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Full Length Research Paper

Effects of a certified organic fertilizer on the yield and market quality of root parsley (*Petroselinum crispum* (Mill) Nym. ex A.W. Hill ssp. *tuberosum* (Bernh.) Crov.)

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The study shows the results of a four-year study on the effects of *Siforga*, a certified organic fertilizer on the yield and market quality of the root of the parsley variety *Berliner medium long*. The researched fertilizer quantities were at the rates of 500, 1.000, 2.000 and 3.500 kg ha^{-1} and the control treatment was a plot where no organic fertilizer was applied. Field trials were conducted in the spring cycle of parsley growing, from 2005 to 2008, in Starcevo, on anthropogenic soil of subtype chernozem with signs of gley in loess. The results of these study show that the lowest root yield was found in the control treatment (23.22 t ha^{-1}), while the highest yield was found in the treatment with 1.000 kg ha^{-1} of Siforga (37.03 t ha^{-1}). The best market quality of parsley root, that is, the largest portion of 1st class roots had 3.500 kg ha^{-1} at rate of Siforga, whereas the poorest quality was obtained at 500 kg ha^{-1} rate of Siforga (75.11%).

Key words: Root parsley, organic fertilizer, root yield, market quality.

INTRODUCTION

The optimum content of biogenic elements and favorable chemical properties of soil, along with the absence of harmful and dangerous matter are a prerequisite for the production of high-quality and safe food of plant origin. With the aim of providing a solution to the challenges of organic fertilization in sustainable agricultural systems, modern industry has offered to the market organic fertilizers with higher content of necessary macro and micro elements, in forms which substantially satisfy the needs of plants and enable application with the machinery already used for the application of mineral fertilizers. One of such industrial organic fertilizers, being the subject of this paper, was tested in field trials with root parsley.

Parsley (*Petroselinum crispum* (Mill) Nym. ex A.W. Hill ssp. *tuberosum* (Bernh.) Crov.) is a biennial herbaceous plant, which forms a leaf rosette and a fleshy root in the first year and in the second year it forms a flower stem and runs to seed. Two botanical varieties are grown; leaf parsley and root parsley. Its fleshy root and leaves are rich in vitamins C and E, β-caroten, minerals (especially potassium, calcium, phosphorus and iron), crude fiber and protein (Buchter-Weisbrodt, 2005). For example, the leaves of tuber-rooted parsley are commonly produced for this purpose till now in Poland (Kołota, 2011). Gajc-Wolska et al. (2006) listed leaf and root of parsley among vegetables with valuable antioxidative properties, reducing a risk for many civilization diseases. The root is usually boiled and added to soups, while fresh or dried leaves are used as a seasoning. Due to the growing use of parsley in nutrition and in order to make its fresh roots and leaves constantly available to the market, it is necessary to sow it in different seasons (Rabin, 1987).

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In order to grow parsley, large quantities of fertilizer are required because it forms considerable foliage and root mass. Back in the mid 20th century, Becker-Dillingen (1950) stated that the expected yield of 10 t ha^{-1} of parsley root required 24 kg ha^{-1} of nitrogen, 23 kg ha^{-1} of phosphorous (P_2O_5) and 76 kg ha^{-1} of potassium (K_2O). Along with 30 t ha^{-1} of burnt manure for the fertilization of parsley, Laumonnier (1962) also recommended the application of the following quantities of fertilizers: 100 kg ha^{-1} N, 95 kg ha^{-1} P_2O_5 and 180 kg ha^{-1} K_2O. The quantity of yield obtained from overwintering plants may depend on the applied cover and fertilization (Rumpel et al., 1995; Biesiada and Kołota, 1996).

Parsley belongs to the group of plants with high nitrate content, therefore a potential unbalanced quantity of nitrogen fertilizers can lead to excessive quantities of nitrates and other nitrogen compounds (Santamaria, 2006). Apart from a well-balanced and timely mineral nutrition, the quality and yield of parsley root are, to a large extent, influenced by the applied farming technology and the choice of irrigation technology, which jointly effect the changes in soil volume and porosity, thereby improving the productive and qualitative properties of parsley (Rumpel and Kaniszewski, 1994; Kaniszewski and Dyśko, 2008). Unfortunately, the issue of mineral nutrition of root parsley has not been explored much in this country; therefore, our research was, to an extent, rendered more difficult. The aim of this study was to determine the effects of the application of different amounts of certified organic fertilizer on the yield and market quality of parsley root.

MATERIALS AND METHODS

A four-year trial was conducted from 2005 to 2008, in Southern Banat (locality Starcevo, Serbia (N 44° 48′, E 20° 41′), on anthropogenic soil of the subtype chernozem with signs of gley in loess. For this study, the seeds of the root parsley variety '*Berliner medium long*' were used (Institute of Vegetables, Smederevska Palanka, Serbia). Certified organic fertilizer *Siforga* (manufactured by the Dutch company MeMon BV, P.O Box 1129 6801 BC Arnhem, The Netherlands) was applied at rates of 500, 1000, 2000 and 3500 kg ha^{-1} (with the proportion of basic macroelements (5% N, 3% P_2O_5 and 8% K_2O). The fifth treatment was the control plot, where organic fertilizer was not applied. According to the new Rulebook on the conditions for classification and determining the quality of fertilizers, variations in the content of nutrients, minimum and maximum values for nutrient content, as well as the declaration content and ways of labeling fertilizers, *Siforga* and similar fertilizers were classified as organic fertilizers by the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia.

Siforga is therefore, an organic fertilizer produced by thermal processing, dehydration and pelletizing of poultry manure. The pellets are 1 to 2 and 2 to 5 mm in size, which enables quality broadcasting by the machinery that is used for the application of conventional fertilizers. Apart from 5% N, 3% P_2O_5 and 8% K_2O, *Siforga* also contains Mg (0, 8%), Ca (9, 1%) and traces of microelements (Fe, Mn, B, Mo, Zn and Cu). Another favorable characteristic of this fertilizer is the fact that it has been enlisted in the register of approved plant nutrition products which can be used in organic farming in Serbia, created by the relevant ministry of agriculture, forestry and water management. The experimental design was a randomized complete block with four replications. The size of the basic experimental plot was 12 m^2 (2 × 6 m). In each study year, previous crop was tomato. Apart from Siforga, none of the other organic or mineral fertilizers were applied in the experimental plot. The 40% of the examined organic fertilizer was incorporated during fall and before plowing and the remaining 60% was applied in March, before sowing.

In each study year, sowing was performed by hand, in the second half of March (20/03/2005, 24/03/2006, 18/03/2007 and 24/03/2008), according to the recommendation of Bjelic et al. (2005). The experimental plot had the row spacing of 30 cm and plants were later thinned to the recommended intra row spacing of 3 cm. Sowing depth was 1 cm and sowing rate was 7 kg ha^{-1}. During vegetation, the standard plant management was applied, consisting of thinning, regular weeding and crust breaking; this was done mechanically, without the use of herbicides. Prior to root digging, leaves were harvested and above-ground mass was removed from the plot. In each study year, root harvesting was done in the third decade of October. After removing the leaves, roots were washed thoroughly in cold water, cleaned and then weighed.

Analysis of the technological quality of the root is defined by the SRPS Standard E.B1.132 from 2009 (Rulebook on technological and other requirements for fruits, vegetables and their products intended for industrial processing; "Official Gazette RS", No. 63/09). According to the Rulebook on the quality of fruits, vegetables and mushrooms (2004), before its placement on the market, parsley is classified into two classes, 1st and 2nd. Parsley of 1st class must be whole, uniform in shape and size, without branches and must have root juice. According to the size of the diameter of parsley, it is graded and marketed with the root diameter of 10 to 30 mm and a diameter over 30 mm of root. Parsley of 2nd class must comply with the aforementioned conditions, but the roots need not to be uniform in shape and size. In order to determine market quality of root, 100 roots were taken from two middle rows each and then weighed according to proscribed standards.

Agroecological conditions

Meteorological factors during vegetation were different in each of the four study years (Tables 1 and 2). Soil drought or excessive soil moisture during the period of intensive growth in July and August, lead to the decrease in quality and yield of the market-usable parsley leaf and root (Rumpel and Kaniszewski, 1994). During vegetation period in 2005, the amount of rainfall had the values which were in accordance with average rainfall for several years. The exceptions in this year were the month of March with precipitation that was 12.9 mm larger than the average precipitation for several years and August with 117.5 mm of rainfall, which was the largest rainfall during the study and which was 66.2 mm more than the ten-year average. Rainfall deficit was recorded in May (15 mm), September (54.3 mm) and October (42 mm). Regarding the rainfall during vegetation period in 2006, annual rainfall sum was 515.8 mm, which was 39.5 mm more than the average for several years. The largest rainfall surplus of 69.9 mm was recorded in June and the largest deficit of 60.3 mm was in July, in comparison to the average for several years.

Even distribution of rainfall in this year helped to facilitate undisturbed growth and development of parsley root. The driest month and the only month without precipitation during the four-year period of research, was April 2007. The absence of rainfall in April was somewhat compensated with high reserves of winter moisture, which substantially mitigated the initial development of parsley. In July, precipitation was 15.1 mm, which amounts to 20.4% of the average for several years. Rainfall deficit in April and July, followed by a large number of high temperature + low humidity days and

Table 1. Monthly precipitation sums (mm) for the experimental locality.

Year	XI - II	III	IV	V	VI	VII	VIII	IX	X	Σ
2005	232.4	38.8	60.4	38.1	72.4	67.0	117.5	34.7	12.4	673.7
2006	211.6	78.0	86.4	35.6	137.3	13.6	116.9	28.8	19.2	727.4
2007	182.1	99.6	0.0	80.3	80.3	15.1	32.2	73.6	102.1	665.3
2008	251.7	59.5	34.0	48.0	81.5	37.2	24.6	87.9	18.1	642.5
$\bar{x}$	219.5	69.0	45.2	50.5	92.9	33.2	72.8	56.3	38.0	677.2
95′ – 04′	181.0	25.9	61.0	53.1	67.7	73.9	51.3	89.0	54.4	657.3

Table 2. Average monthly temperatures (°C) for the researched locality.

Year	XI - II	III	IV	V	VI	VII	VIII	IX	X	$\bar{x}$
2005	2.1	4.8	12.1	17.2	20.3	22.7	20.8	18.4	12.7	14.6
2006	2.2	5.7	13.3	17.5	20.5	24.7	21.5	19.3	15.0	15.5
2007	5.9	9.6	14.3	19.8	24.1	25.3	24.2	16.4	11.8	16.8
2008	3.2	9.0	13.7	19.4	23.3	23.5	23.9	16.7	14.6	16.4
$\bar{x}$	3.4	7.3	13.4	18.5	22.0	24.1	22.6	17.7	13.5	15.8
95' – 04'	3.1	7.1	12.7	18.4	22.0	23.3	23.4	17.0	12.6	15.5

Table 3. Basic agrochemical characteristics of chernozem with signs of gley in loess.

Depth (cm)	pH (KCl)	$CaCO_3$ (%)	Humus (%)	Total N (%)	P_2O_5 (mg in 100 g of soil)	K_2O (mg in 100 g of soil)
0 - 30	7.32	3.85	3.53	0.231	28.0	46.2
30 - 60	7.20	5.35	3.36	0.222	22.9	37.5

extremely high daily temperatures, has made 2007 one of the least favorable years for agriculture. Rainfall distribution in 2008 was undoubtedly favorable especially large precipitation was recorded in the period of winter dormancy and during March. However, slower sprouting and decrease in the final number of plants per unit caused the decrease in the yield and market quality of parsley root.

According to the values of average monthly temperatures, the first two study years have approximately same values, while the third and fourth year have similar values of this meteorological indicator. During winter (November-February) in 2005 and 2006, average monthly temperatures were 2.1 and 2.2°C, respectively which was around 1°C lower than the average for several years. In the same period of the production years 2007 and 2008, measured average values were 5.9 and 3.2°C, respectively. This bears out the fact that 2007 had one of the warmest winters. Average monthly temperature for the whole vegetation season in 2005 was 0.9°C lower than the ten-year average. In 2006, this value was the same as the value for the average of several years. In 2007, it was 1.3°C higher and in 2008 it was 0.9°C higher than in the same comparative period. Average monthly temperatures in March and April 2005 were 4.8 and 12.1°C, respectively which was 2.3°C and 0.6°C, lower respectively, when compared to the ten-year average. Regarding the whole study period, the only other average monthly temperature that was lower in comparison to the average of several years was recorded in March and it was 2.3°C lower, which is important for the normal development of sprouts because plants are sensitive to temperature stress in the sprouting stage.

The 'warmest' recorded year was 2007, when average monthly temperatures were higher than the ten-year average. In the second and third decade of July and in the first decade of August, we had 30 with high temperature + low humidity days (max. daily temperature higher than 30°C) and in the 14 days of this period, extremely high maximum daily temperatures of up to 43°C have been measured. Such high temperatures were also accompanied by drought in this period. Similar situation was recorded in 2008, with slightly lower average monthly temperatures when compared to 2007, except in the case of September and October. According to agrochemical analyses, this soil type is characterized by highly productive soil properties (Table 3). The pH value expressed as KCl in both depths (0 to 30 cm and 30 to 60 cm) is above 7.2, which assigns this soil to the group of alkaline soils.

The values of humus are around 3.45%. Easily accessible K_2O and P_2O_5 have the values of optimum to high content of these elements, which is the result of ample fertilization, rather than the existence of natural reserves. Testing for the significance of differences across mean values of examined factors (organic fertilizers and year) was done by using the analysis of variance model, with the following mathematical formula:

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

Where, (i=1,2,3; j=1,2; k=1,2,3,4)

All significance values were calculated by using the F-test and LSD-test for the significance threshold of 5 and 1%. A two-way analysis of variance (ANOVA) was carried out with the statistical software Statistica Vers.8, while the regression analysis of the effect of increasing fertilizer quantities on yield and quality class of parsley root was done with the software package OriginPro Vers.7.5.

Table 4. Parsley root yield (t ha^{-1}) at increasing quantities of „Siforga" organic fertilizer.

Siforga rate (kg ha^{-1})	$N:P_2O_5:K_2O$ (kg ha^{-1})	Year				Average
		2005	2006	2007	2008	
0	0:0:0	26.91	39.07	17.43	9.46	23.22
500	25:15:40	34.17	46.76	19.84	16.05	29.20
1000	50:30:80	37.38	53.45	33.72	23.55	37.03
2000	100:60:160	39.62	47.52	27.44	25.01	34.90
3500	175:105:280	40.00	50.08	34.30	23.52	36.97
Average		35.62	47.37	26.54	19.52	-

	Year	Siforga rate	Year × Siforga rate
$LSD_{0.05}$	2.02	2.25	4.51
$LSD_{0.01}$	2.68	3.00	5.99

RESULTS AND DISCUSSION

The ANOVA F-test showed that parsley root yield in the experiment was equally affected by the applied rates of *Siforga* organic fertilizer and weather conditions of the year ($F_{pr}<0,001$), while the effect of their interaction was slightly smaller, but statistically significant ($F_{pr}=0,012$). In a four-year average, the highest root yield (37.03 t ha^{-1}) was obtained in the fertilization with 1.000 kg ha^{-1} of Siforga (Table 4). Root yield in this treatment was considerably higher than in the unfertilized control treatment (by 59%) and in the treatment fertilized with 500 kg of Siforga (by 27%). The increase of fertilizer quantity to 2000 and 3500 kg ha^{-1} did not cause the expected increase in root yield that is, root yield after fertilization with 3500 kg ha^{-1} of Siforga was almost identical to the yield after 1000 kg, while the fertilization rate of 2000 kg ha^{-1} of Siforga produced lower yield in comparison to the previous one, although this decrease was not significant statistically.

Regarding individual years, the situation was similar to the yearly average. Although, the highest yields in 2005 and 2007 were obtained with fertilization rates of 3500 kg ha^{-1} of Siforga, statistically significant differences were not determined in comparison to the trial with 1000 kg ha^{-1} of this fertilizer. Therefore, although the effect of this organic fertilizer on the increase of parsley root yield is unquestionable, it can be concluded that it is statistically justified only up to the fertilizer quantity of 1000 kg ha^{-1}. Possible causes of subsequent stagnation (or even a slight decrease in root yield in individual years) at increased quantities of this fertilizer should be sought in the high natural fertility of the soil on which the trials were conducted; then in the increased lushness of the above-ground parts of parsley and the impossibility of substantial root widening (thickening) at intra row plant spacing of 3 cm. Even though this study did not examine the yield of above-ground mass, it has been observed visually that it was significantly higher in trials with increased dosages of Siforga. Some future studies are needed to determine the influence of Siforga to the ratio of weight of above-ground parts to root yield, because there are not existing relevant data. Both in individual years and in the average for several years, root yield at increasing quantities of *Siforga* organic fertilizer followed the curves of quadratic regression (Figure 1). Based on the regression equation ($Y=-2,22056E\text{-}6X^2 + 0,01117X + 24,39189;\ R^2=0,83$), theoretically, regressionally averaged maximum root yield (38,44 t ha^{-1}) is obtained at the fertilization with approximately 2500 kg ha^{-1} of Siforga. On the basis of these findings on the significance of differences across the examined treatments, it is evident that theoretically calculated fertilizer quantities required for the maximum root yield differ considerably from the statistically (and probably financially) justified quantities.

When comparing the results of numerous authors (Sazonova, 1990; Sokolowska et al., 1994; Rumpel and Kaniszewski, 1994; Pasikowska et al., 2002; Podlaski et al., 2003; Bjelić et al., 2005) with the results obtained in our study, it can be observed that root yields produced on the anthropogenic soil of the subtype chernozem with signs of gley in loess were significantly higher. Turnip-rooted parsley is only one of the three parsley types that is cultivated for its roots, which are fleshy tap roots as opposed to the branching adventitious root systems of the plain-leafed and curly-leafed cultivars (Petropoulos et al., 2006). Moreover, Petropoulos et al. (2008) investigated the effect of N application on the growth and nitrate concentration of curly-leafed and turnip-rooted parsley under local Mediterranean conditions in comparison with the traditionally grown plain-leafed form. This is, in the first place, the consequence of favorable agrochemical properties of this soil type, primarily due to its high potassium content (Kastori, 2001), the large quantities of which are necessary for the production of parsley (Table 4).

Market quality of root in field trials that is, portion of 1^{st} class roots, was predominantly affected by weather conditions of the year, while the influence of applied

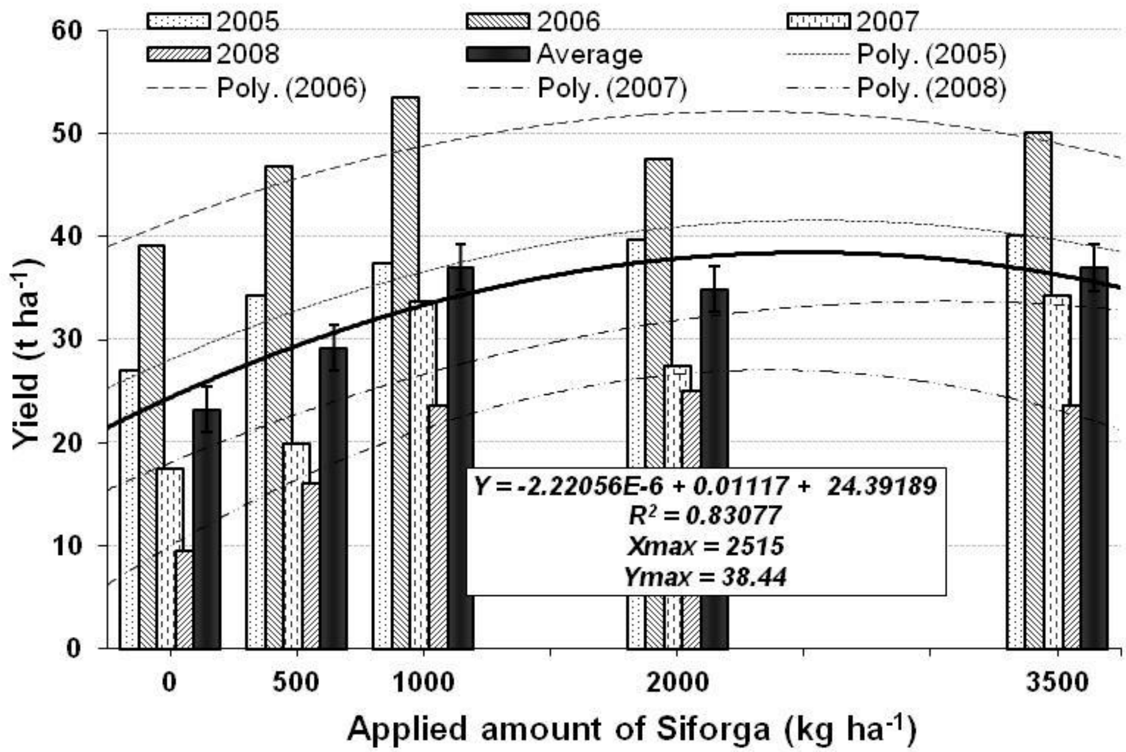

Figure 1. Dependence of parsley root yield on the applied amounts of "Siforga" .

Table 5. Market quality of parsley expressed by the percentage of 1st and 2nd root class (%).

Siforga rate (kg ha^{-1})	Year								Average:	
	2005		2006		2007		2008			
	I cl.	II cl.	I cl.	II cl.	I cl.	II cl.	I cl.	II cl	I cl.	II cl.
0	77.53	22.47	77.03	22.97	74.88	25.12	72.49	27.51	75.48	24.52
500	80.03	19.97	75.86	24.14	71.26	28.74	73.28	26.72	75.11	24.89
1000	82.31	17.70	76.50	23.50	73.45	26.55	73.68	26.32	76.48	23.52
2000	80.35	19.65	77.16	22.84	73.42	26.58	74.32	25.68	76.31	23.69
3500	79.47	20.53	77.54	22.46	74.77	25.23	74.63	25.37	76.60	23.40
Average	79.94	2006	76.82	23.18	73.55	26.45	73.68	26.32	-	-

	Year	Siforga rate	Year × Siforga rate
LSD 0.05	1.24	1.39	2.77
LSD 0.01	1.65	1.85	3.69

amounts of Siforga was considerably lower (Table 5). The yields of 1st class roots, depending on growing season so in the average for all four study years, the largest portion of 1st class root (76.60%) was obtained at fertilization with the largest quantity of Siforga; but the difference in root quality was statistically significant only in comparison to the dosage of 500 kg ha^{-1} of this fertilizer. However, when comparing the individual portions of 1st class root by individual years, no reliable conclusions on the effect of Siforga on the market quality of root could be drawn. So, in 2005, the quality was highest (82.31% of 1st class root) in the trial where 1000 kg ha^{-1} of this organic fertilizer was applied; in 2006 and 2008 at fertilization with largest amounts and in 2007 without the fertilization with Siforga. According to many authors, Hamburg parsley cultivars are characterized by differentiated aptness to forming bifurcated roots (Rumpel and Kaniszewski, 1994; Petropoulos et al., 2006; Gruszecki, 2007; Gruszecki and Sałata, 2010).

On the other hand, the effect of the year on the market

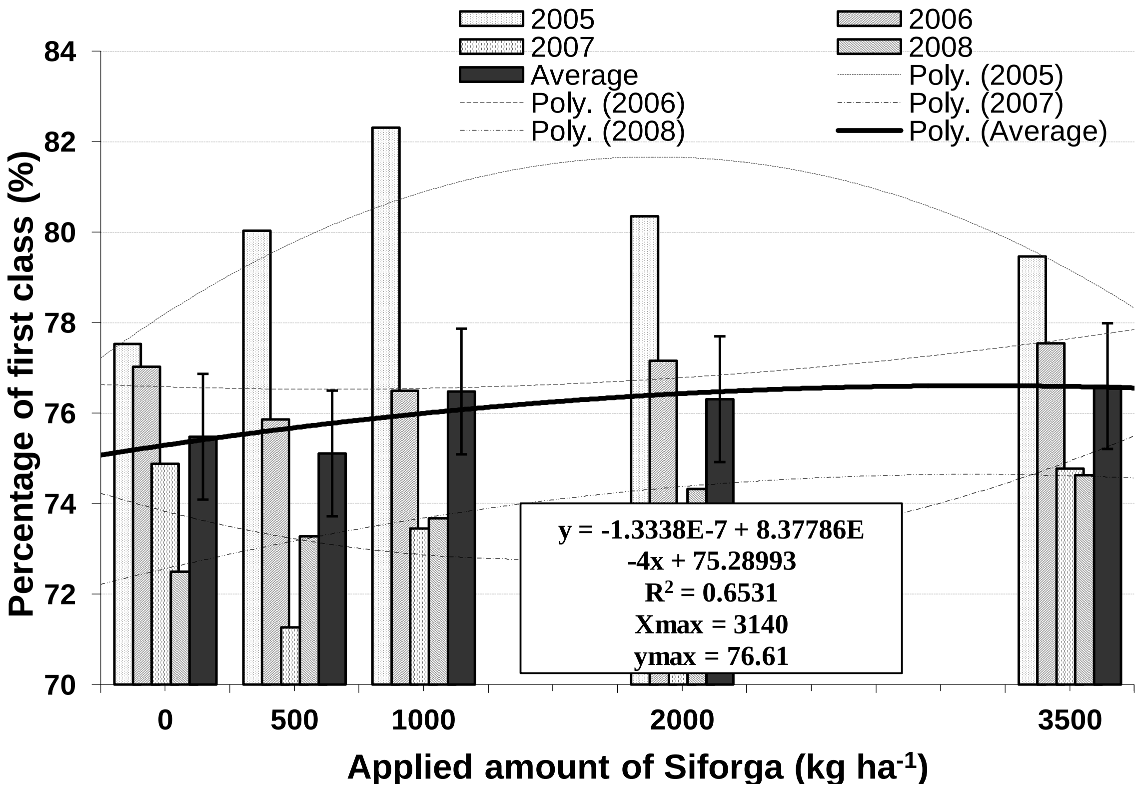

Figure 2. Percentage of 1st class root (%) depending on the applied amounts of "Siforga".

quality of root was extremely large (Figure 2). The largest portion of 1st class root, both in average and in all individual treatments of fertilization with Siforga, was obtained in the first study year (2005). In this year, only portion of 1st class root exceeded the value of 80%. In 2006, average portion of 1st class root was 76.82%, whereas in 2007 and 2008 it was significantly lower (73.55 and 73.68%, respectively). The dominant influence at the root of market quality in the experiment, that is, the percentage representation of the roots of the 2nd class, had the conditions of the year (Gruszecki and Sałata, 2010), while the influence of the applied amount Siforga was significantly lower (Table 5 and Figure 3). On average, for all four studied years the largest number of 2nd class root (76.60%) was obtained when fertilizing with 500 kg ha^{-1} of Siforga, as compared to research in Poland on heavy clay soil, less by about three times (Kołota, 2011). On the other hand, in 2007 it was recorded, the highest (26.45% of 2nd class root) effect of fertilization by Siforga on productivity of the 2nd class roots. Root diameter was larger than 25 mm in all evaluated cultivars which is the limit for the first quality market product (Pokluda, 2003).

Conclusion

On the basis of the conducted study on the effects of certain meteorological factors and different levels of nutrition provided with a certified organic fertilizer on the yield and market quality of root parsley, it can be concluded that: the highest yield of parsley root in the trial was obtained with 1000 kg ha^{-1} of Siforga which amounted to 37.03 t ha^{-1}, the lowest root yield was recorded in the control plots where organic fertilizer was not applied, market quality expressed as the percentages of 1st and 2nd quality root class did not depend on Siforga fertilization treatments, but, on meteorological conditions in the study year varied also the highest root yield (47.37 t ha^{-1}) was obtained in 2006 in all treatments, when observing all four study years, whereas the lowest root yield (19.52 t ha^{-1}) in 2008. The study has justified the application of Siforga industrially manufactured certified organic fertilizer as a possible replacement for manure in mineral nutrition of root parsley on a highly productive soil type.

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