INFLUENCE OF FERTIGATION ON FRUIT YIELD IN HIGH DENSITY APPLE ORCHARDS UNDER GLOBAL CLIMATIC CHANGES

INFLUENŢA FERTIRIGĂRII ASUPRA RECOLTEI DE FRUCTE ÎN LIVEZILE INTENSIVE DE MĂR ÎN CONTEXTUL SCHIMBĂRILOR CLIMATICE GLOBALE

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Abstract. *The large increase of air temperature, in number of sunshine hours and lower rainfalls in the summer months, leads to the necessity of irrigation application using water saving techniques. This work goal is to present and recommend some orchard fertigation systems in apple and to highlights some results obtained in high density orchards. At Research Institute for Fruit Growing Pitesti-Romania, according to variety, the fruit productions obtained in an experimental high density apple orchard (3,077 trees ha^{-1}), were 19.3 t ha^{-1} up to 30.0 t ha^{-1}, in the second year after planting, and 29.7 t ha^{-1} to 38.5 t ha^{-1}in the third year from orchard establishment. For all fertilizer graduations, the cultivar 'Golden Delicious' clone B yielded the highest production 30.0 t ha^{-1}, followed by 'Jonagored' cultivar with 22.3 t ha^{-1} and respectively 'Fuji Kiku' Clone 8 with 19.3 t ha^{-1}, the differences being statistically insured.*

Key words: drip irrigation, environmental stress, rainfall deficit

Rezumat. *Tendinţa de creştere a temperaturii aerului şi a insolaţiei, asociată cu scăderea regimului de precipitaţii din lunile de vară, a impus treptat necesitatea aplicării irigărilor localizate, caracterizate prin eficienţă sporită în aplicarea udărilor. Această lucrare prezintă şi recomandă un astfel de sistem de fertirigare la specia măr şi evidenţiază câteva rezultate obţinute într-o livadă intensivă. La I.C.D.P. Piteşti - România, în funcţie de soi, producţia de fructe obţinută într-o plantaţie experimentală de măr de mare densitate (3.077 pomi/ha, plantaţi la 3,25 m x 1,0 m), a fost cuprinsă între 19,3 t/ha şi 30,0 t/ha, în anul II de la plantare, iar în anul III între 29,7 t/ha şi 38,5 t/ha. În medie pentru variantele de fertirigare, soiul 'Golden Delicious' clona B a înregistrat cea mai ridicată recoltă de fructe (30 t/ha), urmat fiind de soiul 'Jonagored' cu 22,3 t/ha şi soiul 'Fuji Kiku' Clona 8 cu 19,3 t/ha, diferenţele dintre ele fiind asigurate statistic.*

Cuvinte cheie: irigare localizată, stres ambiental, deficit pluviometric

INTRODUCTION

Under the climatic conditions from Central and South-Eastern Europe, periods of increasing frequent droughts become a limiting factor in increasing fruit production. Previous studies have shown that the impact of climate change on fruit trees species is already felt. By the end of 1990, the onset of fruit trees flower bud blossom in Germany has advanced a few days (Chmielewski et al., 2005) and the growing season in Europe was extended by 10 days in the last 10 years. Mateescu *et al.*, 2009, estimated that, in Pitesti, Romania, according to projections made by

regional climate model RegCM3/SRES A1B, annual average air temperature will increase by 1.5°C from 2020 to 2050 compared to the current conditions. The biggest increases are expected in the warm period of the year respectively during April-August period (1.6°C in May, 2.6°C in June, 2.8°C in July and 1.0°C in August). Annual amounts of rainfalls will decrease by an average of 91.1 mm, the largest decreases being projected, again, in the summer period. Chitu et al., 2009, stated that in Maracineni between 1969 and 2009, there was a statistically assured trend of weather warming, of sunshine hours and rainfalls deficit increasing and of the annual rainfalls decreasing. The months having the highest abnormal weather were June, July and August. The largest slope of temperature and Penman-Monteith potential evapo-transpiration increase has been registered, however, in August. Under these conditions, even if in climatic areas favourable for growing fruit trees, is increasing the rainfall deficit in summer months, growing fruit trees in high density systems require more efficient methods of irrigation and fertilization.

Fertigation, although widespread in arid areas, until now, little research have been performed on the application of fertigation in wetter areas (Treder, 2006). Many authors have argued that a highly accurate application, both for water and fertilizers, can be achieved by simultaneous administration by fertigation. Thus we obtain the advantage of simultaneous supply of mineral elements in accordance with the trees needs (Neilsen et al. 2001; Weinbaum et al. 1992). It creates favourable conditions for reducing the amounts of fertilizers applied and to minimize adverse impacts of excess application on the environment (Neilsen and Neilsen, 2002). From morphological point of view, fruit trees species are characterized by a low density of roots per unit of soil surface (10 to 100 times lower than the weeds), especially apple trees grafted on low vigour rootstocks (Neilsen et al., 1997). Consequently, a high efficiency in the distribution of fertilizers requires repeated applications, precise placement and high retention rates in the area explored by the great mass of roots.

Given the need to reduce the adverse effects of changes in the recent years of meteorological factors and phenological dynamics, through allocation and more stringent control of technological factors, we have undertaken at the Research Institute for Fruit Growing Pitesti - Romania, a study regarding the effect of different fertigation systems on apple trees.

MATERIAL AND METHOD

The researches were carried out at RIFG Pitesti - Romania during 2007-2009 periods. In the spring of 2007 a trial was established in a high density apple orchard with the trees planted at 3.25 x 1.00 m (3,077 trees ha^{-1}). The trial was a bifactorial one and included 18 variants (3 x 6) with 5 trees in repetition plot, following the subdivided plots design. The experimental factors taking into the study included: A factor, the cultivar: the biological material was represented by 'Jonagored', 'Fuji Kiku' Cl. 8 and 'Golden Delicious' clone B cultivars, grafted on M9 T 337 rootstock; B factor, the nutrients doses applied together with irrigation water and has had six graduations: b1 - untreated control, and treated with the annual fertilizer rates (kg ha^{-1}): b2 - $N_{(20)}:P_2O_{5-(10)}:K_2O_{(30)}:MgO_{(10)}$, b3 - $N_{(40)}:P_2O_{5-(20)}:K_2O_{(60)}:MgO_{(20)}$, b4 - $N_{(60)}:P_2O_{5-(30)}:K_2O_{(90)}:MgO_{(30)}$, b5 - $N_{(80)}:P_2O_{5-(40)}:K_2O_{(120)}:MgO_{(40)}$, b6 - $N_{(100)}:P_2O_{5-(50)}:K_2O_{(150)}:MgO_{(50)}$.

The experimental plot was placed on a plane terrain, located on the second terrace of the Arges River, the soil being brown eumesobasic, slightly podzolic şi pseudogleic one. As regards the texture, in the experimental plot soil was a sandy loam one, with a good aeration and water holding capacity. The soil reaction was slight acid (pH=5.8 - 6.8). Generally, the humus content was under 3%, indicating a low supply in nitrogen of the soil. The mobile phosphorus ranged between 8-10 ppm, showing a medium supplied soil. Analysis of the soil degree of bases saturation indicated that the soil had a low to medium natural fertility. The nitrogen index value was under 2%, revealing a low supplied soil with nitrogen. The orchard soil training system was a combination of grasses cover between the trees rows and herbicides in stripes of 1.0-1.2 m wide, along the trees rows.

The influence of the experimental factors was quantified using the following set of biological indicators: trees cross trunk section area (CTSA, cm^2), annual increase of trees cross trunk section area (AICTSA, cm^2), mean number of flower buds per tree (MNFB), percent of harvested fruits versus total number of flowers per tree (HFN/FLN, %), mean number of harvested fruits per tree (HFN), fruits mean weight at harvest time (FMW, g), and fruits mean production (PROD, t ha^{-1}). The high amount of the experimental data was stored and processed by the variance analysis, using the specialised program SPSS 14.0 with its bifactorial ANOVA calculation model and by correlations method (Pearson coefficients').

RESULTS AND DISCUSSIONS

Effect of experimental variants on fruit bearing processes in the second year after orchard establishment. The fruits production registered in the experimental device were pretty high for an orchard in the second year: 19.3 - 30.0 t ha^{-1} according the cultivar (fig. 1).

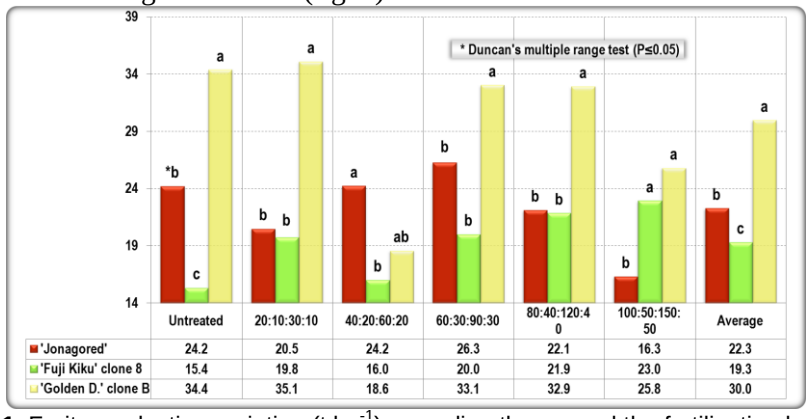
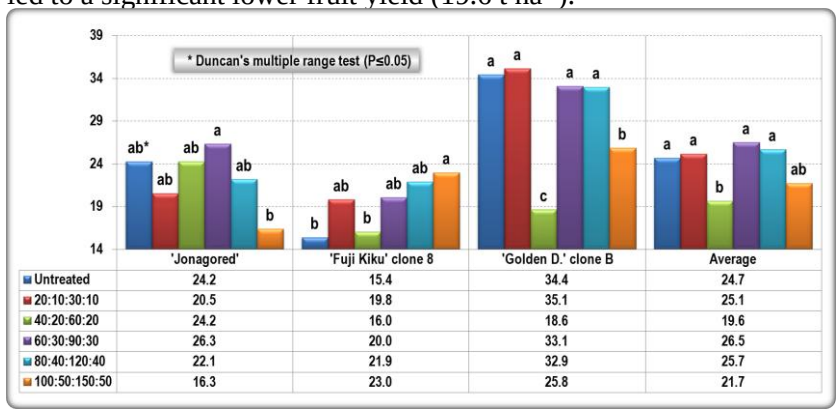


Fig. 1. Fruits production variation (t ha^{-1}) according the cv. and the fertilization levels

With few exceptions (fertilization with $N:P_2O_5:K_20:MgO$ in rates of 40:20:60:20 kg ha^{-1}), for all fertilizers graduations, 'Golden Delicious' clone B cultivar registered the highest fruit yields, over 30.0 t ha^{-1}, followed at statistical assured differences, by the cvs. 'Jonagored' with 22.3 t ha^{-1} and 'Fuji Kiku' with 19.3 t ha^{-1} respective, if the average values of fertilization levels are analyzed (Fig. 1).

If we analyze the fruits production variation (t ha^{-1}) according the fertilization level, for different cultivars (fig. 2), has been found that the yield

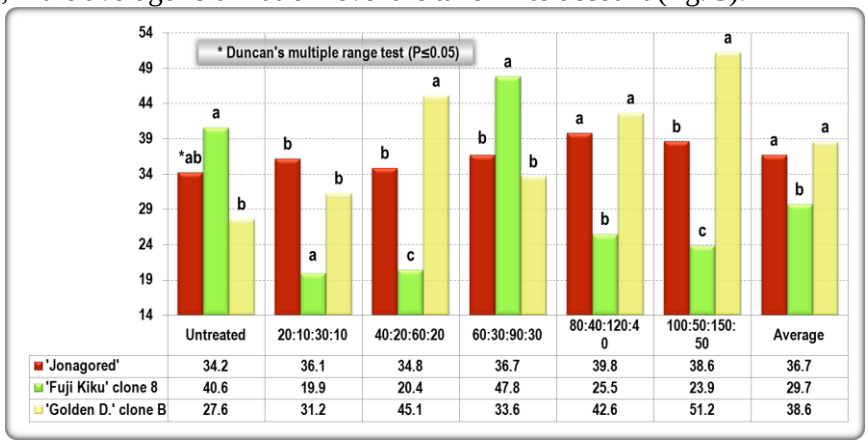
levels induced by different quantities of fertilizers applied in the second year after orchard establishment, are similar from the statistical point of view (21.7 – 26.5 t ha^{-1}), except the fertilization level of $N:P_2O_5:K_20:MgO$, 40:20:60:20 kg ha^{-1}, which led to a significant lower fruit yield (19.6 t ha^{-1}).



	'Jonagored'	'Fuji Kiku' clone 8	'Golden D.' clone B	Average
Untreated	24.2	15.4	34.4	24.7
20:10:30:10	20.5	19.8	35.1	25.1
40:20:60:20	24.2	16.0	18.6	19.6
60:30:90:30	26.3	20.0	33.1	26.5
80:40:120:40	22.1	21.9	32.9	25.7
100:50:150:50	16.3	23.0	25.8	21.7

Fig. 2. Fruits production variation (t ha^{-1}) according to fertilization level, for different cultivars

Effect of experimental treatments on fruit bearing process in the third year after orchard establishment. Although did not bear the highest number of fruits per trees, 'Jonagored' cultivar together with 'Golden Delicious' clone B registered the highest fruit yields (36.7 and respective 38.6 t ha^{-1}), which are significantly different compared to the one obtained by 'Fuji Kiku' cultivar (29.7 t ha^{-1}), if the average fertilization level are taken into account (fig. 3).



	Untreated	20:10:30:10	40:20:60:20	60:30:90:30	80:40:120:40	100:50:150:50	Average
'Jonagored'	34.2	36.1	34.8	36.7	39.8	38.6	36.7
'Fuji Kiku' clone 8	40.6	19.9	20.4	47.8	25.5	23.9	29.7
'Golden D.' clone B	27.6	31.2	45.1	33.6	42.6	51.2	38.6

Fig. 3. Fruit yield variation (t ha^{-1}) according to cultivar and different fertilization levels

Assessment of the fertilizers influence (fig. 4), reveal that in the third year after orchard establishment, the yield tends to be higher by increasing the quantity of fertilizers, the fruits productions ranging between 36.0 – 39.4 t ha^{-1}, on the cultivars average. The highest influence was registered on 'Golden Delicious' clone B cultivar. In this case, the indicator fruits yield (t ha^{-1}), in the variant

fertilized with N:P_2O_5:K_20:MgO, 100:50:150:50 kg ha^{-1} was almost double, (51.2 t ha^{-1}) versus untreated control (27.6 t ha^{-1}).

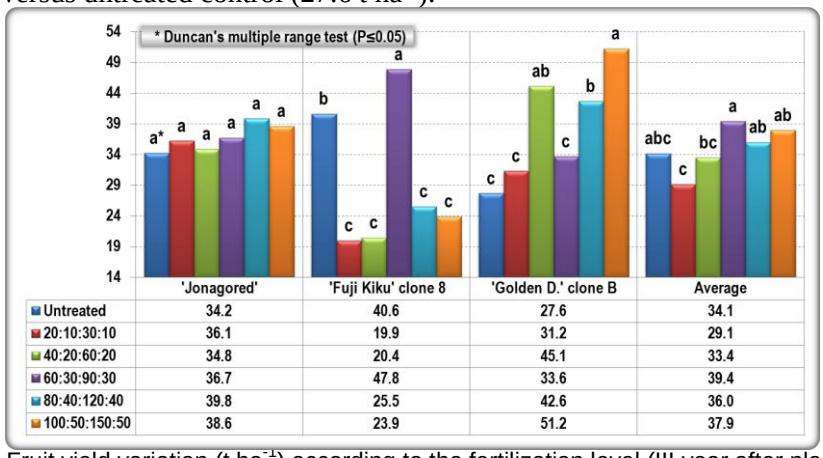


Fig. 4. Fruit yield variation (t ha^{-1}) according to the fertilization level (III year after planting).

Assessment of the correlations between the increasing fertilizers quantities applied in the orchard and the indicators defining the fruits production in the second and third years after orchard establishment (Table 1), evidenced the fertilizers favourable effect on MNFB in 2008 (r=0.107*), MNFB'09 (r=0.138**), on HFN'09 (r=0.178**) as well as on PROD'09 (r=0.146**). PROD'09 of the three apple cvs. was influenced with 86.1% (r=0.928**, with the extreme values between 0 and 74.5 t ha^{-1}) by the HFN (extremes between 0 and 142 fruits $tree^{-1}$) and insignificantly by FMW'09 variation, (r=0.012, extremes between 105 and 315 g $fruit^{-1}$).

Table 1

The correlation matrix between the fertilizers applied and the productivity indices in the IInd year (2008) and IIIrd year (2009) from orchard establishment (simple Pearson coefficients)

	N, P_2O_5, K_2O, MgO (kg/ha/year)	CTSA '08	MNFB '08	HFN '08	AICTSA '08	MNFB '09	HFN '09	HFN/FLN '09	FMW '09	PROD '09
N, P_2O_5, K_2O, MgO	1	-0.068	0.107*	0.034	-0.072	0.138**	0.178**	-0.048	-0.065	0.146**
CTSA '08	-0.068	1	-0.589**	-0.702**	0.912**	0.308**	0.080	-0.196**	0.276**	0.212**
MNFB '08	0.107*	-0.589**	1	0.826**	-0.676**	-0.360**	-0.070	0.275**	-0.164**	-0.156**
HFN '08	0.034	-0.702**	0.826**	1	-0.807**	-0.416**	-0.074	0.301**	-0.131**	-0.148**
AICTSA '08	-0.072	0.912**	-0.676**	-0.807**	1	0.413**	0.129**	-0.266**	0.232**	0.247**
MNFB '09	0.138**	0.308**	-0.360**	-0.416**	0.413**	1	0.264**	-0.643**	-0.007	0.292**
HFN '09	0.178**	0.080	-0.070	-0.074	0.129**	0.264**	1	0.167**	-0.312**	0.928**
HFN/FLN '09	-0.048	-0.196**	0.275**	0.301**	-0.266**	-0.643**	0.167**	1	-0.150**	0.117*
FMW '09	-0.065	0.276**	-0.164**	-0.131**	0.232**	-0.007	-0.312**	-0.150**	1	0.012
PROD '09	0.146**	0.212**	-0.156**	-0.148**	0.247**	0.292**	0.928**	0.117*	0.012	1

Figure 5 is representative for the results obtained in the high density apple orchards established at RIFG Pitesti - Romania, and presented in this paper.

a) b)

Fig. 5. High density apple orchard, in the third year after establishment: a) 'Golden Delicious' clone B cultivar and b. 'Jonagored' cv.

CONCLUSIONS

Early in the third year after orchard establishment the tendency of fruits production increase was noticed as a consequence of the applied fertilizers quantities ($N:P_2O_5:K_20:MgO$), from unfertilized to 100:50:150:50 kg ha^{-1}, the obtained fruits production ranging between 36.0 - 39.4 t ha^{-1}, on cvs. mean values.

The highest fruits production increase was registered at 'Golden Delicious' clone B cv., on which in the variant fertilized with $N:P_2O_5:K_20:MgO$ at the rates of 100:50:150:50 kg ha^{-1}, the production was almost double (51.2 t ha^{-1}) compared to the one obtained in the untreated control variant (27.6 t ha^{-1}).

It was noticed the favourable effect of the fertilizers application by fertigation on the number of flower buds in the second year (r=0.107*) and in the third year (r=0.138**), on the fruits number per tree (r=0.178**) and on fruits production (r=0.146**), in the third year after orchard establishment.

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