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ASSESSMENT THE IMPACT OF FERTILIZATION ON POTATOES YIELDS IN SMOLYAN REGION OF BULGARIA

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Abstract

An assessment has been made of the impact of fertilisation on potato yields. A four-year field fertiliser experiment was carried out in the region of Smolyan, Bulgaria during the period 2009-2012. Nine fertilisation variants were investigated: N, P, K, NP, NK, NPK, NPKMg with fertiliser rates of 120 kg N/ha, 60 kg P_2O_5/ha, 100 kg K_2O/ha and 33 kg Mg/ha. It has been found that nitrogen fertilisation was an essential factor for yield formation. However, adding either phosphorus or potassium did not result in a statistically different yield compared to the one received only using nitrogen. Balanced fertilisation with the three primary nutrients (NPK) ensures the highest returns. The costs of adding both phosphorus and potassium fertilisers were small compared to the value of additional production. This makes the combination of the three fertilisers economically justified. Adding magnesium did not result in a statistically proven increase in yield, but magnesium may improve the quality of production and the resistance of plants to biotic and abiotic stress.

Key words*: potatoes, fertilisation, yields, revenue, conditional profit.*

INTRODUCTION

Potatoes are a traditional crop for agriculture in Bulgaria, especially in mountain areas where the alternatives for other crops are limited. In recent years, however, the area planted and production in the country has declined. Average yields are relatively unchanged, but there has been significant variation over the years. Reducing production is a sign that producers are losing interest in this crop due to low and unstable profits.

Potato production is concentrated in two regions of Bulgaria - Southwest and South Central, where 86% of the areas planted are located and for 88% of the potatoes are produced. Soils in both regions are relatively weak fertile, but the climate conditions are favourablefor cultivating this crop. Growing potatoes in mountain areas is an essential element of crop rotation and income generation for farmers (Beluhova-Uzunova, 2018).

The purpose of this article was, based on a field experiment conducted during the period 2009-2012, to assess the best combination of fertilisers for potatoes production.

To do so, field experiments were conducted in the South Central Region, Smolyan area (GPS coordinates 41°36'48.6" N 24°40'00.1" E) during the period 2009-2012 on shallow brown forest soil (Cambisols - coarse). Smolyan area is located in the Rhodopi Mountains, and it is one of the leading potato growing areas in the country

MATERIALS AND METHODS

The trail was organised in the randomised block design in 4 replications, on 25 m^2 plots. The experiment included nine variants: the control (not fertilised) - $N_0P_0K_0$ and eight fertilisers combinations $N_{120}P_0K_0$; $N_0P_{60}K_0$; $N_0P_0K_{100}$; $N_{120}P_{60}K_0$; $N_{120}P_0K_{100}$; $N_0P_{60}K_{100}$; $N_{120}P_{60}K_{100}$; $N_{120}P_{60}K_{100}Mg_{33}$. The rate of the fertilizers application were N -120 kg/ha, P_2O_5 - 60 kg/ha, K_2O - 100 kg/ha, MgO - 33 kg/ha. The potatoes planting distance was 25 x 70 cm. Ammonium nitrate (NH_4NO_3), triple superphosphate ($Ca(H_2PO_4)_2$) and potassium sulphate (K_2SO_4) was used for fertilisation. For the ninth variant, potassium magnesium sulfate (K_2O - 30%, MgO - 10%) was used as a source of potassium and magnesium. The entire fertiliser rates were introduced into the soil before planting. Every year, the experiment was conducted on a new terrain to avoid monoculture. The potatoes were grown on non-

irrigated conditions. The English hybrid, mid-early to mid-late potato variety 'Picasso', was grown without irrigation.

To study the effect of the various fertilizer combinations, the method of the comparison of the mean values of independent samples with equal variances was employed (one-tailed test). The null hypothesis (H_0) was that the average yields of the fertilized trials are equal or smaller than the one of control. The alternative hypothesis (H_1) was that the average yields of the fertilized trials are larger compared to the control.

$$H_0: \mu_f <= \mu_c \quad H_0: \mu_f - \mu_c <= 0$$

$$H_1: \mu_f > \mu_c \quad H_1: \mu_f - \mu_c > 0$$

The hypotheses were tested with, EXEL software. The economic effect of the different fertilisers combinations was estimated by comparing the resulting revenue with the costs of fertilization.

RESULTS AND DISCUSSIONS

The descriptive statistics of the experiment are presented in Table 2.

For the four-year study period, the yields ranged from 12280 kg/ha in the non-fertilized control to 23109 kg/ha in the eighth variant, which included the fertilisation with the three NPK elements plus magnesium. The yields of all variants were abnormally low during the fourth year - 2012.

This was due to the extremely low rainfallsd uring the potato growing season (Table 1). They were particularly low in July (only 13 mm), the period of intense plant growth and the formation of potato tubers.

Table 1: Amount of precipitation during vegetation period of potatoes by months and years of experience (mm)

Years /mont	VI	VII	VIII	IX	Total
2009	140.0	171.6	6.6	106.6	424.8
2010	184.0	203.1	24.5	74.7	486.6
2011	94.5	43.7	131.0	54.7	324.0
2012	46.5	13.4	49.6	37.3	146.8

Source: Rozhen meteorological station (nearest meteorological station to experimental fields)

The tests for the differences in the average yields of the experiments are presented in Tables 3, 4 and 5.

When comparing the control (0) and all other variants (Table 3), we can reject the null hypothesis of no differences in the average yields for the variants that include nitrogen fertiliser - variants 1, 4, 5, 7, 8. However, we cannot do so for the other variants 2, 3 and 6. These variants include phosphorus or potassium fertiliser or both fertilisers, but no nitrogen. This means that we can find statistical support that the average yields are higher for the trials that include nitrogen, but not for the experiments where nitrogen is absent, regardless of what other fertilisers are used. The conclusion that can be made here is that the use of nitrogen fertiliser was crucial for the formation of the yield. This was confirmed by other authors who have investigated the influence of nitrogen fertilisation on potato development and productivity (Joern & Vitosh 1995; Sharifi et al., 2005; Kavvadias et al., 2012; Manolov et al., 2014).

The use of phosphorus and potassium fertilisers in the absence of nitrogen may not guarantee a higher yield compared to the not-fertilized control, but Kansay and Tejada (2019) found out that the most limiting factor of potato production in Ethiopia was not nitrogen but phosphorus. Also, potassium is a nutrient that may not affect the yield, but it has a strong effect on the quality parameter of tubers - dry matter, specific gravity, starch and vitamin C content (Khan et al., 2012; Manolov et al., 2016).

Following this line of thought, the interesting question is, if a nitrogen fertiliser was used, what would be the combination of phosphorus and potassium that would help to receive higher yields. To answer this question, variant one was assumed as a control, (applying only nitrogen), and comparison was made for a difference in yields with the other variants where the other two fertilisers (phosphorus and potassium) were also used (Table 4). In this case, we can reject the null hypothesis of no differences in the average yields for the variants that include all three fertilisers - variants 7 and 8. However, we cannot do so for the variants 4 and 5, where except nitrogen only phosphorus or potassium was used.

Table 2. Descriptive statistics of the potatoes yields

Variants	Indicators		2009	2010	2011	2012	Average
0	Average yield	kg/ha	13 600	16 490	12 603	6 429	12 280
$N_0P_0K_0$	Min	kg/ha	13 200	15 440	10 429	4 018	4 018
	Max	kg/ha	14 400	17 360	14 598	8 482	17 360
1	Average yield	kg/ha	17 200	23 860	20 295	9 241	17 649
$N_{120}P_0K_0$	Min	kg/ha	16 400	22 600	16 723	4 911	4 911
	Max	kg/ha	18 000	24 920	23 652	13 393	24 920
2	Average yield	kg/ha	15 200	22 440	15 335	6 830	14 951
$N_0P_{60}K_0$	min	kg/ha	14 400	21 200	13 152	5 893	5 893
	max	kg/ha	15 600	23 600	18 938	7 857	23 600
3	Average yield	kg/ha	15 200	18 260	10 594	6 022	12 519
$N_0P_0K_{100}$	min	kg/ha	14 000	16 960	5 589	4 911	4 911
	max	kg/ha	16 800	19 200	17 214	7 143	19 200
4	Average yield	kg/ha	17 600	22 440	19 969	11 924	17 983
$N_{120}P_{60}K_0$	min	kg/ha	16 400	20 760	19 420	8 286	8 286
	max	kg/ha	18 800	23 920	20 464	16 518	23 920
5	Average yield	kg/ha	17 200	21 710	17 346	13 214	17 368
$N_{120}P_0K_{100}$	min	kg/ha	16 000	20 800	13 125	10 179	10 179
	max	kg/ha	18 000	23 440	21 179	16 429	23 440
6	Average yield	kg/ha	14 000	20 340	13 359	6 763	13 616
$N_0P_{60}K_{100}$	min	kg/ha	13 200	18 840	11 027	2 679	2 679
	max	kg/ha	15 200	21 480	14 491	12 500	21 480
7	Average yield	kg/ha	19 600	27 310	24 528	16 004	21 861
$N_{120}P_{60}K_{100}$	min	kg/ha	18 800	25 840	20 188	14 286	14 286
	max	kg/ha	20 400	29 160	28 304	18 571	29 160
8	Average yield	kg/ha	20 400	28 030	26 997	17 009	23 109
$N_{120}P_{60}K_{100}Mg_{33}$	min	kg/ha	19 200	26 200	20 991	15 179	15 179
	max	kg/ha	21 600	30 080	32 750	19 286	32 750

Source: Calculated with data on from the experiments

Table 3. Test for difference in the average yields of fertilised variants compared to the not fertilised control

Number of variants	0	1	2	3	4	5	6	7	8
Fertilization	$N_0P_0K_0$	$N_{120}P_0K_0$	$N_0P_{60}K_0$	$N_0P_0K_{100}$	$N_{120}P_{60}K_0$	$N_{120}P_0K_{100}$	$N_0P_{60}K_{100}$	$N_{120}P_{60}K_{100}$	$N_{120}P_{60}K_{100}Mg_{33}$
Mean	12 280	**17 649****	14 951	12 519	**17 983****	**17 368****	13 616	**21 861****	**23 109****
Variance	16 094 627	35 787 756	34 512 433	29 048 771	19 540 977	13 874 598	29 113 844	23 808 452	29 809 950
Observations	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Hyp.Mean Diff.		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Df		26.00	26.00	28.00	30.00	30.00	28.00	29.00	28.00
t Stat		2.98	1.50	0.14	3.82	3.72	0.79	6.07	6.39
P(T<=t) one-tail		0.00	0.07	0.44	0.00	0.00	0.22	0.00	0.00
TCritical one-tail		1.71	1.71	1.70	1.70	1.70	1.70	1.70	1.70

*Significant at 0.05; **Significant at 0.01

Table 4. Test for difference in the average yields of fertilised with NPK variants compared to the control fertilised only with N

Number of variants	2	4	5	7	8
Fertilization	$N_{120}P_0K_0$	$N_{120}P_{60}K_0$	$N_{120}P_0K_{100}$	$N_{120}P_{60}K_{100}$	$N_{120}P_{60}K_{100}Mg_{33}$
Mean	17 649	17 983	17 368	**21 861***	**23 109****
Variance	35 787 756	19 540 977	13 874 598	23 808 452	29 809 950
Observations	16	16	16	16	16
Hyp.Mean Diff.		0	0	0	0
Df		28.00	25.00	29.00	30.00
t Stat		0.18	-0.16	2.18	2.70
P(T<=t) one-tail		0.43	0.44	0.02	0.01
t Critical one-tail		1.70	1.71	1.70	1.70

*Significant at 0.05; **Significant at 0.01

Table 5. Test for difference in the average yields of the variant with Mg compared to the control fertilised with NPK

Number of variants	7	8
Fertilization	$N_{120}P_{60}K_{100}$	$N_{120}P_{60}K_{100}Mg_{33}$
Mean	21 861	23 109
Variance	23 808 452	29 809 950
Observations	16	16
Hyp.Mean Diff.		0
Df		30.00
t Stat		0.68
P(T<=t) one-tail		0.25
t Critical one-tail		1.70

This means that we find statistical support that the average yields were higher for the trials that include all the three fertilisers together, but not for the variants where nitrogen was applied along with only one of the other two fertilisers. The conclusion that could be made was that adding only one of the fertilisers (phosphorus or potassium) to the nitrogen do not guarantee higher yields. Only the joint application of all three fertilizers can ensure such yields.

Melkamu, (2010) and Rana et al. (2017) found that fertilisation with N, P, K, and Mg provides higher yields of potatoes with the highest efficiency of nutrient use. Both variants 7 and 8, includes all three types of fertilisers, but in the variant 8 also magnesium was included. To test for a difference in yields between these variants, the variant 7 was assumed as a control. In this case, we can not reject the null hypothesis of no differences in the average yields. The conclusion that can be made is that adding magnesium did not guarantee higher yields. Magnesium, however, has a positive effect on the quality of production and the resistance of plants to abiotic and biotic stress.

The economic assessment was done with the following prices: ammonium nitrate - 1.41 BGN/kg; the triple superphosphate - 1.25 BGN/kg; the potassium sulphate - 2.65 BGN/kg and potassium-magnesium sulphate - 2.80 BGN/kg. The price of potatoes was assumed to be 0.70 BGN/kg. (one Euro = 1.95583 BGN lev).

Since we did not find statistical support for the differences in the average yields between the control and the variants with no nitrogen fertiliser (2, 3, 6) (Table 3), the average yields of all of them were assumed to be equal to the control - 12 280 kg/ha (variant 0).

Also, we did not find statistical support for the difference in the average yields between the variant with only nitrogen fertiliser (2) and the variants where the nitrogen was combined with phosphorus or potassium (4, 5). Therefore, for these variants, the average yields were assumed to be equal to 17649 kg/ha (variant 2). Following the same logic for the variants 7 and 8, we assume an average yield of 21861 kg/ha (variant 7).

It is clear from Table 6 that the best option, highest conditional profit (the difference between revenues and costs of fertilisers only) was achieved for variant 7.

Table 6: Evaluation of applied fertiliser rates

	Variants	Average yields kg/ha	Revenue BGN levs	Costs of fertilisers BGN levs	Conditional profit BGN levs
0	$N_0P_0K_0$	12 280	8596	0	8596
1	$N_{120}P_0K_0$	17 649	12354	169	12185
2	$N_0P_{60}K_0$	12 280	8596	75	8521
3	$N_0P_0K_{100}$	12 280	8596	265	8331
4	$N_{120}P_{60}K_0$	17 649	12354	244	12110
5	$N_{120}P_0K_{100}$	17 649	12354	434	11920
6	$N_0P_{60}K_{100}$	12 280	8596	340	8256
7	$N_{120}P_{60}K_{100}$	21 861	15303	509	14794
8	$N_{120}P_{60}K_{100}Mg_{33}$	21 861	15303	524	14779

CONCLUSIONS

Several conclusions can be drawn from this study. First, the results from the experiment indicated that nitrogen fertilisation was an essential factor for the formation of the yield in the region of Smolyan, Bulgaria, where the soil is relatively weak. Second, focusing primarily on nitrogen fertilisation was not always the best strategy. What guarantees higher yields was the balanced fertilisation with all three main fertilisers: nitrogen, phosphorus and potassium.

Third, the low profits from potato production could not be a result of high fertiliser prices. The costs for fertilisation were negligible compared to the extra yield they generate. If the profits of potato production are low, this could not be a result of the fertilisers' prices, but rather a result of the other production factors, not included in the experiment. Fourth, calculating the revenue for the different

experiments, methodologically, is better to be done with yields that we have proved that was different compared to the control.

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