Response of peaches to fertilizer application and nutrient use efficiency in Bulgaria

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Abstract

"Best agricultural practices for sustainable crop nutrition in Bulgaria" was the topic of an extensive research project supported by the International Plant Nutrition Institute (IPNI) during the period 2009-2012. Omission plot trials (control, N, P, K, NP, NK, PK, NPK, NPKMg) were arranged in field, vegetable, fruit crops and wine grapes. One of the tested crops were peaches, which are an important fruit crop in the country. The peach trials were carried out on two locations in the two most suitable regions for peach growing in the country (Sliven and Petrich). This paper presents the effect of fertilization on the yield and nutrient omission (N, P and K) from the triple fertilizer combination. Two nutrient use efficiency (NUE) indicators, partial factor productivity (PFP) and agronomic efficiency (AE), were estimated. The results showed that the peaches' response was quite different in the two locations. In Sliven, where the soil fertility was better, the main limiting nutrient was nitrogen and in Petrich, the main limiting nutrient was potassium in accordance with the low K level in the soil in this region. The NUE indicators showed better efficiency in Petrich. PFP for NPK treatment was higher in Petrich – 100 kg kg^{-1} per unit nutrient in comparison with Sliven (57 kg kg^{-1}). AE for N was almost the same for both sites – 20 kg kg^{-1} (Sliven) and 22 kg kg^{-1} (Petrich). AE for P and K was two times higher in Petrich compared to Sliven. The results at both sites suggest that fertilizer recommendations for peaches should account for the specificity of the site in question.

Keywords: peach, omission effects of nutrients, nutrient use efficiency (NUE)

INTRODUCTION

Peach is one of the main fruit crops grown in Bulgaria. Because of climatic diversity in Bulgaria, large industrial plantations were established mainly in several distinct regions (valley of Tundzha, on the Black Sea, the valleys of rivers Struma and Kamchia) (Mitov et al., 1996). The fertilization of peach plantations is one of the main agricultural practices, which keeps plant growth and fruiting of trees. Among the three major nutrients, nitrogen is the element which strongly affects the vegetative plant growth, yield and fruit size (Bussi et al., 1994; Nario et al., 2003; Olmstead et al., 2015; Pascual et al., 2016). The effectiveness of phosphorus is comparatively low, especially when it is applied in high rates (Taylor and Issell, 1971). Potassium also influences the yield but is important for the fruit quality as well (Mikhael et al., 2010). The overall efficiency of applied fertilizers depends on the nutrient: it is about 50% for N, less than 10% for P, and about 40% for K (Baligar et al., 2001). Important for increasing the nutrient use efficiency (NUE) is applying the 4R conception (right source, right rate, right time and right place), which can increase the nutrient efficiency a further 10 to 30% (Dobermann, 2007; Fixen, 2009). "Best agricultural practices for sustainable crop nutrition in Bulgaria" was the topic of an extensive research project supported by the International Plant Nutrition Institute (IPNI). One of the main goals of the project was studying the nutrient response in different crops, including peaches.

MATERIAL AND METHODS

Two representative sites for peaches growing in Bulgaria were chosen to conduct the

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experiments. One of the trials was situated in the center of Southern Bulgaria, the region of Sliven (42°37’40.6”N 26°17’33.3”E). The second site was situated in South-West Bulgaria, the region of Petrich (41°24’52.5”N 23°12’26.4”E). The soil and climate conditions of the experimental sites are in the most favorable regions for peach production in the country. The peach cultivars were ‘Red Haven’ in Sliven (4 years after planning at the beginning of the experiment) and ‘Hale’ in Petrich (5 years after planting). The planting distance between the trees was 5×2.80 m, which is 14 m^2 $tree^{-1}$. The soil types were Fine-Silty, Mixed, Mesic Mollic Xerofluvents in Sliven and Sandy, Mixed, Mesic, Typic Xerofluvents in Petrich (Table 1).

Table 1. Soil characteristics and initial nutrient status.

Site	Sample depth (cm)	Clay content (%)	Humus content (%)	pH (KCl)	P_2O_5 (mg 100 g^{-1})	K_2O (mg 100 g^{-1})	MgO (mg 100 g^{-1})
Sliven	0-30	51.6	2.8	5.4	8.0	25	34
	30-60	50.2	2.7	5.0	7.0	20	34
Petrich	0-30	16.6	1.4	6.0	10.0	12.1	27
	30-60	24.8	0.8	6.0	9.3	8.8	18

The fertilizers used in the experiment were ammonium nitrate (N – 33.4%), triple superphosphate (P_2O_5 – 46%), potassium sulphate (K_2O – 50%) and potassium-magnesium sulphate (K_2O – 30%, MgO – 10%) only for the trial in Petrich. The layout of both trials was the same with addition and omission treatments: 1. unfertilized control; 2. N; 3. P; 4. K; 5. NP; 6. NK; 7. PK; 8. NPK and 9. NPKMg (only at the Petrich location). The fertilizing rates for both trials were: Sliven – N 120 kg ha^{-1}, P_2O_5 80 kg ha^{-1}, K_2O 120 kg ha^{-1}, Petrich – N 120 kg ha^{-1}, P_2O_5 100 kg ha^{-1}, K_2O 140 kg ha^{-1}, and MgO – 47 kg ha^{-1}. The nitrogen fertilizer rate was split in two part: half of it was applied early in the spring when the vegetative growth started. The second half was applied at the end of May, beginning of June. Phosphorus and potassium were applied every autumn before tillage of the orchard.

A randomized complete block design with four repetitions with two trees per replication was established. The trials were carried out over a period of four years (2009-2012). The effect of omission of every nutrient from the triple combination (NP, NK, PK) and the respective share of every nutrient from the total NPK omission effects were calculated. The omission effect of the primary nutrients N, P and K were calculated according to the following formula:

$$\text{N omission } (N_{om})\text{: Yield}_{NPK} - \text{Yield}_{PK} \text{ (kg ha}^{-1})$$

$$\text{P omission } (P_{om})\text{: Yield}_{NPK} - \text{Yield}_{NK} \text{ (kg ha}^{-1})$$

$$\text{K omission } (K_{om})\text{: Yield}_{NPK} - \text{Yield}_{NP} \text{ (kg ha}^{-1})$$

$$\text{Nutrient share in \%} = \text{Omission of single nutrient}/(\text{Omission}_N + \text{Omission}_P + \text{Omission}_K)$$

The obtained data were processed to calculate the two agronomic indexes for describing the nutrient use efficiency:

$$\text{Partial factor productivity (PEP)} = Y/F \text{ (kg kg}^{-1})$$

$$\text{Agronomic efficiency (AE)} = (Y-Y_0)/F \text{ (kg kg}^{-1})$$

where Y = yield of treatment with nutrient applied; Y_0 = yield with no nutrient applied; F = amount of nutrient applied.

RESULTS AND DISCUSSION

The relative yields outline a better nutrient response in Petrich where the soil fertility was lower than in Sliven (Table 2). Usually nitrogen is the most important nutrient that should be applied to ensure normal tree growth (Nario et al., 2003; Olmstead et al, 2015; Pascual et al., 2016). The trials showed that N was the main limiting nutrient – alone or in combination with P and K. These treatments (N, NP, NK) ensure a 7 to 12% higher yield at Sliven and a 8 to 23% higher yield in Petrich in comparison to the control trees. The best results in Sliven were obtained at NPK fertilization – 15% higher yield than in the control treatment. Chatzitheodorou et al. (2004a, b) also found the lowest productivity of 'Red Haven' peach cultivar in treatment P, K, PK and control in a similar experiment in Northern Greece.

Table 2. Average peach yields and relative yields for experimental period (2009-2012).

Treatment	Sliven (Red Haven)		Petrich (Hale)	
	Yields (t ha^{-1})	Relative yields (%)	Yields (t ha^{-1})	Relative yields (%)
Control	15.76	100	25.42	100
N	17.60	112	27.49	108
P	16,39	104	26.28	103
K	16.12	102	29.14	115
NP	17.11	109	30.96	122
NK	16.86	107	31.39	123
PK	15.77	100	29.27	117
NPK	18.14	115	33.90	133
NPKMg			35.72	141

The low potassium content in the soil in Petrich (Table 1) likely determined the good potassium addition response (15% yield increase), which is the highest yield increase for the application of any of the three single nutrients (Table 2). The best results in Petrich and Sliven were obtained after NPK fertilization. The yield from the NPK treatment in Petrich was 33% higher compared to the control. The yield difference between the same treatments in Sliven was 15%. Magnesium addition to NPK increased the yield with about 6%. In general, the results obtained for peaches at both sites showed that the balanced NPK fertilization was the most effective.

Nutrient addition and omission effects are among the modern NUE indicators (Dobermann, 2007; Fixen, 2009; Murell, 2009). In the present study N, P and K omission effects for peaches at both sites were used as indicators for nutrient use efficiency assessment (Figure 1). In fact, the omission effect gives information about the yield losses when the application of a given nutrient is omitted. The data show quite different results in the two locations. In Sliven, the biggest yield loss was when N was omitted while lower losses were observed when P or K were omitted. In Petrich, the omission responses did not differ as much as in Sliven but the yield losses for the three nutrients were significant. The highest yield losses in Petrich were registered after omitting K in accordance with the low K level in the soil. The sum of N, P and K omission effects were also quite different in the two locations. The cumulative effect of the omission for the three elements was 4.7 t ha^{-1} for Sliven and 8.1 t ha^{-1} for Petrich. Beside the direct nutrient omission effects, their share in the total NPK omission effect was also indicative for the nutrient use efficiency (Figure 2). The results again show differences between the two locations. In Sliven, the omission of N led to the highest (about 50% of total yield loss) reduction of the fertilizer efficiency. In Petrich, the omission of each of the three nutrients led to almost the same yield loss, a slightly higher loss for K was observed.

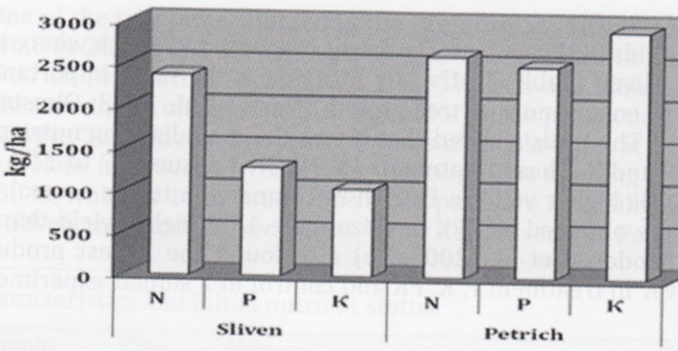

Figure 1. Nutrient omission effects in peaches (kg ha^{-1}).

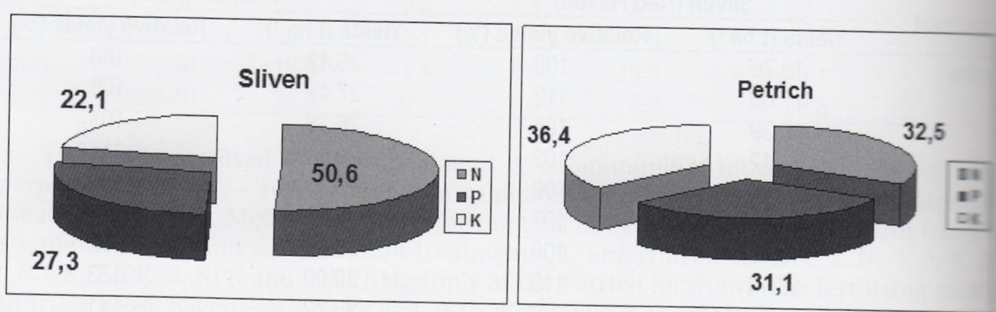

Figure 2. Share of individual nutrients from the total NPK omission effect (%).

NUE indicators PFP and AE are presented in Table 3. PEP of N for peaches was higher compared to the values of the indicator for cereal crops, which was determined to be 40-90 kg kg^{-1} (Fixen et al., 2015) (Table 3). This was probably due to the higher yields of peaches. PFP for P and K were in the range of normal values for the field crops cited by Fixen et al. (2015). The different yield level and nutrient responses at both sites conditioned the differences between these NUE indicators, which were higher in Petrich in spite of the higher fertilization rates for P and K. On both locations, the highest PFP was obtained for P. PFP for the common NPK application in Petrich was almost two times higher compared to PFP in Sliven.

Table 3. Nutrient PFP and AE for peaches.

Location	PFP (kg kg^{-1})			AE (kg kg^{-1})				
	N	P_2O_5	K_2O	NPK	N	P_2O_5	K_2O	MgO
Sliven	147	205	134	57	20	16	9	
Petrich	229	328	208	100	22	32	21	39

The AE of N and P in peaches was in the normal range of both nutrients for cereal crops, 15-30 and 15-40 kg kg^{-1}, respectively (Fixen et al., 2015). AE of K was considerably lower in comparison to the AE of cereal crops, established as 75-200 kg kg^{-1} (Table 3). AE for N was almost the same at both sites. For P and K the same indicator was two times higher in Petrich compared to the Sliven site. High AE was obtained from Mg in Petrich (Table 3), which is probably due to the low content of available magnesium especially in deep soil layers (Table 1).

CONCLUSIONS

To summarize, the yield level was quite different at the two sites – almost twice higher in Petrich than in Sliven. Peaches responded different, depending on the site specificity, although in both sites the most effective treatment was the balanced NPK application. In Sliven, where the soil fertility was higher, the main limiting nutrient was N and its omission contributed about 50% of the total omission yield loss. In Petrich, where K content in the soil was low, the main limiting nutrient was K and its omission contributed about 36% of the total omission yield loss. The NUE indicators PFP and AE showed a higher efficiency in Petrich than in Sliven. The results from both sites suggest that the nutrient management of peaches should take site-specific factors into consideration.

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