,9	126	0,49
Water	16,7	2,4	2,3	127	0,51
KNO_3 (0,25%)	18,7	2,9	3,3	135	0,78
KNO_3 (0,50%)	21,8	3,6	4,1	150	0,91
KNO_3 (1,00%)	19,8	3,2	3,8	142	0,82
$Ca(NO_3)_2$ (0,203%)	18,3	2,7	3,3	132	0,74
$Ca(NO_3)_2$ (0,406%)	19,9	3,4	3,9	143	0,84
$Ca(NO_3)_2$ (0,812%)	18,9	3,1	3,7	140	0,79
LSD (P<0,05)	0,99	0,45	0,23	1,12	0,25

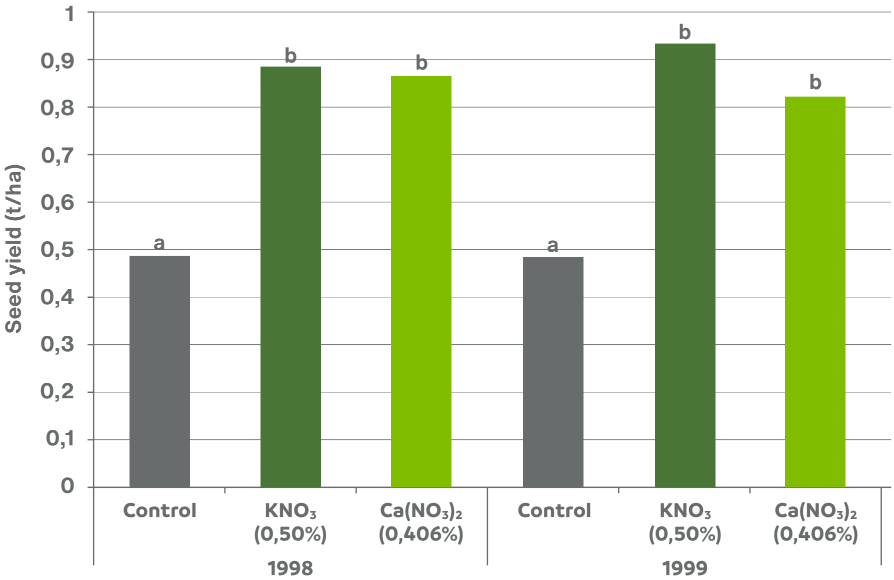

Figure 1. The effect of foliar treatments on the seed yield (t/ha) of grasspea in two growing seasons.

Sarkar, R.K. and G.C. Malik. 2001. Effect of foliar spray of potassium nitrate and calcium nitrate on grasspea (Lathyrus sativus L.) grown in rice fallows. Jointly supported by Lathyrus Lathyrism newsletter 2: 47-48.

Pomegranate

Pomegranate

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Foliar applied potassium nitrate improved pomegranate fruit quality.

Foliar Yield & Quality

The objective of the experiment was to study the effects of potassium nitrate on qualitative parameters of pomegranate. The trial was conducted at a seven year old orchard on a sandy loam soil with pH 7,2 in Iran. Treatments consisted of spraying potassium nitrate (0, 250 and 500 mg/L) early August when fruit size was about 30 mm in diameter. Five replications per treatment were carried out in a randomized block design. Carob moth (Ectomyelois ceratoniae) is a pernicious pest for pomegranate fruit that strongly reduces commercially fruit production. A significant decrease in calyx diameter and increase in calyx length with 250 mg/L KNO_3 spray are the main barriers against Carob moth a pest in pomegranate (Table 1). As the potassium nitrate level increased, aril diameter and length decreased (Table 1). Results showed that 250 mg/L potassium nitrate increased juice volume, juice weight and total soluble solids (TSS) statistically significantly compared to the control and the 500 mg/L treatments (Table 2). The Authors suggested that application of potassium nitrate as spraying in suitable time will be useful management practice improving fruit quality and reducing harmful effects of carob moth.

Table 1. Effects of foliar potassium nitrate application on calyx and aril characteristics of pomegranate.

Treatments	Calyx D. (mm)	Calyx L. (mm)	Aril D. (mm)	Aril L. (mm)
Control	19,6 a	15,9 b	7,3 a	10,7 a
KNO_3 250 mg/L	14,4 b	22,2 a	6,6 b	10,7 ab
KNO_3 500 mg/L	19,7 a	16,2 b	6,3 b	10,2 b

Note: D = diameter, L = length.

Table 2. Effects of foliar potassium nitrate application on juice characteristics of pomegranate.

Treatments	Juice volume (mL)	Juice weight (g)	TSS (°brix)
Control	60,3 b	64,0 b	15,6 ab
KNO_3 250 mg/L	84,7 a	87,1 a	16,2 a
KNO_3 500 mg/L	71,6 ab	77,2 ab	14,5 b

Khayyat, M., A. Tehranifar, M. Zaree, Z. Karimian, M.H. Aminifard, M.R. Vazifeshenas, S. Amini, Y. Noori and M. Shakeri. 2012. Effects of potassium nitrate spraying on fruit characteristics of 'Malas Yazdi' pomegranate. Journal of Plant Nutrition, 35(9): 1387-1393.

Potato

Potato

sqmnutrition.com

Increased yield and quality of potato tubers by application of potassium nitrate with drip irrigation in semi-arid conditions.

Fertigation *Yield & Quality*

Field experiments on potato supplied with nutrients through drip irrigation, were conducted at the DeirAlla agricultural research station located at Jordan valley. Land is limited in Jordan and most of the production area for potatoes is under semi-arid conditions. Nutrient practice can be improved to improve sustained productivity, besides other measures such as the development of locally adapted high yielding varieties. Understanding plant growth and nutrient uptake in response to different fertiliser strategies is important to maximise growth and nutrient uptake efficiencies. In relative amounts, potassium is the second mineral element after nitrogen of importance for optimal growth and development of the potato crop. Therefore, the effect of four potassium nitrate fertiliser doses was assessed in potato cultivar Spunta planted under drip irrigation in a clay loam soil at a plant density of 25.000 tubers/ha.

T1: 0 kg/ha KNO_3
T2: 130 kg/ha KNO_3 (57 kg/ha K_2O)
T3: 260 kg/ha KNO_3 (114 kg/ha K_2O)
T4: 380 kg/ha KNO_3 (172 kg/ha K_2O)

Water supply was dosed according to crop need, based on the evapotranspiration. Evapotranspiration was estimated from the measured soil water content. Water use efficiency (WUE) was calculated for each treatment as tuber yield divided by seasonal evapotranspiration.

Potassium nitrate was applied by direct injection in the main line of the drip irrigation system, starting from plant emergence, in 10 applications during the crop season. All treatments received a total of 180 kg N/ha and 420 kg P/ha, injected weekly in the drip irrigation system. Potatoes were harvested 110 days after planting.

The total fresh tuber yield per plant increased linearly with increasing potassium nitrate rate (Figure 1). This was mainly due to the increase in average tuber weight. Tuber weight increased with 11,2% (T1), 16,6% (T2) and +32,5% (T3) relative to the average tuber weight of the control treatment.

Quality aspects of the tubers also increased with increasing potassium nitrate rates. Ascorbic acid content in tubers at the highest rate of potassium nitrate was 38% higher compared to the control (Figure 1). Specific gravity (a measure of processing quality) increased up to 1,92% (T4), and ash content increased progressively with increasing levels of potassium nitrate. Protein of the potatoes also increased significantly with increasing potassium nitrate rates (Figure 2). Additionally the content of carbohydrates and fat was higher in tubers of plants receiving more potassium nitrate.

Evaluation of the loss of tuber yield with drying (15 h at 105°C) indicated that plots receiving potassium nitrate had the lowest reduction of weight compared to the control (Figure 2). This was attributed partly to the increase in potato dry matter. Authors discussed that this may also be a beneficial effect of increased potassium content. The maintenance of tuber moisture content during storage by K-application in the field has been previously reported.

Fertigation with potassium nitrate was proposed as improvement of sustainable water management. Crop water use efficiency values showed a pronounced increase with increasing potassium nitrate rate. More than 25% higher WUE in kg of tuber per m^3 of water was observed at the two highest rates of potassium nitrate. This was due to the increase of fresh tuber yield per plant at the same amount of water provided with the drip irrigation.

It is evident from this trial that increasing the use of potassium nitrate in of potato grown under fertigation in Jordan, will benefit farmers by increasing yield without increasing the use of water. As an extra benefit, it will additionally increase quality parameters of the tubers.

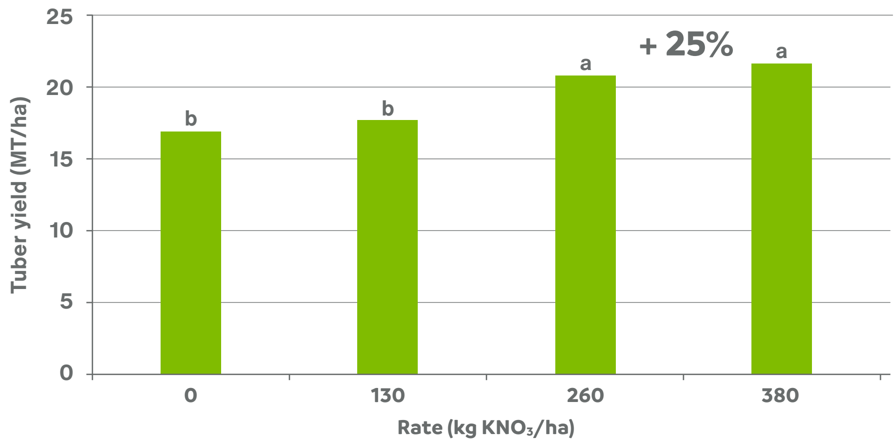

Figure 1. Average tuber yield in potato fertigated by drip irrigation with increasing rates of potassium nitrate added to the nutrient solution. Means labelled with the same letter are not significantly different (LSD, 5%).

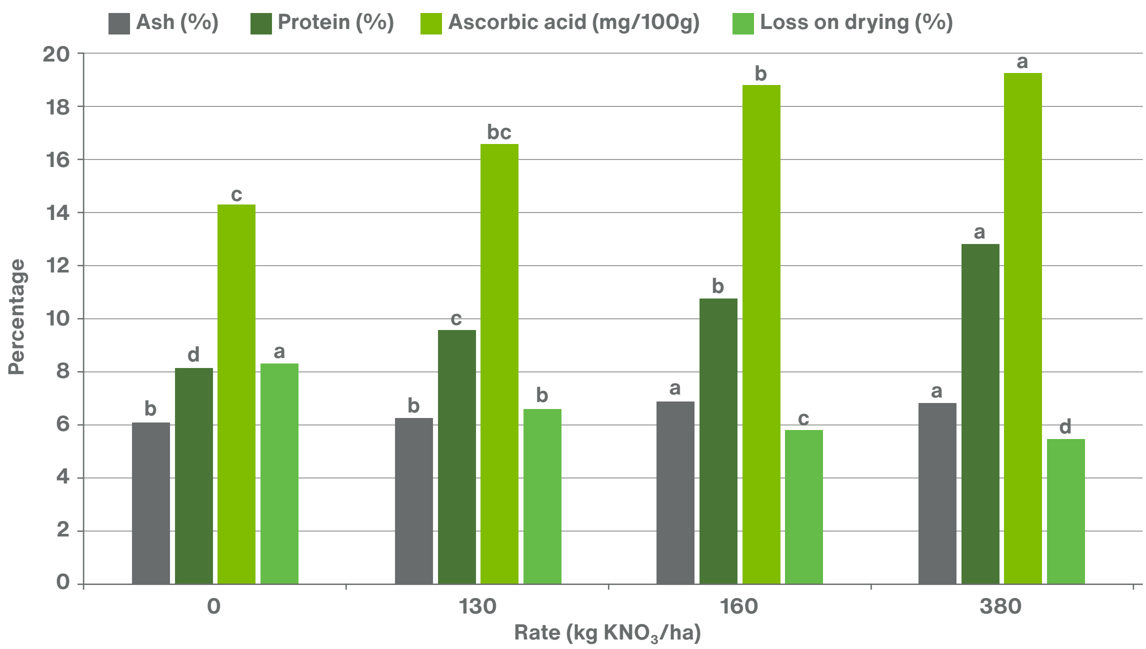

Figure 2. Average tuber quality parameters response to increasing rates of potassium nitrate added to the nutrient solution. Means labelled with the same letter are not significantly different (LSD, 5%).

Haddad, M.; Bani-Hani, N. M.; Al-Tabbal, J. A.; Al-Fraihat, A. H. 2016. Effect of different potassium nitrate levels on yield and quality of potato tubers. Journal of Food, Agriculture & Environment14 (1) :101-107.

High nitrate to ammonium ratio in the fertilizer programme favoured potato yield, quality and grower's net income.

Fertigation *N-sources*

In South Africa, potatoes are produced on soils low in pH, clay content and organic matter in the Sandveld and Koue Bokkeveld of the Western Cape. These three factors are contributing to conditions unfavourable for high microbial activity, essential for the nitrification of applied ammonium. High ammonium ratios in fertiliser programmes can lead to cation antagonism, ammonium toxicity and low nitrogen use efficiency, contributing to environmental and economic unsustainability.

A field trial was conducted at Sandberg, planted during July 1999. Nine treatment combinations at four replications were used in each treatment. The trial was designed to determine the effect of three ratios of ammonium versus nitrate (80:20, 50:50 and 20:80) at three levels of N (170, 260, 350 kg N/ha), on potato yield and quality. The high nitrate treatments yielded highest and at total N-levels 260 and 350 kg/ha, also were the only treatments reaching a specific gravity (SG) above 1,075 kg/m^3, as preferred by the processing industry because the SG is used as an estimate of the solids or dry matter content of the tubers. Best results in terms of grower return were achieved when 80% of the required nitrogen was applied as nitrate. A positive net margin above R 8000 ha^{-1}, was only achieved at N-level 350 kg/ha and a 20:80 ammonium vs. nitrate ratio (calculated at a price of R 11 per 10 kg).

Knight, F.H., P.P. Brink, N.J.J. Combrink and C.J.van der Walt. 2000. Effect of nitrogen source on potato yield and quality in the Western Cape. FSSA Journal 2000: 157-158.

Potassium nitrate outperformed potassium sulphate and potassium chloride in terms of potato tuber yield and size.

Fertigation *K-sources*

Bester and Maree (1990) clearly showed the benefit of potassium nitrate as opposed to potassium chloride or potassium sulphate fertilization for potato in a pot experiment. Nutrient quantities applied were equal. Under controlled nutrition and environmental conditions, potassium nitrate application gave rise to greatest tuber yield (Figure 1). Greater number of tubers and significantly larger-sized tubers were produced by the potassium nitrate fed potato plants (Table 1).

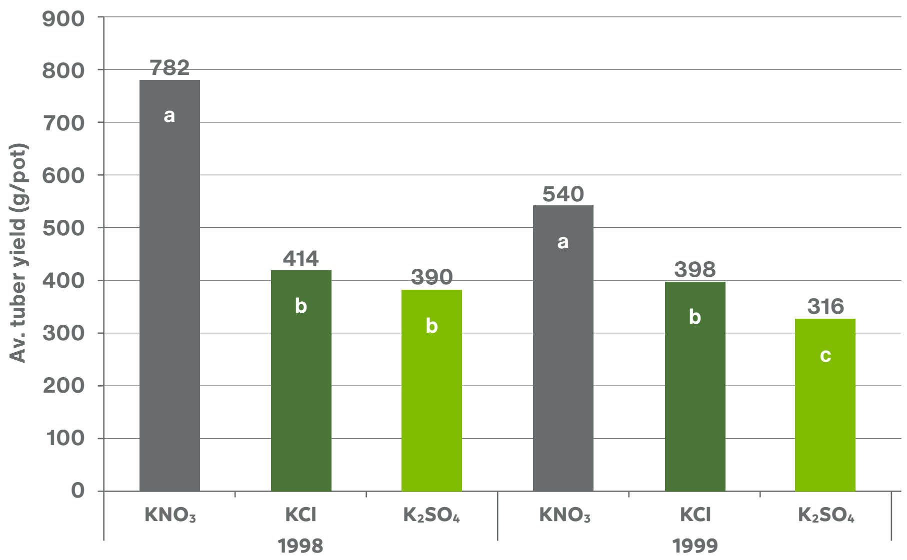

Figure 1. Average tuber yield (g/pot) for three K-sources in two cropping seasons.

Table 1. Effect of the K-sources on average tuber weight (g) and number of tubers produced.

Treatments	Av. individual tuber weight (g)		Av. no. of tubers per plant	
	1984	1985	1984	1985
KNO_3	92,5 a	96,6 a	9,4 a	5,9 a
KCl	74,3 b	91,0 a	5,8 b	4,5 b
K_2SO_4	72,6 b	71,1 b	5,9 b	5,0 ab

Bester, G.G. and P.C.J. Maree. 1990. Invloed van kalium bemestingstowwe op knolopbrengs en persentasie droëmateriaal van Solanum tuberosum L. knolle. S. Afr. Tydskr. Plant Grond, 7: 40-44.

Foliar potassium nitrate application increased potato tuber yield.

Foliar *Yield & Quality*

In India a 3-years trial on potato (Solanum tuberosum L.) was carried out to study the effect of foliar potassium nitrate application on potato yield. On a coarse loamy, non-calcareous soil the application of nitrogen (urea) or foliar KNO_3 application showed little effect on potato yield in the absence of potassium application. In presence of potassium, a statistically significant increase in the tuber yield was obtained with increasing level of nitrogen and foliar application of KNO_3. Among the 2 foliar fertilizers, i.e. KCl (MOP) and KNO_3, potassium nitrate resulted in the highest yield at concentration of 2% which was superior to 1%. The increase in yield levels is related to the increase in the size of the tubers.

Brar, M. S. and N. Kaur. 2006. Effect of soil and foliar applied potassium and nitrogen on yield of potato (Solanum tuberosum) in alluvial soils of Punjab, India. The Indian Journal of Agricultural Sciences, 76 (12): 740-743.

Potassium nitrate sprays improved tuber size and tuber yield of potato.

Foliar *Yield & Quality*

A field experiment was conducted to evaluate the response of potato crop to foliar applied potassium nitrate in terms of vegetative growth, tuber yield and tuber size of potatoes grown on a loam-sandy soil in the semi-arid environment of Central East of Tunisia. The experimental layout was a randomized complete block design with 4 treatments and 3 replications. The four treatments were 0, 0,5, 1 and 2 g KNO_3/L and were supplied as a foliar spray at 45, 55 and 70 days after planting. Increasing potassium nitrate rates resulted in a significant increase ($P<0,05$) in plant height, leaves number, leaf area, leaf relative water content and chlorophyll a concentration. All potassium nitrate treatments showed significant increases in mean tuber weight and tuber diameter (Table 1). The foliar KNO_3 sprays increased the tuber yield compared to the control, although statistically non-significant (Table 1). The treatments were applied early in the growing season, so possible more pronounced effects on yield may be obtained with later applications during the tuber-bulking or tuber maturating stages.

Table 1. Effect of foliar potassium nitrate applications on tuber quality and tuber yield of potato.

Treatments	Mean tuber weight	Tuber diameter	Tuber yield	
g KNO_3/L	g	cm	g/plant	
0	110 a	4,0 a	1246 a	
0,5	129 ab	4,5 ab	1405 a	+13%
1,0	139 ab	5,1 b	1405 a	+13%
2,0	155 b	5,4 b	1454 a	+17%

Mean values with same letter are not significantly different from each other, Duncan test (α=0,05).

Dkhil, B. B., M. Denden and S. Aboud. 2011. Foliar potassium fertilization and its effect on growth, yield and quality of potato grown under loam-sandy soil and semi-arid conditions. International Journal of Agricultural Research, 6: 593-600.

Rice

Rice

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Greater rice grain yield at increased number of foliar potassium nitrate applications.

Foliar   Yield & Quality

In 2009, researchers in Vietnam conducted experiments with foliar KNO_3 (13% N and 45% K_2O) sprays in paddy rice in North Vietnam to evaluate its effect on yield and yield components, nutrient uptake, as well as agronomic and economic efficiency. Four field experiments were conducted at two locations including: a degraded sandy soil site at Bac Giang Research Station located in Hiep Hoa District, Bac Giang Province (exchangeable K: 31 ppm), and an alluvial clay soil site on the Red River Delta in Xuan Truong District, Nam Dinh Province (exchangeable K: 59 ppm). The degraded soil is prone to leaching of K, and the alluvial soil is associated with K fixation. Both of these soils displayed very low soil exchangeable K contents, making them potentially very responsive to K addition.

Foliar KNO_3 was provided along with combinations of basally applied urea, SSP (Single SuperPhosphate), KCl, and 8 t/ha of FYM (spring rice only). Foliar applications occurred at one or more different growth stages: Active Tillering (AT), Panicle Initiation (PI), and End of Flowering (F), and each application provided 300 liters of a 3% concentration, equal to 9 kg KNO_3/ha, or 4 kg K_2O/ha and 1.1 kg N/ha. Hills from 4 m^2 of area centered in each replicated plot were harvested for grain yield determination with 14% moisture. Yield components were determined from 10 hills collected from the sampling zone surrounding the harvest area, as was the procedure for determining dry biomass at the AT, PI, and F stages.

The response to direct FYM application can be quantified in spring rice and was significant ($p = 0.05$) at the degraded soil site at Bac Giang, but not at the alluvial soil site at Nam Dinh (Table 1). In summer rice, check plots showed a significant difference between the basal NP treatment and basal NP plus foliar KNO_3 applied at each of the three growth stages selected. Reliance on basal K alone produced yields that were equal to those resulting from foliar KNO_3 alone at three of the four sites (i.e. excluding the summer rice season at Nam Dinh) where three splits of foliar KNO_3 was superior. Supplementation of the full basal K rate with three foliar KNO_3 applications (T9) produced the highest average yield response across seasons and sites (Table 1). This treatment produced 11% more spring rice and 16% more summer rice on degraded soil; 16% more spring rice and 15% more summer rice on alluvial soil compared to use of basal KCl alone (T3). Single sprays resulted in a more modest yield response of 7% averaged over sites and seasons, while two sprays generated an average yield response of 11% and three sprays an average yield response of 15% (Figure 1). Interestingly, significantly higher yields (10% average response) were also obtained with the combination of three foliar KNO_3 sprays and up to 50% less KCl provided through a base dressing (T10 and T11).

Table 1. Treatments, application stages, applied dose rates and yields for the two trial sites in Vietnam.

Treatment description[1]		Foliar KNO_3 timing[2]			Yield [3] (MT/ha)		
		AT	PI	EF	SS	CS	av.
1a	NP without FYM	0	0	0	4,25	5,61	4,93
1b	NP	0	0	0	5,05	6,80	5,93
2	NP	+	+	+	5,03	6,59	5,81
3	NP (Basal 100% MOP)	0	0	0	5,03	6,13	5,58
4	NP (Basal 100% MOP)	+	0	0	5,34	6,57	5,95
5	NP (Basal 100% MOP)	0	+	0	5,34	6,72	6,03
6	NP (Basal 100% MOP)	0	0	+	5,33	6,62	5,97
7	NP (Basal 100% MOP)	+	+	0	5,50	6,82	6,16
8	NP (Basal 100% MOP)	0	+	+	5,54	6,84	6,19
9	NP (Basal 100% MOP)	+	+	+	5,71	7,08	6,40
10	NP (Basal 75% MOP)	+	+	+	5,63	6,88	6,25
11	NP (Basal 50% MOP)	+	+	+	5,54	6,78	6,16
12	NP (Basal 50% & 50% at PI)	0	0	0	5,26	6,59	5,93
	LSD (P=0,05)				0,13	0,46	

[1] In spring rice, all treatments received FYM except 1a. In summer rice, no FYM was applied

[2] 0= no foliar K, + = 9 kg KNO_3/ha/application, AT = Active Tillering (20 to 25 DAT), PI = Panicle Initiation (50 to 55 DAT), EF = End of Flowering (25 to 28 days before harvest).

[3] Grain yields are adjusted to 14% moisture, SS=Sandy Soil, CS=Clay Soil, av.=av. both soils

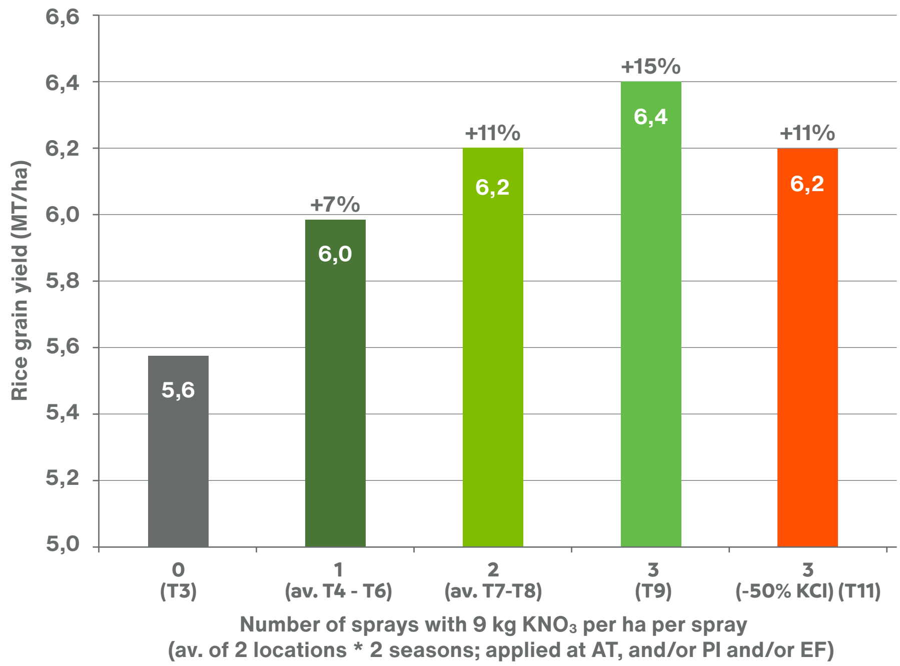

Figure 1. The effect of number of foliar treatments on the rice grain yield (MT/ha) in two growing seasons spring and summer on two trial sites (AT= active tillering, PI= panicle initiation and EF= end of flowering).

Economic analysis found a steady increase in net income under single, double, and triple sprayings at both the degraded and alluvial sites (Figure 2). In addition, net income was maintained when basal KCl was decreased by up to 50% in combination with three foliar KNO_3 spray applications, as well as for the treatment that completely substituted basal KCl with three foliar applications of KNO_3 (T2).

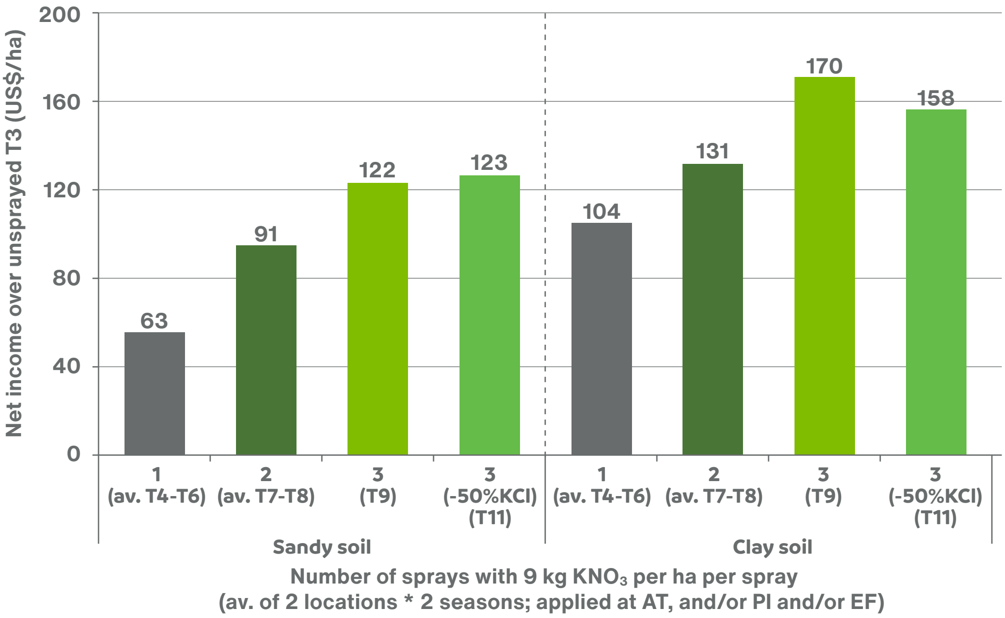

Figure 2. The positive effect of potassium nitrate sprays on net income (US$/ha) over T3 (100% KCl and no foliar spray).

Son, T.T., L.X. Anh, Y. Ronen and H.T. Holwerda. 2012. Foliar potassium nitrate application for paddy rice. Better Crops/Vol. 96 (No. 1): 29-31.

Foliar applied potassium nitrate outperformed soil application of potassium sulphate in terms of rice yield and growers net income.

Foliar *Yield & Quality*

A field trial was conducted in Pakistan to study the effect of foliar application of potassium nitrate (KNO_3) in comparison to soil incorporated potassium sulphate (K_2SO_4) on the growth and yield of fine rice "Super Basmati". The trial was laid out using randomized complete block design with three replicates. The five treatments were: soil application of K_2SO_4 (70 kg/ha), foliar application of KNO_3, without soil application, at 0,5%, 1,0%, 1,5% and 2,0% on 40 and 60 days after transplanting. Foliar KNO_3 sprays at 1,5% and 2,0% increased paddy yield by 5,74% and 10,85% in comparison to that of soil incorporated K_2SO_4 (Table 1). The increase in yield with foliar sprays is credited to the increase in number of tillers, panicle length, grains per panicle and 1000-grain weight. The 1000-grain weight was statistically significantly higher for the soil applied K_2SO_4 and the foliar KNO_3 at 1,5% and 2,0% compared to the foliar sprays at 0,5% and 1,0% KNO_3. There seemed to be a certain threshold value for foliar KNO_3 spray solution to have an increasing effect on rice yield. The 1,5% and 2,0% spray solution outperformed the control soil application in terms of paddy yield and farmers' net income (Table 1 & Figure 1). It is recommended to apply foliar KNO_3 at 1,5% and 2,0% solutions on 40 and 60 days after planting rice to increase net returns and enhance paddy yield.

Table 1. Economic analysis of foliar KNO_3 application against soil applied K_2SO_4.

Treatments	Paddy yield	Gross value	Total expenses	Net income
	(MT/ha)	(Rs. 1200 / 40 kg)	(Rs.)	(Rs./ha)
70 kg/ha K_2SO_4 (S)	4,70 b	141.000	89.777	51.223
0,5% KNO_3 (F)	3,81 c	114.300	86.509	27.791
1,0% KNO_3 (F)	3,76 c	112.800	87.341	25.459
1,5% KNO_3 (F)	4,97 ab	149.100	88.173	60.927
2,0% KNO_3 (F)	5,21 a	156.300	89.005	67.295

Note: S = Soil applied, F= foliar applied

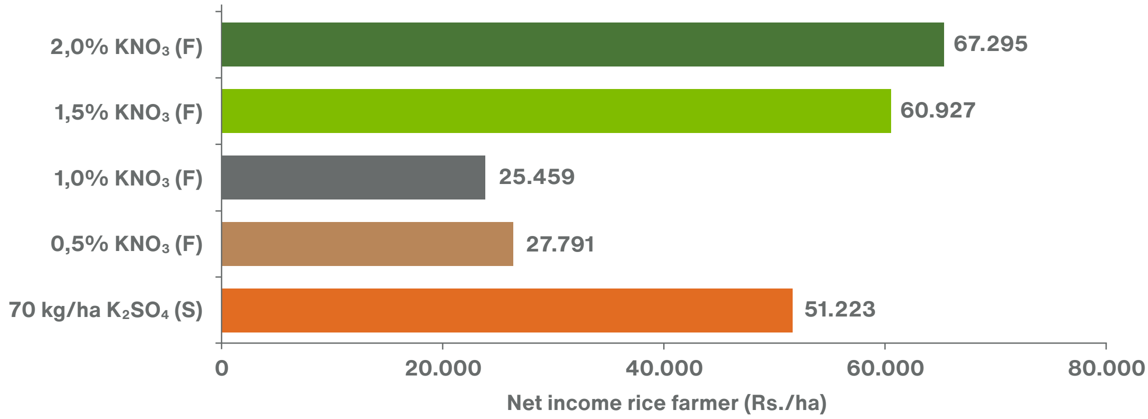

Figure 1. Effect of foliar KNO_3 application on the net income of the rice farmer (F=foliar applied, S=soil applied).

Khan, A. W., R.A. Mann, M. Saleem and A. Majeed. 2012. Comparative rice yield and economic advantage of foliar KNO_3 over soil applied K_2SO_4. Pakistan Journal of Agricultural Science, 49(4): 481-484.

Foliar applied potassium nitrate reduced rice lodging incidence from 40% to 15%.

Foliar *Yield & Quality*

Decreased lodging and increased stalk strength are associated with proper K nutrition. Therefore, the effect of K treatments on lodging of Baldo tall rice variety was studied at Qulin, Missouri (USA) in 1999 and 2000. A silty loam soil having 123 kg NH_4OAc extractable K/ha was used. Preplant application consisted of 54 kg K_2O/ha and midseason of two applications of 27 kg K_2O/ha, using KCl as K source. Two applications of 14 kg K_2O/ha as potassium nitrate (2 * 30 kg = 60 kg KNO_3/ha) were compared to soil-applied KCl at midseason. Lodging of Baldo was significantly reduced by foliar applications with potassium nitrate at midseason (Figure 1).

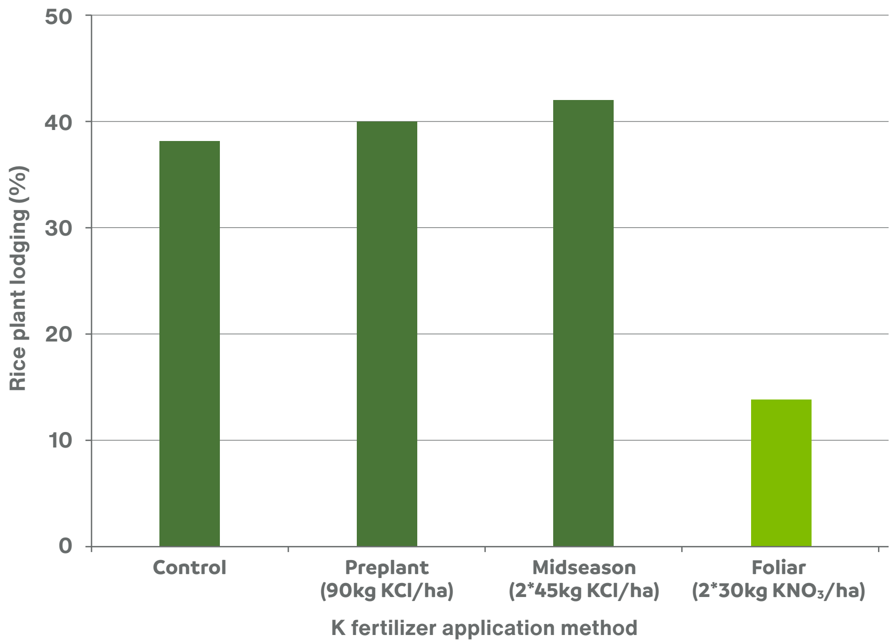

Figure 1. Effect of K treatments on lodging of Baldo tall rice variety averaged across 1999 and 2000.
Dunn, D., and G. Stevens. 2005. Rice potassium nutrition research progress. Better crops, 89: 15-17.

Soybean

Soybean

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Soybean development increased with 50-75% nitrate in the nutrient solution and seeds accumulated less polyamines compared to no or 75% ammonium.

Fertigation N-sources

The nitrogen source (NH_4^+ -N or NO_3^- -N) can influence plant quality. For most plants, the use of NH_4^+ as dominant source in the nutrient solution can lead to impaired growth or be toxic. Simultaneous addition of NO_3^- to medium containing NH_4^+ can alleviate potential toxicity of NH_4^+. The optimum ratio of NO_3^- :NH_4^+ is less than one. Plants exposed to high NH_4^+ concentrations will accumulate compounds such as sugars, or N-containing osmolytes such as proline or polyamines, to become more tolerant to ammonium induced damage. Stress tolerance in plants is found to be linked to the conversion of free-polyamines to bound- or conjugated-polyamines. Free-polyamines become conjugated-polyamines when they are connected to other low molecular mass organic compounds, e.g. organic acids and bound-polyamines when covalently linked to high molecular mass molecules, e.g. nucleic acids or membrane proteins.

In an experiment on vegetable soybean (Glycine max cv. "Li-xiang 95-1") in Nanjing, China, the effect of NO_3^- :NH_4^+ ratio on plant development and polyamine accumulation was investigated. The objective of this experiment was to elucidate the effects of nitrogen forms on polyamine levels, and their possible role in plant growth and development of the seeds.

Plants were grown in a 1:1 mixture of peat:vermiculite in pots in a greenhouse under natural light, with a nitrification inhibitor (dicyandiamide) added to the substrate. In a randomized design with three replicates, each pot with three plants was irrigated every three days with 1 L of nutrient solution (pH 6,5-6,8, EC 2,6-2,8 dS/m) containing different nitrogen forms, supplied as $Ca(NO_3)_2$, KNO_3, $NH_4H_2PO_4$ or NH_4Cl. Total N content of the nutrient solution was kept stable at 16 mM and 4 NO_3^- :NH_4^+ ratios were investigated (Table 1). To obtain identical K, Ca, Mg and total N and P rates, changes in the NO_3^- :NH_4^+ ratios were balanced by varying the Cl^- concentration provided as KCl, $CaCl_2$ or NH_4Cl. At physiological maturity, the plants were harvested and a number of growth parameters were assessed. The accumulation of polyamines in time was determined in fresh seeds, harvested every 3 days during the seed developing stage till harvest, for three polyamines in free, conjugated and bound form: (putrescine (Put), spermidine (Spd), spermine (Spm)).

The ratio of both nitrogen forms had statistically significant effects on plant growth, pod development and seed weight (Table 1). Plants performed best in the treatments where at least 50% of the nitrogen was supplied as NO_3^-, and treatments with 75% NO_3^- consistently improved the plant growth parameters more than 50% NO_3^-.In contrast, plants given 75% NH_4^+ remained smaller, attained the lowest shoot, root and seed weight and the lowest number and ratio of pods and flowers per plant.

In general, the content of free-polyamines in seeds decreased gradually during the growth period, whereas the content of bound- and conjugated-polyamines increased in time. Until 21 days after flowering, no difference was observed between plants given the different nutrient solutions. At the end of the seed development phase (24-30 days after flowering) the lowest level of free-polyamines Put and Spd was found in plants given 100% NO_3^- or 75% NH_4^+ and these also showed the highest level of bound- or conjugated-polyamines. The highest levels Spm were measured in plants given 100% NO_3^- or 75% NH_4^+, for all forms of Spm. The authors speculate that the bound- and conjugated-polyamines might be involved in the protection of the plant cells from stress induced by an imbalance in the NO_3^- :NH_4^+ ratio, with polyamines acting as nitrogen reservoirs and free radial scavengers, and maintaining the integrity of membranes, nucleic acids and proteins.

Table 1. The effect of four different NO_3^- :NH_4^+ ratios in the nutrient solution on the development of vegetable soybean. Means (± SD) followed by the same letter are not significantly different at p<0,05 (Duncan's). DW=Dry Weight.

Treatments	Plant height	Pods/plant	Pod : Flower	Seed DW	Root DW	Shoot DW
NO_3^- :NH_4^+	(cm)	(No.)	(ratio)	(g/100 seeds)	(g/plant)	(g/plant)
100:0	56,4 b	18,9 a	0,78 a	16,9±0,3 c	2,3±0,3 c	9,3±0,4 c
75:25	62,3 a	20,2 a	0,79 a	22,7±0,5 a	3,8±0,6 a	12,6±0,6 a
50:50	60,7 a	18,1 a	0,73 b	19,4±0,4 b	3,2±0,5 b	10,7±0,5 b
25:75	51,8 c	12,7 b	0,68 c	13,9±0,2 d	1,6±0,4 d	6,9±0,4 d

Chen, L., Q.-Q. Liu, J.-Y. Gai, Y.-L. Zhu, L.-F. Yang & C. Wang, 2011. Effects of nitrogen forms on the growth and polyamine contents in developing seeds of vegetable soybean. Journal of Plant Nutrition 34 (4): 504-521.

Foliar applied potassium nitrate and urea phosphate increased soybean yield.

Foliar *Yield & Quality*

The effect of foliar applications with potassium nitrate and urea phosphate on soybean yield was studied. Four experiments were conducted at four different locations in Argentina (Table 1). A single foliar spray was applied in the R3 growth stage (pod initials). Greatest yield was obtained with a mix of 6% potassium nitrate (7,5 kg/ha) and 2% urea phosphate (2,5 kg/ha), applied in 120 L/ha (Figure 1).

Table 1. Foliar treatment details on soybean.

Treatments	Potassium nitrate	Urea phosphate	Dilution	Concentration
	(kg/ha)	(kg/ha)	(L/ha)	%
1	10,0		200	5 -
2	10,0		120	8 -
3	7,5	2,5	120	6 2
4	5,0	5,0	120	4 4

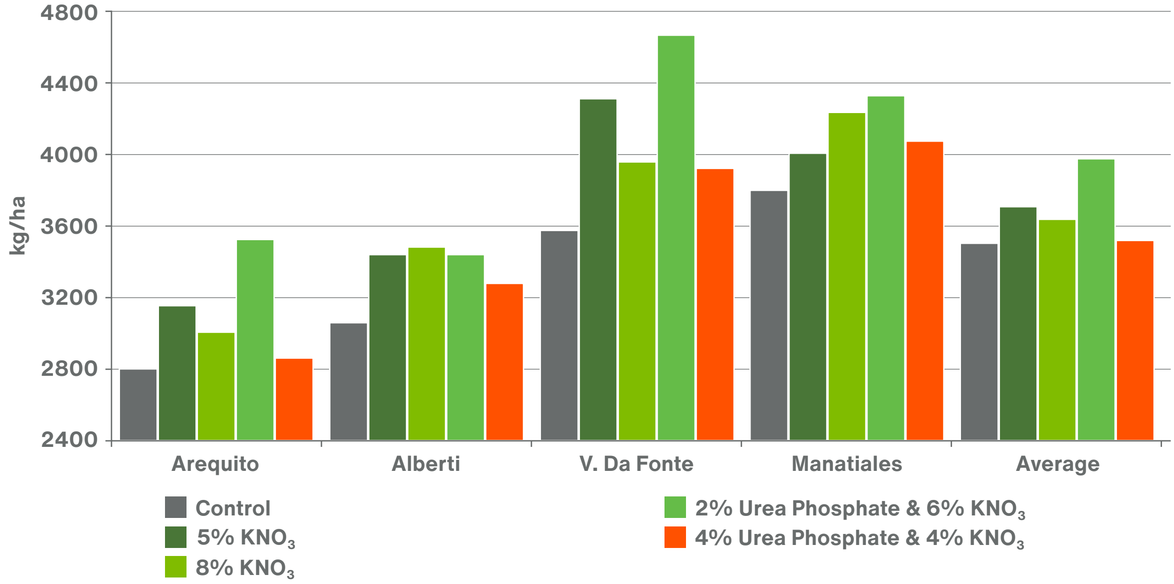

Figure 1. The effect of foliar sprays on soybean yield at 4 different locations in Argentina.

Melgar, R., M.E. Camozzi, M. Torres Duggan and J. Lavandera. 2001. Evaluación de Magnum P44 y nitrato de potasio en soja. INTA, Centro Regional Buenos Aires Norte, Estación Experimental Agropecuaria Pergamino: 1-3.

Potassium nitrate greatly influenced disease reduction of Phytophthora stem rot in soybean under lab conditions.

Foliar *Pest & disease reduction*

The objective was to study the effect of KNO_3 application in various concentrations (0,4, 4, 10, 20, 30 mM) on Phytophthora stem rot disease reduction, the growth rate and zoospore release of Phytophthora sojae under laboratory conditions.

1. Effect of potassium nitrate application on disease reduction.

The application of 4–30 mM potassium nitrate (0,4-3 kg KNO_3/1000 L) to the growing medium, prior to disease inoculation, greatly reduced incidence of Phytophthora stem rot disease in the two soybean cultivars (Figure 1).

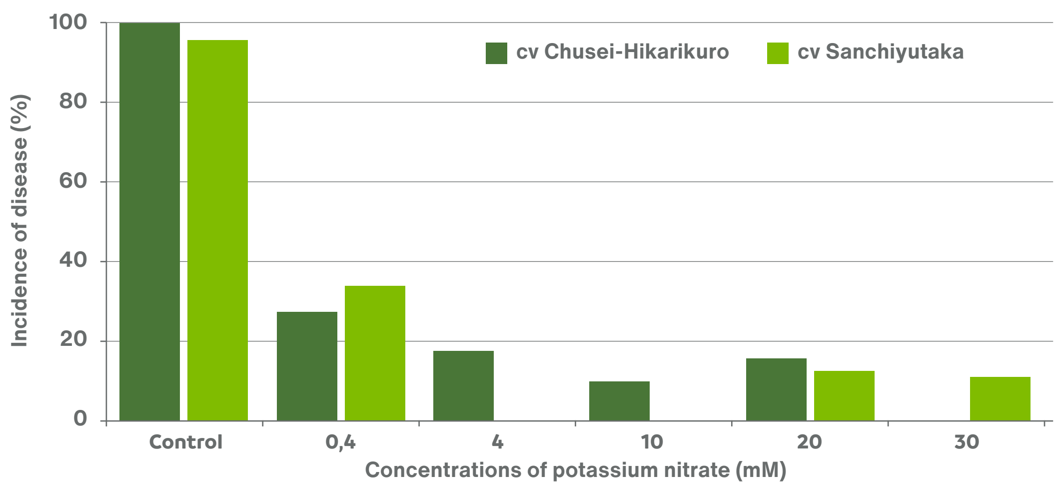

Figure 1. Effect of potassium nitrate on the incidence of P. sojae disease in two soybean cvs, 16 days after inoculation.

2 Effect of potassium nitrate application on mycelium growth.

A concentration of 20–30 mM potassium nitrate led to a slight decrease in the mycelium growth rate of the PJ-H30 isolate on PDA medium (Figure 2).

These results might be found, due to multiple effects of direct suppression on mycelium growth in combination with the response of the host plant tissue to potassium nitrate.

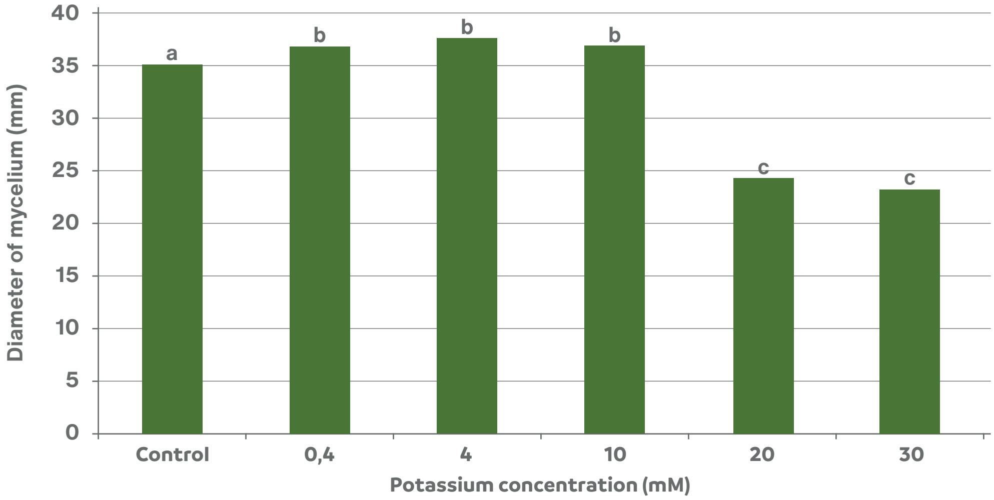

Figure 2. Effect of PN application on growth rate of PJ-H30 isolate after 7 days incubation at 23°C.

3. Effect of potassium nitrate application on zoospore release.

All levels of potassium nitrate (0,4-30 mM) significantly ($P < 0,05$) reduced the release of zoospores (Figure 3).

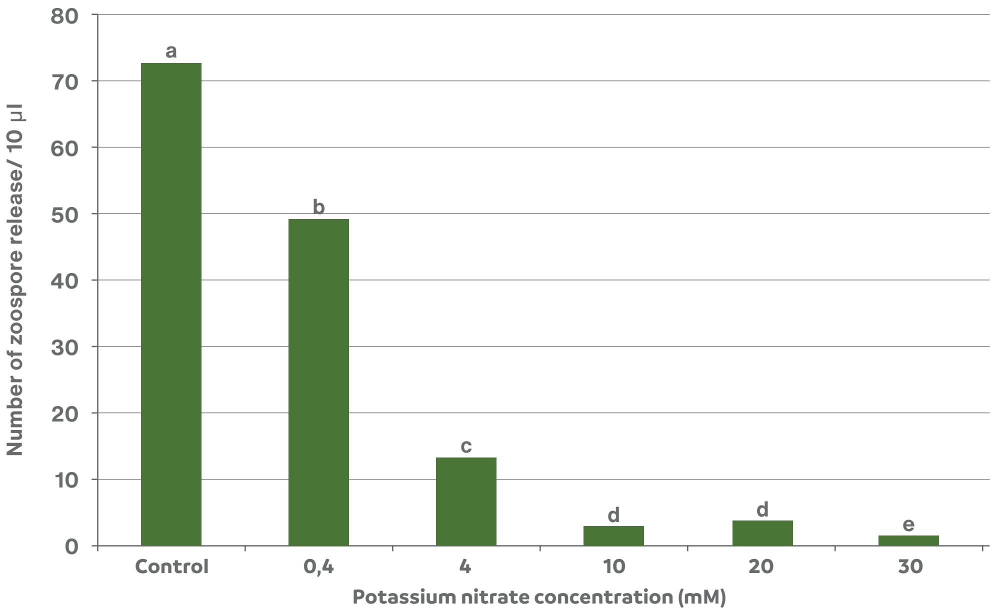

Figure 3. Effect of potassium nitrate on zoospore release from PJ-H30 isolate on Lima bean agar after 12 h incubation at 21°C.

4. *Distribution and accumulation of potassium using Scanning Electron Microscope (SEM) observation in soybean seedlings.*

Results indicate that increased potassium concentrations in plants were associated with disease reduction in both cultivars (Figure 4).

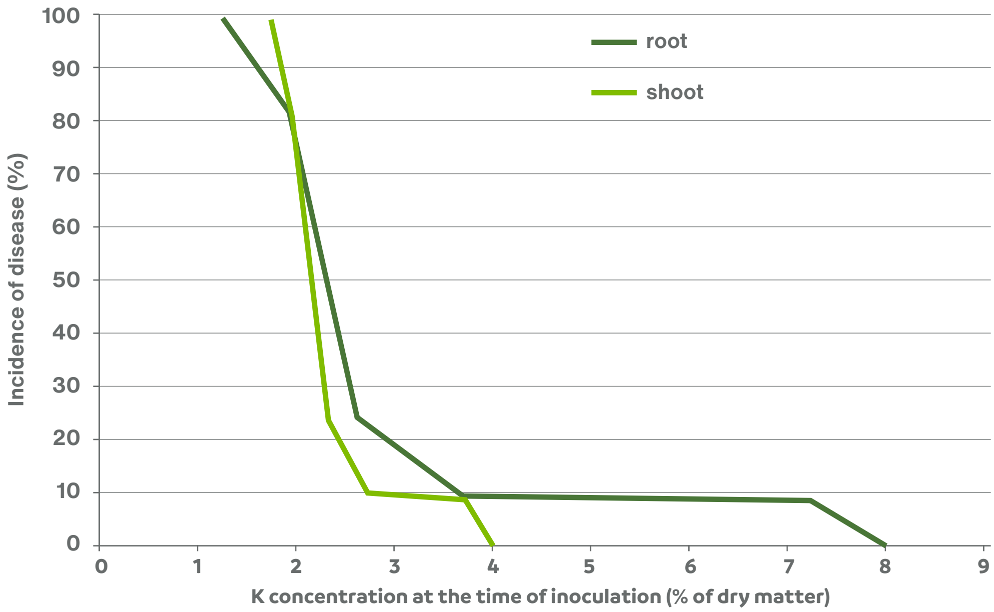

Figure 4. Relationship between K content in shoots and roots and incidence of disease on Glycine max cv Chusei-Hikarikuro, 16 days after inoculation.

The results of these four experiments suggest the possibility of applying a solution containing 20–30 mM of potassium nitrate (2-3 kg KNO_3/1000 L) to decrease the incidence of disease in agricultural fields by the response of plant tissues to potassium nitrate.

Sugimoto, T., K. Watanabe, M. Furiki, D.R. Walker, S. Yoshida, M. Aino and K. Irie. 2009. The effect of potassium nitrate on the reduction of Phytophthora stem rot disease of soybeans, the growth rate and zoospore release of Phytophthora sojae. Journal of Phytopathology, 157(6): 379-389.

Seed priming with potassium nitrate significantly improved soybean plant traits, compared to the untreated control.

Seed priming

Soybean seeds were primed in a laboratorial study with 1% solution of potassium nitrate for 24 hours at 20°C and tested under field conditions in Iran. According to the results from the laboratory experiments, germination percentage, germination rate and seedling dry weight were improved. In the field study, seeds primed with KNO_3 showed the highest values for all of the evaluated traits; the number of pods per plant, the number of seeds per pod, 1000-seed weight, height, LAI and the yield (Table 1 and 2). Seed priming significantly improved the soybean plant traits compared to the control (no priming).

Table 1. The results of the KNO_3 and control treatment for the laboratorial traits: germination percentage (GP), germination rate (GR) and seedling dry weight (SDW).

Treatments	Laboratorial traits		
	GP	GR	SDW
	(%)	(per day)	(g)
KNO_3	74	0,39	0,05
Control	58	0,17	0,03
Difference (abs.)	16	0,22	0,02
Difference (%)	**28,3**	**129,4**	**66,7**

Table 2. The results of the KNO_3 and control treatment for the field traits: number of pods per plant (NPPP), number of seeds per pot (NSPP), 1000 seed weight (1000-SW), height (H), leaf area index (LAI) and seed yield.

Treatments	Field traits					
	NPPP	NSPP	1000-SW	H	LAI	Seed Yield
			(g)	(cm)		(kg/ha)
KNO_3	36	2,7	146	65	5,1	2993
Control	23	2,2	138	46	3,4	2075
Difference (abs.)	13	0,5	8	19	1,7	918
Difference (%)	**56,5**	**24,1**	**6,2**	**43,4**	**47,2**	**44,3**

Mohammadi, G. R. 2009. The effect of seed priming on plant traits of late spring seeded soybean (Glycine max L.). Am. Eurasian J. Agric. Environ. Sci, 5 (3): 322-326.

Stone fruit

Stone fruit

Foliar sprays containing potassium nitrate increased fruit number and fruit size in peach.

Foliar Yield & Quality

Foliar application of nutrients and the interactive effect of NAA (auxin), KNO_3 and iron (as NaFeEDDHA) on nutrient status, shoot and yield characteristics of peach were investigated. This study was carried out on peach trees (Prunus persica L.) cv. Early Coronet in an orchard in Seiujh, Kurdistan Region, Iraq, in 2008. The soil was sandy clay loam with high pH and high calcium content. Each tree was sprayed till point of runoff with a solution containing KNO_3 (0%, 0,1% or 0,2%), combined with either NAA (0 or 5 mg/L) or iron (0, 30 or 60 mg NaFeEDDHA per liter). The surfactant agent Tween-80 was added to all the solutions at 0,01%. Two consecutive sprays were applied starting one month after fruit set: at April 24 and May 25. The experimental design was factorial in randomized complete blocks with three replicates. The best treatment - resulting in the highest average shoot dry weight, total chlorophyll, fruit number, fruit length, fruit diameter and total carotene - was the foliar spray with 5 mg/L NAA, 0,2% KNO_3 and 60 mg NaFeEDDHA per liter.

Al-Bamarny, S.F.A., M.A. Salman and Z.R. Ibrahim. 2010. Effect of some chemical compounds on some characteristics of shoot and fruit of peach (Prunus persica L.) cv. Early Coronet. Mesopotomia J. of Agric. 38 (Supplement 1).

Addition of potassium nitrate to thiourea enhanced dormancy break and increased yields of peach and nectarine.

Foliar Dormancy breaking

To break dormancy, thiourea (1%) and the combination of thiourea (1%) + potassium nitrate (2%) were applied as single sprays on two peach cultivars and one nectarine cultivar in Turkey. Both treatments showed an increase in yield in each cultivar compared to the control and affected the fruit quality positively and increased fruit size. When sprayed together in nectarine (cv. Weinberger), thiourea 1% and potassium nitrate 2% resulted in statistically significantly greater yield than the control treatment or thiourea 1% alone, and a side effect was two days earlier ripening and harvesting (Figure 1).

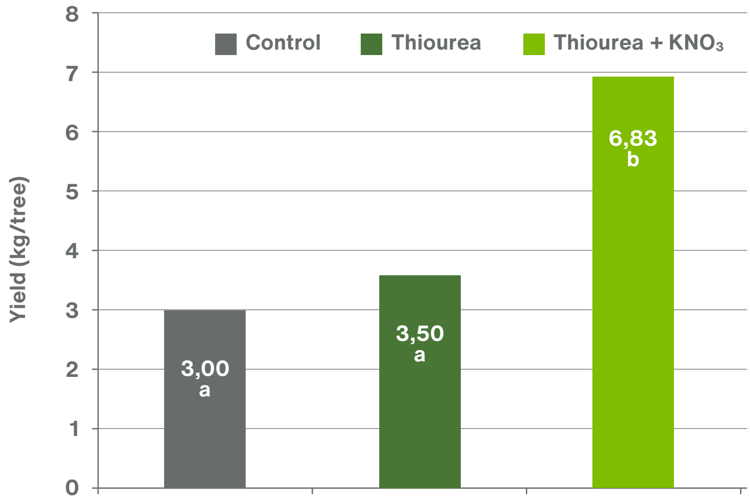

Figure 1. The effects of thiourea and KNO_3 + thiourea applications on the yield of Nectarine (cv. Weinberger).

Kuden, A. B., A. Kuden, and N. Kaska. 1993. The effects of thiourea and potassium nitrate + thiourea treatments on the release from dormancy of peaches and nectarines. Acta Horticulturae IV International Symposium on Growing Temperate Zone Fruits in the Tropics and in the Subtropics 409: 133-136.

The addition of potassium nitrate to rest-breaking chemicals in subtropical tree crops improved their efficacy by 20-30%.

Foliar *Dormancy breaking*

Several experiments were conducted in southeast Queensland, Australia, to determine whether combinations of new rest-breaking chemicals could induce more uniform bud break and increase flowering of a range of low-chill temperate and subtropical species (low-chill stone fruit, i.e. nectarine cv Springbite, persimmon and custard apple).

The most successful rest-breaking chemicals were Armobreak (alkolated amine) and Waiken (mix of fatty acid esters), but only when combined with potassium nitrate, which greatly improved their efficacy by 20-30%. Potassium nitrate alone has a mild rest-breaking ability.

In custard apple when sprayed together, Waiken (emulsified vegetable oil) 3% and potassium nitrate 5% resulted in statistically significantly greater number of laterals and flowers per meter main branch length than the control treatment or Waiken 3% alone on current season wood (Figure 1).

Potassium nitrate has a synergistic effect with other dormancy- breaking substances, improving branching, flowering, fruit-set and early fruit maturation.

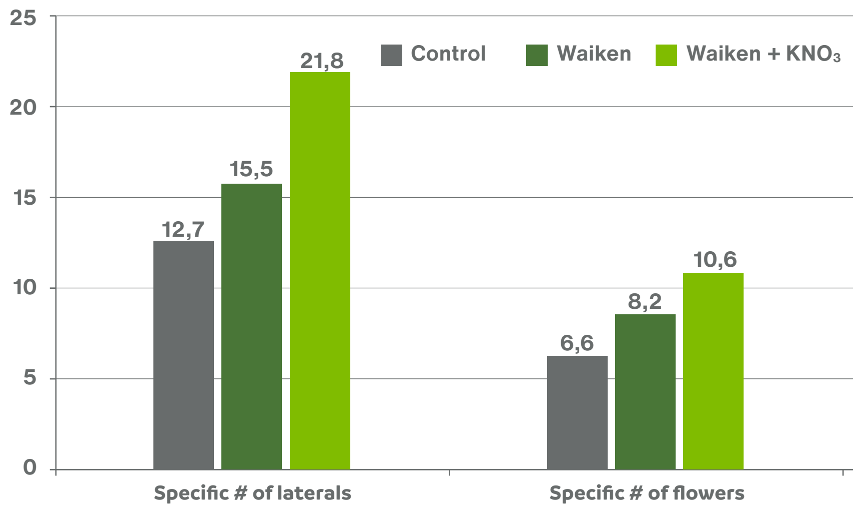

Figure 1. Effect of Waiken 3% and KNO_3 5% sprays in custard apple on number of laterals and flowers per meter branch length on current season wood.

George, A. P., R. H. Broadley, R. J.Nissen, and G. Ward. 2000. Effects of new rest-breaking chemicals on flowering, shoot production and yield of subtropical tree crops. Acta Horticulturae International Symposium on Tropical and Subtropical Fruits 575: 835-840

Potassium nitrate sprays increased peach fruit weight and potassium content in the leaves.

Foliar *Yield & Quality*

In a commercial peach orchard in northern Greece the effect of various foliar products was studied. The 12 years old trees of the cultivar 'Andross' were grown at a clay loam soil. The experiment was repeated for three years with five replications of eleven treatments. Three foliar sprays (with 10 day interval) for each treatment were applied before stage two of the fruit development (before pit hardening). Foliar application of all calcium products plus boron did not affect mean fruit weight compared to the control. Sprayings with KNO_3 (3 kg per 1000 kg water) increased fruit weight significantly (Table 1). The K concentration of leaves was statistically significantly increased in all three years with KNO_3 foliar applications.

Table 1. Effect of foliar applied potassium nitrate on peach fruit weight.

Treatments	Fruit weight (g)		
	Year 1	Year 2	Year 3
Control	160	165	170
KNO_3	177	179	181
LSD (0,05)	7,5	9,1	11,1

Sotiropoulos,T., I. Therios and N. Voulgarakis. 2010. Effect of various foliar sprays on some fruit quality attributes and leaf nutritional status of the peach cultivar 'Andross'. Journal of Plant Nutrition, 33(4): 471-484.

Foliar potassium nitrate sprays for increased fruit size of 'Patharnakh' pear.

Foliar   Yield & Quality

The aim of the study was to improve size and quality of 'Patharnakh' pear fruits through foliar sprays of potassium fertilizers at Punjab Agricultural University in India. The sixteen-year-old plants were sprayed with KNO_3 and K_2SO_4 at 1,0, 1,5 and 2,0% in three sets, i.e., one, two and three sprays. First spray was given at 15 days, second at 30 days and third at 45 days after full bloom. Results showed that foliar potassium application significantly improved the fruit size as compared to control. Similarly, the number of K sprays had a positive effect on final fruit size. Maximum fruit size was recorded with three sprays of KNO_3 at 1,5 per cent. Soluble solids were increased with various potassium treatments and number of applications.

Gill, P. P. S., M. Y. Ganaie, W. S. Dhillon, and N. P Singh. 2012. Effect of foliar sprays of potassium on fruit size and quality of 'Patharnakh' pear. Indian Journal of Horticulture, 69(4): 512-516.

Potassium nitrate sprays were as effective, or better, than soil applied potassium chloride in 'French' prune trees in terms of correcting K-deficiencies or dry yields.

Foliar   Yield & Quality

'French' prune trees (Prunus domestica syn. 'Petite d'Agen') grown on a fine-textured Wyman loam soil were sprayed with KNO_3 in Gridley, California (USA). Spray applications (20-22 litres/tree, 43-48 kg/ha) of KNO_3 were compared with single annual soil applications of potassium chloride (1,4-2,3 kg/tree) or sprays of urea + KNO_3 with respect to leaf potassium and nitrogen concentrations, fruit size, drying ratio and dry yield. KNO_3 sprays were as effective or better than soil-applied potassium chloride at maintaining adequate levels of potassium throughout the season. Lowest leaf potassium values, below the adequate level of 1,3% potassium, were found in the trees where no potassium was applied. These trees developed potassium deficiency symptoms. Trees showing below optimum leaf-potassium levels showed a clear yield benefit following spraying. Trees deprived of potassium were the lowest yielding. It was concluded that foliar KNO_3 sprays applied four times throughout the growing season can correct relative potassium deficiency in 'French' prune an can obtain dry yields equivalent to those obtained with soil applications of KCl.

Southwick, S.M., W. Olson, J. Yeager and K.G. Weis. 1996. Optimum timing of potassium nitrate spray applications to 'French' prune trees. Journal of the American Society for Horticultural Science 121(2): 326-333 .

Potassium application increased fruit weight and diameter in nectarines.

Fertigation *K-sources*

A field trial with three sources of K (KNO_3, K_2SO_4 and KCl) applied at 300 kg K_2O per hectare, was carried out for 4 years to evaluate responses of early nectarines cv. Fairlane. The orchard with four-year-old nectarines was located in the Coltauco Valley (Chile). The soil was a deep Mollisol, medium textured (loamy sand) and with a slight drainage limitation. Next to the three K treatments all treatments received nitrogen as urea at a rate of 200 kg/ha, with the control treatment receiving only urea. Fertilizers were applied yearly during early spring at the bottom of the first, second and third irrigation furrow. The treatments were arranged according to a randomized complete block design with four replicates.

All three K sources were equally effective in increasing leaf K levels. Leaf K concentrations increased from 10 g kg^{-1} in the control to 15 g kg^{-1}. All K treatments significantly increased fruit weight and diameter in the years 1998, 1999 and 2000 (Table 1). The incremental effect in diameter was closely related to internal K requirements rates. Fruit yield was increased by potassium fertilizers in a dry year. This was caused by the largest fruit set (natural set, without thinning) observed in K-treated trees. Fruit firmness at harvest or after 30 days storage at 0°C was little affected by the treatments, but KNO_3 and KCl increased fruit firmness in some seasons.

Table 1. Effect of K source (300 kg K_2O per hectare per year) on average fruit weight of nectarine.

Treatments	Fruit weight (g)		
	1998	1999	2000
Control	135 b	108 b	138 b
KNO_3	147 a	120 a	147 a
K_2SO_4	144 a	117 a	146 a
KCl	143 a	118 a	145 a

Ruiz, R. 2005. Effects of different potassium fertilizers on yield, fruit quality and nutritional status of 'Fairlane' nectarine trees and on soil fertility. In: V International Symposium on Mineral Nutrition of Fruit Plants, Acta Hort. 721: 185-190.

Combination of foliar applied potassium nitrate with 'Waiken' can effectively break floral bud dormancy in peach and nectarine.

Foliar *Dormancy breaking*

An experiment was conducted in Khun Wang (Thailand) on rest-breaking products to modulate rest and flowering on low-chill peach cv. Florida Grande and nectarine cv. Sun Wright. Trials were conducted on 5-year-old trees using randomized complete block designs, with treatments applied to six single tree replicates. Treatments were: control (water), KNO_3 5%, Waiken (fatty acids) 2%, Waiken 2% + KNO_3 5%, Waiken 4% and Waiken 4% + KNO_3 5%. Rest-release treatments were applied on 7 November 2001 in year 1 and on 20 November 2002 in year 2. All treatments were already sprayed eight times with 2,5% KNO_3 in autumn. The combination of Waiken + KNO_3 exhibited a higher bud break percentage compared to the control in peach and nectarine (Table 1 & 2), advanced flowering by up to 1-2 weeks and concentrate flowering intensity. Waiken and KNO_3 may increase fruit set and resulted in increased yield per tree in Florida Grande and Sun Wright varieties (Table 1 & 2). No effect on fruit quality of peach and nectarine was found in this study.

Table 1. Effect of treatments on flower bud break and yield of peach var. Florida Grande.

Treatments	Flower bud break (%)	Yield /tree (kg)	Yield /tree (kg)
	2002	2003	2003
Control	69,8 ab	13,2	2,6 b
KNO_3 5%	69,4 ab	11,8	5,3 ab
Waiken 2%	62,5 b	13,2	5,7 ab
Waiken 2% + KNO_3 5%	74,0 ab	14,0	6,4 a
Waiken 4%	64,9 b	12,3	3,4 ab
Waiken 4% + KNO_3 5%	80,0 a	11,3	5,4 ab

Table 2. Effect of treatments on flower bud break and yield of nectarine var. Sun Wright.

Treatments	Flower bud break (%)	Yield /tree (kg)	Yield /tree (kg)
	2002	2003	2003
Control	85,5	3,0 b	3,6
KNO_3 5%	89,3	4,3 ab	4,6
Waiken 2%	93,7	4,7 ab	3,5
Waiken 2% + KNO_3 5%	99,0	4,5 ab	4,2
Waiken 4%	95,6	5,7 a	5,3
Waiken 4% + KNO_3 5%	94,7	3,7 ab	3,4

Noppakoonwong, U., P. Sripinta, P. Pasopa, S. Subhadrabandhu, A.P. George and R.J. Nissen. 2004. A trial of rest-breaking chemicals on low-chill peach and nectarine. Production technologies for low-chill temperate fruits, 19: 73-80.

Strawberry

Strawberry

sqmnutrition.com

Supplementary potassium nitrate and calcium nitrate ameliorated the negative effects of salinity on plant growth and fruit yield of strawberry.

Fertigation *Salinity relief*

A pot experiment was carried out with two strawberry (Fragaria x ananassa Duch.) cultivars, Oso Grande and Camarosa in sand culture to investigate the effects of supplementary calcium nitrate and potassium nitrate to plants grown at high NaCl (35 mM) in complete nutrient solution supplied via the roots. Composition of nutrient solution was (mmol/L): 19,3 N, 1 P, 6 K, 5 Ca, 2 S, 2 Mg and (µmol/L) 52 Na, 50 Fe, 46 B, 9,1 Mn, 0,8 Zn, 0,3 Cu and 0,1 Mo. Treatments consisted of: nutrient solution alone (C), C + 5 mM $Ca(NO_3)_2$ + 5 mM KNO_3 (C+CaN+PN), nutrient solution + 35 mM NaCl (C+S), C+S+ 5 mM $Ca(NO_3)_2$ (C+S+CaN), C+S+ 5mM KNO_3 (C+S+PN), and C+S + 5mM $Ca(NO_3)_2$ +5mM KNO_3 (C+S+CaN+PN). The volume of nutrient solution supplied to the plants ranged from 50 mL to 250 mL per pot depending on the amount of solar radiation, temperature and plant size.

The plants grown at high NaCl had less dry matter, fruit yield, and chlorophyll content than those grown in normal nutrient solution for both cultivars. Both supplementary $Ca(NO_3)_2$ and KNO_3 partly mitigated the detrimental effect of salinity on fruit yield but were most effective when used together (Figure 1). Fruit weight, fruit number and total soluble solids decreased with high salinity. Supplementary $Ca(NO_3)_2$ and KNO_3 were both very effective in restoring those parameters but best results were observed when supplied together. Also membrane permeability increased with high NaCl and was statistically significantly reduced by supplementary $Ca(NO_3)_2$ and KNO_3.

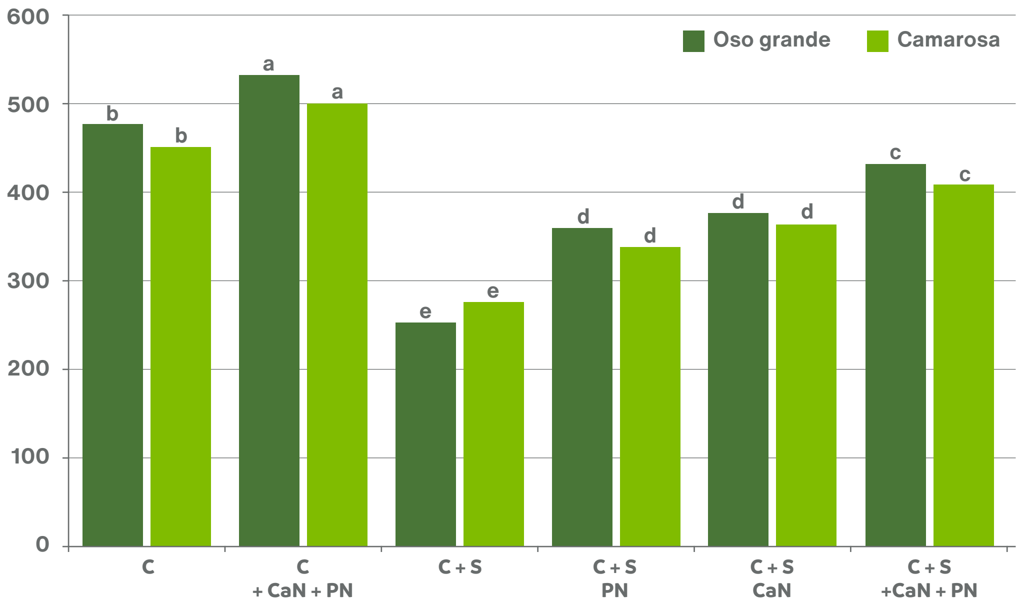

Figure 1. The effect of treatments on the fruit yield (g/plant) of two strawberry cultivars. Note: C, plants receiving normal nutrient solution; S, 35 mM sodium chloride; CaN; 5 mM $Ca(NO_3)_2$; PN, 5 mM KNO_3.

Kaya, C., B.E. Ak and D. Higgs. 2003. Response of salt-stressed strawberry plants to supplementary calcium nitrate and/or potassium nitrate. Journal of Plant Nutrition, 26(3): 543-560.

Nitrate-fed fertigated strawberries had higher biomass and increased carboxylate and calcium content, compared to ammonium-fed plants.

Fertigation *N-sources*

The effect of four root temperatures and five NO_3^-/NH_4^+ mole ratios, at a constant total N in the fertigation was studied in strawberries (Table 1). The solution was fertigated in 1-L pots using continuous flow technique. Total N uptake, uptake of NO_3^- or NH_4^+, plant development, and the amount of mineral ions in the leaves and roots were measured.

Maximal N uptake in the plant was dependent on temperature and growth phase, with highest uptake during a phase of vegetative growth at 25°C. In almost all cases the N uptake was higher when both N-sources were present in the nutrient solution. During flowering and fruit development, the plants showed preference for uptake of NO_3^-. When harvest was finished and the plants exhibited vegetative growth a preference for the uptake of NH_4^+ over NO_3^- was observed. Possibly the variation in carbohydrate content of various plant organs, or changes in the internal metabolism associated with vegetative or reproductive development are responsible for this shift in NO_3^- preference. A higher dry matter content was found in plants fed exclusively with NO_3^-, compared to NH_4^+ fed plants at the extreme root temperature of 10°C and 32°C. In contrast, at normal temperatures of 17°C and 25°C, plants given nutrient solution with a ratio NO_3^- :NH_4^+ of maximally 1:1, obtained a higher dry weight of leaves compared to NO_3^- only (Table 1).

At low root temperatures, NH_4^+ fed plants did not show root damage, whereas at the highest root temperature (32°C), roots of these plants disintegrated. The explanation for this is most probably the fact that NH_4^+ metabolism occurs exclusively in the roots and requires carbohydrates inside the root cells, where there is an intensive competition with respiration for sugar reserves. At higher temperatures the need for sugar in other plant parts is also increased, enhancing this competition.

The effect of N form on the cation concentration was found to be significant in most cases. In NO_3^- fed plants, K^+, Ca^{2+} and Mg^{2+} concentration in the roots was higher compared to NH_4^+ fed plants. In the leaves Ca^{2+} was also higher in NO_3^- fed plants. The leaf-Mg^{2+} was unaffected by the form of nitrogen, and the effect of N form on leaf-K^+ varied with temperature, with higher K^+ in NO_3^- fed plants with root temperatures lower than 17°C. Regarding the concentration of anions, an increase of NO_3^- concentration in the leaves was found for plants grown on either N form. Chloride and sulphur concentration were increased in NH_4^+ fed plants and P was decreased in NO_3^- fed plants.

The balance of the concentration of total mineral cations minus the concentration of total mineral anions (C-A), is nominally equivalent to the concentration of carboxylate anions. This was found to be higher in the leaves than in the roots for all temperatures and N forms. In the roots, the nominal carboxylate content of the roots decreased with higher temperatures with both N forms, and was higher in NH_4^+ fed plants. In contrast in the leaves of plants fed with NO_3^-, the leaf carboxylate content was not dependent on temperature, but was still negatively correlated in NH_4^+ fed plants. Leaf carboxylate content in general was lower in NH_4^+ fed plants than in NO_3^- fed plants. This is explained by the reduction of NO_3^- in the leaves, that is linked to the production of organic acids, or to a higher consumption of carboxylates in NH_4^+ fed plants at higher temperatures. The authors point to the importance of calculating the ionic balance as this enables us to understand the carboxylate production in various plant organs, and to demonstrate the importance of nitrogen form on plant carboxylate metabolism and consumption as function of root temperature.

Table 1. The effect of root temperature and NO_3^-/NH_4^+ ratio on dry weight of strawberry (grams leaves/plant). Means with the same letter are not significantly different within each root temperature treatment. * plants had died due to root damage.

NO_3^-/NH_4^+ mole ratio		Root temperature (°C)			
NO_3^- mmol L^{-1}	NH_4^+ mmol L^{-1}	10	17	25	32
7,0	0,0	2,5 a	2,1 b	2,6 b	2,2 a
5,0	2,0	2,8 a	3,0 a	1,4 d	1,4 c
3,5	3,5	1,4 c	2,8 a	4,5 a	1,7 b
2,0	5,0	1,9 b	2,4 b	1,5 d	1,5 c
0,0	7,0	2,0 ab	2,2 b	1,8 c	-*
LSD (0,05)		0,51	0,36	0,30	0,12

Ganmore-Neumann, R. and U. Kafkafi, 1985. The effect of root temperature and nitrate/ammonium ration on strawberry plants. II. Nitrogen uptake, mineral ions and carboxylate concentrations. Agron. J. 77:835-840.

Potassium nitrate outperformed other dormancy breaking agents in increase of flowering and fruit weight of strawberry.

Foliar *Dormancy breaking*

The aim of this study was to assess the effect of different rest breaking agents on alleviation of negative effects of unfulfilled chilling requirements on vegetative and generative growth of strawberry cv. 'Merak' in subtropic conditions. Foliar applications of four different dormancy breaking chemicals, each at two dose rates, were compared: potassium nitrate at 1,5 and 3,0%, dormex (H_2HCN) at 0,5 and 1%, gibberellic acid (GA_3) at 50 and 100 mg/L, volk oil at 2,5 and 5,0% and a control (spray with distilled water). Induced but dormant young rooted daughter plants were potted in 3L plastic pots filled with 2:1 sandy loam soil:compost and fertigated with Hoagland solution. After 2 weeks of establishment (in the beginning of November) the treatments were foliar applied. The plants were grown for 3,5 months in outside conditions at the Agriculture and Natural Resource College of Darab city in the Fars province of Iran, till and during harvest. The experiment was laid out in a randomized complete block design with 8 replications.

Number of flowers and number of inflorescences (clusters of flowers) of plants treated with the both doses KNO_3 in the foliar spray increased significantly compared to the other treatments (Table 1). Additionally, also the average fruit weight of primary and secondary fruits of a fruit cluster were increased when 3% KNO_3 was foliar applied (Table 1), and this was reflected in the highest number of achenes counted on these fruits. Achenes are the true fruits ("nuts") of strawberry, and fertililized achenes will stimulate fruit growth after pollination. Berry weight is highly correlated with achene spacing and achene number. Observations on vegetative growth indicated that foliar application with KNO_3 also led to the highest augmentation of leaf area and increased root length compared to the control. All rest breaking agents showed effect compared to the untreated control, but only the foliar applied potassium nitrate applications resulted in the maximal effect on both plant growth and fruit weight of strawberry.

Table 1. The effect of rest breaking agents on number of flowers, number of inflorescences and weight of primary and secondary fruits in strawberry cv. 'Merak' plants. Means followed by the same letter are not significantly different at 5% probability using Duncan's t-test.

Treatments	Number of flowers	Number of inflorescences	Av. fruit weight primary fruit (g)	Av. fruit weight secondary fruit (g)
Control (water spray)	6,0 b	3,4 bc	13,7 b	13,4 b
KNO_3 1,5%	8,4 b	4,7 a	14,6 b	14,3 ab
KNO_3 3%	11,9 a	3,5 a	16,7 a	14,9 a
Dormex 0,5%	7,8 b	2,8 bc	13,5 b	13,3 ab
Dormex 1%	8,2 b	3,6 b	13,0 b	13,8 ab
GA_3 50 mg/l	3,2 c	2,5 c	13,0 b	12,6 ab
GA_3 100 mg/l	3,0 c	1,8 d	12,3 b	12,3 c
Volk oil 2,5%	5,2 bc	2,7 c	13,9 b	13,1 b
Volk oil 5%	5,4 bc	3,7 b	14,1 b	13,4 b
Volk oil 5%	5,4 bc	3,7 b	14,1 b	13,4 b

Eshghi, S., M.R. Safizadeh, B. Jamali and M. Sarseifi. 2012. Influence of foliar application of volk oil, dormex, gibberellic acid and potassium nitrate on vegetative growth and reproductive characteristics of strawberry cv.Merak. J. Biol. Environ. Sci, 6(16): 35-38.

Potassium nitrate improved earliness of fruit maturation in strawberry.

Foliar *Dormancy breaking*

In strawberry, hydrogen cyanamide (HC) and potassium nitrate (PN) can be used to break the dormancy. To study the effects of these substances, four experiments were carried out in Spain to find the most suitable spray product, dose and period of application. In one of the experiments with 3,0% potassium nitrate and 0,5% HC, potassium nitrate gave earlier yields (P=0,05), but total yields were similar. Average fruit weight of plants treated with potassium nitrate and HC were higher than control plants at the end of the season (Table 1).

Table 1. Commercial production and average fruit weight after spray application directly to the crown of potassium nitrate (PN) and hydrogen cyanamide (HC).

Treatments	Commercial production (g/plant)		Average fruit weight (g/fruit)	
	31 Mar	31 May	31 Mar	31 May
Control	36,4 b	138,5 a	10,2 a	10,5 b
PN 3%	56,7 a	140,1 a	12,2 a	11,7 a
HC 0,5 %	38,1 b	127,1 a	10,7 a	11,2 a

Maroto, J. V., S. Lopez-Galarza, A. San Bautista, B. Pascual, J. Alagarda and M.S. Bono. 1997. Response of strawberry plants to hydrogen cyanamide and potassium nitrate applications. Acta Horticulturae VIII International Symposium on Plant Bioregulation in Fruit Production 463: 153-158 .

Foliar applied potassium nitrate is an effective bud break inductor for strawberry plants.

Foliar *Dormancy breaking*

A pot-experiment in soilless culture (perlite) was conducted with strawberry (Fragaria ananassa) cv. 'Selva' under greenhouse conditions in Iran. This study was designed to evaluate if it was possible to break the dormancy of day-neutral strawberry plants with potassium nitrate or chilling. Treatments included: control plants, plants treated with 1,5% KNO_3 and plants treated with 3,0% KNO_3. All three treatments were combined with 4 chilling treatments: no chilling, 44, 74 and 114 degree-days of chilling. During chilling plants were exposed to low temperatures (9–11°C) and short day-lengths (7–8 h), which led to cessation in growth of the plants. The highest leaf area, chlorophyll content and petiole length resulted from plants treated with 1,5% KNO_3 without chilling (Table 1). The results showed that potassium nitrate application alone at the proper time is inductive and has nutritional effects on growth and development of strawberry plants. However, according to the results of this research chilling only is not able to induce plant growth completely.

Table 1. Effects of potassium nitrate treatments on growth induction of strawberry plants without chilling.

Treatments	Leaf area (mm^2)	Chlorophyll content*	Petiole length (mm)
1,5% KNO_3	248 a	3,52 a	68 a
3,0% KNO_3	208 b	3,44 a	63 a
Control	182 c	3,04 b	54 b

* expressed as mg/g leaf fresh weight.

Khayyat, M., S. Rajaee, M. Shayesteh, A. Sajadinia and F. Moradinezhad. 2010. Effect of potassium nitrate on breaking bud dormancy in strawberry (Fragaria ananassa, Duch.) plants. Journal of Plant Nutrition, 33: 1605-1611.

Sunflower

Sunflower

sqmnutrition.com

Potassium nitrate sprays positively affected vegetative characteristics of sunflower and safflower grown under salinity.

Foliar *Salinity relief*

The effect of 250 ppm foliar application of KNO_3 was assessed on growth and activity of nitrate reductase (NR) in the leaves of sunflower and safflower, subjected to different levels of salinity. In sunflower, leaf area and fresh and dry weight of leaves were increased by 32%, 36,4% and 43,4% respectively in comparison with the non-sprayed control (Table 1). The KNO_3 foliar spray also increased the nitrate content, NR activity and soluble proteins (Table 2). Potassium nitrate sprays also increased the K concentration and decreased the Cl concentration in the leaves in both crops for all three salinity levels. In sunflower and safflower the benefits of KNO_3 foliar spray are demonstrated, irrespective to the plant growth under non saline or saline conditions.

Table 1. Effect of foliar application of KNO_3 on vegetative characteristics of sunflower under different salinity levels. LAI = Leaf Area Index, LFW = Leaf Fresh Weight and LDW = Leaf Dry Weight.

Sunflower		LAI (cm^2)	LFW (g)	LDW (g)
Non Saline	Control	2894	65,8	13,9
	Foliar KNO_3	3857	97,5	22,6
0,3% sea-salt dilution	Control	2424	52,5	10,5
	Foliar KNO_3	3465	80,4	17,8
0,6% sea-salt dilution	Control	1806	34,2	6,7
	Foliar KNO_3	2652	53,8	11,9

Table 2. Effect of foliar application of KNO_3 on amount of nitrate, nitrate reductase activity and soluble proteins of sunflower under different salinity levels.

Sunflower		Nitrate content leaves µmol $(g\ fw)^{-1}$	Nitrate reductase activity µmol NO_2 $(g.fw.hr)^{-1}$	Soluble proteins mg/g fw
Non Saline	Control	25,6	9,4	25,8
	Foliar KNO_3	29,4	11,0	29,2
0,3% sea-salt dilution	Control	23,5	8,7	24,0
	Foliar KNO_3	27,5	10,3	27,9
0,6% sea-salt dilution	Control	18,7	7,1	19,0
	Foliar KNO_3	22,5	8,5	23,3

Jabeen, N. and R. Ahmad. 2011. Foliar application of potassium nitrate affects the growth and nitrate reductase activity in sunflower and safflower leaves under salinity.Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 39(2): 172-178 .

Foliar applied potassium nitrate was effective in improving growth of salt-stressed sunflower plants.

Foliar Salinity relief

In order to study the effectiveness of foliar-applied potassium (K^+, 1,25%) using different salts (KNO_3, KCl, K_2SO_4, K_2CO_3, KH_2PO_4, and KOH) in improving the inhibitory effect of salt stress on sunflower plants, a greenhouse experiment was conducted in Pakistan. Sodium chloride (150 mM) was applied through the rooting medium to 18-days old plants and after 1 week of salt treatment; amounts of 25 mM solution of K-source were applied twice with a 1-week interval as foliar spray. Salt stress adversely affected the growth, yield components, gas exchange, and water relations, and also caused nutrient imbalance in sunflower plants. However, foliar-applied different sources of potassium improved shoot and root fresh and shoot dry weights, achene yield, 100-achene weight, photosynthetic rate, transpiration rate, stomatal conductance, water-use efficiency, relative water content, and leaf and root K^+ concentrations of sunflower plants, grown under saline conditions. Of the different salts, KNO_3, K_2SO_4, K_2CO_3 and KH_2PO_4 were more effective than KCl and KOH in alleviating salt-induced inhibitory effects on sunflower plants. These more effective K sources improved the growth and some key physiological processes of sunflower plants.

Saeed Akram, M., M. Ashraf, M. Shahbaz and N. Aisha Akram. 2009. Growth and photosynthesis of salt-stressed sunflower (Helianthus annuus) plants as affected by foliar-applied different potassium salts. Journal of Plant Nutrition and Soil Science, 172(6): 884-893.

Tomato

Tomato

The effect of nitrate /ammonium / urea proportions and potassium concentrations on the production of tomato seedlings.

Fertigation N-sources

In Mexico, tomato seedlings are propagated in greenhouses before transplant in open field tomato cultivation. Most of the substrates used during propagation do not contain sufficient quantities of nutrients to fulfill the seedlings requirement for optimal development. In this study the objective was to evaluate the effect of nitrogen form in this cultivation, since it is known from literature that replacement of a small proportion of the nitrate-nitrogen by ammonium can improve plant growth. Additionally the effect of increasing potassium rate was studied, as potassium is the second major element needed by tomato plants and may alleviate potentially negative effects of ammonium in the nutrient solution. In a completely randomized, factorial design, the effect on four proportions of NO_3^- /NH_4^+ /urea and two concentrations of potassium in the nutrient solution on seedling growth and mineral composition of the plants were evaluated.

Seeds were sown in polystyrene containers with 30 cm^3 holes filled with 1:1 turf vermiculite mixture, and nutrient solutions were applied directly with germination of the seeds till the end of the experiment 46 days after sowing. The rate of nutrients was increased in steps every 10 days from 50% to 75%, till reaching 100% of the final concentration of both cations and anions of 20 mol/m^3. Steiners recipe for nutrient solution was modified, with 12 mol/m^3 N as standard. The four treatments with differing ratios of the three N-sources are given in Table 1. Potassium was applied in two concentrations, 7 and 9 mol/m^3.

The results showed that a number of parameters describing seedling quality increased by replacing 15% of the total nitrate-nitrogen by a similar amount of urea or a mixture of ammonium and urea (Table 1). The mineral composition of leaves and roots responded to the treatments as well. At 7 mol/m^3 of K, the content of N in leaves and roots increased when 15% of the NO_3^- was replaced by any of the other N-sources (Figures 1,2). The P-content of leaves and roots increased with replacement of 15% of the NO_3^- with ammonium, but remained at similar levels when replaced by urea.

An interaction between the N-source ratio and the amount of K in the nutrient solution was observed on the concentration of N in the leaves, stem and roots, and on the content of calcium or magnesium in the roots. Increasing the dose of K in the nutrient solution decreased the amount of N accumulated in the leaves in the presence of ammonium (85/15/0) compared to the standard K dose. In the roots, increased dose of K decreased the amount of N accumulated in the roots in the presence of urea (85/15/0 and 85/7,5/7,5). Calcium and magnesium uptake in the roots were not influenced by increased K-dose, except when 15% urea was added, in which case the cation-concentration in the roots was lowered.

Table 1. Response of parameters indicative of quality of tomato seedlings to nutrient solutions differing in ratio of three N-sources. Means followed by the same letters are not significantly different (Tukey, P ≤ 0,05).

Ratio N-sources in n.s.	Stem diameter	Root volume	Total plant mass	Shoot/Root
NO_3^- /NH_4^+/Urea	(mm)	(ml)	(g DW/plant)	(ratio DW)
100/0/0	3,7 b	0,18 c	1,2 ab	8,7 b
85/15/0	3,8 b	0,19 bc	1,2 b	9,1 b
85/0/15	4,0 a	0,20 b	1,3 a	10,4 a
85/7.5/7.5	3,8 b	0,22 ab	1,3 ab	9,0 b

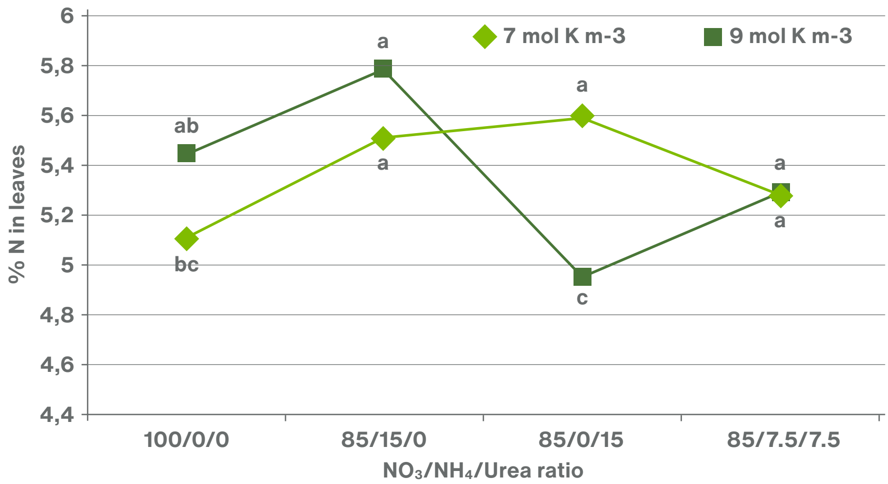

Figure 1. Percentage nitrogen (N) in the leaves of tomato seedlings supplied with nutrient solutions containing three different N-sources in 4 ratios, and 2 rates of potassium (K). Data points labeled with the same letters in each column and row are not significantly different (Tukey, P ≤ 0,05).

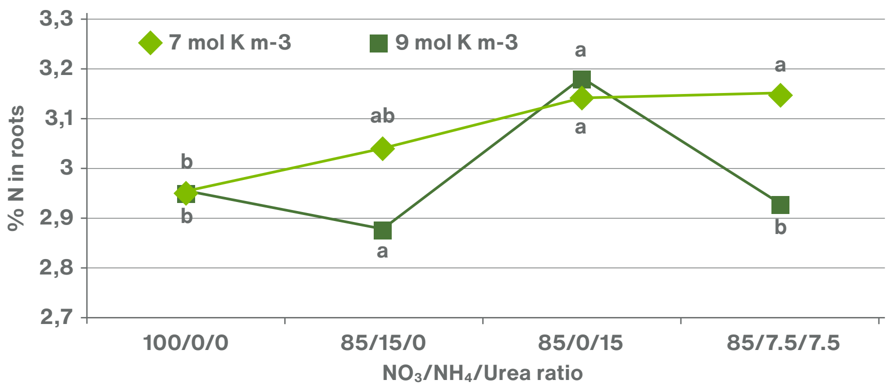

Figure 2. Percentage Nitrogen (N) in the roots of tomato seedlings supplied with nutrient solutions containing three different N-sources in 4 ratios, and 2 rates of potassium (K). Data points labeled with the same letters in each column and row are not significantly different (Tukey, P ≤ 0,05).

Parra-Terraza S., E. Salas-Núñez, M. Villarreal-Romero, S. Hernández-Verdugo, P. Sánchez-Peña, 2010. Relaciones nitrato/amonio/urea y concentraciones de potasio en la producción de plántulas de tomate. (Nitrate/ammonium/urea proportions and potassium concentrations in the production of tomato seedlings.) Rev. Chapingo Ser.Hortic 16 (1): 37- 46.

Higher yield in tomato on hydroponics with 4:1 ratio nitrate: ammonium in the nutrient solution and added bicarbonate.

Fertigation *N-sources*

The assimilation of dissolved inorganic carbon (bicarbonate (HCO_3^-) and CO_2), taken up from the soil solution, occurs in the cells of roots of higher terrestrial plants. In root tissue, bicarbonate is transformed to carboxylates, or constitutes a carbon-skeleton used in the synthesis of amino acids. These organic compounds can be transported by the xylem to the shoots where they aid photosynthesis, or remain to be assimilated in the roots for synthesis of carbohydrates.

The availability of dissolved inorganic carbon can influence the rate at which NH_4^+ can be detoxified by its assimilation into organic compounds. The long term effect of elevated HCO_3^- contents on plants, depends to a great degree on the form of N (NO_3^- or NH_4^+) available to them and the pH of the nutrient solution. In a greenhouse in Poland, a trial was performed on tomatoes cv. Perkoz F1 on a hydroponic mineral medium. The aim was to study the effect of the combination of various doses of NO_3^- :NH_4^+ in the nutrient solution and simultaneous treatment with bicarbonate, or without it, on the yield of tomatoes and their chemical composition. A constant level of HCO_3^- was maintained by controlling the pH of the nutrient solution at 6,9, permitting the conversion of almost the whole inorganic carbon pool to bicarbonate. The total N was kept constant at 3 mmol, bicarbonate was supplied at 5 mmol. Sodium nitrate and ammonium chloride were used as the N-sources.

The fruit yield of plants grown with NH_4^+ as the sole N-source, was approximately 25% lower than that of plants grown on NO_3^- only (Figure 1). The poorer productivity of the NH_4^+ plants could have resulted from a reduced biomass production in early stages of growth. When N was supplied as 4:1 NO_3^- :NH_4^+ , the fruit yield increased 20% compared to NO_3^- as the sole N-source. It is possible that this effect is the result of a balanced level of carboxylates and amino acids supplied from the roots via the xylem to the shoot, due to the availability of both nitrogen sources in the root. At 1:1 NO_3^- :NH_4^+ ratio in the nutrient solution, yields were comparable to plants supplied only with NO_3^-.

Measurements of the amount of carboxylate (malate and citrate) in the fruits, led to the general conclusion that the accumulation of carboxylates in fruit was negatively correlated with an increased NH_4^+ concentration in the nutrient solution. The content of reducing sugars was negatively influenced by NH_4^+; when ammonium was the sole N-source, the accumulation of reducing sugars in the fruit was 20% lower than for plants grown with NO_3^- only. When NH_4^+ and NO_3^- were applied together, the reducing sugar content was intermediate. Addition of bicarbonate increased the amount of reducing sugars, with the highest increase when combined with NO_3^-, and it increased the carboxylate content of fruits in all treatments.

In tomato, the carboxylates imported by the xylem can lead to a release of CO_2, that can be directly assimilated in the photosynthetic process of the fruit, and on this path contribute to an increase in the accumulation of sugars.

The enrichment of the nutrient solution with bicarbonate stimulated fruit bearing depending on the applied NO_3^- :NH_4^+ ratios. The results showed that the best yields were obtained in media containing mainly nitrate with 25% ammonium (4:1 NO_3^- :NH_4^+) and enriched with bicarbonate. This resulted in an increase of 86% compared to that of plants grown NO_3^- as the sole N-source, without bicarbonate.

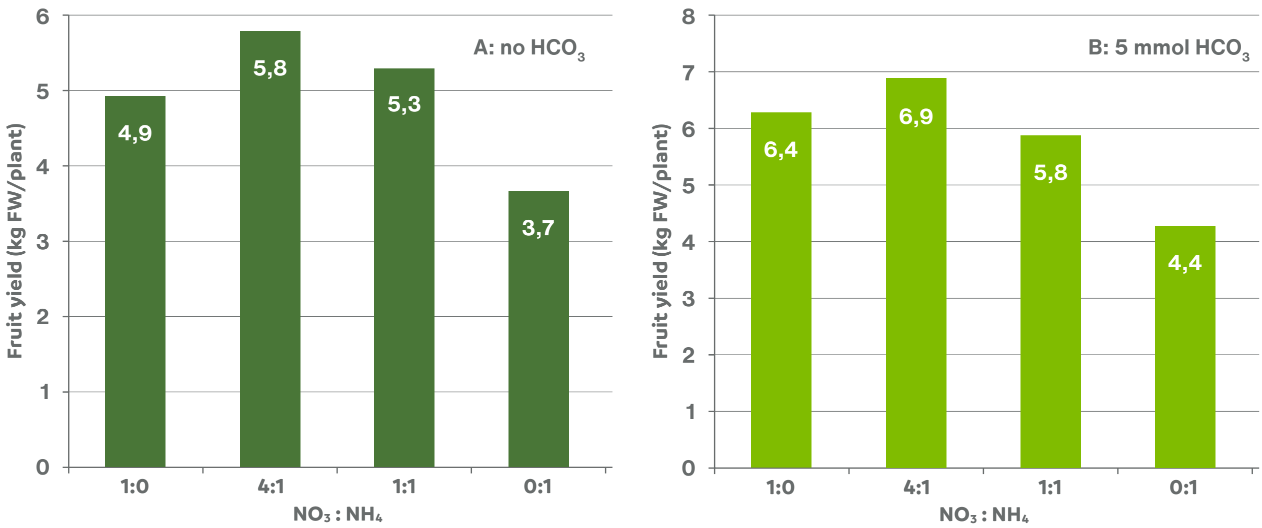

Figure 1. Fruit yield of tomato cultivated on mineral media containing 3 mmol N-source as NO_3^-, NH_4^+ or both forms in two ratios, without (A) or with (B) 5 mmol HCO_3^-. The data are the mean of five replicates of five plants each.

Bialczyk, J., Z. Lechowski, D. Dziga & E. Mej, 2007. Fruit yield of tomato cultivated on media with bicarbonate and nitrate/ammonium as the nitrogen source. Journal of Plant Nutrition 30:149-161.

Tolerance of tomato to root-knot nematodes (Meloidogyne javanica) increased in plants receiving nitrate nutrition compared to those receiving ammonium nutrition.

Fertigation *Pest & disease reduction*

Plant nutrition can affect nematode development indirectly by improving growth. The effect of various ratios of NH_4^+/NO_3^- in the nutrient solution on parasitism by the root-knot nematode Meloidogyne javanica was studied in a greenhouse in Israel. Tomato plants were grown in a hydroponic system with sand, either in plastic 0,75 L pots or in 50 L containers, fertigated with Hoagland solution in which the nitrogen was introduced as one of the three ratios of NH_4^+/NO_3^- : 100/0, 50/50 or 0/100. Seedlings were inoculated with M. javanica 14 days after transplant and one and two months after inoculation plant samples were taken for assessment of plant biomass, leaf and root content of N, P and K and the nematode infection degree.

In the 0,75 L pots the total biomass (root+shoot) two months after inoculation was lower in the plants given 100% NH_4^+. Inoculated plants were smaller compared to nematode-free plants, and the difference in plant weight was 20% larger in the ammonium (100/0)-fertilised plants compared to the nitrate (0/100)-fertilised plants. Although the population in number of nematodes/mm root was initially lower for the 100% NH_4^+ -fertilised plants, there was no difference between the treatments after two months.

In the 50 L containers inoculated with M. javanica, NH_4^+ - treated plants were less developed with more – nematode related - necrotic symptoms compared to NO_3^-- treated plants. Infected root systems were poorly developed and discoloured, especially those of NH_4^+ - treated plants. Fresh weight biomass was severely affected by nematodes in the first month, with the most decrease in weight due to nematode inoculation in the NH_4^+ - treated plants (Figure 1).

After two months this effect of N-source on the relative decrease in biomass between healthy and nematode infested plants was no longer apparent, but the absolute weight was higher for plants fertigated with 50-100% NO_3^- in the nutrient solution compared to 100% NH_4^+ -fed plants.

During the second month conspicuous differences in N, P and K content were seen between nematode-free and inoculated plants, particularly marked in the nitrate treatment: nematode-free plants had higher concentration of these elements in the top of the plants, inoculated plants showed higher concentrations in the roots. Tissue parasitized by root-knot nematodes may function as a metabolic sink, and this may explain accumulation of potassium within the galls induced by nematodes, since potassium accompanies carbohydrate anions from shoots to roots.

The results indicate that there is no difference in plant resistance to nematode attack between NH_4^+ and NO_3^- N-nutrient forms. However, a remarkable increase in tolerance to root-knot nematode damage in plants receiving nitrate nutrition was evident. This can be explained by the interrelationship between N-source in the nutrition and carbohydrate metabolism. Carbohydrates are required to prevent toxic accumulation in the roots of free ammonium for plants fed with NH_4^+ and this mechanism can only function satisfactorily when carbohydrate supply is adequate: metabolic energy that would otherwise be used for protein or cell wall synthesis is utilized in an unproductive manner when the only supply of N is NH_4^+. This can explain why plants fertilised with NO_3^- could develop better, despite nematode infection.

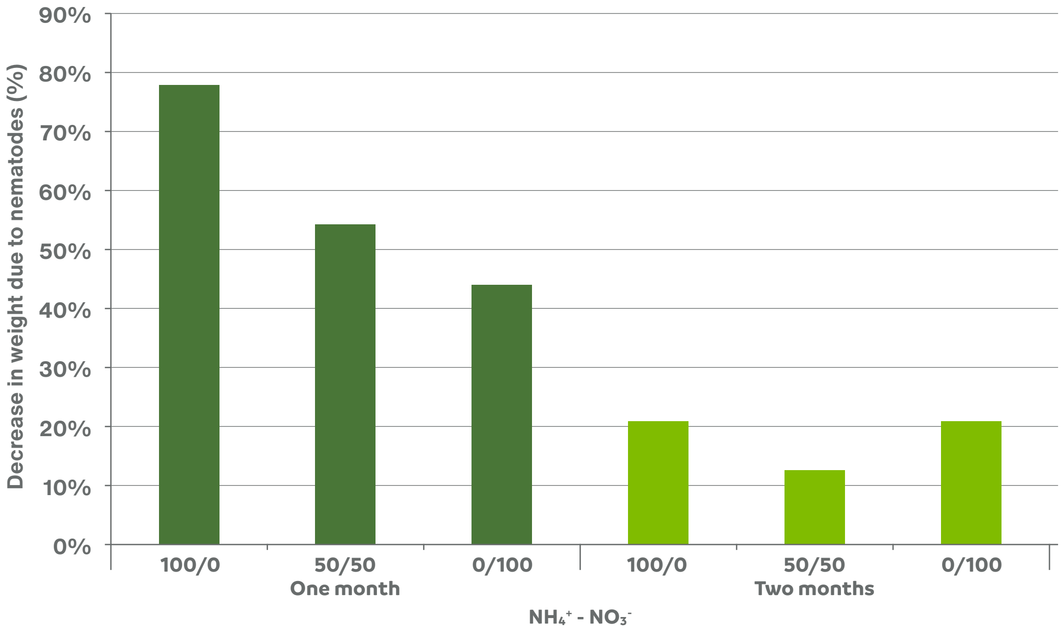

Figure 1. Relative* decrease in plant weight between M. javanica-infected and non-infected tomato plants, receiving ammonium and nitrate fertilisation in different ratios, one and two months after inoculation (50-liter containers, sand culture). * Based on shoot+root fresh weight: (weight non-infected – weight infected) / weight non-infected.

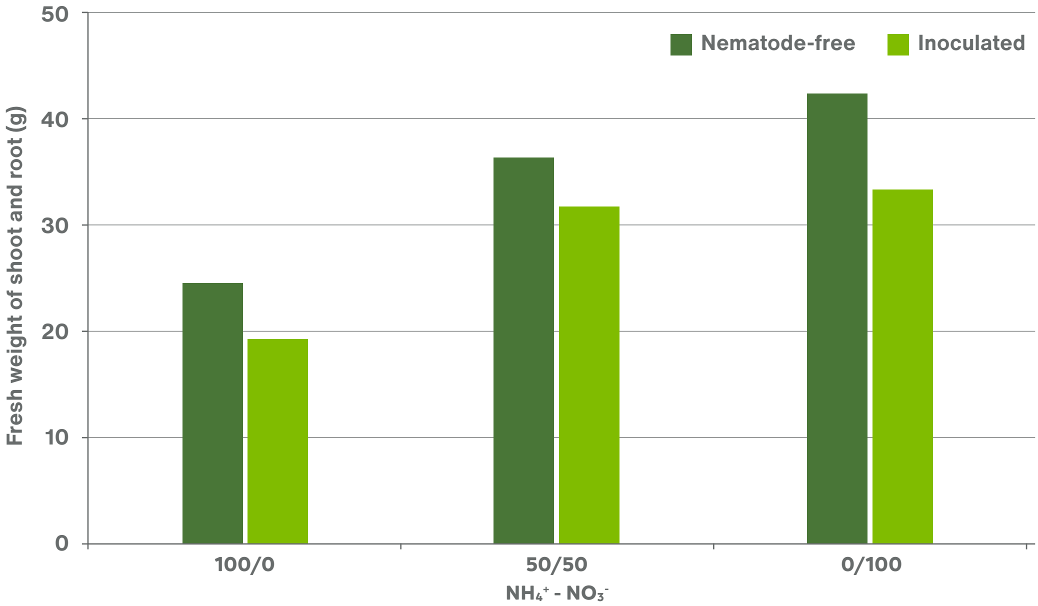

Figure 2. Plant fresh weight (shoot+root) of M. javanica infected and non-infected tomato plants measured two month after nematode inoculation. Plants were grown in 50 L containers receiving ammonium and nitrate fertilisation in different ratios.

Spiegel, Y., E. Cohn and U. Kafkafi 1982. The influence of ammonium and nitrate nutrition of tomato plants on parasitism by the root-knot nematode. Phytoparasitica 10: 33-40.

Tomato plant protection to root-knot nematode (Meloidogyne incognita) with potassium nitrate.

Foliar *Pest & disease reduction*

Gradients of salts of the specific ion repellents for Meloidogyne incognita - NH_4^+, K^+, Cl^- and NO_3^- - have been demonstrated to shield tomato roots from infestation in soil. The strategy of these greenhouse experiments was to interpose a salt barrier in a soil column between the plant roots and the nematodes. Potassium nitrate was found to produce a negative chemotaxis for 2nd-stage juveniles of Meloidogyne incognita (J2) as it creates a chemical "shield" around the root system to protect. Tomato seedlings treated with 30 mg/L ($3x\ 10^{-4}$ M) KNO_3 showed increased plant length and increased root growth without root knot formation after 21 days of incubation with M. incognita J2. Untreated plants were shorter and showed root knot formation. Potassium nitrate outperformed potassium chloride in protection against the root-knot nematode (Table 1).

Table 1. Percentage protection to the number of eggs produced by the root-knot nematode.

	KNO_3	KCl
% protection* ± S.D.	79,1 ± 6,7	12,3 ± 9,8

* By comparing number of eggs produced in treated vs. untreated plants

Castro, C. E., H. E. McKinney, and S. Lux. 1991. Plant protection with inorganic ions. Journal of Nematology 23.4: 409-413.

Seed priming with potassium nitrate reduced the emergence time of processing tomatoes.

Seed priming

Seeds of processing tomato (variety UC 82 B) were primed in a solution of K_2HPO_4 and KNO_3 (-1,25 MPa) for 12 days at 15°C and air-dried afterwards. Seeds were sown in a farmer's field in Darlington Point, Australia, to evaluate under practical conditions the effect of seed priming on the emergence, growth, development and harvestable yield of processing tomatoes. An early season and a mid-season sowing were made in each of two growing seasons.

Processing tomato seed priming reduced growing degree days of air temperature above 10°C, required for 80% emergence, by about 35% from each sowing (Table 1). Primed seedlings emerged 4 to 5 days earlier than unprimed in the early sowings and 1 to 2 days in the later sowings. Seed priming did not result in larger plants; unprimed plants reached the same size at a later date. The earliness of the primed crops was maintained throughout the ontogeny, with no change in the final yield.

Table 1. Growing degree days of primed and unprimed seeds in two growing seasons.

Treatments	Sowing date			
	1983		1985	
	Oct. 12	Oct. 21	Oct. 3	Oct. 15
	Growing Degree Days to 80% emergence			
Primed	37	45	45	35
Unprimed	57	67	70	55
% Reduction due to priming	35	33	36	36

Barlow, E. W. R. and A.M. Haigh. 1986. Effect of seed priming on the emergence, growth and yield of UC 82B tomatoes in the field. Acta Horticulturae 200: 153-164.

Nitrate based nutrition increased yield and reduced blossom end rot incidence in fertigated tomato in comparison to ammonium based nutrition.

Fertigation *N-sources*

Few plant species perform well when NH_4^+ is the sole source of nitrogen, and many plants develop symptoms of toxicity when subjected to high concentrations of NH_4^+. The damage can be observed as leaf chlorosis, reduced net photosynthesis, lower plant yield, lower cation content and changes in metabolite levels such as amino acids or organic acids.

To investigate if grafting can alleviate the negative effects of ammonium nutrition in a sensitive crop such as tomato, three experiments were carried out in 2008-9, in randomized complete blocks in a greenhouse in Germany. Tomato plants of the cv. Moneymaker were either self-grafted or grafted onto the popular rootstock "Maxifort". For the first two experiments (in 4 repetitions), plants were transferred to 2L glasses filled with aerated nutrient solution. Vegetative growth parameters and nutrient content of leaves were assessed. In the first experiment the response of plants to 5 pH levels was investigated in a nutrient solution with a high NO_3^- : NH_4^+ ratio. The second experiment compared the effect of grafting under four different ratios of NO_3^- : NH_4^+ in the nutrient solution, at a constant pH of 5,7±0,1 and total N of 23 mM. The effects of exposure to these ratios of the two nitrogen sources in practice, on nutrient content of the plant and yield, was investigated in the third experiment, on plants grown in gullies supplied continuously with nutrient solution, at a plant density of 1,6 plants/m^2, in two repetitions of 6 plants per plot (Table 1).

The pH of the nutrient solution did not have an effect on plant growth nor on N, P or K content in leaves. It did affect the content of other nutrients in the leaves 20 day after transplant: Ca, Mg and Cu concentrations increased, and Fe, Mn and Zn concentrations decreased as pH of the nutrient solution increased from 3,5 to 7,5. This is in line with models predicting the effect of pH on nutrient uptake of plants. Grafted plants had higher Ca, Fe, Zn and Cu concentrations compared to self-grafted plants, but there were no significant interactions between grafting and response to pH.

In the second and third experiment, leaf biomass and fruit yield decreased in response to an increase of NH_4^+ in the nutrient solution, and macro and micro-element concentrations were also affected by NO_3^- : NH_4^+ ratio. The grafting combination did not influence these parameters, nor was an interaction found between N-form and grafting.

Uptake of the major cations Ca^{2+} and Mg^{2+} was reduced with increasing external NH_4^+ concentrations (Table 1). This is explained by the mechanism of charge balance in ion uptake, when the uptake of ammonium cations prevents uptake of other cations to maintain electro-neutrality in the plant. The reduction in plant growth and yield in this experiment is explained by these low calcium and magnesium concentration in the leaves. Calcium deficiency during NH_4^+ nutrition can induce loss of membrane integrity, lowering magnesium concentration and negatively affecting the function of mitochondria and chloroplasts. This explanation is supported by gas exchange measurements during this experiment, which showed a significant decrease in photosynthetic activity for the 70% and 100% NH_4^+ treatments. The decrease in marketable yield with increasing NH_4^+ in the nutrient solution resulted mainly from the increase of fruit physiological disorders (BER), reducing the number of marketable fruits per plant. BER incidence in this experiment was increased with increasing ammonium concentration in the nutrient solution, and negatively correlated with calcium content in the tomato fruits and leaves (Table 1). The grafting of the cultivar 'Moneymaker' on the rootstock 'Maxifort' did not alleviate the negative effects of ammonium nutrition in a sensitive crop such as tomato.

Table 1. Effect of NO_3^- : NH_4^+ ratio in nutrient solution on yield, blossom end rot (BER) and nutrient content in the leaves of fertigated tomato. N-form had a significant effect on all parameters, but no statistically significant variation was found between the graft combinations (two way ANOVA with significant linear effect at $p \leq 0,05$ (*) or 0,01(**). NS=not significant).

$NO_3:NH_4$ (%)	Marketable yield (kg/plant)	BER (% of total yield)	Ca (g/kg)	Mg (g/kg)
100:0	1,2	5,0	27,7	4,0
70:30	1,2	7,5	16,9	3,1
30:70	0,7	11,6	17,5	2,7
0:100	0,6	18,8	11,8	2,5
Significance	*	**	*	**
Graft combination				
Self-grafted	0,9	12,9	18,0	3,2
Grafted	1,0	8,6	18,9	2,9
Significance	NS	NS	NS	NS

Borgognone, D., G. Colla, Y. Rouphael, M. Cardarelli, E. Rea and D. Schwarz, 2013. Effect of Nitrogen Form and Nutrient Solution pH on Growth and Mineral Composition of Self-Grafted and Grafted Tomatoes. Scientia Horticulturae, 149: 61-69.

Calcium and magnesium content in tomato leaves increases with higher nitrate:ammonium ratio or addition of bicarbonate in the nutrient solution.

Fertigation *N-sources*

Nitrogen is the only plant nutrient that can be absorbed by the plant in three forms: as anion (NO_3^-), as cation (NH_4^+), or as amino acids, in molecular form ($CO(NH_2)_2$). When plants are provided with both nitrate and ammonium simultaneously, the activity of the enzyme phosphoenolpyruvate carboxylase (PEPC) in the roots is increased. It is suspected that this enzyme plays a role in the process of assimilation of the ammonium cation in the roots by aiding the production of carboxylate skeletons that are used to store metabolic intermediates during the synthesis of amino acids.

Most of the carbon needed for these skeletons is derived from assimilation in the leaves of atmospheric CO_2, but the roots can take up inorganic carbon from the carbon supply in the soil as well. In hydroponics, bicarbonate ions could be a carbon source for the production of organic acids. The objective of this study was to study the combined effect of three nitrate:ammonium ratios and three bicarbonate dosages, to see if addition of bicarbonate to high dose of ammonium would prevent damage that can be observed in tomato plants when fertigated with an excess of ammonium.

Seeds of tomato cultivar “Slolly F-1” were sown in 1:1 peat:vermiculite and transplanted on day 46 after sowing to a hydroponic system in volcanic rock (tezlonte). In a Mexican greenhouse, the plants received the various nutrient solutions during propagation and cultivation (Table 1), and were cultured to production. Seedling growth and harvest parameters were assessed. Nutrient content of leaves, fruits and stems was measured. The osmotic value of the nutrient solution was adjusted to be the same for all HCO_3^- doses (0,72 atm.). Total N concentration was kept at 11-12 $mol_c\ m^{-3}$ and pH for the hydroponic solution was adjusted to 5,5.

No consistent interactions were found between bicarbonate and the nitrate/ammonium ratio. In the seedlings, a lower root volume and magnesium content in the leaves was found in the treatment with 70/30 nitrate/ammonium, and a lower content of calcium was found in all treatments where ammonium was added compared to 100% nitrate (Table 1). At 5 $mol_c\ m^{-3}$ of bicarbonate in the medium, the root volume of seedlings decreased and calcium content of the leaves was lower when no bicarbonate was added.

The lowered uptake of Ca^{2+} to the leaves found in the seedlings fed with 70/30 nitrate/ammonium, was also found in the leaves of the mature plants under this treatment (Table 1). This can be explained by the plant's effort to maintain electrostatic balance and taking up the positively charged NH_4^+ at the expense of the doubly positively charged Ca^{2+}. A deficit of calcium in tomato plants can lead to loss of fruits due to blossom end rot, even though this physiological disorder was not manifested in this trial. Similarly, the negative charge of the nitrate (NO_3^-) or the bicarbonate (HCO_3^-) molecule can result in a synergistic uptake of the positive Ca^{2+} ion, as is seen in the increased calcium content in both seedling and adult leaves grown on 100% nitrate or on the highest dose of bicarbonate. Addition of the positively charged ammonium ion increases uptake of anions, such as phosphate, manifested in an increase of P content in the stems of seedlings and fruiting plants in the treatment with 70/30 nitrate/ammonium.

Yield was lower at the lowest nitrate/ammonium ratio, though the difference was not statistically significant (Table 1). Therefore, no conclusions on a possible mitigating effect of HCO_3^- on damage due to a low nitrate/ammonium ratio in the nutrient solution could be drawn. Due to the characteristics of the medium used for the hydroponic culture, i.e. tezlonte, the authors suggest that the ammonium in the nutrition was nitrified quickly, avoiding the negative effects on yield after lowering nitrate/ammonium ratios which have previously been found in literature. The authors conclude that for tomato grown on tezlonte, it is safe to replace a part of the nitrogen in the fertigation by ammonium up to a maximum of 30%.

Table 1. Response of various parameters to varied nitrate/ammonium ratio or addition of bicarbonate to the nutrient solution of fertigated tomato. Means followed by the same letter are not significantly different (Tukey p≤ 0,05).

Nitrate/ Ammonium ratio	Seedling root volume	Ca in seedling leaves	Mg in seedling leaves	Ca in leaves at harvest	P in stem at harvest	Yield kg fruit/plant
(%)	(ml)	(%)	(%)	(%)	(%)	
100/0	0,26 a	1,7 a	0,8 ab	3,9 a	0,10 b	4,4 a
85/15	0,24 ab	1,4 b	0,9 a	2,4 b	0,18 a	4,5 a
70/30	0,23 b	1,0 c	0,7 b	2,5 b	0,23 a	4,2 a
HCO_3^- (molc m^{-3})						
0	0,26 a	1,0 c	0,9 a	2,1 b	0,27 a	4,4 a
2,4	0,26 a	1,4 b	0,7 a	2,7 a	0,14 b	4,3 a
4,7	0,21 b	1,6 a	0,8 a	3,9 a	0,08 c	4,4 a

Parra Terraza, S., P. Lara Murrieta, M. Villarreal Romero and S. Hernández Verdugo, 2012. Plant growth and tomato yield at several nitrate/ammonium ratios and bicarbonate concentrations (Crecimiento de plantas y rendimiento de tomate en diversas relaciones nitrato/amonio y concentraciones de bicarbonato.). Rev. Fitotec. Mex. 35(2):143-153.

Potassium nitrate is a safe source of nitrate nitrogen in intensive growing conditions at high temperatures and increases uptake of calcium and magnesium compared to ammonium.

Fertigation *N-sources*

The effect of ammonium on plant growth and plant nutrient content was reviewed using trial results on a variety of crops grown in fertigated soil-less cultures.

In soil-grown crops, rate of nitrification in the soil is very quick under normal conditions, and ammonium fertilizer is nitrified within a week. As a result nitrate is the main N-source for field crops. Conditions such as low temperatures, acid soils and extensive leaching prevent nitrification or favor accumulation of NH_4^+ ions in the soil. This leads to acidification of the root environment and decrease in uptake of divalent cations such as Ca^{2+} and Mg^{2+}.

Effect of N-source on transport of N

Introduction of soilless culture systems with substrates of very low buffer capacity have emphasized the importance of theoretical knowledge on effects of ammonium-based nutrition for commercial vegetable production. Fertigation by drip-lines supplies the plant with various nitrate:ammonium ratios according to the type of fertilizer used. NH_4^+ is mainly metabolized to organic compounds in the root and the nitrogen is transported to the leaves in these compounds. In contrast, NO_3^- is transported as anion to the leaves and metabolized there. As a consequence, translocation of nitrogen in metabolites after uptake of NH_4^+ in the root is less affected by root temperature than transport of nitrogen as NO_3^-, which is limited at low temperature. This may explain better performance of fertigation containing both nitrogen sources compared to nitrate only, at lower temperatures. Trials reviewed in this paper show that crops vary in their response to nitrate:ammonium ratios, mainly due to differences in tolerance to higher concentration of nitrogen supplied with ammonium: for instance tomato thrives when ratio of ammonium is maximally 50%, while Chinese cabbage may die in the presence of 5 mM ammonium.

Ammonium induced damage due to carbohydrate consumption at high temperatures

In strawberries, fertigation with NH_4^+ as sole nitrogen source led to increasing damage in the root system at increasing root temperatures, culminating in root death at 32°C. Additionally, in these plants lower soluble sugar content in both root and crown was observed at all temperatures in a range of 10-32°C, compared to plants fertigated with NO_3^- as sole nitrogen source. This negative impact of NH_4^+ on the soluble sugar content was more evident in the roots. The actual concentration of soluble sugars in the roots is the balance between supply and consumption. Root deterioration caused by NH_4^+ seems due to a combination of increased oxygen consumption, increased carbohydrate consumption and location of the metabolism of NH_4^+ in the root. At higher temperatures, the potential for root damage is aggravated by a higher need for sugar for the NH_4^+ metabolism than can be supplied by photosynthesis. Respiration rates at higher temperatures are increased, soluble oxygen is low, and in addition, O_2 and carbohydrate demand in the plant for other metabolic processes competes with the demand created by NH_4^+ metabolism.

The authors conclude that ammonium is potentially harmful for the crop at high temperatures, though safe at lower temperatures. The key factor deciding suitability of ammonium for a crop is the balance of the rate of sugars transported to the roots minus the demand for root respiration. As long as sugar reserves and supply are available in the root, NH_4^+ can serve as source of N, but at higher consumption of sugars in the roots, NO_3 is better source.

Effect of N-source on uptake of divalent ions (Ca^{2+}, Mg^{2+})

The same conditions in the soil that prevent nitrification and favor ammonium accumulation (low temperature, acidity and extensive leaching), can cause a decrease in calcium and magnesium in plants grown under these conditions. The ammonium ion has a positive charge and thus it competes with these divalent cations when taken up by the plant. In all crops included in this review, ammonium or low pH reduced the plants calcium and magnesium content compared to nitrate fed plants. For example, in tomato, the content of Ca^{2+} and Mg^{2+} in the shoot increased with an increasing relative concentration of NO_3^-, at all temperatures.

Kafkafi, U. 1990. Root temperature, concentration and the ratio NO_3^-/NH_4^+ effect on plant development. Journal of Plant Nutrition 13(10): 1291-1306.

Soil and foliar application of potassium nitrate enhanced fruit yield and quality of tomato under salinity conditions.

Fertigation *Foliar* *Salinity relief*

A pot experiment on tomato (Solanum lycopersicum L.) was done to examine how to improve yield and quality under saline conditions. The trial was conducted in a glasshouse in Pakistan to study the effect of potassium nitrate rates and mode of application under 3 salinity treatments (0, 7,5 and 15 dS/m, induced by increasing dose of NaCl). Potassium nitrate was applied to the soil (0, 3,3 and 6,6 mmol/kg) or as foliar spray (4,5 and 9 mM). All treatment combinations were performed on four cultivars: 2 salt-tolerant (Indent-1 and Nagina) and 2 salt-sensitive (Peto-86 and Red Ball) field tomato genotypes. Tomato plants, at the 5-leaf stage, were transferred to pots containing 12 kg of field-collected sandy loam soil. Recommended doses of N (210 kg/ha) and P (125 kg/ha) fertilizer were applied, and the amount of N added in the form of KNO_3 was taken into consideration. No additional Ca, Mg, S, or B fertilizers were applied, as the basic soil contents of these nutrients in the soil were sufficient to support tomato plant growth. The experiment was laid out in a randomized complete block design with 3 replicates, using factorial arrangement.

Applications of KNO_3 in increasing rates resulted in higher yields, both in total fruit weight and in number of fruits, regardless of the mode of application, in absence of salt stress. Potassium nitrate also increased the fruit size. Generally, with increasing salinity stress (7,5 and 15 dS/m), fruit yield decreased significantly. Mainly, this was due to the size of fruits, that decreased with increasing salinity. In contrast, fruit size increased with increasing potassium nitrate concentration.

For plants exposed to salinity , KNO_3 alleviated the negative effects of salinity and resulted in a dose dependent increase in plant height and yield of both salt-tolerant and salt-sensitive groups as compared to respective control treatments. However, salt-tolerant genotypes maintained better growth and produced higher yields than the salt-sensitive genotypes across all salinity levels, and showed better response to the treatments with KNO_3. Total soluble solids, titratable acidity, pH, and dry matter content of fruits, were significantly improved both by increasing salinity and potassium nitrate application.

To conclude, the use of salt-tolerant tomato genotypes and an increased application of potassium nitrate, both in soil and foliar applications, could be used as an effective approach to economically utilize salt-affected soils for tomato production.

Amjad, M., J. Akhtar, M. Anwar-Ul-Haq, S. Imran and S.E. Jacobsen. 2014. Soil and foliar application of potassium enhances fruit yield and quality of tomato under salinity.Turkish Journal of Biology, 38: 208-218.

Nutrient solution containing 7 mM nitrate and 1 mM ammonium improved tomato yield and fruit quality and reduced blossom end rot incidence.

Fertigation N *N-sources*

The objective of this study was to determine the optimal ratio of NO_3^- to NH_4^+ in the nutrient solution, to counter saline conditions. The effect on yield and fruit quality of tomatoes under protected growing conditions with or without addition of NaCl in the nutrient solution with varied NO_3^-:NH_4^+ ratios was assessed. Tomatoes were grown in a greenhouse in Rehovot, Israel. Commercially raised 30-day-old seedlings were transplanted into 10 L pots containing 4-mesh washed perlite. The basic nutrient solution consisted of N:P:K at 8:1:6 mM. The nitrogen was applied as NH_4^+ (in ammonium sulphate) at 0, 1, 2 or 4 mM, combined with NO_3^- to reach the total N of 8 mM N in the nutrient solution. Main fertilizer used to increase nitrate level in the nutrient solution was potassium nitrate. Salinity treatment commenced 10 days after transplanting, and salt concentration was gradually increased from 0 to 45 mM NaCl over 14 days. Total EC of the nutrient solution was 2,7 dS/m for the control without NaCl, and 7,4 dS/m for the salinity treatments.

Initial experiments were performed on four tomato hybrid cultivars: two large- and two small-fruit hybrids. Significant differences in yield depression under saline conditions were observed. The effect of nitrogen source on alleviation of salinity was studied in detail on the large-fruit cultivar most sensitive to an increase of salt in the nutrient solution: cv. “R144”.

The highest fruit yields were recorded for the treatment with ratio of 7 mM NO_3^- to 1mM NH_4^+, (5980 g fruit/plant without NaCl, and 3320 g fruit/plant under saline conditions). Decreasing the nitrate concentration to 6 or 4 mM in the nutrient solution resulted in lower marketable yields in both control and salinity treatments (Table 1).

In the control group (no NaCl added) the treatment with 1:1 NO_3^-:NH_4^+ ratio in the nutrient solution reduced the yield by 26% compared to the optimal yield achieved with the 7:1 NO_3^-:NH_4^+ ratio.

Yield reductions under saline conditions were attributed to the decline in fruit weight. Water uptake by tomato plants theoretically declines with the increase in salt concentrations in the nutrient solution. This could cause a decrease in fruit weight. However, it is unlikely that the addition of 1 mM NH_4^+ to 7 mM NO_3^-, increased water transport to the fruit, since the total soluble sugar content of tomatoes was not affected by N form. The harvesting time in this experiment was delayed with one week when ammonium was applied. This extended fruit development period is probably a reason for the increased fruit size. In the control without NaCl, decreased fruit weights were observed only in the treatment with 1:1 NO_3^-:NH_4^+ ratio.

Increasing NH_4^+ concentration in the solution resulted in increased BER (Blossom End Rot) incidence in both control and salt treatments (Table 1). The highest ammonium concentration (4mM) resulted in the lowest LAI and leaf dry matter content at both NaCl levels (0 and 45 mM) as compared with 1 or 2 mM NH_4^+. The incidence of BER increased with increasing NH_4^+ levels, and addition of NaCl further worsened the incidence of BER.

The fruit quality in tems of percentage total soluble sugars, titratable acidity and fruit serum electrical conductivity increased markedly with increased salinity. The N source did not affect these parameters. The authors conclude that the use of mainly NO_3^- with the addition of up to 1 mM NH_4^+ can counteract adverse effects of salinity, as it improved fruit size with minimal loss of fruit quality.

Table 1. The effect of N-source and salinity on tomato fruit yield and fruit quality (Indeterminate hybrid cultivar “R144”). Within each column, means followed by the same letter do not significantly differ at 5% level (general least square models in JMP).

NO_3^- (mM)	NH_4^+ (mM)	NaCl (mM)	Marketable yield (g/plant)	Blossom End Rot (g/plant)	Mean fruit weight (g)
8	0	0	5480 ab	158 d	141 a
7	1	0	5980 a	236 c	143 a
6	2	0	5160 bc	247 c	140 a
4	4	0	4430 c	356 c	126 b
8	0	45	2810 d	763 b	82 d
7	1	45	3320 d	821 b	103 c
6	2	45	2700 d	954 ab	89 cd
4	4	45	1670 e	1183 a	87 d

Ben-Oliel, G., S. Kant, M. Naim, H.D. Rabinowitch, G.R. Takeoka, R.G. Buttery and U. Kafkafi. 2005. Effects of ammonium to nitrate ratio and salinity on yield and fruit quality of large and small tomato fruit hybrids. Journal of Plant Nutrition, 27(10): 1795-1812.

Foliar potassium nitrate sprays decreased blossom end rot incidence and increased yield in tomato.

Foliar   Yield & Quality

A study was carried out to investigate the effect of 2 levels of gibberellic acid (10^{-4} and 10^{-8}) and 2 levels of potassium nitrate (6 and 8 mM) as foliar sprays on the growth, leaf-NPK content, yield, fruit quality parameters and the blossom end rot incidence of tomato. Tomato plants of cultivar Tivi F1 were grown outside during the 2013-2014 growing season in Ilam, Iran. The soil of the experimental field was silty loam in texture with a pH of 7 and containing 107 mg/kg K. Foliar sprays were applied two times with a back-held sprayer at 30 days after transplanting and when the fruits were berry-sized.

Foliar potassium nitrate application alone statistically significantly decreased blossom end rot while increasing leaf-NPK content, chlorophyll content and nitrate reductase activity. The 8 mM potassium nitrate application increased the chlorophyll content of the leaves to its maximum (48 SPAD). This was a significant increase relative to the control and other treatments. The nitrate reductase activity increased from 3 in the control to 6,9 with 8 mM KNO_3. The number of branches per plant and the mean plant height increased significantly with foliar application of GA_3 and KNO_3 either alone or in combination. The combination of both foliar sprays also significantly increased the number of flowers per cluster from 19 in the control to 36 with 10^{-8} GA_3 and 8 mM KNO_3. The yield, fruit weight and fruits per plant of tomato increased significantly with foliar application of KNO_3 and GA_3 either alone or in combination (Table 1). The potassium nitrate foliar sprays significantly decreased blossom end rot (Table 1). With regard to fruit quality, the application of GA_3 at 10-8 mM, 8 mM potassium nitrate and combination of both sprays increased fruit lycopene content, total soluble solids, vitamin C and titratable acidity compared with the control treatment.

From this study, it can be concluded that spraying with gibberellic acid and potassium alone or in combination increased vegetative growth and yield and quality of tomato.

Table 1. Effect of KNO_3 and GA_3 foliar sprays on yield and quality of tomato.

Treatments	Yield (MT/ha)	Fruits per plant	Fruit weight (g)	Blossom End Rot incidence (%)
Control	**12 c**	**76 c**	**60 c**	**20 a**
10^{-4} mM GA_3	17 bc	80 b	78 bc	18 ab
10^{-8} mM GA_3	22 a	97 a	111 a	18 ab
6 mM KNO_3	**17 bc**	**83 b**	**85 bc**	**9 cd**
8 mM KNO_3	**22 a**	**97 a**	**112 a**	**3 d**
10^{-4} mM GA_3 + 6 mM KNO_3	18 b	90 ab	88 b	15 bc
10^{-4} mM GA_3 + 8 mM KNO_3	18 b	91 ab	94 ab	11 c
10^{-8} mM GA_3 + 6 mM KNO_3	23 a	95 ab	101 ab	15 bc
10^{-8} mM GA_3 + 8 mM KNO_3	24 a	100 a	130 a	10 c

Kazemi, M. 2014. Effect of gibberellic acid and potassium nitrate spray on vegetative growth and reproductive characteristics of tomato. J. Biol. Environ. Sci., 8(22): 1-9.

Potassium nitrate outperformed alternative K-sources in terms of processing tomato yield and quality.

Fertigation *K-sources*

A series of experiments was conducted in Hungary, Spain, Italy and Israel to evaluate the specific contribution of potassium nitrate to yields and quality parameters of processing tomatoes (Lycopersicon esculentum Mill.).

In Hungary, 92 kg ha^{-1} of side-dressed K_2O applied as potassium nitrate (NOP) was proven superior to potassium chloride (MOP) and to potassium sulfate (SOP) as based on total marketable yield (12,8% over control) (Figure 1), mean fruit weight (3,9% over control) and dry matter content (26,1% over control).

In Spain, side dressing with 92 kg ha^{-1} of K_2O, applied as potassium nitrate, improved plant performance by increasing mean plant yield, °Brix and mean fruit weight by 25%, 5,13%, and 5,15%, respectively. Total yield was increased from 59 to 70 t ha^{-1} (Figure 2). Consequently, the added income to the grower far exceeded his marginal costs for fertilizers.

In Italy, application of 260 kg ha^{-1} of K_2O was most effective (total yield =187 t ha^{-1}) when 70% of this dosage was applied as potassium nitrate via fertigation during the growing season. This treatment generated higher yields compared to application of the entire N-P-K or the entire P-K rates as a single pre-transplant application (156 t ha^{-1}, or 177 t ha^{-1}, respectively) (Figure 2). Additional benefits of the fertigation treatment were a higher proportion of class I fruit and an increased mean fruit weight; however, °Brix was somewhat reduced.

In Israel, the authors found a convex parabolic response of lycopene yield and concentration in tomatoes of 4 different cultivars to the K concentration in the nutrient solution. Lycopene concentration of 207 mg kg^{-1} in fruit fresh matter was obtained when K concentration in the nutrient solution was 8 meq L^{-1}. Highest lycopene concentrations were observed when fruit dry matter was 4,5% or higher. Nitrate was found to be the best form of nitrogen for maximum lycopene concentration in the fresh fruit (Figure 2).

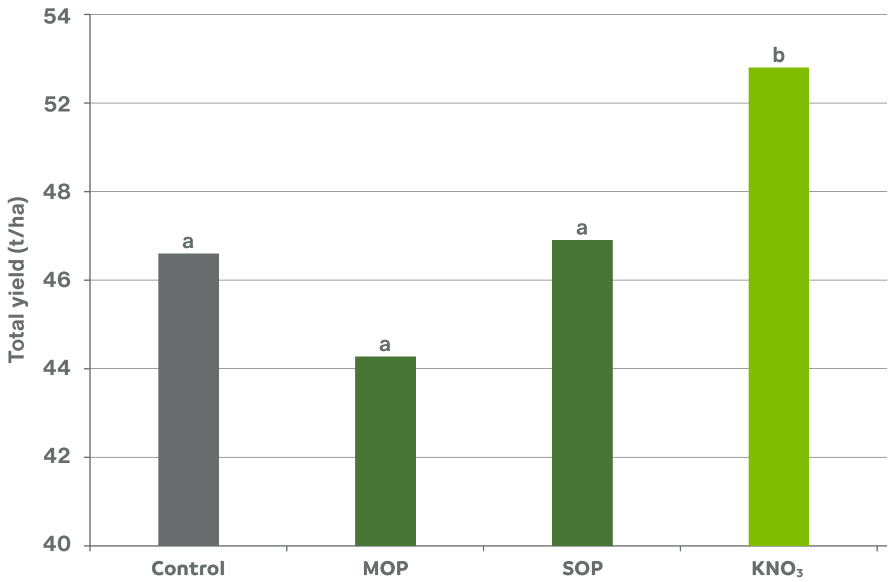

Figure 1. The effect of different K-sources on the total tomato yield in Hungary.

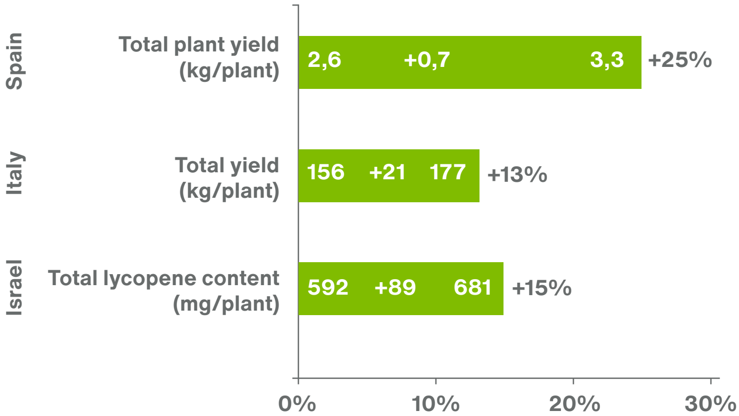

Figure 2. The yield increase (%) by using potassium nitrate in processing tomato. In Italy only base dressing is compared with 70% KNO_3 as fertigation. For Israel the benefits of only nitrate is compared to nitrate/ammonium combination.

Achilea, O. and U. Kafkafi. 2002. Enhanced performance of processing tomato by potassium nitrate-based nutrition. VIII International Symposium on the Processing Tomato 613: 81-87.

Potassium nitrate alleviated detrimental effect of salinity in tomato.

Fertigation *Salinity relief*

The objective of this study was to investigate salinity tolerance in five tomato (Lycopersicon esculentum Mill.) cultivars in response to increasing levels of potassium nitrate. Tomato seedlings were transplanted in pots filled with washed sand and grown in a greenhouse in the Sultanate of Oman and fed by half-strength Hoagland solution. The treatments were: control (EC of 1,3 mS/cm), 50 mM NaCl (EC of 5,5 mS/cm), 50 mM NaCl + 4 mM KNO_3 (EC of 6,8 mS/cm), 50 mM NaCl + 8 mM KNO_3 (EC of 7,5 mS/cm) and 50 mM NaCl + 16 mM KNO_3 (EC of 8,0 mS/cm). Fertigation was applied three times per week and treatments were arranged in a randomized block design with four replicates per treatment.

Stem height of tomato was reduced under salinity conditions (50 mM NaCl) by 11% but was increased by 6% with the application of 4 mM KNO_3 to 50 mM NaCl compared to the untreated control. Percent fruit set was not significantly affected by the salinity treatment, but when 4 or 8 mM KNO_3 was added to the nutrient solution the percent fruit set was statistically significantly increased over control plants (Figure 1). Addition of 4 and 8 mM KNO_3 also resulted in a statistically significant improvement of number of fruits, fruit quality (total soluble solids) and yield compared to the control (Figure 1). The addition of 16 mM KNO_3 to the saline solution was found to be detrimental as indicated by lower plant dry weight as compared to the control, possibly due to the high level of salinity.

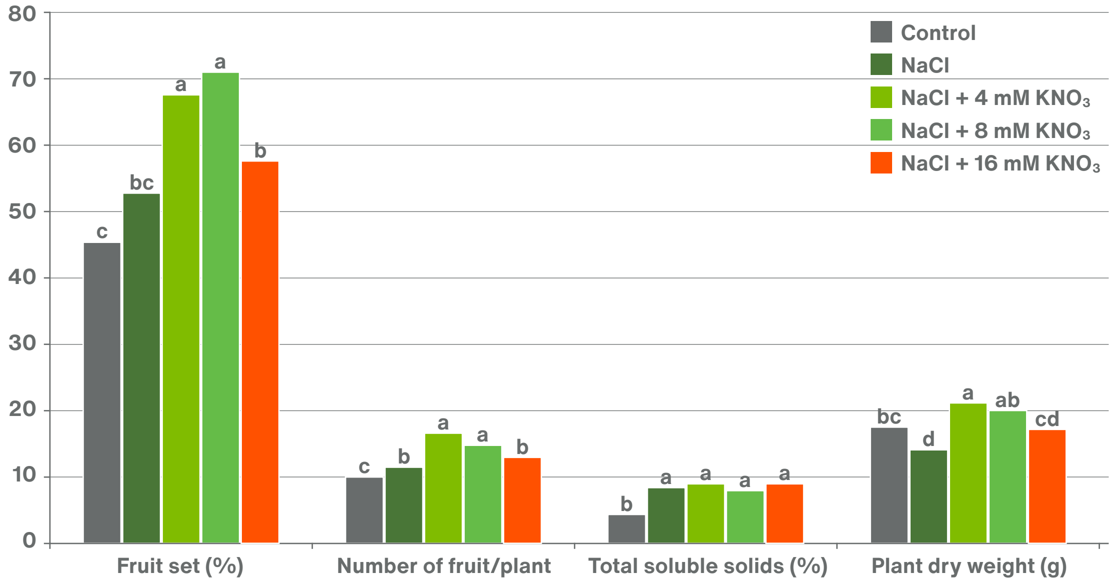

Figure 1. The effect of salinity and potassium nitrate on plant performance characteristics in greenhouse tomatoes. Means within categories having the same letter are not significantly different from each other at 5% level.

Satti, S. M. E. and M. Lopez. 1994. Effect of increasing potassium levels for alleviating sodium chloride stress on the growth and yield of tomato. Communications in Soil Science and Plant Analysis, 25 (15-16): 2807-2823.

Potassium nitrate and calcium nitrate alleviated the NaCl-effect on the reduction of tomato fruit weight.

Fertigation *Salinity relief*

The objective of this study was to investigate the effects of potassium nitrate and calcium nitrate application on tomato cultivars subjected to NaCl stress. The experiment was conducted at a greenhouse in Oman. Seedlings of tomato (Lycopersicon esculentum Mill) were transplanted at the five leaf stage to pots filled with coastal sand. Plants were irrigated with half-strength Hoagland nutrient solution supplemented with 50 mM NaCl solution, 50 mM NaCl + 20 mM $Ca(NO_3)_2$, 50 mM NaCl solution + 2 mM KNO_3, 50 mM NaCl + 20 mM $Ca(NO_3)_2$ + 2 mM KNO_3 or were not supplemented. The experimental design was a randomized complete block design with four replications. Each block had 25 plants with five cultivars and five salt treatments.

Salinity stress significantly decreased flowering in all treatments relative to the control. However the addition of KNO_3 and $Ca(NO_3)_2$ with NaCl in irrigation water significantly increased fruit set over the control and NaCl-treated plants. Fruit weight was suppressed with NaCl stress, but improvement in fruit weight and hence yield was achieved when potassium nitrate and calcium nitrate were added to the saline water (Figure 1). Plants treated with KNO_3 and $Ca(NO_3)_2$ were able to overcome and alleviate the NaCl-effect on the reduction of fruit weight.

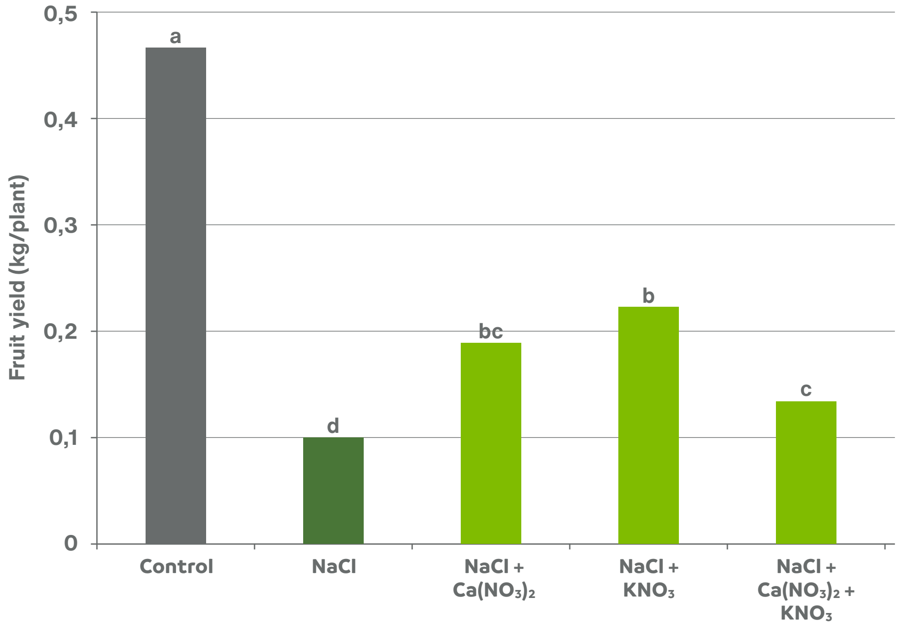

Figure 1. The effect of salinity and calcium nitrate and potassium nitrate treatments on tomato fruit yield.

Satti, S. M. E., M. Lopez, and F.A. Al-Said. 1994. Salinity induced changes in vegetative and reproductive growth in tomato. Communications in Soil Science & Plant Analysis, 25(5-6): 501-510.

Low ammonium/nitrate ratio for high yields and high fruit quality of tomato.

Fertigation *N-sources*

The effect of ammonium/nitrate ratio in pH-controlled flowing nutrient solutions on tomato (cv. Angela) yield and quality was studied. Six different proportions of NH_4-N / (NH_4+NO_3)-N in 6 meq N/l nutrient solutions: 0, 10, 20, 30, 50 and 100% were tested in a greenhouse experiment in Israel. The pH of all the treatments was kept uniform and constant around 6,8 by utilizing shallow one-way-flowing nutrient solutions, chemical composition of the solutions is described in Table 1. Each of the six treatments tested was replicated four times in randomized blocks. The highest marketable yield (4,06 kg/plant) was obtained from the 0 NH_4-N treatment (100% NO_3), and no considerable decrease in yield was observed in the 10-30% NH_4-N treatments (Figure 1). Significantly lower yields were measured in the 50% (2,99 kg/plant) and 100% (1,63 kg/plant) NH_4-N treatments, due to reduced number of fruits per plant and reduced average fruit weight. The high-ammonium-level treatment exerted a detrimental effect on the vegetative development of the plants: decreased leaf area, thinner stem, smaller inflorescences and decreased number of flowers. The chemical composition of the plants was affected by the high ammonium treatments: more N and less K, Ca and Mg were detected. The application of 10-50% ammonium-N in the nutrient solution increased the percentage of high quality fruit and decreased the percentage of soft fruit after 8 days of storage at 18°C. Low concentrations of 10-30% NH_4-N had no detrimental effect on tomato yield, but indeed greatly improved its quality after storage.

Table 1. The chemical composition of the nutrient solutions used in the experiment.

	Percentage of NH_4-N of total nitrogen (NH_4+NO_3) in the nutrient solution					
	0%	10%	20%	30%	50%	100%
	meq/l					
KNO_3	4	4	3,6	2,4	0	0
NH_4NO_3	0	0,6	1,2	1,8	3	0
$Ca(NO_3)_2*4H_2O$	2	0,8	0	0	0	0
$(NH_4)_2SO_4$	0	0	0	0	0	6
K_2SO_4	0	0	0,4	1,6	2	2
KCl	0	0	0	0	2	2
H_2PO_4- (as H_3PO_4)	1	1	1	1	1	1
EC of solution (mS/cm)	**1,5**	**1,5**	**1,5**	**1,5**	**1,6**	**1,9**

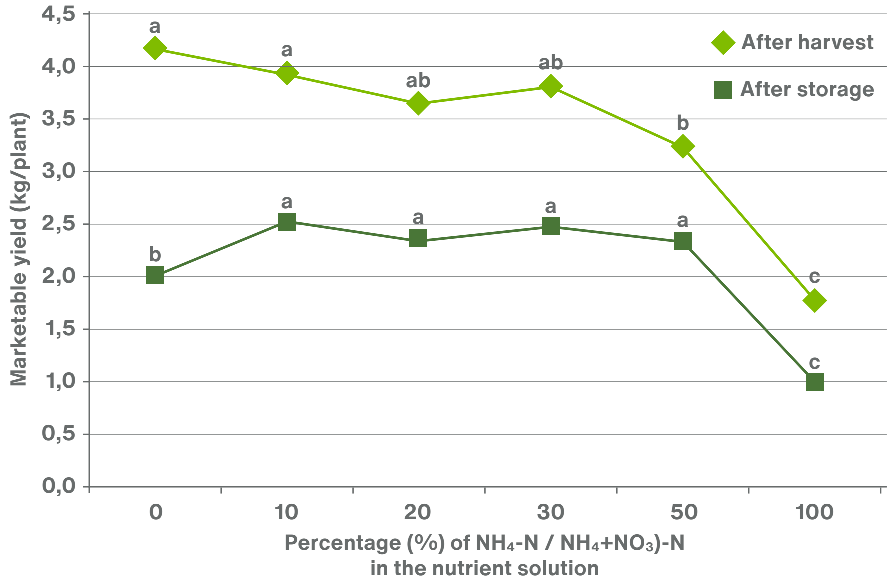

Figure 1. The effect of NH_4-N / (NH_4+NO_3)-N in the nutrient solution on the marketable yield after harvest (after 2 days of storage at 18°C) and marketable yield after storage (8 days of storage at 18°C). Different letters indicate significant differences between values.

Feigin, A., M. Zwibel, I. Rylski, N. Zamir and N. Levav. 1980. The effect of ammonium/nitrate ratio in the nutrient solution on tomato yield and quality. Symposium on Research on Recirculating Water Culture, Acta Horticulturae 98: 149-160.

High nitrate-N fertilisation decreased the incidence of blossom-end rot.

Fertigation *N-sources*

In this experiment, tomato plants (cv Sonato) were transplanted in rockwool cubes and grown in a flowing culture system supplied with nutrient solution at a flow rate of approximately 2 liters per minute. Three different proportions of ammonium-N (0, 20 and 40%, the balance being supplied as nitrate) were compared in this study. Inclusion of a proportion of ammonium-N in the nutrient solution decreased the amount of acid required to maintain the pH but increased the incidence of blossom-end rot (Table 1). The numbers of fruit affected by blossom-end rot increased somewhat by inclusion of 20% ammonium-N, and more markedly by addition of 40% ammonium-N. At the start of the season, when prices are high, the incidence of blossom-end rot is particularly undesirable. Especially the first trusses in this experiment were affected, although damaged fruits were observed during much of the season. Plants grown with high ammonium-N developed magnesium and calcium deficiencies symptoms, presumably due to antagonism between ammonium ions and these divalent cations. Both the calcium and magnesium contents of the leaves declined with increasing levels of ammonium-N (Table 2). The tolerance level for ammonium-nitrogen in a flowing culture system is thus very low, and the degree of pH control is rather limited.

Table 1. The effect of ammonium-N on the percentage of tomato fruit affected by blossom-end rot.

Percentage of tomato fruit affected by blossom-end rot			
Number of harvests	Nitrate to ammonium-N ratio		
	100-0%	80-20%	60-40%
1-4	0	24	46
1-8	1	6	19
1-23	0,4	2	7

Table 2. The effect of ammonium-N on the content of calcium and magnesium in tomato leaves.

Content in tomato leaves	Nitrate to ammonium-N ratio		
	100-0%	80-20%	60-40%
% Ca	1,82	1,48	0,87
% Mg	0,29	0,25	0,20

Massey, D., and G. W. Winsor. 1980. Some responses of tomatoes to nitrogen in recirculating solutions. Symposium on Research on Recirculating Water Culture, Acta Horticulturae 98: 127-137.

Wheat

Wheat

sqmnutrition.com

Foliar applied potassium nitrate alleviated salinity stress in winter wheat.

Foliar *Yield & Quality*

The response of a salt-resistant and a salt-sensitive wheat cultivar under salinity stress to foliar applied KNO_3 was studied in China. Both cultivars were sown in vermiculite boxes. Control seeds were germinated and raised in Hoagland nutrient solution (0 mM NaCl, 6 mM KNO_3). In the saline treatments, seeds were exposed to 100 mM NaCl. Foliar applied KNO_3 (10 mM; 1 g KNO_3/L) was applied at wheat heading stage for three consecutive days. A randomized block of four treatments and two different winter wheat cultivars with 6 replications per treatment was designed.

Although wheat grain yield of both cultivars was statistically significantly increased due to foliar application of potassium nitrate under saline conditions, the salt-resistant cultivar was more productive under salinity stress than the salt-sensitive cultivar (Figure 1).

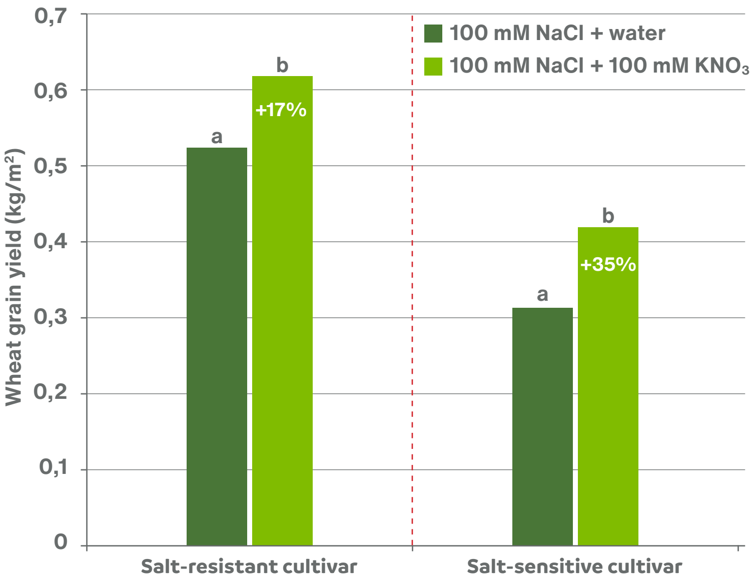

Figure 1. Effect of foliar KNO_3 on wheat grain yield under saline conditions for two winter wheat cultivars (cultivars are analyzed separately, $P<0,05$).

Foliar application at heading stage also statistically significantly elevated flag-leaf chlorophyll concentration. This enhanced the gas exchange under salinity stress, as well as the leaf-area index, spike length and the plant height. Grain quality characteristics were also improved in the salt-resistant cultivar by foliar application of potassium nitrate under saline conditions compared to the salt-sensitive cultivar. Their findings suggest that cultivating the salt-resistant wheat cultivar combined with foliar application of KNO_3 at heading stage may alleviate salinity injuries and produce higher grain yield and better grain quality under saline conditions.

Zheng, Y., X. Xu, M. Simmons, C. Zhang, F. Gao and Z. Li. 2010. Responses of physiological parameters, grain yield, and grain quality to foliar application of potassium nitrate in two contrasting winter wheat cultivars under salinity stress. Journal of Plant Nutrition and Soil Science, 173(3): 444-452.

Potassium nitrate foliar applications maximise yield of salt tolerant wheat under saline conditions, combined with silicon in nutrient solution.

Foliar *Salinity relief*

Optimal supply of mineral nutrients at the right crop stage can be effective to ameliorate the deleterious effects of salinity and help to sustain productivity under salt stress. A trial in pot-grown wheat was performed in East Azerbaijan, Iran, to investigate the interactive effects of potassium nitrate as foliar spray and silicon (as K_2SiO_3) in the nutrient solution in alleviating NaCl-induced injuries. After laboratory screening of three winter wheat cultivars, the most salt tolerant (cv. Pishgam) was chosen to be used in a greenhouse trial. Five plants per pot (25 cm ø) were grown in 1:1 perlite:vermiculite hydroponic substrate. Plants were watered daily with 1 L of Hoagland's nutrient solution (pH 5,6) and at the trifoliate stage three dosages of both NaCl (20; 60 and 100 mmol NaCl L^{-1}) and silicon (0; 2 and 4 mmol K_2SiO_3 L^{-1}) were added to the nutrient solution. Potassium nitrate foliar sprays in four concentrations (0; 0,5; 1 and 2 g/L) were applied twice, at stem elongation and booting stage. The treatments were arranged in a 4×3×3 factorial randomized complete block design with three replications.

Content of Na, K and Si in the whole plant at harvest and amount of proline and chlorophyll in the flag leaf, and relative water content and photosynthetic active radiation of the flag leaf at seed filling, were all significantly affected by the three factors salinity , potassium nitrate and silicon. It was found that NaCl stress significantly increased proline accumulation and sodium content in the plant tissues while it decreased potassium accumulation by plants. However, exogenous application of silicon and potassium nitrate reduced sodium uptake, increased potassium and consequently improved plant weight, 100-seed weight, seed yield, ear length, and photosynthesis rate.

A strong positive correlation was found between K content of the plant and all yield parameters, and a strong negative correlation between these parameters and sodium content (Table 1). The flag leaf's relative water content, photosynthetic active radiation and chlorophyll content were strongly correlated with ear length, and ear length was an important determinant of seed yield.

The main factor influencing ear length positively, was the dosage of potassium nitrate in the foliar spray, and there was no interaction of KNO_3 dosage with salinity (Figure 1). Salinity decreased ear length, and there was an interaction between the effects of silicon and salinity on this parameter. The highest seed yield was obtained when 4 mmol L^{-1} silicon and 2 g L^{-1} potassium nitrate were applied. Salt stress decreased seed yield regardless of the silicon rate in the nutrient solution, but silicon application improved seed production at each level of NaCl.

The authors conclude that utilization of the salt-tolerant wheat cultivar (Pishgam) combined with two foliar applications of potassium nitrate (2 g L^{-1}) at stem elongation and the wheat booting stage and addition of silicon (4 mmol L^{-1}) in the fertigation can be a promising approach to obtain higher grain yield on saline lands.

Bybordi, A. 2014. Interactive Effects of Silicon and Potassium Nitrate in Improving Salt Tolerance of Wheat.Journal of Integrative Agriculture 13(9): 1889-1899.

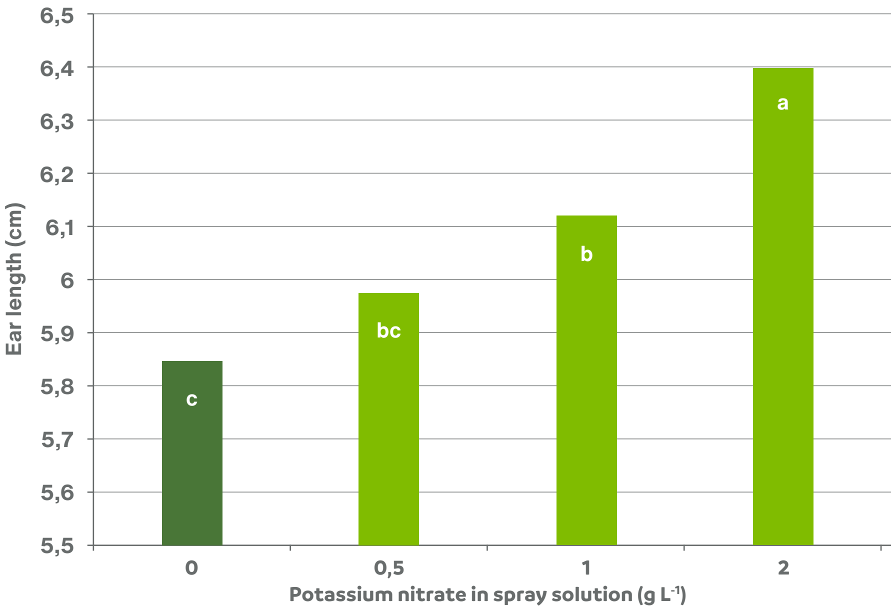

Figure 1. Main effect of potassium nitrate foliar application on ear length, averaged over all salt conditions and silicon rates. Columns labelled with the same letter are not significantly different (Duncan's, 5%)

Table 1. Correlation coefficients between different traits of wheat affected by salinity , silicon and potassium nitrate (ns=no statistically significant correlation)

	Na	K	Si	Plant weight	Seed yield	100-seed	Ear length	Rel. water cont.	Chlorophyll	Photosynthesis
Na	1									
K	-0,43	1								
Si	-0,43	ns	1							
Plant weight	-0,53	0,53	-0,19	1						
Seed yield	-0,83	0,65	0,26	0,74	1					
100-seed weight	-0,43	0,47	ns	0,70	0,68	1				
Ear length	-0,75	0,66	ns	0,83	0,96	0,77	1			
Rel. water content	-0,79	0,68	ns	0,79	0,94	0,66	0,93	1		
Chlorophyll	-0,86	0,60	ns	0,76	0,91	0,70	0,90	0,92	1	
Photosynthesis	-0,82	0,62	0,21	0,60	0,86	0,46	0,81	0,85	0,82	1

Miscellaneous

Miscellaneous

Potassium nitrate outperformed potassium chloride and potassium sulphate as the K source in making up fertigation solutions for crops growing in desert soils under highly saline conditions.

Fertigation *K-sources* *Salinity relief*

In this study, differences in growth vigour of Valencia orange trees, or Williams banana or Rodade tomato plants, either potted in river sand or river sand/$CaCO_3$, was assessed in relation to fertigation solutions composition, the solutions having been made up with either KNO_3, KCl or K_2SO_4. The experiment was conducted in South Africa in a nursery enclosed with 40% shade-cloth. 120 Valencia orange trees, and 120 Williams banana and 120 Rodade tomato plants, were transplanted into 2.7 l pots containing river sand or river sand/calcium carbonate (80:20 v/v), and treated with one of four nutrient solutions. One solution contained only $Ca(NO_3)_2$ and NaCl, and was applied to all the plants. The remaining three solutions were made up using the same fertilizers except for that supplying K. The K source was KCl, K_2SO_4 or KNO_3. As a consequence the NO_3^- to NH_4^+ ratio differed between solutions as well as the Cl^- or SO_4^{-2} content. NaCl was added to every solution to impose salinity stress. Elemental content except for that of S and Cl was equal in the K-containing nutrient solutions. Identical experiments were performed on each plant type.

In banana, orange and tomato growth was most vigorous in the plants treated with the solution made up with KNO_3 and least vigorous in the plants treated with the solution made up with KCl (Figures 1, 2 and 3). This was reflected by height increases, and fresh weight and number-of-leaf differences when the plants were lifted. Number of primary roots in banana was commensurate with vigour. Enhanced vigour in the plants treated with the solution made up with KNO_3 may have additionally resulted from promoted cationic nutrient uptake. The NO_3^-/NH_4^+ ratio was greatest in the KNO_3 solution. Number of leaves showing marginal necrosis in banana or number of wilted leaves in tomato indicated greatest salinity stress following fertigation with the solution made up with K_2SO_4. In tomato, number of flower trusses, fruit number and yield were greatest where the KNO_3 solution was applied and least where KCl solution was applied. Differences in individual fruit weight were not observed.

The results clearly indicate a benefit in using KNO_3 as opposed to KCl or K_2SO_4 in fertigating crops growing in desert soils where the irrigation waters are generally saline.

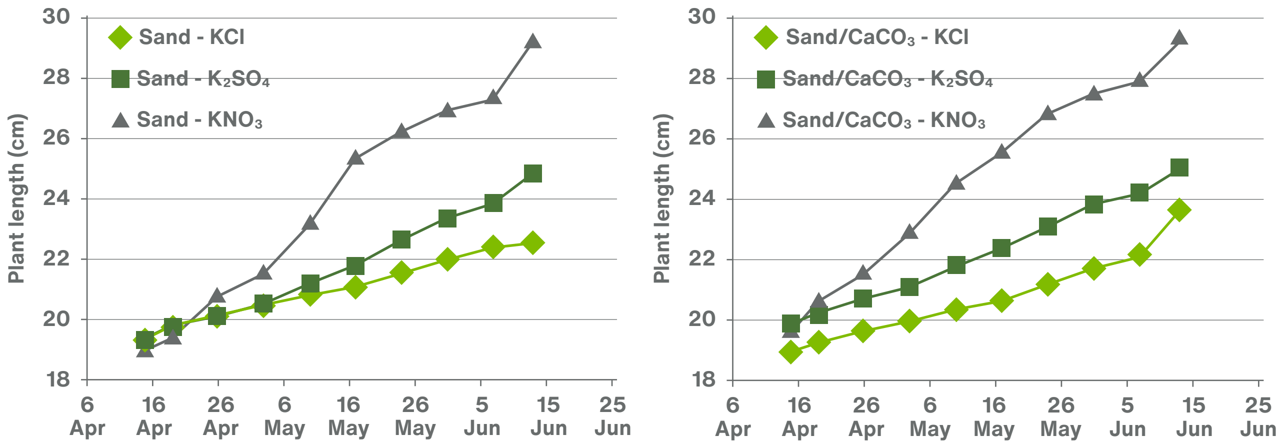

Figure 1. Banana plant lengths on each date of measurement.

Left: Sand medium; Right: sand/$CaCO_3$ medium.

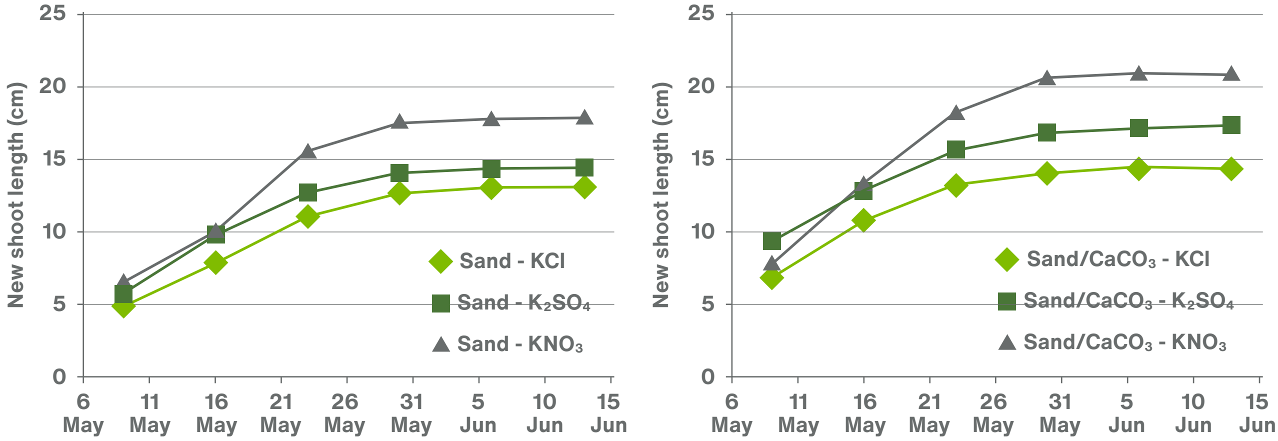

Figure 2. Orange new shoot lengths on each date of measurement.

Left: Sand medium; Right: sand/$CaCO_3$ medium.

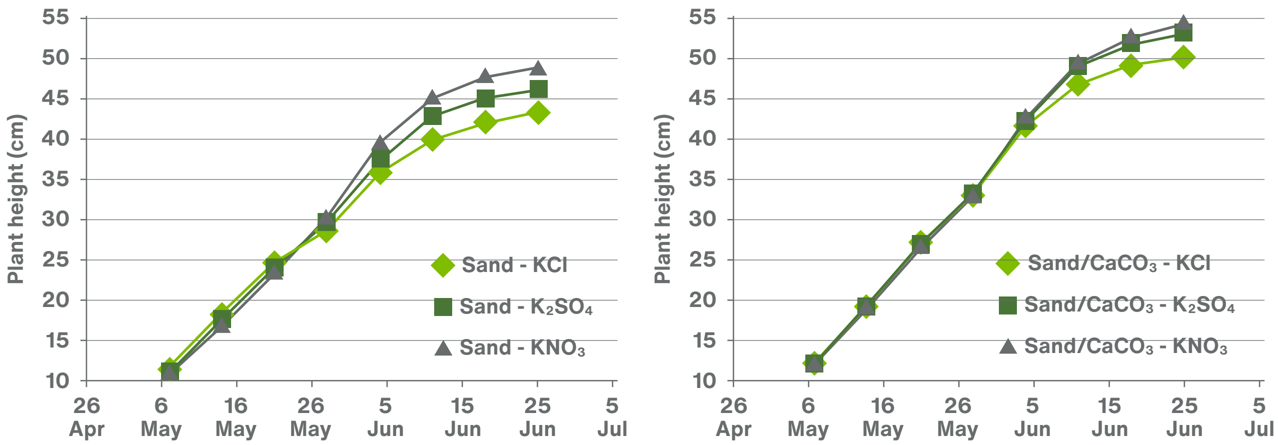

Figure 3. Tomato height on each date of measurement.
Left: Sand medium; Right: sand/$CaCO_3$ medium.

Oosthuyse, S.A. and H.T. Holwerda. 2014. Nutrient salt balance differences on the growth of potted banana, orange or tomato plants growing in sand or sand/$CaCO_3$ and fertigated with highly saline solutions. International Society for Horticultural Science (IHC Brisbane 2014): 1-10.

Potassium nitrate alleviated salinity stress in cash crops.

Fertigation *Salinity relief*

This paper is a compilation of several representative studies (Imas et al., 1995; Feigin et al., 1991; Satti et al., 1994; Bar et al., 1997 and Levy et al., 2000) featuring substantial data establishing the concept that constant application of 2-10 mM potassium nitrate in the fertigation solution considerably aids in alleviating salinity problems. This concept is validated for five moderately salinity-sensitive crops representing the three main sectors of agriculture: sweet corn for annual field crops, citrus for perennials, and tomato, lettuce and Chinese cabbage for greenhouse-grown vegetables. Most of those studies can be found in this book of abstracts as well. The most important advantage of KNO_3 versus many other fertilizers is that its contribution to salinity buildup is negligible. Both K and nitrate, which are the building blocks of this fertilizer, are macronutrients, and therefore, they are taken up in large rates while non-nutrient residues are not left in the soil. Potassium nitrate can counteract the deleterious effects of the chloride and the sodium in plant metabolism.

Achilea, O. 2002. Alleviation of salinity-induced stress in cash crops by Multi-K (potassium nitrate), five cases typifying the underlying pattern. In: International Symposium on Techniques to Control Salination for Horticultural Productivity, Acta Hort. 573: 43-48.

Highest yields obtained with 5 mM potassium nitrate under saline and non-saline growing conditions in Chinese cabbage and lettuce.

Fertigation *Salinity relief*

The purpose of this study was to test the response of Chinese cabbage (Brassica campestris L. Pekinensis group cv. Kazumi) and lettuce (Lactuca sativa L. cv 'Salinas') to the combination of salinity and KNO_3 levels. The experiments were conducted in an unheated greenhouse using an aero hydroponic system. A standard nutrient solution was used as a control (EC = 1,8 dS/m) or salinized by a combination of 34 mM NaCl and 9 mM $CaCl_2$ (EC = 6 dS/m). Three levels of potassium nitrate (1, 5 or 10 mM) were added and plant performances of Chinese cabbage and lettuce were checked at 51 – 63 days after transplanting.

In Chinese cabbage, salinization of the nutrition solution resulted in the development of severe toxicity symptoms. The fresh weight of the Chinese cabbage was significantly increased by the addition of KNO_3 to the nutrient solution under both saline and non-saline conditions. The highest yield of both total fresh and dry weight was found for the 5 mM KNO_3 treatment (Figure 1). A further increase of the KNO_3 concentration did not result in increased salt tolerance.

In lettuce, grown under saline conditions the fresh weight increased only for the 5 mM potassium nitrate treatment (Figure 2). A response curve to salt stress within an EC range of 1,25 – 11,25 dS/m showed that the threshold value (the salinity level beyond which yield reduction takes place) was between 4,70 and 5,35 dS/m in the 5 and 10 mM treatments. In lettuce, grown under non saline conditions, the fresh weight increased with increased potassium nitrate levels.

Leaf analysis of the plants revealed a clear pattern of increase in K and N (Kjeldhal) and decrease in Na and Cl contents as a direct response of the KNO_3 treatments. The highest yields of fresh weight of both crops were obtained from the 5 mM KNO_3 treatment, under both saline and non-saline conditions.

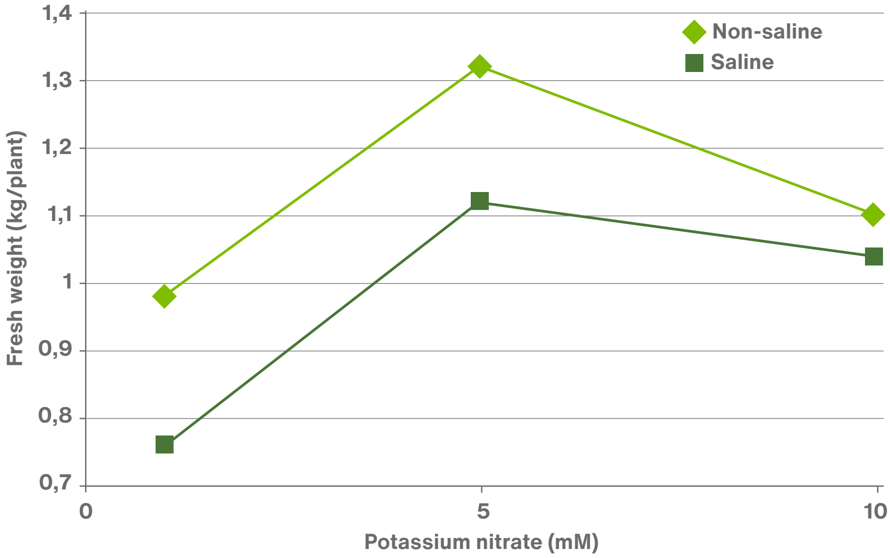

Figure 1. The effect of saline conditions and potassium nitrate on the fresh weight of Chinese cabbage tops at harvest.

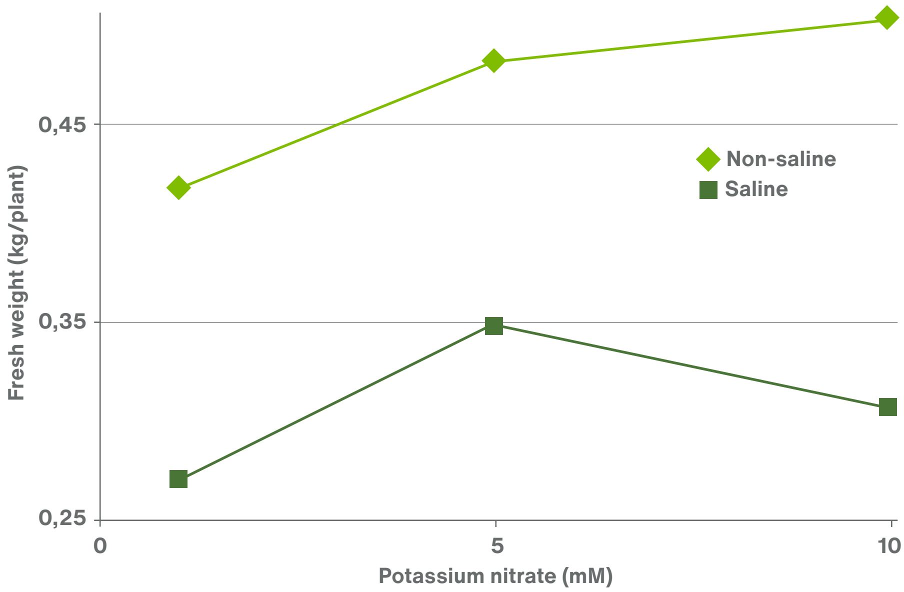

Figure 2. The effect of saline conditions and potassium nitrate on the fresh weight of lettuce heads. Samples taken 63 days after transplanting during harvesting.

Feigin, A., E. Pressman, P. Imas and O. Miltan. 1991. Combined effects of KNO_3 and salinity on yield and chemical composition of lettuce and Chinese cabbage. Irrig. Sci. 12: 223 - 230.

Potassium nitrate feeding increased yields in citrus and tomato.

Fertigation *Foliar* *K-sources* *Yield & Quality*

Fertigation and foliar applications with potassium nitrate have proven to be highly efficient in fulfilling the potassium requirements for many crops. The combination of potassium and nitrate in this fertilizer has been found to be beneficial in improving fruit size, dry matter, colour, taste and integrity and resistance to biotic and abiotic stresses, for citrus and tomato fruit. Moreover, the integration of potassium nitrate in routine management or in specific growth stages results in remarkably positive benefit to cost ratio.

Foliar sprays with potassium nitrate significantly increased acid and sugar contents of citrus fruits. Moreover, fruit size was significantly increased as well (Table 1). Small size fruit is a problem for growers because it reduces grower's return for oranges, grapefruits and tangerines. Citrus fruit size can be significantly increased by spraying the trees with potassium nitrate at concentrations of 3-6% (Table 2). Spraying potassium nitrate also decreased the crop loss reduction by decreasing fruit splitting in Nova tangerine and fruit creasing in Valencia orange (Figure 1).

Table 1. Effect of KNO_3 sprays on Mineola's tangelo acid and sugar contents, and fruit size (Fuente and Ramirez, 1993).

Treatments	Acid (%)	Sugars (Brix°)	Mean fruit diameter (cm)
Control	0,55 a	8,0 a	8,2 a
4x foliar spray KNO_3 (6%)	0,80 b	11,2 b	9,0 b

Fuente Orozco, H. and A. Ramirez. 1993. Nitrato de potassio (KNO_3) foliar para mejorar la calidad en citricos. Faculdad de agronomia, Universidad de Caldas, Colombia.

Table 2. Effect of KNO_3 sprays on citrus total yield and fruit size.

Treatment	Shamouti orange *		Ruby grapefruit **		Nova tangerine ***	
	Total kg/tree	Medium-jumbo size share (%)	Total box/ tree	Mean weight (g)	Total kg/ tree	% fruit >62 mm in diameter
Control	102,8 a	36 a	7,9 a	356 a	55,9 a	26,6 a
KNO_3	125,3 b	61 b	8,8 ab	374 ab	71,3 b	51,7 b

* One foliar spray, KNO_3 4% + 2.4. D 20 ppm. (Kanonitz et al.,1995)

** Sixteen fertigation applications with total of 1060 kg/ha KNO_3. (Boman,1995)

*** One foliar spray, KNO_3 suspension 15%. (Rabber et al., 1997)

Boman, B.J. 1995. Effects of fertigation and potash source on grapefruit size and yield. In: Dahlia Greidinger International Symposium on fertigation, Technion, Haifa, Israel. 55-66.
Kanonitz, S., H. Lindenboum and J. Ziv. 1995. Increasing Shamouti fruit size with 2.4 D and NAA. Alon Hanotea 49: 410-413 .
Rabber, D., Y. Soffer and M. Livne. 1997. The effect of spraying with potassium nitrate on Nova fruit size. Alon Hanotea. 51: 382-386.

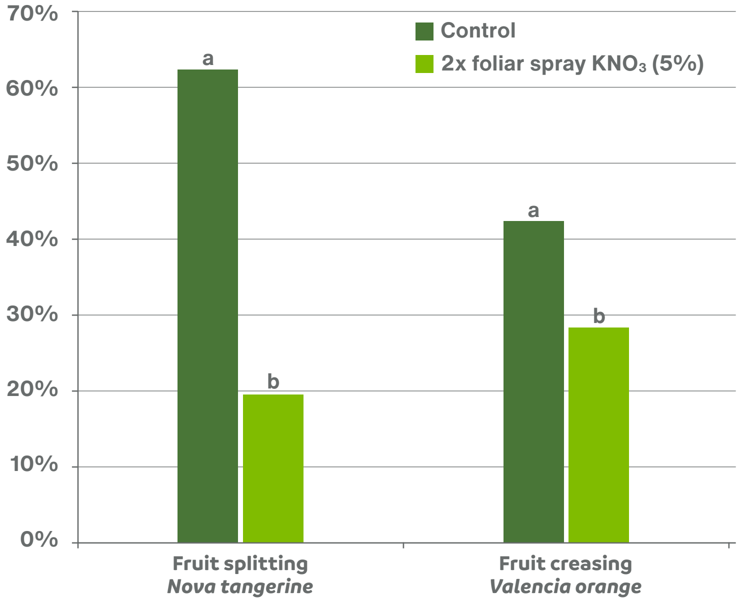

Figure 1. Effect of KNO_3 on citrus fruit rind disorders. KNO_3 was applied in June and in the first half of August (Lavon et al., 1992 and Bar-Akiva, 1975).

Bar-Akiva, A. 1975. Effect of foliar applications of nutrients on creasing of “Valencia” oranges. HortScience 10(1): 69-70.

Lavon, R. S. Shapchiski, E. Muhel and N. Zur. 1992. Nutritional and hormonal sprays decreased fruit splitting and fruit creasing of “Nova”. Hassade 72: 1252-1257.

An experiment with tomatoes was carried out in order to see the effect of various K-sources (KNO_3, KCl and K_2SO_4) on the tomato yield. Potassium nitrate was superior to the other K-sources regarding dry matter yield level (Figure 2) and mean berry weight.

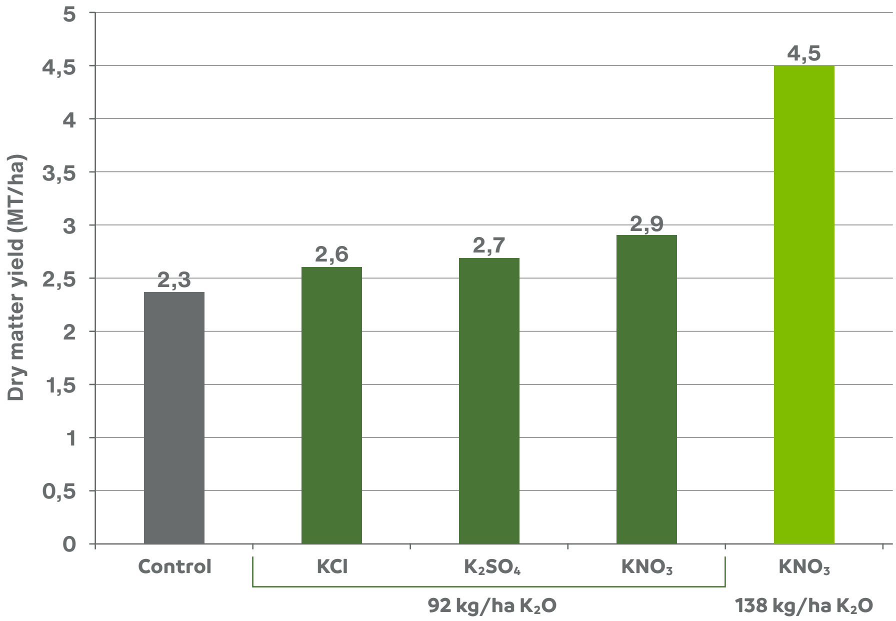

Figure 2. The effect of various K-sources on the dry matter yield of tomatoes.

Achilea, O. 1999. Citrus and tomato quality is improved by optimized K nutrition. Springer Netherlands - Improved Crop Quality by Nutrient Management: 19-22.

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