The effects of foliar nutrition containing various macro and microelements on the growth and development of young grafted walnut (*Juglans regia* L.) plants

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Summary: The Stopgril liquido (S), a foliar fertilizer containing nitrogen, calcium and magnesium was used to improve the spring and the summer growth of grafted walnut plants in the second year of cultivation in the nursery. To accomplish early termination of vegetative growth and good lignification, the composed mineral fertilizer Hascon M 10 AD (H) containing phosphorous, potassium and microelements B, Mn and Mo was applied on the same plants. Four treatments (S, H, SH, C) were applied three times in a growing season. Their effects on the height and the basal diameter of the plants in the nursery depended on the starting height of the plants and the time of application. During the first growth period in the orchard, the number of developed buds on the plant, the circumference of the plants and their height were influenced by the treatment in the previous year in the nursery. According to the results obtained through the investigation, three applications of Stopgril + Hascon in the nursery per year can be recommended in order to obtain high enough and well lignified two-year-old grafted walnut plants.

Key words: walnut, *Juglans regia* L., foliar nutrition, grafted plants.

Abbreviations: L – a low plant (40–45 cm), H – a high plant (60–65 cm); S – Stopgril, H – Hascon, SH – Stopgril + Hascon, C – control; LS – low plant + Stopgril, ... HC – high plant + control.

Introduction

The foliar nutrition represents a complementary measure for supplying plant nutrients, generally taken up by roots (*Mengel*, 2001). It is the method of supplying mineral nutrients, especially trace elements to the parts of the higher plants where they are needed, that give better results than the methods involving root application (*Jurgens*, 1987).

The foliar supply can be a very efficient way to overcome nutrient deficiencies. It depends much on the nutrient quantity required. In general, for macronutrients, much higher quantities and repeated spray applications are necessary, compared to micronutrients (*Mengel*, 2001).

Foliar fertilization circumvents restrictions in soil nutrient uptake and transport, and corrects transient and localized nutrient deficiencies (*Weinbaum* et al., 2001), which can result in reduced foliar concentrations of other nutrients, chlorophyll, specific amino acids, and enzyme activity (*Lavon* et al., 1999).

In spite of the effect that foliar nutrition can be inconsistent due to interactions among variables such as tree age, tree phenology, leaf ontogeny, tree nutrient status, and environmental and management variables (*Weinbaum* et al., 2001), there are numerous advantages of applying foliar fertilization in fruit trees.

Stampar et al. (1999) reported about the improved yield and the share of the first quality class in apple varieties like Elstar, Jonagold and Golden Delicious after foliar fertilization with Zn, B, P and Ca (Phosyn programme). The application of the spray containing Ca, K, B, Zn, Cu and Fe fertilizers three times during the season is also favourable for the yield and quality in Le-Conte pear (*Gobara*, 1998). *Veberic* et al. (2002) reported about the influence of the foliar application of the mineral nutrients P and K on photosynthesis and termination of vegetative growth in the apple cv. Golden Delicious. In olive trees, the foliar application of macro elements (N, P, K) increased their productivity (*Toscano* et al., 2001). The foliar fertilization with P, K, Mn, B and Mo caused larger sizes of fruits, and increased the contents of sugars (glucose, sorbitol and soluble solids), and organic acids (malic, citric). It showed a trend towards a decrease in the contents of fructose, sucrose, fumaric acids, boron, and zinc, but had no influence on the contents of shikimic acid, juice pH and titrable acids (*Hudina and Stampar, 2000, 2001*). Foliarly applied calcium reduced rain-induced cracking in cherries (*Brown* et al., 1995; *Callan*, 1986; *Meheriuk* et al., 1991). It also reduced stem-end splitting in some apple varieties (*Andrews* et al., 1999) and improved flesh firmness and fruit handling in

peach (*Avanzato* et al., 2001). Calcium chloride sprays increased cold hardiness of 'Anjou' pear trees (*Raese*, 1996). Foliar application of B at the time of flowering in apple, hazelnut, walnut, pistachio and sweet cherry often resulted in an increase of fruit set (*Gu* et al., 1995; *Rosecrance* et al., 1996; *Zhang & Brown*, 1999, *Usenik & Stampar*, 2001). In hazelnut, cvs. Barcelona and Tonda di Giffoni, during the time of ovary development and fertilization, boron and zinc applications reduced the number of blanks, influenced on flower induction and increased yield (*Shresta* et al., 1987; *Solar & Stampar*, 2001). The sprays of boron plus zinc, which were applied in the pre-bloom period, enhanced the cropping of previously winter-damaged apple trees (*Stover* et al., 1999). Magnesium and manganese are commonly applied via foliar sprays in apple orchards to prevent or alleviate the incidence of leaf blotch and early leaf drop in susceptible varieties (*Thalheimer & Paoli*, 2001; *Porro* et al., 2001).

Foliar fertilization trials were mostly focused on the quality and quantity of yield in many fruit species. Almost no information could be found about the impact of foliar supply on vegetative growth, especially in connection with the growth of the young fruit plants during the cultivation in the nursery before being planted in the orchards.

A walnut grafted plant of good quality is two years old and has a well developed root system. The shoot above the ground is supposed to be at least 1 m high, with very good lignification and with well developed terminal and lateral buds.

Over a cultivation period in the nursery, the grafted walnut plants usually exhibit a weak growth during the early period of development, although it is not early enough for the termination of vegetative growth and can not give sufficient lignification during the autumn.

To increase the spring growth of walnut plants the Stopgril liquido, a foliar fertilizer containing nitrogen (10%), calcium (8.3%) and magnesium (17.4%) was used. To achieve early autumn termination of vegetative growth and improve the lignification, the composed mineral fertilizer Hascon M 10 AD containing phosphorus (15%), potassium (20%) and microelements (B 0.1%, Mn 0.1%, Mo 0.01%) was applied.

Material and method

Plant material

The experiment was conducted in two places over the period of two years. In the walnut nursery in Lozice (Vipava valley) in 2000, and in the walnut orchard in Volcina near Maribor in 2001, 400 plants, cv. Elit (Slovene late leafing and good cropping variety with quality fruits) were treated in the experiment. Prior to the application of foliar nutrition, 200 plants were low in size (40–45 cm), other 200 plants were higher in size (60–65 cm). In January 2001, by the random order, 12 plants per treatment were planted in the production orchard. Their growth was observed to the end of the first growth period.

Treatments

Four treatments were observed, 1 Stopgril (S), 2 Hascon (H), 3 Stopgril + Hascon (SH) and 4 Control (standard fertilization with nitrogen: 30 g / plant). Stopgril was applied during the time of rapid spring growth on June 1 and 17, and at the end of the spring cycle on July 2, always in the same concentration: 0.5 l / 100 l of water. The plants were sprayed with Hascon at the beginning of the summer growth cycle on July 17 in concentration 300 ml / 100 l of water; and twice at the end of summer growth on September 1 and 16 in concentration of 400 ml / 100 l water and 500 ml / 100 l water.

Measurements

In the nursery, during the year 2000, the effects of treatments were seen in the difference of height (cm) and the diameter of plants above the ground (mm). Both parameters were measured prior to the foliar nutrition (May 31), then after the two applications of Stopgril (June 28) and finally at the end of the growth period following all the applications of Stopgril and Hascon (September 26).

In the orchard, during the year of 2001, at the end of May we counted the number of developed buds on above-ground stem of the plants. At the end of the growth period we measured the height of plants (cm), the circumference of stem above the ground (mm), the length of annual shoots (cm) and their diameter (mm).

Statistical data analysis

The differences between the treatments were evaluated with the analysis of variance (ANOVA) and the Duncan Multiple range Test ($p = 0.05$).

Results

Nursery plants

Height of the plants

The height increased during the spring time of rapid growth by 44% (LH) and 62% (HS). The low plants, which had not been treated with the Stopgril were significantly lower than the plants treated with Stopgril (LS) and Stopgril + Hascon (LSH). In the plants, which were measured 60 cm before the treatment, the height increased by 46% (HSH) and 62% (HS) during the spring growth cycle. None of the foliar treatments had significant effect on the plant height (*Table 1*). On the contrary, the untreated plants were even higher than the treated ones (*Figure 1*).

In the summer growth flush the heights of plants increased by 49% (HS, HSH, HC) and 68% (LH, HH). At the end of September the fertilized lower plants reached the height of more than 100 cm, while the untreated ones (LC) were 96 cm high (*Table 1*). The higher plants were measured 142 cm (HSH) and 165 cm (HH) in height (*Figure 1*). The difference between these two treatments was statistically significant.

Table 1 Height of walnut plants (cm) during the second year of cultivation in nursery

Treatment	Date of measurement		
	May 31	June 28	September 26
LS	42.4	68.7 a*	106.6 a
LH	44.4	63.9 ab	107.7 a
LSH	42.4	66.9 a	102.5 a
LC	41.0	60.6 b	95.8 b
HS	60.0	97.2 a	144.9 a
HH	65.6	97.8 a	164.7 b
HSH	64.8	94.8 ab	141.7 ac
HC	65.3	103.8 ac	155.1 d

*Means, marked with the same letter do not have significant statistical differences according to the Duncan multiple-range test ($p \leq 0.05$).

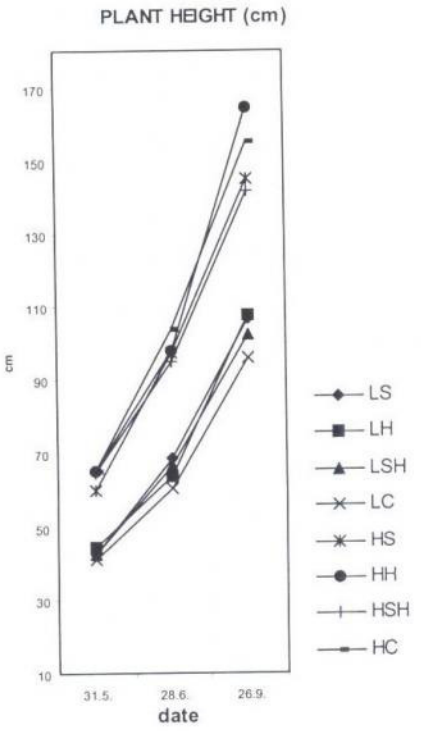

Figure 1 Height of walnut plants (cm) in the nursery, measured in three intervals.
Legend: L – a low plant (40 cm), H – a high plant (60 cm); S – Stopgril, H – Hascon, SH – Stopgril + Hascon, C – Control.

Basal diameter of the plants

During the spring growth flush the basal diameter increased in length by 10% (LC) and 15 % (LS) in the lower plants and by 12% (HH) and 19% (HSH) in the higher ones (*Figure 2*). Among the lower plants, Hascon treatment resulted in the largest basal diameter. Statistically the LH plants differed significantly from LS and LC plants (*Table 2*). The treatments of higher plants showed the following significant differences: HS was different from HH and HSH; HSH was different from HC. The HSH plants were the thickest at the end of June (*Table 2*, *Figure 2*).

From the second to the third measurement, the basal diameter increased in length by 45% (LH) and 59% (LS) in lower plants and by 54% (HC) and 59% (HS) in higher plants. LC plants were statistically significantly thinner compared to other treatments: LS, LH and LSH (*Table 2*, *Figure 2*). Among the higher plants, the thickest were those plants, which were treated with Stopgril + Hascon. They significantly differed from the HS and HC plants, which were the thinnest.

Table 2 Basal diameter of walnut plants (mm) during the second year of cultivation in nursery

Treatment	Date of measurement		
	May 31	June 28	September 26
LS	14.8	17.0 a*	27.0 a
LH	16.4	18.2 b	26.4 a
LSH	15.2	17.3 ab	26.0 a
LC	15.4	17.0 ac	25.1 b
HS	16.6	19.8 a	31.5 a
HH	18.5	20.8 b	32.3 ab
HSH	17.9	21.3 bc	33.5 bc
HC	17.1	19.4 a	29.9 ad

*Means, marked with the same letter do not have significant statistical differences according to the Duncan multiple-range test ($p \leq 0.05$).

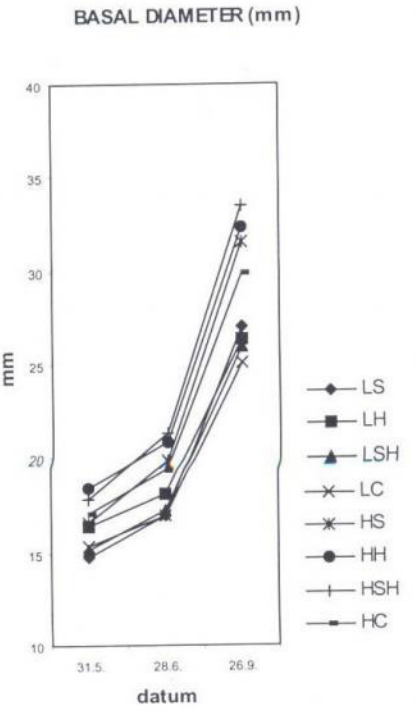

Figure 2 Basal diameter of walnut plants (mm) in the nursery, measured in three intervals.
Legend: L – a low plant (40 cm), H – a high plant (60 cm); S – Stopgril, H – Hascon, SH – Stopgril + Hascon, C – Control.

Plants in the orchard

Height of the plants

After the first growing season in the orchard, the SH plants reached 163 cm in height. They differed significantly from all the other treatments (*Table 3*). Solely Stopgril or Hascon did not have significant effects on the height of plants, neither on the standard fertilization of the soil (Control).

Table 3 Growth parameters of walnut plants in the orchard at the end of the first growth period

Treatment	Height (cm)	Circum ference (mm)	No. of developed buds	Length of annual shoots (cm)	Diameter of annual shoots (mm)
STOPGRIL (S)	157.9 a*	96.7 a	8.2 a	13.9 a	7.8 a
HASCON (H)	155.8 a	89.6 ab	7.6 a	15.6 b	7.7 a
STOPGRIL+ HASCON (SH)	162.9 b	84.6 b	8.8 a	16.1 bc	7.9 a
CONTROL (C)	155.4 a	97.0 ac	5.4 b	14.2 abd	8.3 b

*Means, marked with the same letter do not have significant statistical differences according to the Duncan multiple-range test ($p \leq 0.05$).

Circumference of the plant trunks above the ground

The untreated plants exhibited significantly the largest trunk circumference above the ground compared to SH treatment (*Table 3*). In the case of Stopgril treatment, the circumference of the plants was also significantly larger than in SH treatment.

Number of developed buds/plant

In the untreated plants only 5.4 buds per plant sprouted in comparison to the other treatments, where 7.6–8.8 buds per plant were counted (*Table 3*). The differences were statistically significant.

Length of annual shoots

The SH plants developed the longest annual shoots. Foliar application of Hascon resulted in long annual shoots, too. In the case of Stopgril and without foliar fertilization, the annual shoots were significantly shorter (*Table 3*).

Basal diameter of annual shoots

The untreated plants had the thickest annual shoots, while all foliar treatments resulted quite the same basal diameter of shoots (*Table 3*).

Discussion

In the research it was discovered that foliar nutrition containing macro and microelements had an impact on the growth and development of grafted walnut plants in both, the nursery and the orchard in the period of one year after the planting. Nitrogen, which was applied with the use of Stopgril, stimulated the primary growth of roots. Thus the growth of the above-ground stem and leaves improved as well. The assimilation area was enlarged, the photosynthesis was more intense and the production of carbohydrates increased.

We assume that the supply of nitrogen increased the synthesis of giberelin in the apex of the stem and developing leaves. Thus the cells were lengthened. As the nitrogen was applied early enough (the last in July 2), the leaves of plants aged slowly and most of the nitrogen were translocated into the wood.

Ca, which was added with Stopgril also prevented the leaves from falling too early. Ca accumulated in the apical meristems, where IAA was synthesized as well and it induced the transportation of Ca into the apex *(Faust,* 1989). Ca, which is accumulated in the apex neutralised abscisic acid and thus prevented the early leaf drop. In the late autumn the Ca was translocated into the above ground shoot. The most of it incorporated into the call walls of xylem and played an important role in the complex of polysaccharides and proteins (*Faust,* 1989). Ca together with lignin, which strengthens secondary cell walls, caused firmness of the plants.

Positive effects on the plant growth were also achieved by phosphorus and potassium from Hascon and magnesium from Stopgril. Phosphorus and potassium accelerate the growth of roots and thus influence the whole development of plants. *Faust* (1989) states that the fruit trees in orchards which are throughout cultivated have less roots than the trees in orchards where the green mulching between the rows is in practice. Therefore the P and K uptake is worse in the cultivated orchards. As in the nursery the soil is cultivated, the weak absorption of macro elements is expected and therefore the foliar application of P and K is recommended.

Potassium accumulates in the leaves of juvenile plants. With its activator role of enzymes and keeper of osmotic balance in the cells, potassium influences the weight of roots more than it does the above ground parts (*Faust,* 1989). Phosphorus, of which uptake is better in August than in the early season, (*Faust,* 1989) helps in the synthesis of proteins and matabolism of carbohydrates. Magnesium moves from old leaves to younger ones and influences the intensity of photosynthesis. As magnesium was applied earlier than potassium the antagonistic activity did not appear and the synthesis of albumen was normal (*Faust,* 1989).

The results prove that the effect of the foliar nutrition was greater in those plants which had been lower and weaker prior to the treatment. The low plants (40±5 cm) were higher than the control ones in all foliar treatments, at both times - after the spring growth cycle and at the end of the growth in the nursery. On the contrary, the height of the untreated higher plants (60±5 cm) was larger than in other treatments at the end of spring growth. At the end of September it was lower than the height of plants in the Hascon treatment and higher than those plants, which were treated with Stopgril

and Stopgril + Hascon. A possible explanation for a better growth of lower plants can be their weaker root system, which absorbs less nutrients and causes slower growth during the whole growth period. In such case, a direct application of nutrients on the leaves enables necessary elements to be incorporated into the vital developmental processes immediately and thus causes a better growth of plants.

The best results concerning the plant height and their diameter were achieved with Stopgril and Stopgril + Hascon. We recommend the application of Stopgril or Stopgril + Hascon three times during the second growth cycle in the nursery. The application of only Hascon will not give the desired results. If the annual plants in the nursery are at least 60 cm high or even higher, it is sensible to apply Stopgril + Hascon only in spring and to omit the summer application.

The important effects of the foliar nutrition in the nursery include also the early termination of the growth in autumn, good lignification of the above ground stem and development of buds, which will sprout after planting into the orchard in great numbers. Regarding the plants treated with 'Stopgril + Hascon' proved to be successful when planted in the orchard (the highest, the highest number of developed buds, the longest annual shoots), the SH application in the nursery is sensible and recommended.

The foliar nutrition of walnut plants with macro and some microelements in the nursery is easily conducted and cost efficient. It is estimated that additional number of first class plants is produced and a better initial growth in the orchard achieved. Therefore the foliar fertilizer is recommended to be a regular technological measure in the process of plant propagation in the nursery. The foliar nutrition is especially advantageous when unfavourable weather conditions obstruct a good early development of plants.

References

Andrews, P. K. (2001): How foliar-applied nutrients affect stresses in perennial fruit plants. Int. Sym. on Foliar Nutrition of Perennial Fruit Plants. Meran, Italy, Sept 11–15.

Avanzato, D., Menesatti, P., Raparelli, E., Paglia, G., & Sperduti, M. (2001): Effect of calcium foliar treatments on peach fruit. Int. Sym. on Foliar Nutrition of Perennial Fruit Plants. Meran, Italy, Sept 11–15.

Callan, N. W. (1986): Calcium hydroxide reduces splitting of Lambert sweet cherry. J. Amer. Soc. Hort. Sci. 111:173–175.

Faust, M. (1989): Physiology of temperate zone fruit trees. John Wiley & Sons, New York, 338

Gobara, A. A. (1998): Response of Le-Conte pear trees to foliar application of some nutrients. Egyptian Journal of Horticulture 25 (1): 55–70.

Gu, M. R., Jiang, Y. M., Hang, H. C., Peng, F. T., Gu, M. R., Jiang, Y. M., Hang, H. C. & Pen, F. T. (1995): Translocation and distribution of boron in apple trees foliar-applied at flowering. Acta Agriculturae Nucleatae Sinica 9(2): 86–90.

Hudina, M.& Stampar, F. (2000): Influence of Water Regimes and Mineral Contents in Soil Upon the Contents of Minerals, Sugars and Organic Acids in Pear Fruits (*Pyrus communis* L.) Cv. Williams. Phyton 40: 91–96.

Hudina, M. & Stampar, F. (2001): Effect of P and K foliar fertilization on fruit quality of pears. Int. Sym. on Foliar Nutrition of Perennial Fruit Plants. Meran, Italy, Sept 11–15.

Jurgens, G. (1987): Erfolgreicher Blattdunger-Einsatz im Obstbau 29 (5): 161–165.

Lavon, R., Salomon, R. & Goldschmidt, E.E. (1999): Effect of potassium, magnesium, and calcium deficiencies on nitrogen constituents and chloroplast components in Citrus leaves. J. Amer. Soc. Hort. Sci. 124: 158–162.

Meheriuk, M., Neilsen, G. H. & McKenzie, D. L. (1991): Incidence of rain splitting in sweet cherries treated with calcium or coating materials. Can. J. Plant Sci. 71:231–234.

Mengel, K. (2001): Alternative or complementary role of foliar supply in mineral nutrition of plants. Int. Sym.on Foliar Nutrition of Perennial Fruit Plants. Meran, Italy, Sept 11–15.

Porro, D., Comai, M., Dorigoni, A., Stefanini, M. & Ceschini, A. (2001): Manganese foliar application on apple to prevent leaf drop. Int. Sym. on Foliar Nutrition of Perennial Fruit Plants. Meran, Italy, Sept 11–15.

Raese, T. J. (1996): Calcium nutrition affects cold hardiness, yield, and fruit disorders of apple and pear trees. J. Plant Nutrition 19: 1131–1155.

Rosecrance, R. C., Weinbaum, S. A. & Brown, P. H. (1996): Assessment of nitrogen, phosphorous and potassium uptake capacity and root growth in mature alternate bearing pistachio (*Pistacia vera*) trees. Tree Physiology 16: 949–956.

Shrestha, G. K., Thompson, M. M. & Righetti, T. L. (1987): Foliar-applied boron increases fruit set in 'Barcelona' hazelnut. J. Amer. Soc., Hort. Sci. 112: 412–416.

Solar, A. & Stampar, F. (2001): Influence of boron (B) and zinc (Zn) application on flowering and fruit-set in hazelnut (*Corylus avellana* L.), cv. Tonda di Giffoni. Acta Horticulturae 556: 307–312.

Stover, E., Fargione, M., Risio, R., Stiles, W. & Iungerman, K. (1999): Prebloom foliar boron, zinc, and urea applications enhance cropping of some 'Empire' and 'McIntosh' apple orchards in New York. HortSci. 34: 210–214.

Stampar, F., Hudina, M., Dolenc, K. & Usenik, V. (1999): Influence of foliar fertilization on yield quantity and quality of apple (*Malus domestica* Borkh.). In: Anac, D., Martin-Prevel, P. (eds.). Improved crop quality by nutrient management. Dordrecht, Kluwer Academic Publishers: 91–94.

Thalheimer, M. & Paoli, N. (2001): Foliar absorption of Mn and MG: effects of product formulation, period of application and mutual interaction on apple. Int. Sym. on Foliar Nutrition of Perennial Fruit Plants. Meran, Italy, Sept 11–15.

Toscano, P., Godino, G. & Briccoli - Batti, C. (2001): Foliar fertilization: a valid alternative for olive cultivar. Int. Sym. on Foliar Nutrition of Perennial Fruit Plants. Meran, Italy, Sept 11–15.

Usenik, V. & Stampar, F. (2001): Effects of Zn- and B- foliar application on the sweet cherry fruit set and yield. Int. Sym. on Foliar Nutrition of Perennial Fruit Plants. Meran, Italy, Sept 11–15.

Veberic, R., Stampar, F. & Vodnik, D. (2002): Autumn photosynthesis of 'Golden Delicious' apple trees – the effects of picking and fertilisation treatment. Gartenbauwissenschaft 67 (3): 92–98.

Weinbaum, S. A., Brown, P.H. & Scott Johnson, R. (2001): Foliar nutrient applications in decidous orchards: Physiological and agrotechnical perspectives. Int. Sym. on Foliar Nutrition of Perennial Fruit Plants. Meran, Italy, Sept 11–15.

Zhang, Q. & Brown, P. H. (1999): The mechanism of foliar zinc absorption in pistachio and walnut. J. Amer. Soc. Hort. Sci. 124: 312–317.