Estimation of Soil Fertility from Organic Plantations Strawberries and Raspberries in the South-Eastern Poland

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Keywords: pH, macronutrients, rhizosphere, salinity

ABSTRACT:

Studies conducted in the years 2014-2015 were designed to evaluate of soil fertility from 22 organic farms specializing in the cultivation of strawberries and raspberries from the south-eastern Poland. Evaluated soil sampled in 56 different plantation of strawberries and raspberries. Soil pH was determined in distilled water (pH_{H2O}). Soil fertility determined in the extract of 0.03 M CH3COOH and the content of available forms of nitrate nitrogen ($N\text{-}NO_3$), phosphorus ($P\text{-}PO_4$), potassium (K), calcium (Ca) and magnesium (Mg) were expressed in mg dm^{-3} as well as in mg $100g^{-1}$ dry soil. In addition in soil samples salinity was determined expressed as g NaCl dm^{-3}.

Analysis of the results obtained in the studies showed that the pH of the soils studied (pH_{H2O}) was in the range 4.60-7.60. The content of macronutrients in the soils contained in compartments (mg dm^{-3}): <10.0-19.8 $N\text{-}NO_3$, 2.0-33.0 $P\text{-}PO_4$, 10.0-239.0 K, 107.0-3930.0 Ca, 26.0-134.0 Mg.

Ocena zasobności gleb z ekologicznych plantacji truskawki i maliny w południowo-wschodniej Polsce

Słowa kluczowe: pH, makroskładniki, ryzosfera, zasolenie

STRESZCZENIE:

Badania przeprowadzone w latach 2014-2015 miały na celu ocenę zasobności gleb w 22 gospodarstwach ekologicznych specjalizujących się w uprawie truskawki i maliny, zlokalizowanych w południowo-wschodniej Polsce. Badaniom poddano 56 prób glebowych z plantacji truskawki i maliny. Odczyn gleby (pH) oznaczono w wodzie destylowanej (pH_{H2O}). Zasobność gleby określano w ekstrakcie 0,03 M CH_3COOH, a zawartości dostępnych form azotu azotanowego (N-NO_3), fosforu (P-PO_4), potasu (K), wapnia (Ca) i magnezu (Mg) wyrażono w mg·dm^{-3}, jak również w mg·$100g^{-1}$ suchej gleby. Ponadto w próbkach glebowych określono poziom zasolenia wyrażony jako g NaCl dm^{-3}.

Analiza wyników uzyskanych w badaniach wykazała, że odczyn badanych gleb (pH_{H2O}) zawierał się w zakresie od 4,60 do 7,60. Zawartość makroskładników w badanych próbkach gleb zawierała się w przedziale (mg·dm^{-3}): ≤10,0-19,8 N-NO_3, 2,0-33,0 P-PO_4, 10,0-239,0 K, 107,0-3930,0 Ca, 26,0-134,0 Mg.

1. INTRODUCTION

Organic production in Poland is currently the fastest growing sector of plant production. Between 2003 and 2013 the number of organic farms in Poland increased more than 11-fold from 2 286 in 2003 to nearly 26.6 thousand in 2013. According to the data available under the Eurostat in 2012 Poland was on the 3rd place in the European Union in terms of number of organic farms and their total area occupied almost 670 thousand ha. In the structure of organic crops planted berry species occupy approx. 8.9%, which is 59.6 thousand ha [20].

One of the most important factor providing normal growth, development and yield of crop is optimal nutrition. This condition can be fulfilled only by maintaining proper pH of rhizosphere and ensuring proper absorption of nutrients [6]. The basis for balanced fertilization of soil, according to the Code of Good Agricultural Practice is the calculation of precise dose of fertilizer based on the results of chemical analysis showing the current abundance of the rhizosphere.

The analysis of orchard soils in Poland carried out using the Egner-Riehm`s and Schachtschabel`s methods, which allows to specify the rhizosphere fertility in phosphorus, potassium and magnesium. A lot of authors point to drawbacks this solution, such as the ability to determine only three nutrients (P, K and Mg) and too strong activity of liquids extracts which inflate results and weakly correlate with the amount of nutrients uptaken by plants [3, 18]. The alternative for the assessment of soil fertility by methods of Egner-Riehm and Schachtschabel can be using of Spurway`s method, modified by Nowosielski [14], witch extraction 0.03 M acetic acid [3, 18]. This method, popularly so-called as `Universal` is used in Poland for the assessment of vegetable soil fertility and horticultural substrates and to develop on the basis of the results of fertilizer recommendations. The possibility of using `Universal` method with extraction 0.03 M acetic acid in the assessment of orchard soil fertility was reported by Komosa i Stafecka [8], Stafecka and Komosa [18] and Domagała-Świątkiewicz [3].

The aim of the study was to evaluate soil fertility from organic cultivation of strawberries and raspberries based on `Universal` method of analysis, undertaken after extraction in the extract 0.03 M CH_3COOH.

2. MATERIALS AND METHODS

The study was conducted in autumn 2014 and spring 2015 years. The study included 22 organic farms specializing in the cultivation of strawberries and raspberries from the south-eastern Poland – mostly located on the Lublin plateau and highlands of Sandomierz. Evaluated soils was sampled in 56 different plantation of strawberries cultivar `Honeoye` and `Polka` as well as primocane fruiting raspberries cultivar `Polana`. The soil samples were taken in accordance with applicable standards [15]. The collected soil samples

were subjected to chemical analysis by Universal method [14] after the extraction of 0.03 M acetic acid in a laboratory of the Regional Chemical--Agricultural Station in Lublin and in Sandomierz. Soil reaction (pH_{H2O}), marked potentiometrically, as well as total salt concentration (EC), marked conductometrically, were determined in suspension with a mix of distilled water and examined soil in volumetric ratio 1:2 [14]. The average values of pH_{H2O}, included in the Table 1, was determined after bringing all partial results to the actual numbers of hydrogen ion concentration [H^+]. Soil salinity (EC) was expressed as g NaCl dm^{-3} .
The content of available forms of nitrate nitrogen ($N\text{-}NO_3$) were determined by Bremner`s method (as modified by Starck), phosphorus ($P\text{-}PO_4$) calorimetrically with ammonium vanadomolybdate while potassium (K), calcium (Ca) and magnesium (Mg) by AAS method. The content of available nutrients in the soil were expressed in mg dm^{-3} as well as in mg $100g^{-1}$ dry soil, after determining the actual bulk density of each soil.

3. RESULTS AND DISCUSSION

The basis of the fertilizer recommendation is a correct knowledge of content in the soil available to plants nutrients. Methods applied in Poland as a standard for chemical analysis of orchards soils, Egner-Riehm`s and Schachtschabel`s methods, overstate results and poorly correlate with the amounts uptaken by plants [18]. Previous studies indicate, that in the diagnosis of fertilizing needs of berry plants `Universal` method may be used with extraction of 0.03 M acetic acid [3]. To elaborate of fertilizer recommendations on the basis of soil content obtained after extraction with 0.03 M acetic acid, however, it requires the development of optimal ranges for this method.
The study showed that the pH of soil collected from the organic cultivation of strawberries and raspberries ranged from 4.60 to 7.60 with an average of 5.97 and standard deviation 0.71 (Tab. 1). According to Milosevic et al. [12], the optimal range of pH, measured at 0.01 M KCl for field cultivation of strawberries is in the range 4.60-6.50. Moreover, they indicate that the acidic soil (pH 4.0) are less suitable for strawberry production than alkaline (pH 8.0). Buskiene and Uselis [2] recommended for raspberry cv. `Polana` optimal soil reaction pH on the range 5.5-6.5. These authors emphasize that the alkaline soil pH affects negatively on the nutrition of plants due to difficulties in micronutrients absorption.
The conducted study showed a low content of the available mineral nitrogen ($N\text{-}NO_3$) in the tested samples of soil, containing in the range 1.0-19.8 mg dm^{-3}, with average content 8.65 mg dm^{-3} and SD 4.87 [8, 14]. According to Muramoto et al. [13] strawberry is nitrogen sensitive crop, furthermore yield as well as quality of strawberry fruits are strongly affected by plant N status. Bottoms et al. [1] prove that the content of mineral nitrogen in the soil is poorly correlated with the content of this nutrient in plants of strawberries and therefore those results have of limited value as an indicator of crop N status. In turn Buskiene and Uselis [2] argue that the nutrient requirements of primocane raspberries cv. `Polana` for nitrogen is high and the optimal supply in nitrogen and potassium is a major yield-forming factor. Similarly to nitrogen, low phosphorus content in soils was shown in the research, containing in the range 2.0-33.0 mg dm^{-3}, with average content 17.6 mg dm^{-3}. According to Lacertosa et al. [10] phosphorus content of less than 10 mg dm^{-3} should be considered as a low soil abundance.

Table 1 Estimation of soil properties from organic cultivation of strawberry and raspberry analyzed by Universal method in extract of 0.03 M CH_3COOH [14]

Soil parameter	Range	Average	SD
pH (H_2O)	4.60-7.60	5.97	0.71
EC (g NaCl·l^{-1})	0.06-0.90	0.24	0.16
$N\text{-}NO_3$ (mg·dm^{-3})	1.0-19.8	8.65	4.87
$P\text{-}PO_4$ (mg·dm^{-3})	2.0-33.0	17.6	9.75
K (mg·dm^{-3})	10.0-239.0	95.1	49.0
Ca (mg·dm^{-3})	107.0-3930.0	623.4	775.8
Mg (mg·dm^{-3})	26.0-134.0	68.4	26.5

In the tested soils was recorded from 10.0 to 239.0 mg dm^{-3} of available potassium, with the average content 95.1 mg dm^{-3} and a standard deviation 49.0. According to Kelling et al. [7] optimum range of potassium for strawberry and raspberry cultivation is 91-120 mg dm^{-3}.

In the opinion of Domagała-Świątkiewicz [3] one of the disadvantages of the standard methods used in Poland for the assessment of soil fertility from strawberry and raspberry cultivation (i.e. Egner-Riehm`s and Schachtschabel`s methods) is the need of calcium precipitation before potassium measuring. This procedure excludes the possibility of determination of the content of calcium available in the tested soil. As reported Trejo-Tellez and Gomez-Merino [19] when strawberry plants grow in soil with Ca deficit, leaf blades are crinkled, tips fail to expand fully, and becoming black (so-called "tip-burn"). Furthermore fruits are hard in texture, and acid to the taste. Lieten [11] reporting, that in a soilless cultivation of strawberry Ca application rates lower than 2 mmol l^{-1} significantly reduced vegetative development, runner formation, fruit weight, fruit number and total yield. Author proves, that Ca deficient in strawberry cultivation caused plants "tip burn", cracking of stolons, and glossy curd formation on the inflorescences. In presented study from 107.0 to 3930.0 mg dm^{-3} of available calcium with the average content 623.4 mg dm^{-3} and a standard deviation 775.8 was recorded. According to Kelling et al. [7] optimum range of calcium for strawberry and raspberry cultivation is 601-1000 mg dm^{-3} of soil.

Lacertosa et al. [10] also noticed to maintain optimal ratio between potassium, calcium and magnesium in soil as a most important in cultivation of strawberry and raspberry.

Interesting is a comparison of the results of soil fertility from organic plantation of strawberry and raspberry expressed in mg $100g^{-1}$ dry soil (Tab. 2-3) to the value recommended by the Komosa et al. [9]. Both in the cultivation of strawberries and raspberries in all the tested soils content of mineral nitrogen and phosphorus available to plants it was below the recommended values for Komosa et al. [9]. Low abundance of soil nitrogen and phosphorus content significantly lowers the productivity of plants [6, 19], however at the same time minimizes the risk of runoff of nitrates and phosphates into the ground water. Similar results were reported by Glover et al. [4] and Pushpanjali [16]. Higher levels of nitrate and phosphate in soils from organic cultivation of strawberries were presented by Reganold et al. [17] stating, that the soil with organic farming have greater microbial functional capability and resilience to the stress.

Table 2 Estimation of nutrients contents in the soils from organic cultivation of strawberries analyzed in the extract of 0.03 M CH_3COOH (by Universal method) compared to the value recommended by the Komosa et al. [9]*

Soil parameter	Recommended range (mg 100 g^{-1})*	Percentage of soils containing nutrient:		
		Below range	Optimum range	Above the range
$N\text{-}NO_3 + N\text{-}NH_4$	2.5-5.0	100.0	0.0	0.0
$P\text{-}PO_4$	3.0-6.0	100.0	0.0	0.0
K	5.0-8.0	33.3	44.5	22.2
Ca	25.0-40.0	44.4	19.5	36.1
Mg	3.0-6.0	11.1	63.9	25.0

Table 3 Estimation of nutrients contents in the soils from organic cultivation of raspberries analyzed in the extract of 0.03 M CH_3COOH (by Universal method) compared to the value recommended by the Komosa et al. [9]*

Soil parameter	Recommended range (mg 100 g^{-1})*	Percentage of soils containing nutrient:		
		Below range	Optimum range	Above the range
$N\text{-}NO_3 + N\text{-}NH_4$	2.5-5.0	100.0	0.0	0.0
$P\text{-}PO_4$	3.0-6.0	100.0	0.0	0.0
K	5.0-8.0	20.0	25.0	55.0
Ca	25.0-40.0	10.0	50.0	40.0
Mg	3.0-6.0	0.0	70.0	30.0

In assessing of the fertility of studied soils in potassium 44.5% organic plantation of strawberries and 25% organic plantation of raspberries had the content of this nutrient at an optimal level, recommended by Komosa et al. [9]. Moreover 22.2% of the tested soils from the cultivation of strawberries and 55.0% from raspberries had the higher potassium fertility than recommended (Tab. 2-3).

Higher soil richness of potassium as an optimal range for raspberry suggest Hargreaves et al. [5]. The authors recognize 98-126 mg kg^{-1} (i.e. 9.8-12.6 mg $100g^{-1}$) extractable K as a soil adequate for raspberry production. Regarding these recommendations to the results obtained in presented study, only 45% of tested soils can be included as an optimal and high fertility.

As many as 44% of testing soils with organic cultivation of strawberries and 10% of the organic cultivation of raspberries classified as a soil with a low calcium content. Taking into account the important role of calcium in the growth of plant organisms in the progress of fertilizer recommendations for organic cultivation of strawberry and raspberry emphasis should be on necessity complement this element in the soil.

Conducted research has shown that evaluated soil samples had the best supply of magnesium. In 63.9% of the soils from strawberry cultivation was noted the optimum range of magnesium content, while 25% had a content above the range. In the case of raspberries plantations all tested soils were classified as an optimum or above the range with magnesium content.

According to Bottoms et al. [1] correct diagnosis in the soil of available nutrients can improve the efficiency of fertilization system. Therefore there is a need to develop precise range of soil fertility for the method of analysis of the root environment determining the abundance of available forms of nutrients.

4. CONCLUSIONS

Analysis of the results obtained in the studies showed that the pH of the tested soils (pH_{H2O}) was in the range 4.60-7.60. The content of macronutrients in the soils contained in compartments (mg dm^{-3}): <10.0-19.8 $N\text{-}NO_3$, 2.0-33.0 $P\text{-}PO_4$, 10.0-239.0 K, 107.0-3930.0 Ca, 26.0-134.0 Mg. Comparing the results obtained in the present study to the recommended ranges in the tested soils reported the best supply with magnesium and potassium and worst with nitrate nitrogen and phosphorus.

The conducted research showed a need to develop precise range of soil fertility for the method of analysis of the root environment determining the abundance of available forms of nutrients.

5. ACKNOWLEDGEMENTS

We would like to thank heartily Bioberry Co Limited for support in carrying out of the present study.

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