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Corelation Between Air Temparature, Rainfall and Weekly Fruit Growth Rate in Some Apple Varieties

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Abstract: The paper presents the results of a three year study on the correlation between air temparature, rainfall and weekly fruit growth rate in different apple varieties. The studies involved five high quality apple varieties including Golden Delicious-clone B, Jonagored, Gloster, Breburn and Red Fuji – Naga Fu- 2. The trial was set up at the experimental orchard of the Faculty of Agriculture in East Sarajevo.

The research results showed correlation between air temperature, rainfall and weekly fruit growth rate, significant differencies being observed in the intensity of correlation between the varieties studied. With some varieties the correlation was very weak and with others it was very high. Variations in the intensity of correlation beetwen air temperature, rainfall and fruit growth rate over the research period were induced by climate factors (temparature and rainfall).

Apart from the significant impact of climate factors (temperature and rainfall), significant differences in the intensity of correlation were most likely due to the genotypic specificity of response of each variety to different climate factors under given growth conditions.

Key words: correlation, temperature, rainfall, variety, fruit growth.

Introduction

Fruit growth is also significantly affected by external factors (temperature, rainfall). Fruit growth and development in fleshy fruit goes through four stages. The

initial three stages occur on the tree, starting from the stage of impregnation to fruit picking and the fourth one includes normal fruit ripening after the fruit picking stage. The results of the present study showed that fruit growth was dependent on climate factors (air temperature and rainfalls). The results on the effect of microclimate parameters on the dynamics of fruit growth in length in 2003 suggested very weak correlation between temperature, rainfall and fruit growth rate in varieties *Golden Delicious – Clone B, Morens Jonagored, Gloster*, and *Red Fuji – Naga Fu 2* and the absence of correlation in the *Breburn* variety. Very weak correlation between air temperature, rainfall and fruit growth in length (*Gloster*) and weak correlation of other studied varieties was observed in 2005.

Material and Methods

The study on the effect of climate factors on fruit growth rate during the growing season was conducted over 2003-2005 in five high quality varieties of apples: Golden Delicious-clone B, Jonagored, Gloster, Breburn and Red Fuji – Naga Fu- 2 at an experimental orchard in East Sarajevo. The orchard was established at 862 m altitude in the spring of 2001. The plantation has south-west exposure.

The trees were trained to willowy spindle and the planting distance was 4x1.5m. The rootstock for all the studied varieties was M9 and the surface area of the experimental plantation was 0.2 ha. The orchard was established on acid brown soil or distric cambisol.

The pheno-phase of fruit growth during the growing season was observed by measuring the fruit growth. The measuring of fruit length was performed by "Meba" portable measurer, having the accuracy of 0.1mm.

Measurements were conducted every seven days, starting from the 8th day after the fruit setting till the end of the fruit growth stage. A total of 15 fruits of each variety were randomly sampled for analysis. During the fruit growth, microclimate measurements of air temperature and rainfall were performed daily by standard meteorological equipment. Air temperature was measured by digital hydro thermometer in the crown zone of the orchard at 7:00 a.m., 2:00 p.m. and 9:00 p.m. The amount of rainfall was measured by a recording rain gauge after daily readings at 7:00 a.m. for the previous day. All of the measured values of the meteorological factors were correlated with weekly shoot growth values during the stated period. The multiple correlation and regression method was used to determine the effect of climate factors on the observed traits. The intensity of correlation was determined according to Roemer and Orphal chart:

Coefficient of correlation (r)	correlation strength
0.00 - 0.10	none
0.10 – 0.25	very week
0.25 – 0.40	week
0.40 – 0.50	medium
0.50 – 0.75	high
0.75 – 0.90	very high
0.90 – 1.00	full

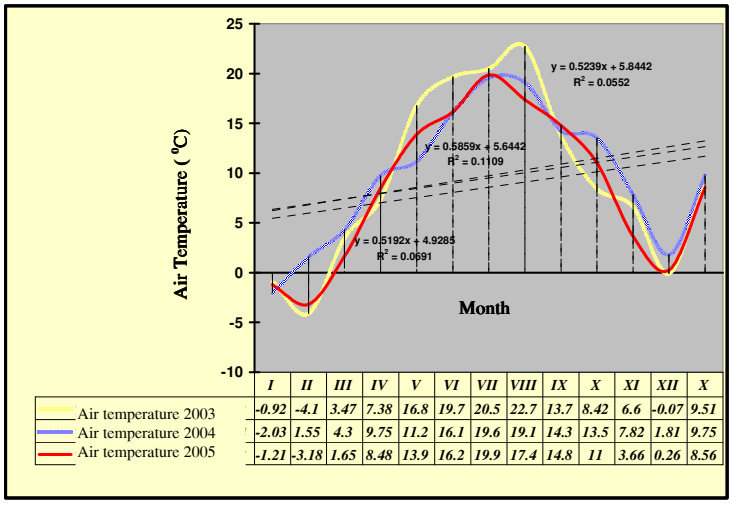
Results and Discussion

The fact that environmental factors have a significant effect on the biological quality of apple varieties was also emphasized by Mratinic *et al*. (2000). These authors report that all alien varieties have to be examined under various environmental conditions prior to their intensive production. Basic physiological processes in plants (assimilation, breathing, transpiration, absorption of nutritive substances and water, etc) occur only at certain temperature limits. Air temperature is one of the most important climate factors, being of high significance for the growth and development of fruits. The evaluation of intensive apple growth in an apple growing region necessitates detailed processing of climate factors (long-term standard) from the long-term average of the closest meteorological station (Krpina *et. al*. 2004). Apart from temperature, water is a major precondition for apple cultivation in contemporary high-density orchards. For normal growth, apples require 1000 mm of rainfall per annum and around 500 mm during the growing season. Furthermore, the required hydrometric coefficient (a correlation between the amount of rainfall and average air temperature in June, July and August), according to Popov, should be 1.5 – 2.7. (Adamic 1980). According to Misic (1994, 2004), apples require 900 mm of rainfall per annum and around 600mm during the growing season. Fruit increase in length is mostly dependent on the biological features of the species and a variety, as well as on environmental conditions (Misic 1978, Lucic *et. al*.1996, Misic 2004). According to the above authors, the optimal temperature for fruit growth is between 15 and 25 °C. Bulatovic and Mratinic (1996) also suggest that temperature is a significant factor affecting fruit growth.

Tacher (1984) also reports that fruit growth is significantly dependent on external factors. Other authors emphasize climate factors as being restricting factors of fruit growth (Childers 1975, Misic 1978, Bulatovic 1984, Stankovic and Jovanovic 1987, Gvozdenovic 1998, Velickovic 2002, Misic 2004). According to Lucic *et. al*. (1996), fruit growth and development of fleshy fruit species goes through 4 stages: three of them occur on the trunk, from the fecundation until the harvest, and the fourth one includes normal fruit ripening after harvest. Bulatovic and Mratinic (1996) specify that the growth and fruit development of fleshy fruit species goes trough three stages. The first one is the cell division stage (division of cells in the tissue of the pericarp and in the blossom box) and the second one – the fruit volume increase stage. The former lasts for 4-5 weeks for apples, according to Westwood (1978), while according to Zandke (1978) - it lasts for 3-4 weeks. It is characterized by cell division, intensive growth and an insignificant increase in fruit volume. It terminates when the nucleus has reached its maximum. The latter stage is the cell growth stage (increases in fruit volume and weight) or the accelerated fruit growth stage, being marked by significant anatomic morphological changes and the formation of organic substance. Fruit increase (growth) at this stage is highly dependent on both the available amount of water and temperature. According to Bulatovic and Mratinic (1996), if the drought started in this period, the fruit growth would stop, which could not be compensated for even with subsequent watering. The third stage or the stage of ripening (on the trunk–physiological ripeness) is characterized by anatomical and physiological changes in the fruit structure and also by the termination of fruit growth, Lucic *et. al*. (1996). The forth stage is the stage of fruit harvest maturity.

The results of the present study conformed to the reports made by the above authors, showing a significant dependence on climate factors (air temperature and rainfall). The results of the present study on the correlation between air temperature and rainfall and fruit growth rate values obtained during the weekly measuring operation over the research period are shown in Tables 1, 2, 3.

Fig. 2. Air temparature movements (°C) in experimental plantations over 2003-2005

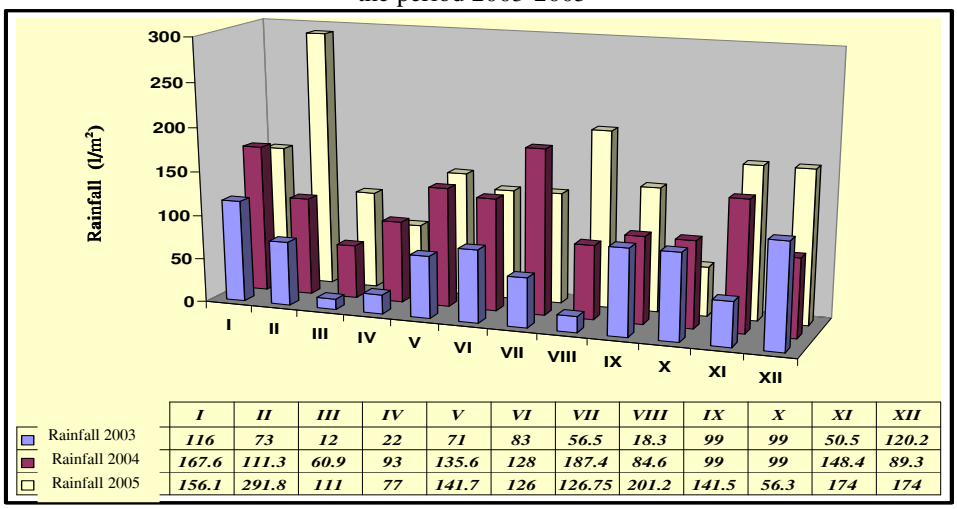


	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	X
Air temperature 2003	-0.92	-4.1	3.47	7.38	16.8	19.7	20.5	22.7	13.7	8.42	6.6	-0.07	9.51
Air temperature 2004	-2.03	1.55	4.3	9.75	11.2	16.1	19.6	19.1	14.3	13.5	7.82	1.81	9.75
Air temperature 2005	-1.21	-3.18	1.65	8.48	13.9	16.2	19.9	17.4	14.8	11	3.66	0.26	8.56

The average annual air temperature (Figure 1) for the experimental plantation in 2003 and 2004 was 9.51 °C and 9.75 °C, respectively, the latter being higher than the long-term standard for Sarajevo area (9.5 °C) by 0.25. In 2005, it was 8.46 °C.

In 2003, the total rainfall amount (Figure 2) for the experimental plantation was 953.00mm, being substantially smaller compared to the amount of rainfall in 2004 and 2005 (1,384.10 and 1,691.35mm), though still above the long-term standard for the region of Sarajevo. Rainfall distribution during the growing season in the studied period was uneven, the lowest rainfall during the growing season being recorded in March, April and August of 2003 (12.00, 20.00 and 18.30, respectively) and in March and August of 2004 (60.00; 90.00 and 84.60mm, respectively).

Fig. 2. Amount of rainfall (l/m^2) in experimental plantations for the period 2003-2005



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Rainfall 2003	116	73	12	22	71	83	56.5	18.3	99	99	50.5	120.2
Rainfall 2004	167.6	111.3	60.9	93	135.6	128	187.4	84.6	99	99	148.4	89.3
Rainfall 2005	156.1	291.8	111	77	141.7	126	126.75	201.2	141.5	56.3	174	174

Tab. 1. Correlation between air temparature, rainfall and fruit growth in lenght at weekly measurements in 2003

Variety	Coefficient of multiple correlation $R_{1.2..3.}$	p – value	Coefficient of multiple determination R^2 (%)	Partial coefficients of correlation				Partial coefficients of determination (%)	
				$r_{1..2..3}$	p – value	$r_{1. 3. 2}$	p – value	$r_{1..2..3}^2$	$r_{1. 3. 2.}^2$
I - Golden Delicious-clone B	0.4505	0.29	20.29	0.4325	0.06	0.3156	0.17	18.71	9.96
II - Morens Jonagored	-	-	-	-	-	-	-	-	-
III - Breburn	0.4080	0.45	16.65	0.3968	0.08	0.2644	0.26	15.75	6.99
IV - Gloster	0.3146	0.94	9.90	0.3129	0.18	0.0957	0.69	9.79	0.92
V - Red Fuji – Naga Fu 2	0.3850	0.67	14.82	0.3836	0.09	0.1948	0.41	14.71	3.79

P < 0.05 (* *significant at 95 % for R* (r) ≠ 0)
P > 0.01 (** *significant at 99 % for R* (r) ≠ 0)
NZ – non-significant

fruit growth in lenght r_1
temperature r_2
rainfall r_3

The study results (Table 1) showed medium correlation (coefficient of multiple correlation was 0.45) between air temperature and rainfall for the *Golden Delicious–Clone B* variety, while the correlation for the other varieties (*Breburn, Gloster and Red Fuji – Naga Fu 2*) was weak (coefficient of multiple correlation was 0.40, 0.31 and 0.38m, respectively).

The effect of air temperature and rainfall on the observed trait in *Golden Delicious - Clone B* was 18.71% (according to the partial coefficient of determination),

while in *Breburn, Gloster* and *Red Fuji-Naga Fu 2* it was 15.75, 9.79 and 14.71%, respectively. In individual terms, the effect of air temperature on the given trait was 18.71% and that of rainfall – 9.96%, in the *Golden Delicious - Clone B*, the effect on the *Gloster* variety being 9.79 % (by air temperature) and 0.92% (by rainfall).

Tab. 2. Correlation between air temparature, rainfall and fruit growth in lenght at weekly measurements in 2004

Variety	Coefficient of multiple correlation $R_{1.2..3.}$	p – value	Coefficient of multiple determination R^2 (%)	Partial coefficients of correlation				Partial coefficients of determination (%)	
				$r_{1..2..3}$	p – Value	$r_{1.3.2}$	p – value	$r_{1..2..3}^2$	$r_{1.3.2.}^2$
I - Golden Delicious-clone B	0.1949	0.32	3.80	0.1897	0.48	0.1057	0.70	3.60	1.12
II - Morens Jonagored	0.2478*	0.03	6.14	-0.1954	0.47	0.0871	0.75	3.82	0.76
III - Breburn	0.0493	0.17	0.24	0.0168	0.95	0.0493	0.86	0.03	0.24
IV - Gloster	0.2015	0.08	4.06	-0.0966	0.72	0.1389	0.61	0.93	1.93
V – Red Fuji – Naga Fu 2	0.1456	0.17	2.12	0.1444	0.59	0.0648	0.81	2.09	0.42

P < 0,05 (* *significant on level 95 % for R* (r) ≠ 0)
P > 0,01 (** *significant on level 99 % for R* (r) ≠ 0)
NZ – non significant

fruit growth in lenght r_1
temperature r_2
rainfalls r_3

The results on the effect of air temperature and rainfall on the observed trait (Table 2) show the absence of correlation in the *Breburn* variety (coefficient of multiple correlation was 0.05) and very weak correlation in *Golden Delicious - Clone B, Morens Jonagored* and *Red Fuji – Naga Fu 2* (coefficients of multiple correlation for the given varieties being 0.19, 0.25, 0.20 and 0.15, respectively). As regards the coefficient of multiple determination, the greatest impact of the studied factors on the studied trait was registered in the *Morens Jonagored* variety (6.14%) and the smallest in *Breburn* (0.24%). Individual impacts of air temperature on the given trait were weak according to the partial coefficient of correlation. For *Golden Delicious - Clone B* and *Red Fuji - Naga Fu 2* the partial coefficients of correlation were 0.19 and 0.15, respectively. Weak negative correlation was recorded in *Morens Jonagored* (partial coefficient of correlation - 0.20) and negative correlation or the absence of correlation - in *Gloster* (partial coefficient of correlation – 0.10). The greatest impact of air temperature on the observed point was recorded with *Breburn* variety (partial coefficient of determination being 0.03%). The partial coefficient of correlation suggests that the effect of rainfall on the given trait ranged from the absence of correlation in *Morens Jonagored* (the coefficient of partial correlation - 0.08), to very weak correlation for the *Gloster* variety (the coefficient – 0.13). The partial coefficient of determination suggests that the effect of rainfall on the weekly fruit growth rate ranged from 0.24% (*Breburn*) to 1.12% (*Golden Delicious - Clone B*) and that of temperature from 0.93% (*Gloster*) to 3.82 (*Morens Jonagored*).

Tab. 3. Correlation between air temparature, rainfall and fruit growth in lenght at weekly measurements in 2005

Variety	Coefficient of multiple correlation $R_{1.2..3.}$	p – value	Coefficient of multiple determination R^2 (%)	Partial coefficients of correlation				Partial coefficients of determination (%)	
				$r_{1..2..3}$	p – value	$r_{1.\ 3.\ 2}$	p – value	$r_{1..2..3}^2$	$r_{1.\ 3.\ 2.}^2$
I - Golden Delicious-clone B	0.2881	0.43	8.30	0.1191	0.66	-0.2005	0.45	1.42	4.02
II - Morens Jonagored	0.2028	0.20	4.11	0.1087	0.69	-0.2009	0.45	1.18	4.04
III - Breburn	0.2834	0.67	8.03	0.1769	0.51	-0.1413	0.60	3.13	1.99
IV - Gloster	0.1651	0.43	2.73	0.0243	0.93	-0.1415	0.60	0.06	2.00
V – Red Fuji - Naga Fu 2	0.2636	0.20	6.95	-0.0688	0.80	-0.2605	0.33	0.47	6.79

$P < 0,05$ (* significant on level 95 % for R (r) $\neq 0$)
$P > 0,01$ (** significant on level 99 % for R (r) $\neq 0$)
NZ – non significant

fruit growth in lenght r_1
temperature r_2
rainfalls r_3

The results on the correlation between air temperature, rainfall and fruit growth in length during the weekly measurements in 2005 (charts) showed very weak correlation in the *Gloster* variety (the coefficient of multiple correlation was 0.16) and weak correlation in the rest of the studied varieties: *Golden Delicious - Clone B, Morens Jonagored, Breburn* and *Gloster* (correlation coefficients: 0.29, 0.20, 0.28 and 0.26). The effect of the studied factors on the observed trait ranged from 2.73% (*Gloster*) to 8.30% (*Golden Delicious*). Individually speaking, the partial coefficient of correlation suggested the following correlation of air temperature and the observed trait: without correlation and negative correlation - for *Red Fuji - Naga Fu 2* (partial coefficient – 0.07) without correlation - for Gloster variety (partial coefficient – 0.02) weak correlation - for *Golden Delicious - Clone B* and *Red Fuji - Naga Fu 2* (partial coefficients of correlation – 0.19 and 0.15, respectively). The partial coefficient of determination suggests that the effect of temperature on the weekly fruit growth rate ranged from 0.06% (*Gloster* variety) to 1.42% (*Golden Delicious - Clone B*) and that of rainfall - from 1.99% (*Breburn*) to 4.02 and 4.04% (*Golden Delicious - Clone B* and *Morens Jonagored*, respectively).

Conclusion

The study results on the microclimate factors (air temperature and rainfall) on the dynamics of fruit growth in length in 2003 showed that correlation was recorded in the *Golden Delicious - Clone B* variety, and weak correlation of the above factors in the other varieties (*Breburn*, *Gloster* and *Red Fuji - Naga Fu 2*), the coefficient of multiple correlation being 0.40, 0.38 and 0.31, respectively.

Air temperature and rainfall for the *Golden Delicious - Clone B* variety have exerted a 18.71% effect on the observed trait, whereas the effect in *Breburn, Gloster* and *Red Fuji - Naga Fu 2* was 15.75, 9.79 and 14. 71%, respectively.

The results on the effect of microclimate parameters (air temperature and rainfall) on the dynamics of fruit growth in length in 2004 suggested a very weak correlation in *Golden Delicious - Clone B, Morens Jonagored, Gloster* and *Red Fuji - Naga Fu 2* and the absence of correlation in the *Breburn* variety (the coefficient of multiple correlation being 0.05). The coefficient of multiple determinations showed that the greatest effect on the given area ranged from the absence of correlation in the *Morens Jonagored* variety to very weak correlation in the *Gloster* variety.

The results on the correlation between air temperature, rainfall and fruit growth in length, during the weekly measurements conducted in 2005 showed a very weak correlation in *Gloster* variety, and weak correlation in the rest of the studied varieties. The effect of the studied factors on the observed trait ranged from 2.79% *(Gloster*) to 8.30% (*Golden Delicious - Clone B*).

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KORELACIONI ODNOS TEMPERATURE VAZDUHA, PADAVINA I VREDNOSTI PRIRASTA PLODOVA KOD NEKIH SORTI JABUKE

- originalni naučni rad –

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Rezime

U radu su prikazani rezultati trogodišnjih proučavanja korelacionih odnosa temperature vazduha, padavina i sedmičnih vrednosti prirasta plodova u dužinu kod različitih sorti jabuke. Proučavanja su obavljena sa pet visokokvalitetnih sorti jabuke: *Zlatni delišes–Klon B*, *Morns Džonagored*, *Gloster*, *Breburn* i *Red Fudži - Naga Fu* – 2. Ogled je postavljen na zasadu Poljoprivrednog fakulteta u Istočnom Sarajevu. Rezultati proučavanja u ispitivanom periodu su pokazali postojanje korelacionih odnosa između temperature vazduha, padavina i vrednosti sedmičnih prirasta plodova i uočene su značajne razlike u jačini korelacije između proučavanih sorti. Korelacija se kretala od jako slabe do jake. Odstupanja u jačini korelacije između temperature vazduha, padavina i vrednosti prirasta plodova u dužinu, posmatrano po proučavanim godinama, posledica su značajnog uticaja klimatskih činilaca (temperatura i padavine) na dato obeležje. Značajne razlike u jačini korelacije, pored značajnog uticaja klimatskih činilaca (temperatura i padavine) na posmatrano obeležje, mogu se tumačiti i kao rezultat genotipskih specifičnosti svake sorte da različito reaguje na klimatske faktore u datim uslovima gajenja.