Response of young apricot trees to natural zeolite, organic and inorganic fertilizers

T. Milošević[1], N. Milošević[2]

[1]Department of Fruit Growing and Viticulture, Faculty of Agronomy, University of Kragujevac, Cacak, Serbia
[2]Department of Pomology and Fruit Breeding, Fruit Research Institute, Cacak, Serbia

ABSTRACT

The study focused on characterizing five apricot cultivars to acknowledge the impact of natural zeolite (Agrozel type), cattle manure, composite NPK (15-15-15) and calcium ammonium nitrate (CAN) on tree vigour, precocity, yield performance and fruit quality attributes. The results showed that Agrozel induced the highest tree growth in all cultivars, yield and cumulative yield in Vera, Harcot and Roxana and yield efficiency in Aleksandar, Vera and Roxana. The higher fruit weight of all cultivars was found after the manure application. Composite NPK plays a major role in soluble solids, total sugars and titratable acidity accumulation, whereas CAN and Agrozel applications resulted in a higher soluble solids/titratable acidity ratio and flesh firmness in most of the cultivars.

Keywords: fruit size; soluble solids content; titratable acidity; tree vigour; yield efficiency

Fertilization is one of significant cultural practices for the agricultural production, including fruit crops. Fertilizers used in apricot orchards influence performance of the scion cultivar. They affect apricot fruit set, fruit quality, tree growth, yield and yield efficiency (Jackson 1970, Asma et al. 2007).

Using organic fertilizers will benefit not only crops, which have undoubtedly both better output and quality of the nutrients available in organic form, but also environment itself. It is also important to note that all manures improve behavior of several elements in soils through their active groups (fluvic and humic acids) which have the ability to retain the elements in a complex or chelate forms and consequently improve the plant growth as well as quantity and quality of yield (Katayama 1993, Kabeel et al. 2005, Stino et al. 2009).

Mineral fertilizers applied to agricultural crops have a great beneficial potential to maximize yields, but they can contribute also to environmental pollution (air, water, soil), when applied in too high quantities, at the wrong time or within inappropriate application techniques. The optimal amount and modern management practice guarantee high yield and quality products and minimize possible negative effects. Studies on the effects of K and P alone or as NPK compounds on apricot tree growth, yield and fruit quality were not investigated enough (Dimitrovski and Cevetkovic 1981, Huguet 1988). Most of the works done on this subject was focused on N fertilization (Crisosto et al. 1997, Asma et al. 2007).

In recent decades, the increasing demand for environmental protection and production of food that does not endanger health requires an increase in production of materials to be used in natural agriculture and horticulture. Natural zeolites, due to their structural, ion exchange and sorption properties and also many other characteristics are well suited for agricultural uses – in animal as well as plant production (Reháková et al. 2004), especially on devastated, degraded and acidic soils. The application of zeolites to soils increases their electrical conductivity (EC), and as a result, it increases nutrient retention capacity, and usually increases soil pH (soil conditioner) (Dwairi 1998). It was verified that when mixed with N, P and K compounds, zeolite enhances the action of such compounds as slow-release fertilizers, both in horticultural and extensive crops (Reháková et al. 2004). Additionally, zeolites improve growth and development of plants and their application resulted in a yield increase (Torii 1978). Since acidic soils are dominant in Serbian fruit orchards, fertilization of fruit trees, including apricot, requires a new management practice (Milosevic and Milosevic 2009).

From these purposes, the objectives of this study were to determine the impact of natural zeolite, organic and conventional mineral fertilizers on tree growth, productivity and fruit quality attributes of five apricot cultivars grown on acidic soil in Western Serbian conditions.

MATERIAL AND METHODS

Plant material and field trial. From 2008 to 2010, five apricot cultivars (Aleksandar, Biljana, Vera, Harcot and Roxana) grafted on Myrobalan seedlings were evaluated. Trees, spaced at 5.5 m × 3 m, were planted in 2007 in a randomized block design with five trees in four replications for each cultivar-fertilizer combination; training system is open vase. Standard cultural practices, except irrigation, were performed. The trial was carried out at the Prislonica near Cacak (43°53'N, 20°21'E, 330 m a.s.l), Western Serbia on soil with 1.62% organic matter, 0.16% total N (N_{tot}), 178 mg/kg P and 220 mg/kg K and sandy-loam texture. The soil pH in 0.01 mol/L KCl was 4.86. Soil analyses were done prior to the experiment.

Weather conditions of Cacak are characterized by the mean growing season temperature and total rainfall of 17.0°C and 408.6 mm for the long term averages, respectively. Discrepancies of these data during experimental period were not observed.

The soil treatments involved the application of the organic fertilizer – cattle manure with 0.5% N, 0.3% P, 0.6% K and 25% organic matter on dry weight (T_1); NPK in the form of 15-15-15, (T_2); calcium amonium nitrate (CAN) with 27% of N_{tot} (T_3) mineral fertilizers, and natural zeolite (Agrozel type, Milosevic and Milosevic 2009) (T_4) included the following: (a) $T_1 = 5$ kg/m^2; (b) $T_2 = 0.05$ kg/m^2; (c) $T_3 = 0.03$ kg/m^2, and (d) $T_4 = 1$ kg/m^2. T_1, T_2 and T_4 were applied in the autumn of 2007, 2008 and 2009, while T_3 was introduced in the spring of 2008, 2009 and 2010. All fertilizers were distributed on the experimental plot in a 1 m wide band along the rows and then rotary-tilled into the soil.

Tree growth and yield traits. Trunk circumference was measured during the end of vegetative cycle 20 cm above the graft union, and the trunk cross-sectional area (TCSA, cm^2) was calculated. Yield per tree (Y, kg), cumulative yield per tree (CY, kg) and yield efficiency (YE, kg/cm^2) (final Y/final TCSA) of each cultivar-fertilizer combination were computed from the harvest data.

Fruit quality attributes. Fruit weight (FW, g), soluble solids content (SSC, °Brix), total sugars content (TS, % on a fresh weight basis), titratable acidity (TA, % of malic acid), SSC/TA rate or ripening index (RI) and flesh firmness (FF, 0.5 kg/cm^2) were measured at commercial ripening. FW were taken using a Tehnica ET-1111 scale (Iskra, Horjul, Slovenia). SSC were assessed by hand refractometer Milwaukee MR 200 (ATC, Rocky Mount, USA) at 20°C; TA was determined using titration device Metrohm 719S (Titrino, Herisau, Switzerland) with 0.1 mol/L NaOH up to pH 8.1. Once the SSC and TA were assessed, the RI was calculated. TS were determined according to the Luff-Schoorl method. FF was measured using a Bertuzzi Penetrometer FT-327 (Facchini, Alfonsine, Italy).

Data analysis. Data were evaluated by the analysis of variance with SPSS 7.0 (SPSS Inc., Chicago, USA). When the *F* test was significant, means were separated by the *LSD* test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Tree growth and yield. Tree growth, as measured by TCSA, was significantly affected by the fertilizers starting from the second year after planting; all cultivars showed higher values in T_4, and lower in T_1 and T_3 (Table 1, Figure 1). In the other fertilizers application, tree growth was intermediate. Thus, Milosevic and Milosevic (2009) described a positive effect of Agrozel on the apple tree growth. Namely, the application of natural zeolites to soils improves the fertility and biological activity of the soil, increases soil pH, increases the production capacity of acid and devastated soils and stimulates growth (Dwairi 1998). On the other hand, Stino et al. (2009) did not find a significant increase concerning vegetative growth of apricot trees when using organic fertilization, which confirmed our results. TCSA shown at all

Table 1. Trunk cross-sectional area (TCSA), yield, yield efficiency and cumulative yield of five apricot cultivars fertilized with Agrozel, organic and inorganic fertilizers, in the second to fourth year after planting

Cultivar	Fertilizer treatment	TCSA (cm^2) year 2010	Yield (kg/tree) year 2010	Yield efficiency (kg/cm^2) year 2010	Cumulative yield (kg/tree) (2008–2010)
Aleksandar	T_1	28.07 ± 1.03^d	5.34 ± 2.01^d	0.19 ± 0.06^c	8.76 ± 2.43^d
	T_2	36.08 ± 1.05^c	7.52 ± 3.12^c	0.21 ± 0.08^b	12.18 ± 3.21^c
	T_3	36.94 ± 1.14^b	10.51 ± 3.99^a	0.28 ± 0.09^a	17.34 ± 4.11^a
	T_4	37.81 ± 1.08^a	10.10 ± 4.01^b	0.27 ± 0.09^a	16.56 ± 3.87^b
Biljana	T_1	54.34 ± 1.12^d	4.81 ± 2.22^d	0.09 ± 0.05^a	7.79 ± 2.57^d
	T_2	58.60 ± 1.05^b	5.26 ± 2.03^a	0.09 ± 0.05^a	8.57 ± 2.71^a
	T_3	56.98 ± 1.09^c	5.09 ± 3.31^b	0.09 ± 0.05^a	8.24 ± 2.66^b
	T_4	61.34 ± 1.07^a	4.95 ± 3.31^c	0.08 ± 0.04^b	8.16 ± 2.39^c
Vera	T_1	24.27 ± 1.07^d	3.00 ± 1.92^d	0.12 ± 0.04^b	4.95 ± 1.99^d
	T_2	31.75 ± 1.18^c	6.26 ± 3.21^c	0.20 ± 0.06^a	10.33 ± 2.87^c
	T_3	32.76 ± 1.08^b	6.53 ± 3.33^b	0.20 ± 0.08^a	10.77 ± 3.03^b
	T_4	35.45 ± 1.05^a	6.62 ± 3.12^a	0.19 ± 0.05^a	10.86 ± 2.98^a
Harcot	T_1	29.21 ± 1.40^b	4.97 ± 3.81^d	0.17 ± 0.05^d	8.25 ± 3.89^d
	T_2	22.89 ± 1.22^c	6.34 ± 3.99^c	0.28 ± 0.08^c	10.52 ± 4.37^c
	T_3	21.39 ± 1.23^d	9.23 ± 4.00^b	0.43 ± 0.09^a	15.32 ± 4.54^b
	T_4	31.16 ± 1.28^a	10.32 ± 3.76^a	0.33 ± 0.09^b	17.13 ± 4.67^a
Roxana	T_1	25.95 ± 1.42^d	8.80 ± 2.33^d	0.34 ± 0.08^c	14.08 ± 2.89^d
	T_2	38.90 ± 1.21^b	12.93 ± 3.04^c	0.33 ± 0.10^c	20.82 ± 3.66^c
	T_3	34.30 ± 1.23^c	15.17 ± 3.56^b	0.44 ± 0.13^b	24.42 ± 4.22^b
	T_4	39.46 ± 1.17^a	19.51 ± 4.21^a	0.49 ± 0.15^a	31.41 ± 4.53^a

For T_1–T_4 see section 'material and methods'; means followed by the same small letters, within the same column, are not significantly different (*LSD* at $P \leq 0.05$)

fertilizers treatments was related to high vigour of the Biljana trees. It can be thus recommended for planting on poor soils.

In the first bearing year (2008), yield was low, ≈ 0.5 kg/tree (data not shown), and there were no significant differences among fertilizer applications. However, in the next bearing years, differences among fertilizers became evident, manure being the one providing the lowest Y for all cultivars (Table 1). The highest Y and CY were recorded from T_4 in Vera, Harcot and Roxana, from T_2 in Biljana, and from T_3 in Aleksandar. Some authors reported that natural zeolites have possibility to increase yields (Torii 1978), especially on poor and acidic soils (Reháková et al. 2004). Also, Asma et al. (2007) reported that N application resulted in an increase in apricot CY compare to P and K applications, which partially confirms our results. In 2010, Y and CY were also affected by the type of cultivar, being always greater in Roxana. A clear influence of genotype on productivity was observed in apricot (Bussi et al. 2003).

YE was significantly affected by the fertilizers (Table 1). In general, the best YE value was recorded in Roxana fertilized with T_4, due to its high yield and low TCSA. The lowest YE was recorded in Biljana. In Aleksandar, T_3 and T_4 induced the highest YE, while the lowest was shown in T_1. In Vera, higher YE was shown in T_1, T_2 and T_3, and lower in T_4. In Harcot, the YE was higher in T_3 and lower in T_1. It seems that response of apricots to fertilizers has an important genotype effect, as previously reported (Chatzitheodorou et al. 2004). Interestingly, T_1 induced the lowest Y, CY and YE

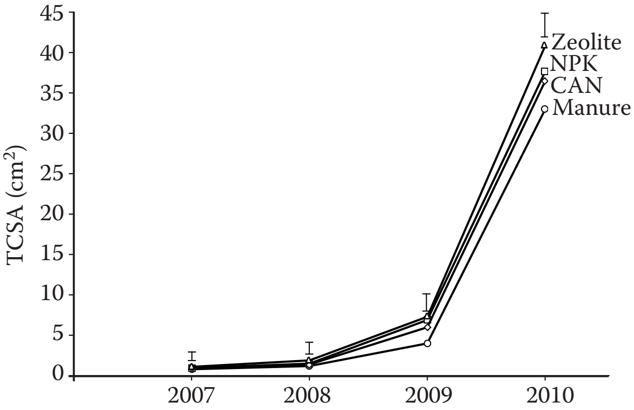

Figure 1. Fertilizers influence on the trunk cross-sectional area (TCSA) of five apricot cultivars from the second (2008) to the fourth (2010) year after planting; vertical lines indicate *LSD* at $P \leq 0.05$. NPK – composite NPK (15-15-15) mineral fertiliser; CAN – calcium amonium nitrate

in all cultivars, except Biljana. This might be due to the slow release of organic fertilizer (Ganzhara 1998), and herewith availability of required mineral nutrients in the root zone (Jackson 1970, Katayama 1993).

Fruit quality. Data analysis indicated that fertilizers had a strong influence on the FW and fruit chemical composition (Table 2). Generally, T_1 induced significantly higher FW in all cultivars. The lowest FW was registered in T_2 and T_3 for Aleksandar, in T_2 and T_4 for Biljana, and in T_4 for Vera, Harcot and Roxana. The increase in FW with T_1 was mainly due to higher availability of nutrients at T_1 throughout the growing season. These results are in accordance with the findings of Chatzitheodorou et al. (2004) and Kabeel et al. (2005). Moreover, some authors reported that

Table 2. Fruit quality attributes of five apricot cultivars fertilized with Agrozel, organic and inorganic fertilizers (data are mean ± SE values from three successive years)

Cultivar	Fertilizer treatment	FW (g)	SSC (°Brix)	TS (%)	TA (%)	RI	FF (0.5 kg/cm²)
Aleksandar	T_1	75.30 ± 3.19^a	17.40 ± 0.70^a	11.81 ± 0.63^d	0.63 ± 0.02^b	27.62 ± 1.02^a	0.74 ± 0.07^a
	T_2	73.34 ± 2.99^b	17.70 ± 0.82^a	12.32 ± 0.76^a	0.71 ± 0.03^a	24.93 ± 0.97^b	0.56 ± 0.06^b
	T_3	73.12 ± 2.76^b	17.35 ± 0.69^a	11.73 ± 0.54^c	0.60 ± 0.02^c	28.92 ± 1.13^a	0.73 ± 0.06^a
	T_4	74.33 ± 3.00^{ab}	17.50 ± 0.73^a	12.01 ± 0.71^b	0.62 ± 0.02^{bc}	28.22 ± 1.09^a	0.77 ± 0.06^a
Biljana	T_1	72.30 ± 4.73^a	16.00 ± 0.70^b	12.95 ± 0.84^c	0.76 ± 0.03^a	21.05 ± 0.98^b	1.50 ± 0.21^a
	T_2	70.43 ± 3.54^b	16.70 ± 0.82^a	13.48 ± 0.91^a	0.79 ± 0.03^a	21.13 ± 1.01^b	1.15 ± 0.18^c
	T_3	71.21 ± 4.12^{ab}	15.80 ± 0.64^c	12.64 ± 0.72^d	0.67 ± 0.02^b	23.58 ± 1.98^a	1.34 ± 0.14^b
	T_4	70.87 ± 3.99^b	16.10 ± 0.71^b	13.00 ± 0.89^b	0.69 ± 0.02^b	23.33 ± 1.76^a	1.41 ± 0.29^a
Vera	T_1	81.10 ± 4.12^a	16.00 ± 0.31^c	12.97 ± 0.75^c	0.58 ± 0.02^b	27.59 ± 1.32^b	1.14 ± 0.08^a
	T_2	80.05 ± 3.75^{ab}	16.70 ± 0.71^a	13.31 ± 0.86^a	0.60 ± 0.02^{ab}	27.83 ± 1.43^b	0.99 ± 0.07^a
	T_3	79.12 ± 3.12^{ab}	15.75 ± 0.63^d	12.66 ± 0.67^d	0.53 ± 0.01^c	29.72 ± 2.06^a	1.11 ± 0.07^a
	T_4	77.58 ± 3.45^b	16.20 ± 0.44^b	13.12 ± 0.81^b	0.61 ± 0.03^a	26.56 ± 1.61^b	1.20 ± 0.08^a
Harcot	T_1	85.00 ± 4.77^a	16.40 ± 0.89^a	9.20 ± 0.69^c	0.92 ± 0.03^a	17.83 ± 0.99^{ab}	1.06 ± 0.08^a
	T_2	83.21 ± 4.12^{ab}	16.95 ± 0.91^a	10.24 ± 0.87^a	0.98 ± 0.04^a	17.29 ± 0.79^b	0.76 ± 0.04^a
	T_3	81.22 ± 3.78^{ab}	16.10 ± 0.62^a	9.68 ± 0.71^b	0.88 ± 0.03^a	18.29 ± 1.04^a	0.98 ± 0.05^a
	T_4	80.40 ± 3.41^b	16.30 ± 0.68^a	9.69 ± 0.81^b	0.94 ± 0.03^a	17.34 ± 0.80^{ab}	1.00 ± 0.05^a
Roxana	T_1	102.10 ± 4.03^a	12.80 ± 0.54^{bc}	6.66 ± 0.39^a	1.11 ± 0.04^a	11.53 ± 1.00^a	0.80 ± 0.10^a
	T_2	100.90 ± 3.07^{ab}	13.50 ± 0.66^a	6.78 ± 0.43^a	1.33 ± 0.05^a	10.15 ± 0.86^b	0.46 ± 0.10^d
	T_3	97.90 ± 4.93^{ab}	12.70 ± 0.27^c	6.37 ± 0.35^a	1.00 ± 0.04^a	12.70 ± 1.76^a	0.74 ± 0.11^b
	T_4	96.10 ± 2.41^b	12.90 ± 0.30^b	6.70 ± 0.41^a	1.03 ± 0.03^a	12.52 ± 1.84^a	0.70 ± 0.17^c

For abbreviations see section 'material and methods'; means followed by the same small letters, within the same column, are not significantly different (*LSD* at $P \leq 0.05$)

the influence of organic fertilizers is not solely attributed to its content of nutrients but also to its beneficial effects on the soil structure and soil pH and used releasing fixed macro- and micronutrients (Eghaball and Power 1994). In the present study, FW was also affected by the type of cultivar, being always greater in Roxana. It seems to indicate that FW has a strong genetic influence (Milošević et al. 2010).

Data presented in Table 2 show that SSC and TS were significantly affected by fertilizers application. The highest and the lowest SSC for Biljana, Vera and Roxana cultivars were induced by T_2 and T_3, respectively, whereas differences among applied fertilizers were not significant for SSC in Aleksandar and Harcot. Similarly, higher TS levels were induced by T_2 in all cultivars, and lover by T_3 (Aleksandar, Biljana, Vera) and by T_1 (Harcot), respectively. Differences among fertilizers were not significant for TS in Roxana. It is clear from the Table 2 that TA was significantly affected by fertilizers, except in Harcot and Roxana. In Aleksandar and Biljana, the highest TA was recorded from T_2, and the lowest from T_3 in the both of them. In Vera, the greatest TA was found from T_4, and the lowest from T_3. These results are similar to the findings of Bussi and Amiot (1998) who reported that N applications had no effects on SS and sugars, but increased with K application. In our study, T_3 significantly decreased SSC, TS and TA. These results were supported and in lined with the literature, because the set of fruit quality traits in our study was the best when applied fertilizer containing K originated from composite NPK (Dimitrovski and Cvetkovic 1981, Bussi et al. 2003). Also, the soil in our trial is an important resource of available K. Additionally, our range of all above values is in accordance with the findings of Rahović (2003).

The RI is an important fruit quality-determining factor in apricot. In Aleksandar and Roxana the highest RI was induced by T_1, T_3 and T_4, and the lowest by T_2; in Biljana, the highest RI was induced by T_3 and T_4, and the lowest by T_1 and T_2 (Table 2). In Vera, T_3 produced high RI when compared with other cultivars. In Harcot, the highest RI was induced by T_3 and the lowest by T_2. Similar tendencies were observed in the other studies (Crisosto et al. 1997). Additionally, beside fertilizers, it can be stated that RI was basically conditioned by the cultivar (Crisosto et al. 2004).

The FF was significantly affected by fertilizers, except in Vera and Harcot (Table 2). In Aleksandar, higher FF was found in T_1, T_3 and T_4 and lower in T_2; in Biljana, the highest values were induced by T_1 and T_4, and the lowest by T_2. In Roxana, the greatest FF was recorded in T_1 and the lowest in T_2. Ballinger et al. (1966) reported that K fertilization had little or no effect on firmness of peaches, while Hernández-Fuentes et al. (2002) indicated that soil applications of fertilizers with high N content reduced fruit firmness of this species, because FF receiving calcium nitrate was higher than the FF of those fertilized with N and composite NPK (Raese 1998). According to Cemagref (1981) the quality standards for apricot at harvest maturity are a firmness value between 3.0 and 0.5 kg/cm^2. From this point, all apricots are suitable for consumers and apricot industry.

It is concluded from the results that five apricots did not always respond to the various fertilizer treatments in the same way, indicating a genotypic effect. This may be attributed to the reason that tree growth, yield and fruit quality of a variety are controlled by its genetic make up rather than the agronomic practices such as fertilization.

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Corresponding author:

Prof. Dr. Tomo Milošević, University of Kragujevac, Faculty of Agronomy, Department of Fruit Growing and Viticulture, Cara Dusana 34, 32000 Cacak, Serbia
e-mail: tomomilosevic@kg.ac.rs