Effects of applications of a complex and N-Ca fertilizer on leaf and fruit nutrient concentrations and some fruit quality parameters in two apple cultivars

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ABSTRACT: The aim of this research was to study the effects of application of 'hydrocomplex' (H) and 'Norway nitrate' (NN) fertilizers on leaf and fruit nutrient concentrations and some fruit quality parameters in the following apple (*Malus domestica* Borkh) cultivars (cvs.): Golden Delicious and Black Ben Davis. Applications of 50 kg NN, 75 kg NN, 50 kg NN plus 50 kg H and 75 kg NN plus 25 kg H per 0.1 hectare significantly increased leaf Ca concentration of the cv. Golden Delicious in comparison with the control in the July 15 sampling period. Boron concentration of leaves of the cv. Black Ben Davis increased steadily throughout the season. Applications of 75 kg H and 75 kg H plus 25 kg NN per 0.1 hectare significantly increased fruit B concentration of the cv. Black Ben Davis at harvest. The ratios N/Ca, K/Ca and K + Mg/Ca in fruit were calculated for all treatments. Applications of 25–75 kg NN, 25–75 kg H as well as the combination of the two fertilizers decreased the ratios N/Ca, K/Ca and K + Mg/Ca of fruits of the cvs. Golden Delicious and Black Ben Davis in comparison with the control at harvest. Applications of 50 kg (NN), 75 kg (H), 25 kg (NN) plus 75 kg (H) and 75 kg (NN) plus 25 kg (H) per 0.1 hectare significantly increased soluble solids of fruits of the cv. Golden Delicious at harvest.

Keywords: calcium; fruit firmness; *Malus domestica*; nutrient balance; soluble solids; storage quality

Apple trees are grown on large areas in some regions of northern Greece. A nutrient survey indicated that phosphorus, potassium and zinc deficiencies were frequent in apple orchards in Greece (Stylianidis, Syrgiannidis 1995).

Fertilization plays a significant role in the productivity of apple orchards as well as in fruit quality (Marcelle 1995). Leaf analysis in apples is mainly a way of assessing the nutritional status of the trees together with other crop factors such as crop yield, regularity of fruiting and vigour of growth (Delver 1980). The nutrients N, K and Ca can greatly influence yield and fruit quality of apple trees (Nosal et al. 1990). The susceptibility of fruits to physiological disorders is increased when fruit N content is too high (Marcelle 1995). Calcium content of apple fruit is directly related with the incidence of bitter pit, internal breakdown, water core and postharvest disease resistance. Potassium and Mg are also associated with bitter pit incidence in apple fruit. The involvement of these elements was attributed to the antagonistic effects to Ca (Fallahi et al. 1997). Boron was also associated with Ca and corking disorders in apple fruit and reduction of bitter pit (Faust, Shear 1968). For predicting storage quality of apples the ratio N/Ca is a good indicator, the best storage quality being associated with low N/Ca. A high fruit potassium content, in conjunction with a low calcium content, greatly increases the risks of fungal and physiological disorders. For evaluating these risks the ratio K/Ca was used as a good indicator (Marcelle 1995).

The objectives of this research were to study the effects of application of various quantities of hydrocomplex (H) and Norway nitrate (NN) fertilizers on leaf and fruit nutrient concentrations and some fruit quality parameters of the apple cultivars Golden Delicious and Black Ben Davis.

MATERIALS AND METHODS

The research was conducted in a commercial apple (*Malus domestica* Borkh) orchard in northern Greece. The trees of the cvs. Golden Delicious and

Table 1. Soil parameters of the experimental orchard

Soil property	Characteristic or value
Texture class	Sandy clay loam
pH	7.20
$CaCO_3$ (%)	1.88
Organic matter (%)	0.94
Electrical conductivity (mS/cm)	0.81

Black Ben Davis were 10 years old and grafted on MM 106 rootstock. The orchard was well managed and yield was approximately 60 kg/tree.

The experimental trees were central-leader trained and planted at a spacing of 4 × 5 m. Control plants were not fertilized. At the end of March, hydrocomplex (H) (12-11-18, MgO: 2.65%, S: 19.9%, B: 0.015%, Fe: 0.35%, Mn: 0.02%, Zn: 0.02%) and Norway nitrate (NN) (15.5% N, 19% Ca) fertilizers were applied at 0–75 kg per 0.1 hectare, in the following combinations: control, 25NN, 50NN, 75NN, 25H, 50H, 75H, 25NN + 75H, 50NN + 50H and 75NN + 25H. The previous year's fertilization per 0.1 hectare consisted of 35 kg N, 12 kg P and 20 kg K. The soil properties of the experimental orchard are given in Table 1. The soil samples were air dried, crushed to pass a 2-mm screen and analysed for pH at a 1:1 soil to water ratio, electrical conductivity in a 1:5 soil to water extract, texture (hydrometer method), $CaCO_3$ with a volumetric calcimeter and organic matter content after wet oxidation (Page et al. 1982).

Leaf samples were collected on July 15 (mid-summer). Leaves were collected from the middle of moderately vigorous shoots from each tree around the canopy periphery, at shoulder height. Fruit samples were collected on September 15 (harvest period). All samples were initially washed once with tap water and twice with distilled water. Leaf samples were dried in a forced draft oven at 68°C for 72h and ground in a mill to pass a 30 mesh screen. Fruit samples were freeze dried. Nitrogen was determined by Kjeldahl's procedure, B by the azomethine-H method (Wolf 1971), P by the ammonium phosphovanadomolybdate method (Jackson 1970) and K, Ca, Mg, Fe, Mn and Zn by atomic absorption spectrophotometry. Flesh firmness was measured by an Effegi penetrometer (11 mm tip). Soluble solids analysis was performed with an Atago PR-1 electronic refractometer.

The experiment was conducted and repeated for two years and the reported data are the means of the two years. The adopted experimental design was a randomized block with 10 replications of 10 treatments (fertilizer combinations) per cultivar. Diffe-

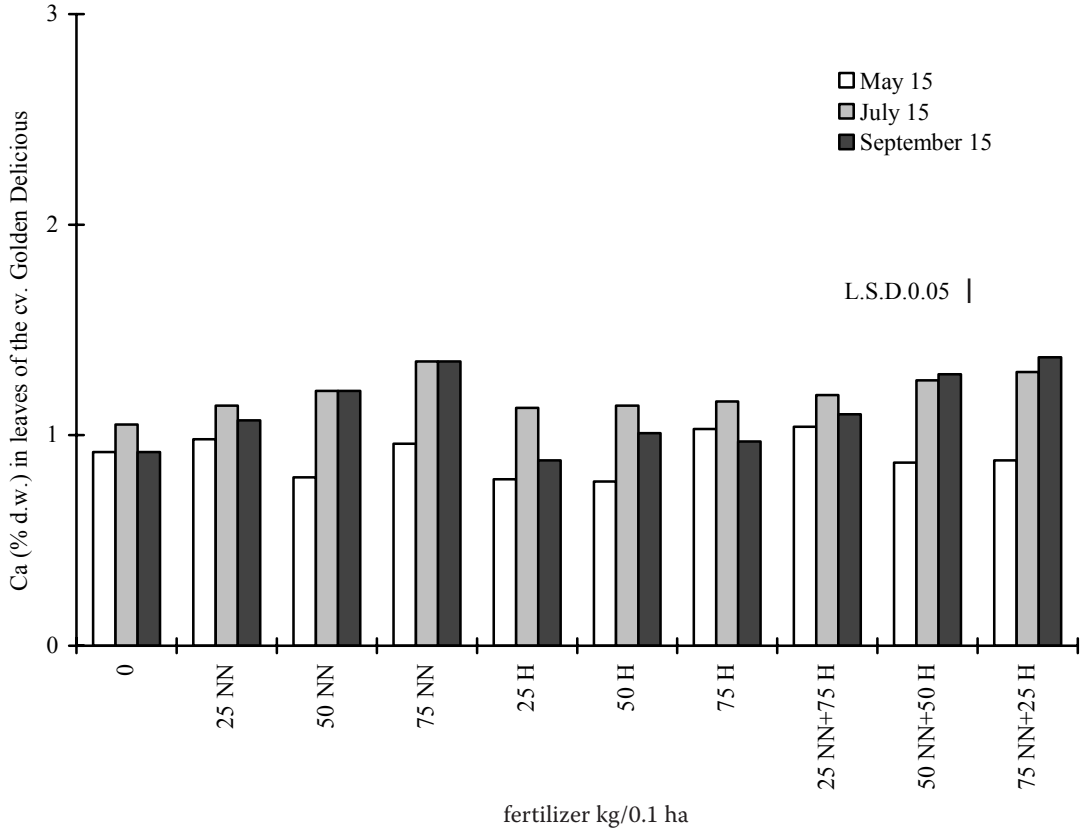

Fig. 1. Effects of application of various amounts of hydrocomplex and Norway nitrate fertilizers on leaf Ca concentration (% d.w.) of 10 years old trees of the cv. Golden Delicious grafted on MM 106 rootstock

rences between means of nutrient concentrations of leaves and fruits were evaluated using L.S.D. at $P < 0.05$.

RESULTS AND DISCUSSION

Application of 50 kg NN, 75 kg NN, 50 kg NN plus 50 kg H and 75 kg NN plus 25 kg H per 0.1 hectare significantly increased leaf Ca concentration of the cvs. Golden Delicious and Black Ben Davis (data shown for the cv. Golden Delicious) in comparison with the control on July 15 (Fig. 1). The role of Ca in postharvest physiology has been extensively studied. Calcium affects fruit quality and senescence by altering intracellular processes and the rate of fruit softening depends on Ca status. Calcium also plays a regulatory role in various processes that influence cell function and signal transduction (Marcelle 1995).

The application of 75 kg H, 50 kg NN plus 50 kg H and 75 kg NN plus 25 kg H per 0.1 hectare significantly increased P concentration of leaves of the cv. Golden Delicious and Black Ben Davis (data shown for the cv. Golden Delicious) in comparison with the control on July 15 (Fig. 2). Leaf P concentration of the cv. Golden Delicious was increased by the application of 0.3–1.2 kg/tree of 11-55-0 fertilizer (Raese 1998). Apple trees of the cv. Jonathan deficient in P showed delayed bud burst and retarded development of a reduced number of vegetative and floral meristems (Taylor, Goubran 1975).

Boron nutrition has been found to affect reproductive growth, especially flowering and fruit set. That B is required for flowering is indicated by the sensitivity of pollen development to low B concentration and the generally high concentration of B that occurs in reproductive parts of the flower (Mozafar 1993). Boron concentration of leaves of the cv. Black Ben Davis increased throughout the season (Fig. 3). The same trend was also observed for the cv. Golden Delicious (data not shown). This is in agreement with the reports of other authors for Cox Orange apple trees (Rowe 1980). It has been shown that the quantity of B taken up by the roots and transported to the shoots is related to the transpiration rate (Raven 1980). Transpiration, xylem stream and leaf venation were emphasized as main factors primarily involved in leaf B accumulation (Gupta et al. 1985). Application of 75 kg H and 75 kg H plus 25 kg NN per 0.1 hectare significantly increased leaf B concentration of the cvs. Black Ben Davis and Golden Delicious (data shown for the cv. Black Ben Davis), in comparison with the control on July 15 and reached the level of 74 μg/g d.w. (Fig. 3). These B concentra-

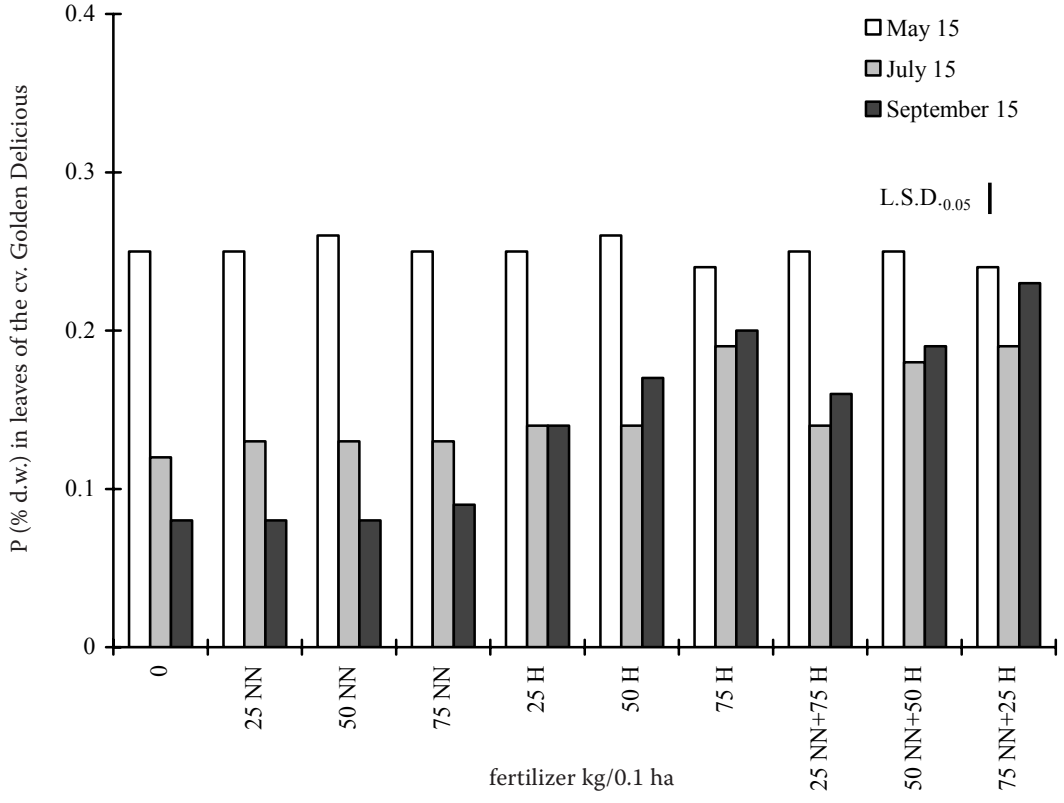

Fig. 2. Effects of application of various amounts of hydrocomplex and Norway nitrate fertilizers on leaf P concentration (% d.w.) of 10 years old trees of the cv. Golden Delicious grafted on MM 106 rootstock

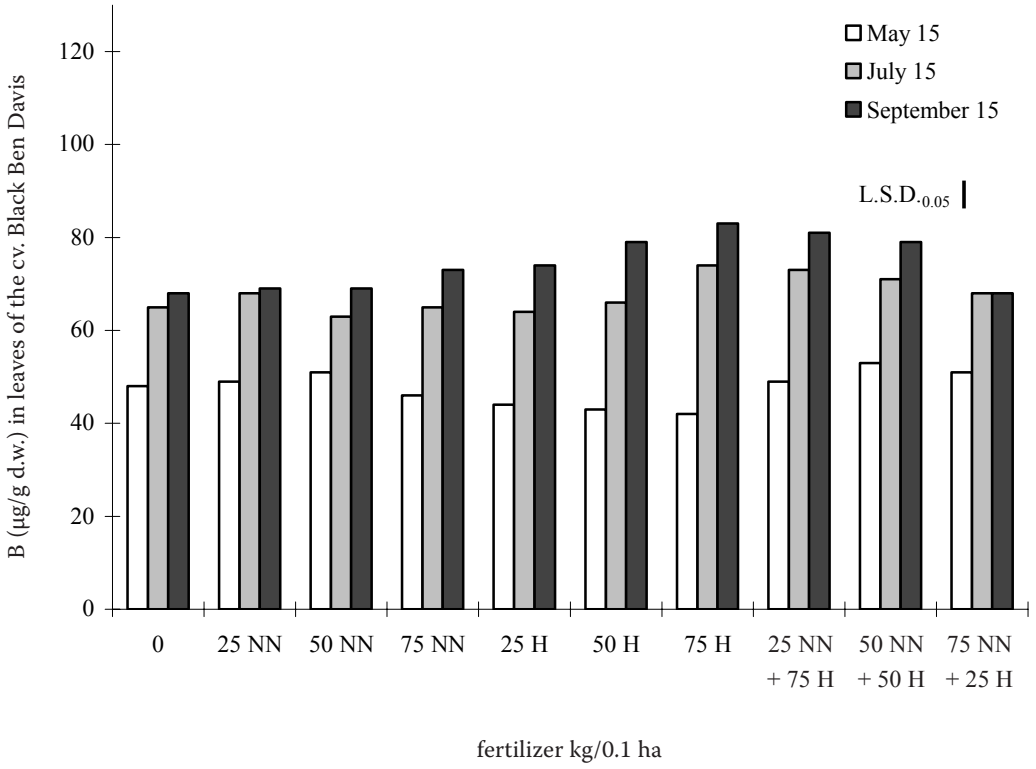

Fig. 3. Effects of application of various amounts of hydrocomplex and Norway nitrate fertilizers on leaf B concentration (µg/g d.w.) of 10 years old trees of the cv. Black Ben Davis grafted on MM 106 rootstock

tions in leaves provide sufficient B for fruit development, without occurrence of corking disorders of fruit (Faust, Shear 1968). Boron concentration of fruits of the cv. Black Ben Davis declined rapidly between the first and the second sampling date (Fig. 4). Application of 75 kg H and 75 kg H plus 25 kg NN per

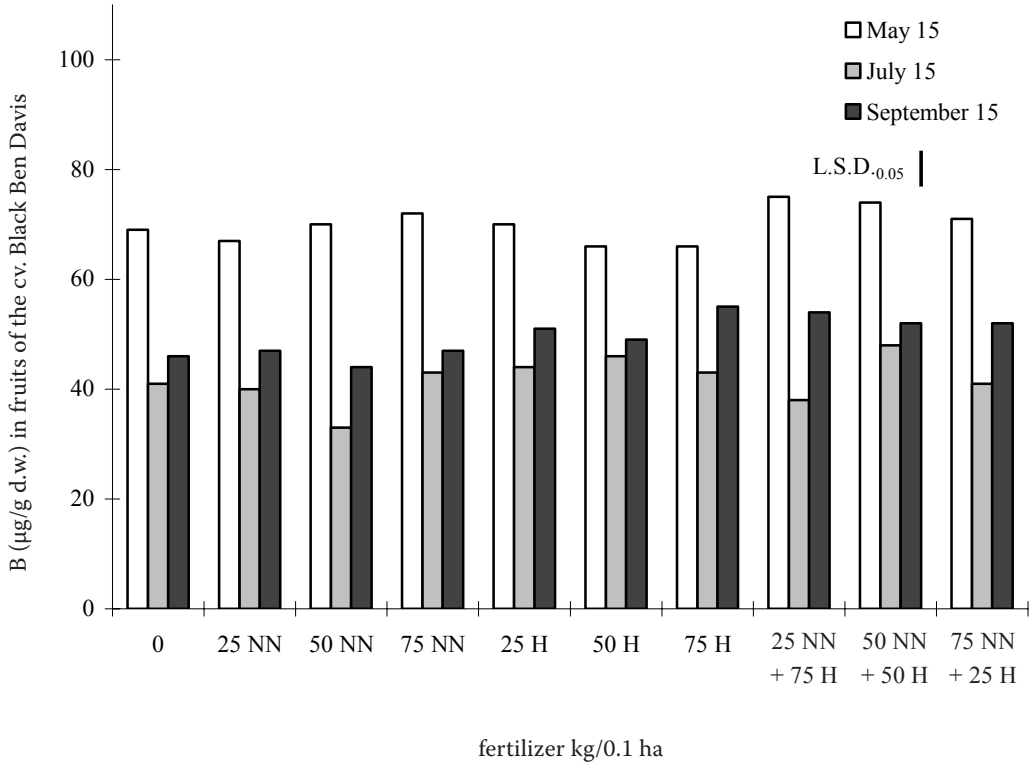

Fig. 4. Effects of application of various amounts of hydrocomplex and Norway nitrate fertilizers on fruit B concentration (µg/g d.w.) of 10 years old trees of the cv. Black Ben Davis grafted on MM 106 rootstock

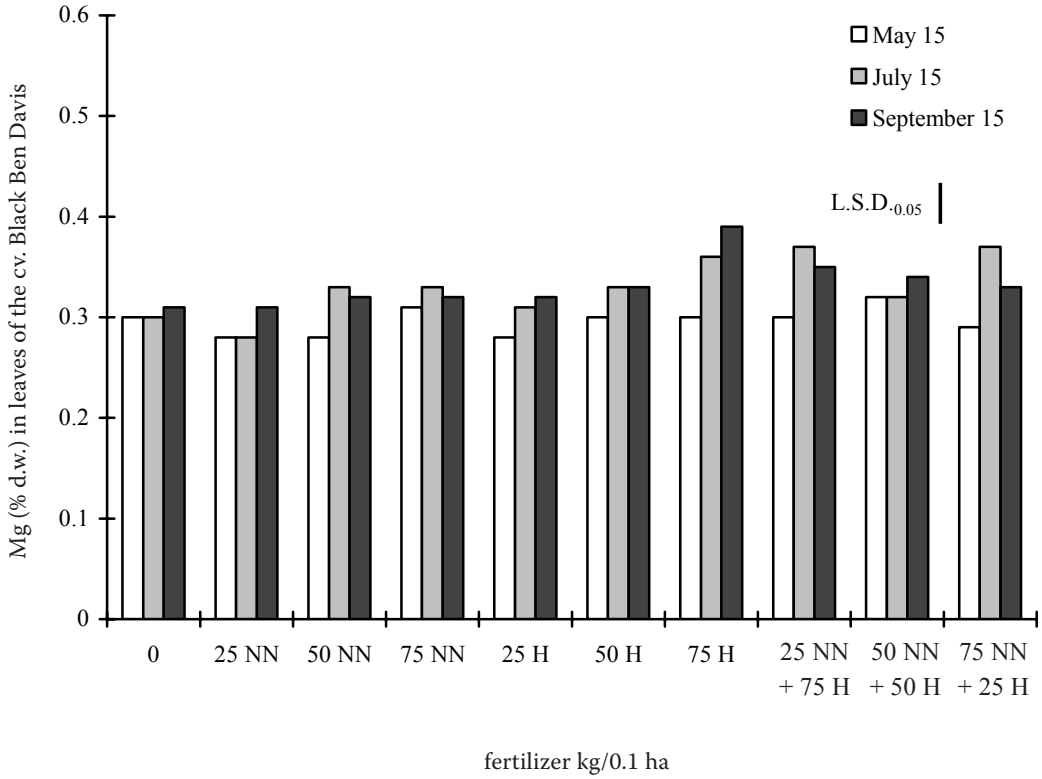

Fig. 5. Effects of application of various amounts of hydrocomplex and Norway nitrate fertilizers on leaf Mg concentration (% d.w.) of 10 years old trees of the cv. Black Ben Davis grafted on MM 106 rootstock

Table 2. Effects of application of hydrocomplex and Norway nitrate fertilizers on the ratios N/Ca, K/Ca and (K + Mg)/Ca in fruits of the apple cvs. Black Ben Davis and Golden Delicious at harvest

Cultivar	Fertilization*	N/Ca	K/Ca	(K + Mg)/Ca
Black Ben Davis	control	2.58	3.25	2.90
	25(NN)**	1.69	2.35	2.62
	50(NN)	2.09	2.43	2.74
	75(NN)	1.92	2.27	2.72
	25(H)	1.87	2.26	2.48
	50(H)	1.94	2.40	2.11
	75(H)	2.24	2.86	2.64
	25(NN)-75(H)	1.40	2.24	2.52
	50(NN)-50(H)	1.49	2.32	2.47
	75(NN)-25(H)	1.51	2.41	2.58
	$L.S.D._{0.05}$	0.19	0.15	0.10
Golden Delicious	control	2.09	4.62	4.92
	25(NN)	1.77	2.69	3.00
	50(NN)	1.79	2.33	3.67
	75(NN)	1.75	2.19	2.44
	25(H)	1.59	2.76	3.06
	50(H)	1.67	3.92	4.15
	75(H)	1.87	3.26	3.60
	25(NN)-75(H)	1.63	2.63	2.94
	50(NN)-50(H)	1.69	2.59	2.84
	75(NN)-25(H)	1.72	2.74	3.02
	$L.S.D._{0.05}$	0.10	0.11	0.12

*fertilizer input: kg/0.1 ha, **(NN) – Norway nitrate, (H) – hydrocomplex

0.1 hectare significantly increased fruit B concentration of the cv. Black Ben Davis in comparison with the control at harvest.

Application of 75 kg H, 75 kg H plus 25 kg NN and 25 kg H plus 75 kg NN per 0.1 hectare significantly increased leaf Mg concentration of the cvs. Black Ben Davis and Golden Delicious (data shown for the cv. Black Ben Davis) in comparison with the control in the July 15 sampling period (Fig. 5). The same increase in leaf Mg concentration was measured for the cv. Golden Delicious (data not shown). Magnesium is associated with bitter pit incidence in apple fruit (Faust, Shear 1968). Fallahi et al. (1997) observed severe bitter pit-like symptoms in fruits of the cv. Golden Delicious infiltrated with Mg, which was due to a high Mg/Ca ratio. Calcium and Mg will exchange for each other (Ferguson, Watkins 1989) and Mg will reduce Ca uptake into fruit tissue. For the cv. Golden Delicious a negative correlation between fruit Mg and the 'Thiault index' could be found. Furthermore, fruit firmness was found to be negatively correlated with fruit Mg content (Marcelle 1995). In the present experiment fruit Mg content was not significantly affected by soil applications of H and NN fertilizers (data not shown).

Although leaf analysis is a diagnostic indicator for optimizing mineral nutrition of fruit trees, it correlates weakly with fruit quality. Thus, fruit analysis is more useful in estimating quality (Fallahi et al. 1985; Marcelle 1995). Because N and Ca play important roles in all aspects of tree physiology, the ratio N/Ca has been used as a good indicator for predicting storage quality of apples, optimal storage quality being associated with low N/Ca ratios. Furthermore, the ratio (K + Mg)/Ca has been used for predicting bitter pit in apples. A high ratio increases the possibility of fruit to develop bitter pit symptoms (Fallahi et al. 1997). The ratio K/Ca is positively correlated with acidity, sugar content, percentage of dry matter, refractometric index, incidence of physiological and fungal diseases, the ratio height/diameter in Golden Delicious fruits and percentage area of red colour in Jonagold. However, the K/Ca ratio is negatively correlated with firmness. Thus, a high K/Ca ratio is associated with a good eating quality and bad storage quality (Marcelle 1995). Apple fruit quality and the N/Ca and K/Ca ratios in fruit were frequently improved with soil application of calcium nitrate fertilizer (Raese 1998). Application of 25–75 kg NN, 25 to 75 kg H as well as the combination of the two fertilizers decreased the ratios N/Ca, K/Ca and K + Mg/Ca of fruits of the cvs. Golden Delicious and Black Ben Davis in comparison with the control during harvest (Table 2).

Table 3. Effects of application* of hydrocomplex and Norway nitrate fertilizers on fruit firmness (kg) and soluble solids (°Brix) in the apple cultivars Golden Delicious and Black Ben Davis

Cultivar	Control	25(NN)**	50(NN)	75(NN)	25(H)	50(H)	75(H)	25(NN)-75(H)	50(NN)-50(H)	75(NN)-25(H)	$L.S.D._{0.05}$
	Fruit firmness (kg)										
Golden Delicious	8.15	8.25	8.30	7.89	8.43	8.35	8.57	8.40	8.30	8.24	0.17
B.B. Davis	7.15	6.90	7.08	6.92	7.65	7.21	7.16	7.59	7.60	7.40	0.26
	Soluble solids (°Brix)										
Golden Delicious	13.10	13.17	13.83	13.00	13.17	13.30	13.50	14.10	13.00	14.50	0.35
B.B.Davis	13.30	13.30	12.80	14.30	13.40	13.60	14.20	13.40	13.80	13.65	0.39

*fertilizer input: kg/0.1 ha, **(NN) – Norway nitrate, (H) – hydrocomplex

Application of 25–75 kg (H) and 25 kg (NN) plus 75 kg (H) per 0.1 hectare significantly increased fruit firmness of the cv. Golden Delicious in comparison with the control at harvest (Table 3). However, the same effect in the cv. B.B.Davis was noticeable when trees were fertilized with 25 kg (H), 25 kg (NN) plus 75 kg (H) and 50 kg (NN) plus 50 kg (H) per 0.1 hectare (Table 3). Fruit firmness is positively correlated with calcium (Marcelle 1995). In another experiment, fruit firmness was greater when trees were fertilized with calcium nitrate during autumn, in comparison with those fertilized with 17-17-17, 21-0-0 or 11-51-0 (Raese 1998).

Application of 50 kg (NN), 75 kg (H), 25 kg (NN) plus 75 kg (H) and 75 kg (NN) plus 25 kg (H) per 0.1 hectare significantly increased soluble solids of fruits of the cv. Golden Delicious, in comparison with the control at harvest (Table 3). Soluble solids of fruits of the cv. Black Ben Davis were increased in comparison with the control when trees fertilized with 75 kg (H), 75 kg (NN), and 50 kg (NN) plus 50 kg (H) per 0.1 hectare (Table 3). Soil application of 150 kg K_2O per hectare in the form of potassium sulphate increased soluble solids of fruits of the cv. Golden Delicious clone B at harvest (Noe et al. 1995). A positive correlation was observed between fruit K content and soluble solids for the cvs. Cox's Orange Pippin and Jonagold, while the opposite effect was observed for N, P and Ca for the cvs. Jonagold, Cox's Orange Pippin and Golden Delicious (Marcelle 1995).

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Účinky aplikací komplexního a dusíkato-vápenatého hnojiva na koncentraci živin v listech a v plodech a na některé parametry kvality plodů dvou odrůd jabloní

ABSTRAKT: Cílem výzkumu bylo studium účinků aplikací vodorozpustného komplexního hnojiva Hydrocomplex (H) a Norského ledku (NN) na koncentraci živin v listech a v plodech a na některé parametry kvality plodů dvou odrůd jabloní

(*Malus domestica* Borkh) – Golden Delicious a Black Ben Davis. Aplikace v dávkách 50 kg NN, 75 kg NN, 50 kg NN plus 50 kg H a 75 kg NN plus 25 kg H na 0,1 hektaru u odrůdy Golden Delicious významně zvýšily koncentrace Ca v listech oproti kontrole 15. července. Koncentrace B v listech u odrůdy Black Ben Davis byly trvale zvýšeny po celé vegetační období. Aplikace 75 kg H a 75 kg H plus 25 kg NN na 0,1 hektaru významně zvýšily koncentraci B v plodech v době sklizně u odrůdy Black Ben Davis. Poměry mezi N/Ca, K/Ca a K + Mg/Ca v plodech byly vypočítány u všech pokusných variant. Aplikace v rozmezí 25–75 kg NN, 25–75 kg H stejně jako kombinace obou hnojiv snížily poměry mezi N/Ca, K/Ca a K + Mg/Ca v plodech v době sklizně u obou odrůd oproti kontrole. Aplikace 50 kg (NN), 75 kg (H), 25 kg (NN) plus 75 kg (H) a 75 kg (NN) plus 25 kg (H) na 0,1 hektaru významně zvýšily obsah refraktometrické sušiny v plodech odrůdy Golden Delicious v době sklizně.

Klíčová sklova: vápník; pevnost plodů; *Malus domestica*; poměr živin; refraktometrická sušina; kvalita po skladování

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