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EFFECTS OF MINERAL AND ORGANIC FERTILIZATION ON EARLY POTATO PRODUCTION

I. MITOVA, N. DINEV and V. VASSILEVA
"N. Poushkarov" Institute of Soil Science, Agrotechnologies and Plant Protection, BG - 1080 Sofia, Bulgaria

Abstract

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The objective of the study was to establish the influence of organic, mineral and organic-mineral fertilization on the growth, development, yield and some quality indicators for early potatoes. A field experiment in crop rotation with early potatoes of the sort Agata was staged on alluvial-meadow soil in 2011-2012. The scenario included a regime without fertilizer, a regime with mineral fertilizer, organic fertilizer (manure) and mixed organic and mineral fertilizer. The highest yield in the conducted experiment (32.42 $t.ha^{-1}$) was obtained under the mixed fertilization regime. The plants under the regime with organic fertilizer showed lower biometric indicators as compared to those fertilized with mineral or organic-mineral fertilizers. As regards quality indicators, the biggest tubers (101.42 g/tuber) were obtained under the mixed fertilization regime with high content of total sugars - 5.1% and low content of nitrates - 49.79 $mg.kg^{-1}$.

Key words: potatoes, yields, quality, mineral fertilization, organic fertilization

Introduction

With Bulgaria's accession to the EU domestic vegetable production is going to be more and more affected by the growing influence of the Common European Market. The fruit and vegetables sector occupies a prominent place in the EU's overall agricultural production with an average share of 16.9%. For Bulgaria the percentage is approximately 20%. The production of vegetables has its specific characteristics and even though our country offers a number of favorable soil and climatic conditions, it occupies but the thirteenth place in terms of volume of fresh vegetable produce.

The period 1998 - 2010 was characterized by a stable trend towards reduction in agricultural plots and yields in the sector which in turn resulted in a twofold reduction in the exports of vegetable produce. Throughout 1998 – 2007 there was an 18.7% reduction in the total area of land under potatoes with average yields ranging within a wide interval of `15000 -`18500 $kg.ha^{-1}$ (Ministry of Food and Agriculture, Department of Agricultural Statistics, 2013).

These are relatively low yields given the country's potential, but to a certain extent they are balanced out by moderate investment with the objective to keep the cost price down to a level lower than the market price. Apart from many other factors problems with domestic vegetable produce are linked to the low quality and yields on account of non-observation of the agro-technical requirements, in particular, deficit, or excessive feeding regime of the cultures grown.

The objective of this study is to determine the influence of organic, mineral and organic-mineral fertilization on the growth, development, yield and some quality indicators for early potatoes.

Material and Methods

The experiment was a part of a perennial vegetable crop rotation (2011-2012), with spring spinach, followed by potatoes, staged on alluvial-meadow soil on the agricultural plot of "*N. Poushkarov" Institute of Soil Science, Agrotechnologies and Plant Protection* in Tzalapitsa. According to the World Reference Base for Soil Resources it is classified as Fluvisol (IUSS Working Group WRB, 2006). We offer a parallel with the internationally accepted classification of soils as it classifies the soil type and gives an idea about its characteristics (Ivanov, 2010; Ivanov, 2011).

E-mail: ndinev@iss-poushkarov.org

The soil is slightly acidic, pH_{H2O}- 6.8; pH_{kcl}- 6.0 with low humus content - 1.33%. The content of inorganic nitrogen is low – 19.8 mg.kg^{-1}. The content of mobile forms of phosphorus and potassium is in medium concentrations - P_2O_5- 13.2 mg.100g^{-1} and K_2O- 24.7 mg.100g^{-1}.

The experiment was carried out with the cultivar "Agata". The potato tubers were planted on March 20 in furrows after a 70 x 2- cm pattern. Production is early, vegetation lasts for 70 days. The scenarios were staged under 4 different variants each on an area of 30 m^2.

The scheme of the experiment includes:

1. variant – control (no fertilizer)
2. variant - 100% manure
3. variant - 100% mineral fertilizer
4. variant - 50% manure +50% mineral fertilizer

The content of nitrogen under the variant with 100% mineral fertilizer is 20kgN.da^{-1} and has been added as ammonium saltpeter. In accordance with recommendations about the fertilization of early potatoes (Pidov et al., 1995; Cholakov et al., 2011; Cholakov and Boteva, 2010) under the variant with mineral fertilizer 12 kgP_2O_5.da^{-1} were added as triple superphosphate and 18 kg of K_2O.da^{-1} as potassium sulphate. Given the content of 1.2% of total nitrogen in the manure, the content of 200 kgN.ha^{-1} was added with 16670 kg.ha^{-1} manure. Under variant 4 , ½ of the fertilizer content of mineral fertilizer and manure have been added.

The height of the plants has been measured in cm and the mass of leaves, stalks and tubers - in g. The surface area of leaves and whole plants has been measured in cm^2 and m^2 gravimetrically. The weight of the dry content (ACB%) has been determined gravimetrically by drying the plant samples at 60^{0}C following preliminary fixation. The content of total sugars has been determined refractometrically – (%) (Digital refractometer – 32 145). The content of nitrates has been determined with an RQ flex plus 10 devices by Merck.

The content of macro and microelements in the soil has been determined by applying standard methodologies (Arinushkina, 1970). The content of ammonium and nitrate nitrogen – colorimetrically, for movable forms of phosphorus and potassium – after the method of Ivanov (1984); for mobile forms of microelements– by extraction with EDTA (0.05 M, pH 7) and ratio 1:4 soil:soilution (Andreu and.Ginemo-Garcia, 1996) , pH – potentiometrically in water solution and potassium chloride solution.

The total nitrogen content of the plants has been determined by applying through decomposition with concentrated H_2SO_4 and 30% H_2O_2. The content of the remaining macro and microelements has been determined through dry burning in muffle furnaces and subsequent dissolution in 20% HCl as recorded by flame photometer (K, Na) and an atomic – absorption spectrophotometer (Ca, Mg). Phosphorus content was detected by color reaction (with Mo-W reaction, by Mincheva and Brashnarova, 1975).

Results

Biometry

The registered values of biometric indicators from two representative scenarios of the development of potato plants show that there are statistical differences between the various fertilization regimes analyzed in the study and the reference scenario (Tables 1 and 2). The indicator for height of the plants, biomass of stalks, leaves and tubers registers a large difference between the fertilized and non-fertilized plants. The height of fertilized plants in the two registered scenarios is 1.7 to 2.9 times bigger than that of the reference plants, the mass of leaves – 3.4 to 8.8 times larger, the mass of stalks – 2.6 to 10.1 times larger and the mass of fertilized tubers - 2.7 to 4.3 times larger than the mass of tubers of the non-fertilized plants.

Table 1
Effects of fertilization on the biometric indicators for potato tubers during the formation of tubers

Variants	Plant height,	No. of offshoots	No. of leaves	No. of potatoes	Mass of leaves,	Mass of stalks,	Mass of potatoes/ 1 plant,
	cm				g	g	g
1. No fertilizer	28.53	5.25	48	13.25	31.12	22.79	469.31
2.100% manure	69.35	7.25	73.5	21.25	161.08	108.13	1390.84
3.100% mineral fertilizer	81.93	8.75	104.5	31.75	274.45	226.06	1850
4. 50% manure+50% mineral fertilizer	83.55	9	95	21.75	215.82	230.23	2025.08
LSD for P≥95%	12.473	0.917	8.079	5.012	20.252	8.664	116.365
LSD for P≥99%	17.486	1.285	11.327	7.027	28.392	12.147	163.135

The fertilized plants and the indicators for number of offshoots, leaves and tubers registered much higher values as compared to the reference plants. With plants fertilized the number of offshoots during the two phenophases exceeds by 38.1 to 72.7% those of the reference plants, the number of leaves is 45.5 to 138.1% larger and the number of tubers - 5.2 to 139.6% larger.

During both phases plants fertilized with manure showed higher values of their biometric indicators as compared to those fertilized with mineral or organic-mineral fertilizers.

During the earlier stage (Table 1) at the formation of the tubers the indicators for height of the plants, number of offshoots and leaves show no statistically substantiated differences between the regimes with mineral and organic-mineral fertilization. The number of tubers and the mass of leaves of the plants subjected to mineral fertilization is bigger than that of plants under a mixed fertilization regime.

During the stage of collecting the tubers (Table 2) there are no confirmed differences between the regimes with organic and organic-mineral fertilization only for the indicators for number of offshoots and mass of leaves. Mineral fertilization as compared to organic-mineral shows higher results in terms of height of the plants, number and mass of leaves and number of tubers. Only in terms of mass of the tubers the plants subjected to mixed fertilization showed the highest yields.

Surface area of leaves

Awareness of processes linked to the formation and growth of the surface area of leaves helps provide a clearer forecast about the productivity of photosynthesis. The total surface area of leaves defines and differentiates the efficiency of the agrotechnics applied, depending on the specific conditions of growing the plants. The formation of biomass is indirectly linked to the surface area of leaves which in turn participates in photosynthesis (Stoimenov and Kirkova, 2009). The surface area of leaves during the various stages of plant development is the subject of various studies.

Variations in the average surface area of a plant in cm^2 for the reference scenario and for fertilized plants have been statistically proven. The total surface area of leaves is determined on the basis of the indicator for average surface area of 1 leaf. The measurements made show that during both phases included in the analysis (Tables 3 and 4) the leaf surface area of 1 m^2 of plants is several times smaller for non-fertilized plants as compared to fertilized plants. With the progress of vegetation (Table 2) the leafing of fertilized plants increases a lot faster than with non-fertilized plants. And while during the flowering phase (Table 3) fertilized plants have between 2.4 and 3.4 times larger surface area of leaves per m^2 as compared to non-fertilized plants, during the phase of the beginning of formation of the tubers (Table 4) this difference increases and is between 4.5 and 7.2 times bigger for fertilized plants. The differences in the size of the registered surface area of fertilized plants under both regimes have been statistically proven. During both measurements the larger surface area of leaves per plant has been registered under the mixed fertilization regimes.

Yields

The yields achieved (Table 5) at the end of May, 7 (2011) days after the planting, categorize the produce as early (Pidov et al., 1995; Cholakov and Nacheva, 2009). The effect of the applied fertilization has been confirmed. The yields achieved under the various fertilization regimes range from 1.6 to 2.3 times higher than yields under the no-fertilizer regime. The highest yield of potatoes (32.4 $t.ha^{-1}$) was achieved under the mixed fertilization regime. The variations in the yields achieved for plants under organic – mineral fertilization and those under organic or mineral fertilization have been statistically proven. The bibliography contains information about

Table 2
Effects of fertilization on the biometric indicators of potato tubers at the gathering of tubers

Variants	Plant height,	No. of offshoots	No. of leaves	No. of potatoes	Mass of leaves,	Mass of stalks,	Mass of potatoes/ Plant,
	cm				g	g	g
1. No fertilizer	44.35	5.5	56.5	28.75	58.45	67.85	957.05
2.100% manure	75.8	7.75	83.75	36.5	198.45	176.225	2593.07
3.100% mineral fertilizer	104.82	8.75	134.5	38.5	313.68	493.45	2745
4. 50% manure+50% mineral fertilizer	86.85	9.5	111.75	30.25	239.18	521.08	3067.93
LSD for P≥95%	8.53	0.832	14.868	7.053	39.399	68.254	219.69
LSD for P≥99%	11.958	1.166	20.843	9.888	55.234	95.687	307.991

higher yields achieved with plants under mineral fertilization as compared to plants under organic fertilization (Cholakov and Nacheva**,** 2009; Jonson, 2006).

Even though the scenario with mineral fertilization of the plants shows a tendency towards higher yields than the yields obtained under organic fertilization there is no statistically proven difference between the two types of fertilization.

On Figures 1 and 2 the relation is shown between the yield of potato tubers and the indicators for vegetative mass and surface area of leaves. The relations are presented with linear equations. The determination coefficients (R^2) have high values and accurately reflect the relation between the analyzed indicators and potato yields. The determination coefficient between the indicators for vegetative mass and yield is R^2= 0.784 and between the surface area of leaves per m^2 and yield - R^2= 0.965.

Quality

Table 5 shows certain indicators which characterize the quality of the potato yield. The size of the tubers is an indicator for the sort, but it is also affected by growing conditions (Pidov et al., 1995; Mitova and Blagoeva, 2008). Books on early potatoes quote the size (mass) of tubers between 60 and 80 g as a reference point (Kartalov et al., 2005). In the con-

Table 3
Effects of organic and mineral fertilization on the leaf surface area of plants at the onset of flowering

Variants	Average surface area of 1 leaf	Average leaf surface area of 1 plant	Leaf surface area of 1 plant	Leaf surface area/1m^2
	cm^2	cm^2	m^2	
No fertilizer	102.2	5007.19	0.5	0.64
100% manure	174.27	12373	1.2	1.52
100% mineral fertilizer	153.02	15455	1.6	2.03
50% manure+50% mineral fertilizer	179.63	17065	1.7	2.16
LSD for P≥95%	33.137	2295.49		
LSD for P≥99%	46.45	3218.11		

Table 4
Effects of organic and mineral fertilization on the surface area of plants at crop-gathering

Variants	Average surface area of 1 leaf	Average leaf surface area of 1 plant	Leaf surface area of 1 plant	Leaf surface area/1m^2
	cm^2	cm^2	m^2	
1. No fertilizer	67.5	3307.5	0.33	0.42
2.100% manure	209.36	14864.6	1.49	1.89
3.100% mineral fertilizer	234.92	19582.1	1.96	2.49
4. 50% manure+50% mineral fertilizer	206.13	23726.9	2.37	3.01
LSD for P≥95%	42.709	3558.38		
LSD for P≥99%	59.875	4988.59		

Table 5
Effects of organic and mineral fertilization on the yields and quality of newly-gathered potato tuber crops

Variants	Yield	Mass of 1 tuber	Dry content	Total sugars	Nitrates
	$t.ha^{-1}$	g	%	%	$mg.kg^{-1}$
1. No fertilizer	14.25	33.29	18.1	4.5	22.35
2.100% manure	23.08	71.04	19.1	4.4	56.22
3.100% mineral fertilizer	25.67	71.3	19.3	4.4	97.92
4. 50% manure+50% mineral fertilizer	32.42	101.42	16.1	5.1	49.79
LSD for P≥95%	4.049				
LSD for P≥99%	5.678				

ducted experiment tubers of such proportions were obtained under the regimes of organic and mineral fertilization. The differences in the size of tubers in plants under organic and under mineral fertilization are small and have not been statistically proven. Plants under mixed fertilization produced the biggest tubers of 101.42 g. Non-fertilized plants produced the lowest yields and the smallest tubers - 33.29 g on average.

The dry content (Table 5) is an important indicator on which the choice of sort and production line depend (consumption, industrial processing, seed production, etc.). Dry content is genetically determined, but its quality depends on a number of external factors, fertilization being the key factor (Mitova and Blagoeva, 2008; Baniuniene and Zekaite, 2008). Similar to the mass of tubers there are no proven variations between plants under organic and under mineral fertilization, but under mixed organic and mineral fertilization the amount of the dry content is substantially smaller. Taking into account the fact that around 50% of potatoes grown in our country are produced in mountainous and semi-mountainous regions (Pidov et al., 1995) the dry content (in relation to plant hardiness) could prove to be a decisive factor in the selection of a suitable sort.

The content of total sugars (Table 5) is almost the same in the tubers of non-fertilized plants, as well as in the varieties with organic and under mineral fertilization. With mixed fertilization tubers, however, the sugar content is considerably higher at 5.1%.

The nitrate content (Table 5) is highest under the mineral fertilization regime - 97.92 mg.kg^{-1} and regardless of the fact that it is the highest nitrate content registered in the experiment, in accordance with the acceptable standards it is much below the critical level for content of nitrates in vegetable produce (Mitova and Dinev, 2001).

Discussion

Potato production is one of the most profitable agricultural practices. Over the past years opportunities to include the culture in biological crop rotations are being considered (Mitova and Blagoeva, 2008; Cholakov and Boteva, 2010). A number of authors have indicated that unilateral addition of organic fertilizers is sufficient to obtain good high-quality produce (Hamm and Gronefeld, 2004; Finckh et al., 2006; Kortbech-Oleson, 2002). Taking into account, however, the unbalanced content of manure, it is also characterized by an imbalance in the macro and micro-element content. For the purposes of this study the ratio of total nitrogen, phosphorus and potassium contained in manure has been N:P:K=1:4.16:2.08. For equal nitrogen content of the mineral fertilizer and manure (2 kg/ha) the phosphorus and potassium content in manure correspond respectively to 8.32kg.ha^{-1} and 4.16 kg.ha^{-1}.

There is a conflict with recommendations for fertilization of early potatoes quoted in reference books (Pidov et al., 1995; Kartalov et al., 2005; Toader et al., 2010). The authors have given as optimum ratio for mineral fertilization the ratio 0.7- 0.9: 0.7- 1.3, depending on the availability of elements in the soil1. The data we have provided show that the ratio between nitrogen, phosphorus and potassium in manure is considerably different than the ratios given in fertilization recommendations. In this case claims (Mitova and Blagoeva, 2008; Cholakov and Boteva, 2010; Cholakov et al., 2011) that organic fertilization with manure (as is the case) is nature-friendly and compliant with sustainable agriculture requirements are incorrect. Under the present experiment fertilization with manure there is not balanced nutrition for the plants in accordance with their needs compared with the equivalent rate of mineral fertilizers.

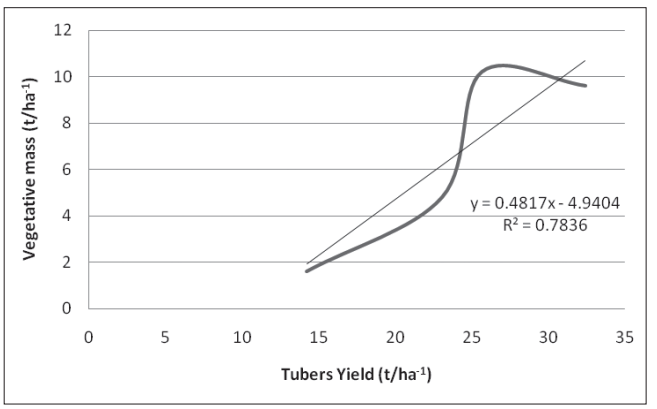

Fig. 1. Dependence of potato yields on the total mass of leaves

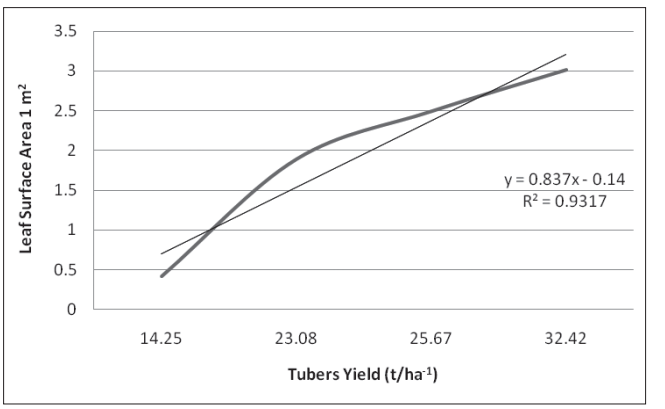

Fig. 2. Dependence of potato yields on the total leaves surface

The scheme of registered biometric indicators provides an overall, indirect and instantaneous view of the growth, development and expected yield of the plants. The first phenophase in the experiment occurred in May when the soil temperature is below the optimum required for mineralization of the organic nitrogen in manure. Nitrogen and the other nutritional elements under the organic fertilization regime were in a form easily assimilated by the plants providing fast and accessible nutrition. This could explain the fact (Table 1) that plants under the regime with application of manure have registered lower biometric indicators as compared to those fertilized with mineral or organic-mineral fertilizer. At the second measurement of biometric indicators (Table 2) - in the phase of gathering the tubers, the same tendency is maintained. Plants fertilized with manure are less developed than those fertilized with mineral and organic-mineral fertilizer. It is a known fact that the coefficient of mineralization of nitrogen in manure during the first year varies in a broad range of 30% to 50%, depending on the type and degree of decomposition of manure as well as on the soil and climate conditions (Mitova and Dinev, 2011). Thus it is natural that even though fertilization rates for mineral and organic-mineral fertilizers and manure are equivalent in terms of their nutritional content, depending on the form of the nitrogen they are absorbed by plants in a different way.

The content of nutritional elements is very important both in terms of defining the quality of ready produce and as an indicator for the control maintained over the nutritional regime. During the stages of the experiment (Table 6) the content of nitrogen in the tubers has been considerably lower than the content mentioned by some authors as the optimum. (Nikolova, 2010; Kartalov et al., 2005). As might be expected the highest content of total nitrogen has been registered in plants under mineral fertilizer. The content of phosphorus, potassium, calcium and magnesium in the potato tubers (Table 6) is comparable to that quoted in reference books (Kartalov et al., 2005). The residual content of oligo and microelements in the soil shows the same tendency for change as their content inside the tubers (Table 7). Regardless of the fact that the selected nitrogen percentage corresponds to recommendations (Pidov et al., 1995; Kartalov et al., 2005) for fertilization of potatoes grown on alluvial – meadow soils, in the particular experiment it turned out to be low. The available data show that the ratio between the nitrogen, on the one hand, and phosphorus and potassium, on the other, considerably diverge from those quoted in recommendations for fertilization. In this case the established opinion that application of manure (in this case) although it is environmentally friendly, is consistent with fertilization requirements has not been confirmed. The staged experiment, taking into account recommendations for fertilization, did not reach the optimum rates, respectively, no balanced nutrition was provided to the plants in accordance with their needs.

Among the quality indicators under review the regime of mixed organic and mineral fertilization has yielded the biggest tubers (101.42 g/tuber) with a high content of total sugars – 5.1% and a low level of nitrates - 49.79 $mg.ha^{-1}$.

Table 6
Nutritional content of potato tubers

Variants	N	K	P	Ca	Mg	Na
	%	%	%	%	%	%
1. No fertilizer	1.09	2.82	0.37	0.04	0.25	0.02
2.100% manure	1.12	2.80	0.37	0.06	0.33	0.02
3.100% mineral fertilizer	1.61	2.79	0.41	0.05	0.29	0.03
4.50% manure+50% mineral fertilizer	1.53	2.51	0.36	0.03	0.31	0.02

Table 7
Agrochemical soil analysis of the 0 - 30 cm layer after completion of the potato experiment

Variants	pH_{KCl}	NH_4-N	NO_3-N	P_2O_5	K_2O
		$mg.kg^{-1}$	mg.kg-1	mg/100 g	mg/100 g
1.No fertilizer	6.5	10.63	5.7	10.4	22.3
2.100% manure	6.9	12.19	0.52	77.5	38.8
3.100% mineral fertilizer	6.7	7.52	13.48	21.91	33.35
4.50% manure+50% mineral fertilizer	6.9	4.41	3.63	30.72	28.5

Conclusions

The highest yield of potatoes (32.4 $t.ha^{-1}$) was obtained under the mixed fertilization regime. Even though in the mentioned experiment the plants under mineral fertilization showed a tendency for bringing higher yields than plants under organic fertilizers there are lacking statistically proven differences between the two types of fertilization.

Of all the analysed quality indicators- the mixed organic and mineral fertilization regime has registered the largest potato tubers (101.4 g/tuber) with a high content of total sugars - 5.1% and low nitrate content - 49.79 $mg.kg^{-1}$.

Plants under the organic fertilization regime registered lower biometric indicators as compared to those fertilized with mineral or organic-mineral fertilizers.

The resulting determination coefficients reflect accurately the link between the vegetative mass and potato yield indicators (R^2= 0.784) and between the mass of leaves per m^2 and potato yield indicators (R^2= 0.965).

Irrespective of the fact that the applied rate of nitrogen is consistent with the recommendations for fertilizing potatoes grown on alluvial-meadow soils, in this particular experiment it proved to be sub-optimal.

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