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EFFECT OF NITROGEN FERTILIZATION IN *TRITICALE* (*X TRITICOSECALE* WITTM.), CULTIVATED AFTER DIFFERENT PREDECESSORS. NITROGEN UPTAKE AND EFFICIENCY

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ABSTRACT

The study is conducted at the experimental base of Department of Plant production at Trakia University, Stara Zagora. Triticale is grown after five predecessors and different nitrogen fertilization rates. The predecessors are wintering peas, spring peas, sunflower, common wheat and triticale. Nitrogen fertilization rates are 0 (N_0), 40 (N_{40}), 80 (N_{80}), 120 (N_{120}) kg ha^{-1} after legumes and 0 (N_0), 60 (N_{60}), 120 (N_{120}), 180 (N_{180}) kg ha^{-1} after the other predecessors. The influence of the predecessors and nitrogen fertilization on the nitrogen uptake, assimilated nitrogen from fertilization, nitrogen utilization and nitrogen required for 100 kg produce of triticale is established. Nitrogen assimilation from fertilization increases with the increase of the nitrogen fertilizer rates. With the obtained yield from triticale an average of 96.53 kg ha^{-1} N is extracted from the soil with the grain, 18.97 kg ha^{-1} N with the straw or a total of 115.50 kg ha^{-1} N. When growing triticale after leguminous predecessors the utilization of nitrogen is 35.39% and after predecessors sunflower, wheat and triticale - 28.76%. Nitrogen required for 100 kg yield of grain of triticale is 1.9 kg of nitrogen when growing after legume predecessors and 2.8 kg of nitrogen after the other predecessors.

Keywords: *triticale, nitrogen uptake, utilization of nitrogen, fertilizer consumption*

INTRODUCTION

The influence of optimized nitrogen fertilization on productivity and quality of triticale has been found by many researchers (Kolev et al., 2011; Kirchev et al., 2012; Kirchev et al., 2014; Gerdzhikova, 2014; Madic et al., 2015). According to Papastylianon et al., 1981; Badaruddin and Meyer, 1994; Gibson et al., 2007, the increase in nitrogen levels leads to an increase of nitrogen content in the triticale grain, but changes in protein content are greater under the influence of the predecessor than fertilizer norms. In addition to the nitrogen, imported with fertilization, triticale also absorbs soil nitrogen from the predecessors (Nance et al., 2007). Triticale has the greater ability to accumulate nitrogen compared to wheat (Paponov et al., 1999). Effective use of nitrogen is an important indicator of the environmental impact on the production of triticale and other energy crops (Lewandowski and Schmidt, 2006). The aim of this study is to determine the impact of predecessors and nitrogen fertilization on the nitrogen uptake, assimilated nitrogen from fertilization, utilization of nitrogen and fertilizer consumption (nitrogen required for 100 kg of produce).

MATERIALS AND METHODS

The survey is conducted in the area of the town Stara Zagora, located in the region of South Central Bulgaria. The study is carried out with Triticale Rogen variety. Cultivation is performed according to the conventional technology of cropping. The soils are Gleic Chromic Luvisols, neutral, and well reserved with K_2O, moderate with P_2O_5 and low with Nitrogen. Triticale is grown after 5 predecessors: Wintering peas (*Pisum arvense* L.), Spring peas (*Pisum sativum* L.), Sunflower (*Helianthus annuus* L.), Wheat (*Tristicum aestivum* L.) and Triticale (× *Triticosecale* Wittm.). Four levels of nitrogen fertilization are applied according to the predecessors as follows: 0 (N_0), 40 (N_{40}), 80 (N_{80}), 120 (N_{120}) kg ha^{-1} after legumes and 0 (N_0), 60 (N_{60}), 120 (N_{120}), 180 (N_{180}) kg ha^{-1} after the other predecessors. The data used in the present study are for the period 2010-2012 - a part of a multi-year experience with triticale. Different metrics are calculated using the following formulas:

NU = Y*NC/1000

ANF = NU fertilized variant – NU non-fertilized variant

UN = ANF/NR%

FC = NR/Y*100

NU – nitrogen uptake, Y – yield (grain, straw), NC – nitrogen content, ANF – assimilated nitrogen from fertilization, UN – utilization of nitrogen, NR – nitrogen fertilizer rate, FC - fertilizer consumption.

RESULTS AND DISCUSSION

Nitrogen content in grain and straw dry matter of triticale

Higher nitrogen content in the grain dry matter of triticale viewed by predecessors, is obtained after predecessor sunflower, average for the period - 24.14 g in 1000 g dry matter (DM) and lower after spring peas - 21.07 g in 1000 g DM. On average, for the three-year period after legume predecessors nitrogen content is lower by 3.71% in the non-fertilized variant compared to cereals and sunflower (Table 1). Nitrogen fertilization leads to increase in the nitrogen content in the DM of triticale grain. The highest values are obtained at fertilizer rate of 180 kg ha^{-1}, applied after non-leguminous predecessors. Nitrogen in the fertilized variants is 9% more than non-fertilized ones on average for the trial period. According to Papastylianon et al. (1981); Badaruddin and Meyer (1994); Gibson et al. (2007), the percentage of nitrogen content in triticale grain increases by increasing nitrogen rates.

Higher nitrogen content after cereals and sunflower compared to leguminous predecessors and with an increase in the applied nitrogen fertilizer rates is also found in triticale straw. On average, for the trial period nitrogen content in grain DM of triticale is 371.82% higher than nitrogen content in straw DM.

Nitrogen uptake with grain+straw yield of triticale

To form a unit of produce plants export from the soil various macro- and trace elements. From the macroelements, nitrogen is important. On average, for the trial period after leguminous predecessors of the non-fertilized variants, nitrogen uptake is 68.14 kg ha^{-1}, and after cereals and sunflower 69.43 kg ha^{-1} - by 1.86% more (Table 1). Introducing increasing rates of nitrogen fertilizer results in increase nitrogen uptake from the soil with grain yield of triticale after all predecessors. After leguminous predecessors, on average for the period export compared to the non-fertilized variant increased by 11.73%, 37.91% and 52.45%, respectively, with mineral nitrogen rates 40, 80 and 120 kg ha^{-1}. On average, after cereals and sunflower, nitrogen uptake is higher than after legumes and increased by 19,18%, 45,95% and 66,95%, respectively, compared to the non-fertilized variant with fertilization at 60, 120 and 180 kg ha^{-1} of nitrogen, respectively. On average for the study period, nitrogen uptake, average from all fertilized variants is 40.06% higher than the average of the non-fertilized variants. Nitrogen uptakes with triticale straw on average, for the three-year period, ranged from 11.41 kg ha^{-1} in the non-fertilized variant to 22.49 kg ha^{-1} for N_{120} after leguminous predecessors and from 15.04 kg ha^{-1} to 23.27 for N_{180} after cereals and sunflower. When comparing nitrogen-free variants between the two groups of predecessors, nitrogen uptake is 24.14% lower after leguminous. After all predecessors export increases by increasing nitrogen fertilization rates. The average value of all non-fertilized variants ix exceeded by that of the fertilized ones by 39.59% on average for the trial period. The amount of nitrogen extracted with grain+straw of triticale in plants fertilized with the highest nitrogen fertilization rate of 180 kg ha^{-1} on average after cereals and sunflower reached 139.25 kg ha-1 and exceeded nitrogen uptake of the non-fertilized variant by 64.87%. N60 and N120 fertilization increases nitrogen uptake compared to the non-fertilized variant by 19.66% and 40.00%, respectively. After leguminous predecessors, nitrogen uptake is lower, both in the non-fertilization variant and the respective fertilization rates compared to non-leguminous predecessors. Here again nitrogen uptake increases with the increase of the nitrogen fertilization rate with biggest amount of nutrients with the main and additional produce being exported as a result of the highest rate of N120 - 126.37 kg ha-1 exceeding export in the non-fertilized variant by 58.86%. At fertilization rates of N40 and N80 this increase is 13.74% and 40.04%, respectively, compared to N0.

Table 1. Yield of grain and straw, kg ha^{-1}, nitrogen content in grain and straw, g/1000 g DM, nitrogen uptake with grain, straw, grain+straw, kg ha^{-1} average for the three-year period

Predecessor	Nitrogen fertilization, kg ha^{-1}	Yield of grain, kg ha^{-1}	Yield of straw, kg ha^{-1}	Nitrogen content in grain, g/1000 g DM	Nitrogen content in straw, g/1000 g DM	Nitrogen uptake with grain, kg ha^{-1}	Nitrogen uptake with straw, kg ha^{-1}	Nitrogen uptake with grain+ straw, kg ha^{-1}
1. Wintering peas	0	3280.4	2897.5	21.75	4.15	71.29	11.95	83.24
	40	3553.8	3546.7	22.27	4.89	79.05	17.45	96.50
	80	4162.5	3934.2	23.46	4.38	97.63	17.23	114.86
	120	4550.8	4310.8	23.11	4.18	105.17	18.05	123.22
	0-120	3886.9	3672.3	22.65	4.40	88.29	16.17	104.46
	40-120	4089.0	3930.6	22.95	4.48	93.95	17.58	111.53
2. Spring peas	0	3295.4	2889.2	19.73	3.81	64.99	10.87	75.86
	40	3572.1	3541.7	20.54	3.20	73.21	11.25	84.46
	80	4181.3	4013.3	21.60	4.41	90.30	17.65	107.95
	120	4581.3	4347.5	22.41	6.18	102.60	26.92	129.52
	0-120	3907.5	3697.9	21.07	4.40	82.78	16.67	99.45
	40-120	4111.5	3967.5	21.52	4.60	88.70	18.61	107.31
3. Sunflower	0	3200.4	2815.0	22.65	5.77	72.46	16.32	88.78
	60	3613.8	3453.3	23.68	6.23	85.51	21.84	107.34
	120	4273.8	3983.3	24.52	4.63	104.74	18.49	123.23
	180	4708.8	4259.2	25.70	4.96	120.95	21.14	142.08
	0-180	3949.2	3627.7	24.14	5.40	95.92	19.45	115.36
	60-180	4198.8	3898.6	24.63	5.27	103.73	20.49	124.22
4. Wheat	0	3252.1	2855.8	20.29	6.11	65.93	17.76	83.70
	60	3646.3	3518.3	21.81	5.95	79.48	21.01	100.48
	120	4341.7	3973.3	23.54	4.35	102.10	17.31	119.41
	180	4760.4	4415.0	23.29	6.85	110.72	30.25	140.96
	0-180	4000.1	3690.6	22.23	5.82	89.56	21.58	111.14
	60-180	4249.4	3968.9	22.88	5.72	97.43	22.86	120.28
5. Triticale	0	3220.0	2836.7	21.69	3.85	69.92	11.05	80.96
	60	3621.3	3486.7	22.99	3.50	83.26	12.19	95.45
	120	4319.2	3765.8	22.50	4.00	97.15	15.03	112.18
	180	4734.2	4324.2	24.52	4.34	116.07	18.73	134.79
	0-180	3973.7	3603.4	22.92	3.92	91.60	14.25	105.85
	60-180	4224.9	3858.9	23.34	3.95	98.83	15.32	114.14
6. Average leguminous predecessors (1-2)	0	3287.9	2893.3	20.74	3.98	68.14	11.41	79.55
	40	3562.9	3544.2	21.40	4.04	76.13	14.35	90.48
	80	4171.9	3973.8	22.53	4.39	93.97	17.44	111.40
	120	4566.0	4329.2	22.76	5.18	103.88	22.49	126.37
	0-120	3897.2	3685.1	21.86	4.40	85.53	16.42	101.95
	40-120	4100.3	3949.0	22.23	4.54	91.33	18.09	109.42
7. Average non-leguminous predecessors (3-5)	0	3224.2	2835.8	21.54	5.24	69.43	15.04	84.48
	60	3627.1	3486.1	22.83	5.23	82.75	18.35	101.09
	120	4311.5	3907.5	23.52	4.33	101.33	16.94	118.27
	180	4734.4	4332.8	24.50	5.38	115.91	23.37	139.28
	0-180	3974.3	3640.6	23.10	5.05	92.36	18.43	110.78
	60-180	4224.4	3908.8	23.62	4.98	100.00	19.55	119.55
	x-0	3249.7	2858.8	21.20	4.70	68.92	13.59	82.51
	x-40-180	4174.7	3924.9	23.10	4.80	96.53	18.97	115.50
	x-0-180	3935.7	3662.8	22.48	4.72	88.94	17.42	106.37

Assimilated nitrogen from fertilization, exported by grain+straw yield of triticale: During the first year of the trial higher assimilation of the exported nitrogen from triticale with the grain+straw yield in the fertilized variants is established on average after predecessors wintering and spring peas - 37.71 kg ha^{-1} on average of the three fertilization rates (Table 2). In the second and third year assimilated nitrogen from fertilization is more on average after non-leguminous predecessors by 31.74% and 23.01%, respectively. On average, for the years of the trial, assimilated nitrogen from fertilization is 14.83% more after cereals and sunflower. Assimilated nitrogen from fertilization increases with increasing the fertilization rates. After leguminous predecessors the values are 10.93; 31.85 and 46.82 kg ha^{-1}, respectively, at N_{40}, N_{80} and N_{120} respectively, and after cereals and sunflower - 16.61; 33.79 and 54.80 kg ha^{-1}, respectively, at N_{60}, N_{120} and N_{180}, respectively, on average for the trial period. On average, from the three fertilization rates nitrogen assimilated from fertilization ranges from 28.29 kg ha^{-1} after wintering peas to 36.59 kg ha^{-1} after wheat on average for the three-year period. **Utilization of nitrogen:** Nitrogen utilization rate depends on the nitrogen assimilated from fertilization. In the first year it ranged from 19.27% after triticale to 50.46% after wintering peas (Table 2). On average, after legumes, the utilization rate of nitrogen is 45.00% and is 63.58% higher compared to the average after the cereal predecessors and the sunflower. In the second year, nitrogen has a slightly higher utilization rate after the group of the non-leguminous predecessors. In the last year, as in 2010, the nitrogen utilization rate is the highest after spring and wintering peas. This tendency is maintained and is on average for the three-year trial period - 35.44% after spring peas and 35.33% after wintering peas and is the lowest after triticale - 26.69%. On average, during the study period, nitrogen utilized from fertilization is 31.41% on average from all fertilization rates after the five predecessors. It is the highest after legumes at fertilization with 80 kg ha^{-1} nitrogen - 39.82%. Of the three fertilization rates on average after legumes, nitrogen utilization 23.05% higher compared to the average after cereal predecessors and sunflower. **Fertilizer consumption (nitrogen required for 100 kg of produce):** The nitrogen required for 100 kg of triticale produce does not differ significantly during the three years of the trial. Lower values were obtained in the first year, and higher - in the last one. Viewed by predecessors, fertilizer consumption is lower after both peas and higher after non-leguminous predecessors - sunflower, wheat and triticale. For the formation of 100 kg of triticale produce after wintering and spring peas and fertilization rate of 40 kg ha^{-1}, between 1,1 and 1,2 kg of nitrogen are needed and at rates of 80 and 120 kg ha^{-1} - from 1,8 to 2,1 kg, and from 2.5 to 2.8 kg nitrogen, respectively. On average, for the three-year trial period after leguminous predecessors 1.1 kg of nitrogen is required at fertilization rate of 40 kg ha^{-1} (Table 3). With increase of nitrogen rates, the amount of nitrogen required to obtain 100 kg of produce is also increased: 1.9 kg and 2.6 kg, respectively, for fertilization with 80 and 120 kg ha^{-1} nitrogen on average for the period. After cereal predecessors and sunflower to obtain a yield of 100 kg produce, 1.7; 2.8 and 3.8 kg of nitrogen are required with fertilization with 60, 120 and 180 kg ha^{-1} nitrogen, respectively, on average during the trial period. The highest is fertilizer consumption at nitrogen fertilization rate of 180 kg ha^{-1} in 2012, when 4.0 kg of nitrogen was needed after cereal precursors and sunflower to form 100 kg of triticale produce.

Table 2. Assimilated nitrogen with grain+straw yield of triticale, kg ha^{-1}and utilization of nitrogen, %

Predecessor	Nitrogen fertilization, kg ha^{-1}	2010	2011	2012	Average	2010	2011	2012	Average
		Assimilated nitrogen, kg ha^{-1}				Utilization of nitrogen, %			
1. Wintering peas	0								
	40	23.20	6.04	10.54	13.26	58.00	15.09	26.35	33.15
	80	38.27	31.33	25.25	31.62	47.84	39.16	31.56	39.52
	120	54.66	30.10	35.19	39.98	45.55	25.08	29.32	33.32
	(40-120)	38.71	22.49	23.66	28.29	50.46	26.45	29.08	35.33
2. Spring peas	0								
	40	7.17	10.08	8.55	8.60	17.92	25.20	21.37	21.50
	80	35.69	34.73	25.86	32.09	44.61	43.41	32.33	40.11
	120	67.27	47.51	46.20	53.66	56.06	39.59	38.50	44.72
	(40-120)	36.71	30.77	26.87	31.45	39.53	36.07	30.73	35.44
3. Sunflower	0								
	60	25.49	12.61	17.60	18.57	42.48	21.02	29.33	30.94
	120	33.82	37.44	32.09	34.45	28.19	31.20	26.74	28.71
	180	53.81	54.37	51.73	53.30	29.90	30.21	28.74	29.61
	(60-180)	37.71	34.81	33.81	35.44	33.52	27.48	28.27	29.76
4. Wheat	0								
	60	17.08	17.56	15.72	16.79	28.47	29.26	26.20	27.98
	120	33.50	40.49	33.14	35.71	27.92	33.74	27.62	29.76
	180	59.13	59.64	53.03	57.27	32.85	33.13	29.46	31.81
	(60-180)	36.57	39.23	33.97	36.59	29.75	32.04	27.76	29.85
5. Triticale	0								
	60	7.80	21.03	14.63	14.49	13.00	35.05	24.38	24.14
	120	21.49	45.34	26.81	31.22	17.91	37.79	22.34	26.01
	180	48.41	62.57	50.51	53.83	26.89	34.76	28.06	29.90
	(60-180)	25.90	42.98	30.65	33.18	19.27	35.87	24.93	26.69

6. Average leguminous predecessors (1-2)	0								
	40	15.18	8.06	9.54	10.93	37.96	20.15	23.86	27.32
	80	36.98	33.03	25.55	31.85	46.23	41.28	31.94	39.82
	120	60.97	38.81	40.69	46.82	50.81	32.34	33.91	39.02
	(40-120)	37.71	26.63	25.26	29.87	45.00	31.26	29.90	35.39
7. Average non-leguminous predecessors (3-5)	0								
	60	16.79	17.07	15.98	16.61	27.98	28.45	26.64	27.69
	120	29.61	41.09	30.68	33.79	24.67	34.24	25.57	28.16
	180	53.78	58.86	51.76	54.80	29.88	32.70	28.75	30.44
	(60-180)	33.39	39.01	32.81	35.07	27.51	31.80	26.99	28.76
	x-40-180	35.12	34.06	29.79	32.99	34.50	31.58	28.15	31.41

On average, for the period for all fertilization rates after leguminous predecessors to produce 100 kg of triticale yield, 1.9 kg of nitrogen is needed - 31.3% less than 2.8 kg of nitrogen after the other predecessors.These results confirm the positive effect of leguminous predecessors on soil fertility and its nitrogen enrichment through nitrogen fixation and determine their role on the productivity of the subsequent crops in the crop rotation.

Table 3. Fertilizer consumption (nitrogen required for 100 kg of produce), kg

Predecessor	Nitrogen fertilization, kg ha^{-1}	2010		2011		2012		Average 2010 - 2012	
		Grain yield, kg ha^{-1}	kg N for 100 kg grain	Grain yield, kg ha^{-1}	kg N for 100 kg grain	Grain yield, kg ha^{-1}	kg N for 100 kg grain	Grain yield, kg ha^{-1}	kg N for 100 kg grain
1. Wintering peas	0	3436.3		3281.3		3123.8		3280.4	
	40	3760.0	1.1	3506.3	1.1	3395.0	1.2	3553.8	1.1
	80	4383.8	1.8	4282.5	1.9	3821.3	2.1	4162.5	1.9
	120	4828.8	2.5	4585.0	2.6	4238.8	2.8	4550.8	2.6
	(40-120)	4324.2	1.8	4124.6	1.9	3818.3	2.0	4089.0	1.9

2. Spring peas	0	3441.3		3317.5		3127.5		3295.4	
	40	3773.8	1.1	3545.0	1.1	3397.5	1.2	3572.1	1.1
	80	4426.3	1.8	4285.0	1.9	3832.5	2.1	4181.3	1.9
	120	4853.8	2.5	4615.0	2.6	4275.0	2.8	4581.3	2.6
	(40-120)	4351.3	1.8	4148.3	1.9	3835.0	2.0	4111.5	1.9
3. Sunflower	0	3347.5		3252.5		3001.3		3200.4	
	60	3800.0	1.6	3575.0	1.7	3466.3	1.7	3613.8	1.7
	120	4500.0	2.7	4355.0	2.8	3966.3	3.0	4273.8	2.8
	180	5017.5	3.6	4631.3	3.9	4477.5	4.0	4708.8	3.8
	(60-180)	4439.2	2.6	4157.1	2.8	3970.0	2.9	4198.8	2.8
4. Wheat	0	3388.8		3287.5		3080.0		3252.1	
	60	3848.8	1.6	3607.5	1.7	3482.5	1.7	3646.3	1.6
	120	4642.5	2.6	4380.0	2.7	4002.5	3.0	4341.7	2.8
	180	5043.8	3.6	4730.0	3.8	4507.5	4.0	4760.4	3.8
	(60-180)	4511.7	2.6	4239.2	2.7	3997.5	2.9	4249.4	2.7
5. Triticale	0	3375.0		3210.0		3075.0		3220.0	
	60	3805.0	1.6	3575.0	1.8	3483.8	1.7	3621.3	1.7
	120	4645.0	2.6	4341.3	2.8	3971.3	3.0	4319.2	2.8
	180	5045.0	3.6	4651.3	3.9	4506.3	4.0	4734.2	3.8
	(60-180)	4498.3	2.6	4189.2	2.8	3987.1	2.9	4224.9	2.8
6. Average leguminous predecessors (1-2)	0	3438.8		3299.4		3125.6		3287.9	
	40	3766.9	1.1	3525.6	1.1	3396.3	1.2	3562.9	1.1
	80	4405.0	1.8	4283.8	1.9	3826.9	2.1	4171.9	1.9
	120	4841.3	2.5	4600.0	2.6	4256.9	2.8	4566.0	2.6
	(40-120)	4337.7	1.8	4136.5	1.9	3826.7	2.0	4100.3	1.9
7. Average non-leguminous predecessors (3-5)	0	3370.4		3250.0		3052.1		3224.2	
	60	3817.9	1.6	3585.8	1.7	3477.5	1.7	3627.1	1.7
	120	4595.8	2.6	4358.8	2.8	3980.0	3.0	4311.5	2.8
	180	5035.4	3.6	4670.8	3.9	4497.1	4.0	4734.4	3.8
	(60-180)	4483.1	2.6	4205.1	2.8	3984.9	2.9	4224.4	2.8
%6/7			69.2		67.9		69.0		68.7

CONCLUSIONS

For the production of 100 kg grain yield, an average of 1.9 kg nitrogen is needed for growing triticale after a leguminous predecessor and 2.8 kg nitrogen for growing after sunflower, wheat and triticale. After leguminous predecessors, nitrogen fertilizer consumption is 31.3% less compared to cultivation after other predecessors. With the obtained yield from triticale an average of 96.53 kg ha^{-1} N is extracted from the soil with the grain, 18.97 kg ha^{-1} N with the straw or a total of 115.50 kg ha^{-1} N (average for fertilization cultivation). The difference in the amount of nitrogen extracted from the soil in triticale cultivation without fertilization and with fertilization is 40% on average. When growing triticale after leguminous predecessors the utilization of nitrogen is 35.39% on average, and after the predecessors sunflower, wheat and triticale - 28.76%. After leguminous predecessors the utilization rate of nitrogen is 18.7% better.

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