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Interactive effect of irrigation and fertilization on the quality of apples

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Abstract

The results of two years research (1999–2000) with selected varieties of apple trees at the Slovak Water Management Enterprise, Vrakunska, Bratislava have been presented. Quality of fruits was considerably influenced by irrigation and fertilization. An increased rate of nitrogen (120 kg ha^{-1}) resulted in bigger shares of selective grade and Class I grades. A similar effect was produced by drip irrigation and typical response of individual varieties was confirmed. In 1999, the share of Selective grade by Gala variety was (93.3%) in the non-irrigated treatment and in the next year its share was 39.59%. An increased rate of nitrogen and complementary irrigation favourably influenced the initiation of flower buds and the variation of yields was reduced. Drip irrigation combined with an increased rate of nitrogen considerably influenced the yield and the varietal effect of the variety was observed on the responses. From the viewpoint of quality of fruits, Jonagold responded the best to regular irrigation and fertigation with 80 kg ha^{-1} of nitrogen. In the first year of investigation, the quality of fruits of Idared variety was homogenous in all treatments, however, in the next year better results were produced by fertigation. The results achieved in the sensorial, chemical and physical analyses of stored fruits of the tested varieties have shown negative impact with an increased rate of nitrogen (120 kg ha^{-1}). Not only quality of fruits, but also per hectare yields achieved by individual varieties are important for evaluation from the viewpoint of practice: in average from all the treatments Gala produced 36.2 t ha^{-1} of apples in 2000 and 10.5 t ha^{-1} in 1999; Jonagold produced 18.3 t ha^{-1} in 2000 and 30.5 t ha^{-1} in 1999; Idared 35.3 t ha^{-1} in 2000 and 8.9 t ha^{-1} in 1999.

Key words: Apple, fertigation, fertilization, irrigation, quality of fruits, yield, varieties.

Introduction

Intensive apple cultivation practices with high planting density (3000-4000 trees/ha) of virus free grafts using dwarfing rootstocks has made it possible to obtain early and high yield up to 30 to 40 tons per ha. Apart from judicious control of pests and diseases, the survey of soil and leaf nutrient contents can help to reach an optimum nutrition, to prevent physiological disorders and chloroses owing to either lack or surplus of nutrients and to avoid fruits being attacked by diseases and reduced storability. As the interaction between mineral nutrition and environmental factors is close, leaf diagnostics seems to be very suitable for the management of crop nutrition.

Water is frequently used as a medium for the transport of nutrients to roots. The need for nutrients can be determined on the basis of leaf diagnostics as it has referred to above. The determined amount shall be adjusted according to different soil and climatic conditions, fixation and mobility of nutrients and their eventual antagonisms. Fertigation is particularly suitable for high-density orchards (Nielsen and Roberts, 1996; Paoli, 1997). Neither optimum nutrient ratio nor high-quality planting material will produce required effect, unless controlled water regime is applied. Atmospheric precipitation on the territory of Slovakia are not distributed as homogeneously as individual crops require it. Hence, irrigation systems need to be built up in modern orchards to make up for insufficient water during critical periods of crops development.

Drip irrigation seems to be two to three times more economical than other methods of irrigation, *e.g.* micro-sprinkling (Pacholak *et al.,* 1995). Integrated crop management technologies applied in given soil and climatic conditions may be successful whereby fertigation plays its important role. The increase of fruits yields owing to irrigation is generally known fact as this has been witnessed and proved by research and practical experience (Dvořák, 1976; Miklós, 1996; Novotný and Čepička, 1982; Novotný and Hrúziková, 1990; Pražák, 1988)

The present investigation was carried out on different apple varieties to ascertain the role of irrigation and fertigation on quality of apple.

Materials and methods

Experiments were conducted at research base in Most pri Bratislave located in maize production belt, with elevation of 133 m. The region is characterised as warm, dry with mild winters. Its mean, long-term (1951-1980) precipitation is 554 mm and mean daily temperature is of 9.7°C. The region is located in the western part of Podunajská nížina lowland, where medium-heavy, alluvial, Calcaro-haplic Chernozem, having good physical properties, prevails. The soil parent material consists of calcareous, sandy to loamy alluvial deposits that changing into sand (1.10 – 1.35 m deep) and gravel (1.35 to 1.6 m deep). Underground water table moves between 6 and 8 m, thus the soil moisture in rhizosphere is not influenced. The contents of humus (*Tyurin*), carbonates

(*Janko*), nitrogen (total), phosphorus (available), potassium and magnesium (*Mehlich II*) have been determined as 2.5 %, 11 %, 0.29 %, 50-60 mg kg^{-1}, 170-280 mg kg^{-1} and 180-210 mg kg^{-1} respectively; the exchangeable pH value 7.6 to 7.7 was recorded. In autumn 1994 the 0.25 ha (30 x 70 m) trial orchard was established with north-south rows 3.5 m apart and apple trees of varieties Gala and Jonagold (1.2 m apart) and Idared (smaller trees 0.9 m apart). The tested varieties were grafted on M9 rootstocks.

Inter-row spaces were cultivated and herbicides were applied to the belts adjacent to tree bases. Plant protection products were applied with a 350 l sprayer. The use of pesticides was subject both to methodological recommendations and following special software applications intended for the evaluation of meteorological variables taken from a HOBO detector measuring air temperature, relative air humidity and dew-coverage of leaves. The Central Control and Testing Institute of Agriculture Forecast and Warning Service was taken into account as well.

The trees were pruned twice (winter and complementary summer pruning) and manual thinning of fruits was carried out in the first fortnight of June. During vegetative phase Netafim system by Net-MC company was used for drip irrigation. Integrated drippers, 1 m apart and with a 2.3 $l\,h^{-1}$ performance, were used within the system.

For the investigation and evaluation of the effect of irrigation one control, not irrigated part (K treatment) of the tested tree crop has been included in the trial with three others (A, B and C treatments), which have got various levels of fertilization.

Virrib moisture detectors by Amet company (Czech Republic) and the neutron probe were used for the measurement of soil moisture twice and once a week, respectively. For the quantification of complementary irrigation the application date, length in time, and per dripper or better said per plant dose of irrigation water were determined.

In 1999 vegetation period, total 136.5 litres of water was applied per tree, hence the soil water deficit has been reduced and the conditions for the growth and development of trees and fruits have been optimised.

In 2000, the year with extremely adverse weather conditions (high temperature and long lasting drought – almost throughout the entire vegetation period) some 665 litres of water per tree was provided for the test crop (Fig. 1). The soil water deficit has been significantly reduced and not only the conditions for the growth and development of apple trees and fruits were met, but also the evapotranspiration of the stand was supported well.

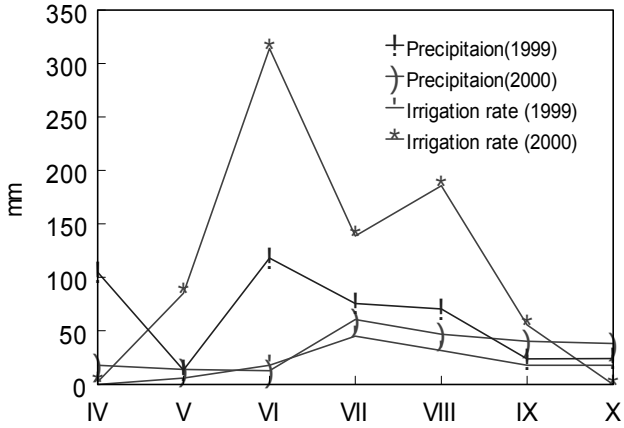

Fig. 1.The atmospheric precipitation and irrigation rate(seasons 1999, 2000)

The French made DOSATRON fertilizer feeder was used for fertigation and the following fertilization treatments were applied:

Treatment A – liquid fertilizer combined with irrigation (fertigation): 80 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5, 125 kg ha^{-1} K_2O;

Treatment B- liquid fertilizer combined with irrigation (fertigation): 120 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5, 125 kg ha^{-1} K_2O;

Treatment C– solid fertilizer combined with irrigation: 80 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5, 125 kg ha^{-1} K_2O;

Treatment K (control) – solid fertilizer, no irrigation (atmospheric precipitation only): 80 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5, 125 kg ha^{-1} K_2O.

Fertigation was applied as follows: Flowering – Kristalon modrý fertilizer (19 % N, 6 % P_2O_5, 20 % K_2O, 3 % Mg, 3 % S), beginning of the development of fruits – Kristalon špeciál fertilizer (18 % N, 18 % P_2O_5 , 18 % K_2O, 3 % Mg, 3 % S), full growth of fruits – Kristalonžltý fertilizer (13 % N, 40 % P_2O_5, 13 % K_2O), prior (3 weeks) to the maturity of fruits – Kristalon biely fertilizer (15 % N, 5 % P_2O_5, 30 % K_2O, 3 % Mg, 2 % S).

The distribution of fruits according to the grades for marketed commodities (pursuant the International Standards for the Quality of Fruits and Vegetables (Jablká, 1998) was as follows:

Grade	Fruits diameters (mm)
Selective	60 - 65
Class I	55 - 60
Class II	50 - 55
Sub-standard	<45, not damaged

Results and discussion

Based on the results of the 1999 quality assessment it may be stated that the biggest Selective grade share was that of Jonagold variety achieved in the Treatment A, followed by Idared variety (in average more than 94 % of the harvested fruits). The biggest Sub-standard grade share was that of Gala variety achieved in the Treatment B. All varieties bore fruits of the Selective grade and therefore the Class I grade and Class II grade shares were too small (Fig. 2).

In the second year, the biggest Selective grade share was that of Idared variety (60 %). The smallest Selective grade share was that of Gala variety. Among all treatments the smallest Selective share has been harvested in the K treatment and the biggest one in the B treatment. The biggest Sub-standard grade and Class II grade shares were harvested from the Gala variety in the Treatment A. The biggest Sub-standard grade and Class II grade shares from the Jonagold variety were harvested in the Treatment K and B. The biggest Sub-standard grade and Class II grade shares from the Idared variety were harvested in the Treatment K and C.

In no year deviations from typical shape and coloration of individual varieties were found. The quality assessment of fruits

Table 1. Quality assessment of fruits of the tested apple varieties (%)

Variety	Treatment	1999				2000			
		Selective	Class I	Class II	Sub-standard	Selective	Class I	Class II	Sub-standard
Gala	A	71.60	4.77	12.07	11.56	56.14	26.00	5.38	12.48
Gala	B	72.13	4.78	7.18	15.91	58.59	36.72	3.71	0.98
Gala	C	88.00	1.58	7.10	3.32	55.15	41.08	0.87	2.90
Gala	K	93.32	0.00	3.51	3.17	39.59	55.64	3.87	0.90
Jonagold	A	98.93	0.00	0.00	1.07	68.10	20.29	8.28	3.33
Jonagold	B	91.32	2.95	0.75	4.98	58.35	27.48	12.50	1.67
Jonagold	C	96.38	0.00	0.00	3.62	66.67	19.45	12.50	1.38
Jonagold	K	92.71	0.00	0.00	7.29	57.52	23.58	18.90	0.00
Idared	A	94.28	0.00	0.00	5.72	69.50	20.03	9.52	0.95
Idared	B	94.39	0.00	0.62	4.99	76.80	12.80	8.80	1.60
Idared	C	91.63	2.71	2.49	3.17	65.00	20.16	13.31	1.53
Idared	K	95.73	0.00	1.48	2.79	64.90	16.96	17.08	1.06

is given in Table 1 and Fig. 2.

Negative, significant correlation was found between treatments and numbers of Selective grade fruits (r=-0.30). A negative, highly significant correlation was observed (r=-0.37) between treatments and weight of Selective grade.

A positive, highly significant correlation was observed between treatments and Class I grade share (r=0.37). A positive, significant correlation (r=0.29) was observed between treatments and Class II grade share. A negative, significant correlation (r=-0.28) was observed between treatments and Sub-standard grade.

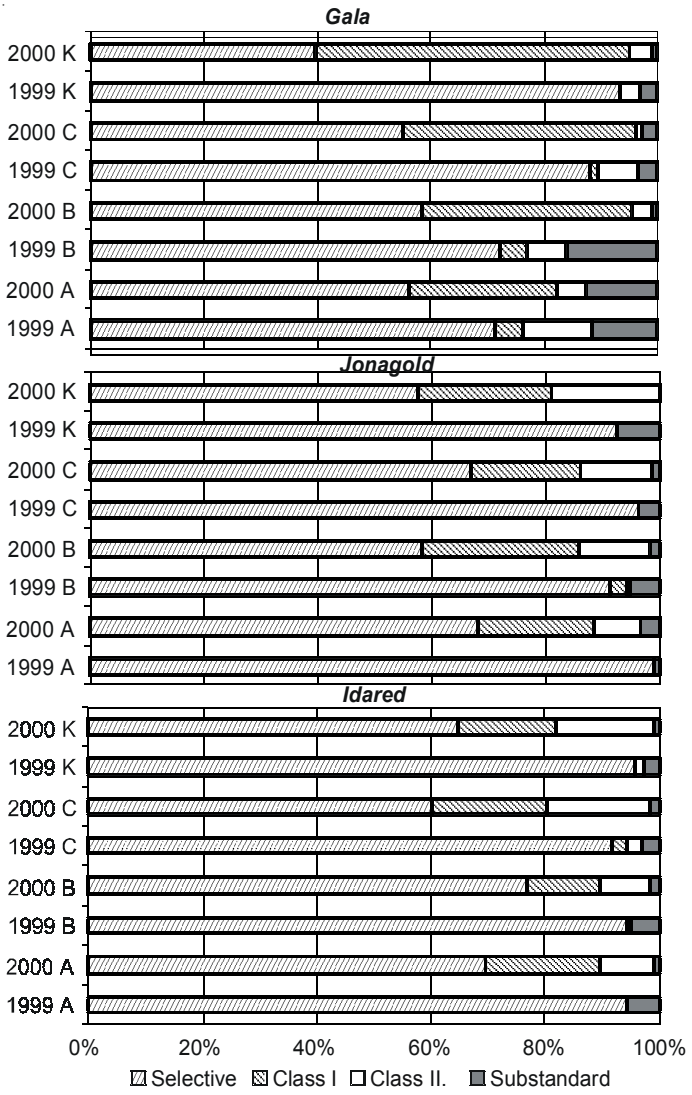

Fig. 2. Variation in different grades of fruit in Gala, Jonagold and Idared cultivars in 1999 and 2000

Post-harvest, chemical analysis of fruits was made and it has been shown that each variety responds to sufficient or lacking water or nutrients in different ways.

The fruits of Gala variety contained more nitrogen than the fruits of other tested varieties, which may be explained by its shorter vegetation period. Similarly, the phosphorus contents in fruits decreases gradually as the vegetation period extends. Fertigation favourably influences the transfer of calcium into fruits, which is very important for their storability.

This has been confirmed in sensorial assessment of fruits coming from individual treatments (A,B,C and K) belonging to individual made by Horèin (2000). The contents of dry matter, fibre, organic acids, saccharides, vitamin C, and calcium have been analysed and the hardness of fruits was determined using a penetrometre.

When using a scaling method, percentile shares of scores have shown a higher quality of Gala variety in comparison with Idared variety, whose quality increases during storage.

The first measurement of Gala variety was carried out on 13th September 1999, the last one on 9th March 2000; the first measurement of Idared variety was carried out on 11th October 1999 and the last one on 22nd June 2000; the first measurement of Jonagold variety was carried out on 8th November 1999 and the last one on 9th March 2000.

In overall profiling concerning general quality, no significant differences were found within individual treatments. When measured later the qualities of Idared and Jonagold improved. In course of the last measurement, symptoms of overmaturing were found in the case of Gala, namely in the treatment B, while the remaining two varieties preserved their quality until the last measurements. In course of these measurements the unfavourable effect of a high rate of fertilizer (Treatment B) manifested itself, hence it may be applied when storage until late January is supposed.

Several authors dealt with the quality evaluation of apples as related with nutrition and irrigation. The softening of apples in course of maturing on tree and cool storage was investigated by

Goliáš *et al.* (2000). In course of storage of three apple varieties (Florina, Rezista and Golden Delicious) the fundamental physical variable of fruits – sub-epidermal damage, hardnesses of peel and flesh - were analysed. The quality and storability of Summerred variety as related with fertigation were investigated by Ericsson (1993). The fertigation with a liquid mixed (N,P,K) fertilizer (Superba S 6.5 – 1.0 – 4.7 micro) in two doses was compared with a mixed fertilizer (NPK 11 – 15 – 18 micro) applied to apple trees in spring, together with drip irrigation or without it. The weight of fruits, their size, contents of minerals and other parameters (coloration, hardness, contents of saccharides and titratable juice acids) were measured twice, *i.e.* at harvest and harvested fruits stored for 2 months at 90-92 % relative air humidity and 3 ºC. The nitrogen content in fruits increased by all measurements. The Superba S fertigation resulted in smaller size and fainter coloration of fruits. The content of saccharides was reduced and the percentile share of rotten fruits increased with higher nitrogen content. The numbers of rotten and bitter-pitted apples increased with higher doses of applied fertilizer. Reports related with the influence of irrigation and nutrition on the quality of fruits are limited.

The results based on two year studies clearly indicate that quality of fruits was considerably influenced by irrigation and fertilization. Higher rate of nitrogen (120 kg ha^{-1}) resulted in bigger shares of Selective grade and Class I grades. A similar effect was produced by drip irrigation and typical responses for individual varieties was confirmed. In 1999, the share of Selective grade by Gala variety was (93.3%) in the non-irrigated treatment and in the next year its share was 39.59%. An increased rate of nitrogen and complementary irrigation favourably influenced the initiation of flower buds and the variation of yields was reduced. Drip irrigation combined with an increased rate of nitrogen considerably influenced the yield and the varietal effect of the variety was observed on the responses. From the viewpoint of quality of fruits, Jonagold responded the best to regular irrigation and fertigation with 80 kg ha^{-1} of nitrogen. In the first year of investigation, the quality of fruits of Idared variety was homogenous in all treatments, however, in the next year better results were produced by fertigation. The results achieved in the sensorial, chemical and physical analyses of stored fruits of the tested varieties have shown negative impact with an increased rate of nitrogen (120 kg ha^{-1}). Not only quality of fruits, but also per hectare yields achieved by individual varieties are important for evaluation from the viewpoint of practice: in average from all the treatments Gala produced 36.2 t ha^{-1} of apples in 2000 and 10.5 t ha^{-1} in 1999; Jonagold produced 18.3 t ha^{-1} in 2000 and 30.5 t ha^{-1} in 1999; Idared 35.3 t ha^{-1} in 2000 and 8.9 t ha^{-1} in 1999.

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