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THE EFFECT OF NITROGEN NUTRITION ON THE PRODUCTIVITY OF WINTER TRITICALE IN CENTRAL LITHUANIA

During the period 2000-2004 field trials with winter triticale were conducted at the LIA in Dotnuva on a light loam Endocalcari – Epihypogleyic Cambisol. The goal of the field trials was to determine optimal conditions for winter triticale nitrogen nutrition and to estimate nitrogen fertilizer efficacy taking into account mineral nitrogen content in the soil. Our experimental evidence suggests that nitrogen fertilizers were effective not every year, the regularities of grain yield variation resulting from fertilizer application also differed. A grain yield increase of 19.5-24.0 % was obtained through nitrogen fertilizer application. A rate of N_{90} *was found to be optimal for triticale. Additional fertilization of triticale was effective only in the normally wet years. The variation in protein content dependend on the weather during the growing season and fertilization level.*

Exhibiting a high yield potential, winter triticale is a promising crop. The area currently sown with triticale in Lithuania is steadily increasing and this increase has been determined by the availability of high-yielding, winterhardy, thick-stemmed, rather satisfactorily drought and disease resistant varieties. Grain chemical composition of triticale determines its rather wide application possibilities: the grain is used in food industry, flour in confectionery, for beer, spirit, and starch production (Seguchi *et al*., 2000). In grain protein, the ratio of amino acids contents is suitable for livestock feeding (Alaru *et al*., 2003, Mikulionienė *et al*., 2002). Winter triticale is well suited for growing on various-textured soils and its cultivation is rational not only from the viewpoint of productivity but also from the viewpoint of optimal soil physical and chemical properties maintenance (Petraitis *et al*., 2002; Malecka *et al*., 2004). The findings on nutrition of triticale, which is a relatively undemanding crop in terms of cultivation conditions, are scarce in literature. Different nitrogen rates are often indicated for winter triticale. On the background of $P_{100}K_{100}$ an optimal nitrogen rate is indicated to be 80 kg ha^{-1} (Paponov *et al*., 1999), more recent research suggests that the highest winter triticale yield was achieved through a nitrogen rate not lower than 120 kg ha^{-1} (Malecka *et al*., 2004), other researchers have reported optimal nitrogen rates to be from 60 to 120 kg ha^{-1} (Bulavina, 1993), 160 kg ha^{-1} or even 180 kg ha^{-1} (Cimrin *et al*., 2004; Mut *et al*., 2005). There has bee done very little research so far under Lithuania's conditions on triticale fertilization, also no tests done designed to estimate the role of soil mineral nitrogen in winter triticale nutrition and to ascertain the yield, yield increase and fertilizer efficacy as influenced by mineral nitrogen (N_{min}). ***The objective of the study*** was to identify optimal nitrogen nutrition conditions for winter triticale and to estimate nitrogen fertilizer efficacy in relation to mineral nitrogen content in the soil.

Materials and methods of research. *Experimental site.* Field experiments were conducted during the period 1999-2004 at the Lithuanian Institute of Agriculture in Dotnuva on a light loam *Endocalcari – Epihypogleyic Cambisol* by a conventional field experiment method. According to the values of agrochemical parameters, the soil pH_{KCl} was 6.0-7.0 (measured potentiometrically), plant available phosphorus and potassium contents – 129-206 mg kg^{-1} (P_2O_5) and 140-201 mg kg^{-1} K_2O, respectively (A-L methods), humus content 1.8-2.1 % (Tyurin) and total nitrogen content 0.12-0.14 % (Kjeldahl).

The soil at the 0-40 cm depth was relatively low in plant available mineral nitrogen ($N\text{-}NO_3$+$N\text{-}NH_4$, measured: $N\text{-}NO_3$ – ionometrically, $N\text{-}NH_4$ spectrophotometrically) ranging from 38.0 ± 0.73 to 55.2 ± 0.93. On average, in spring at the beginning of triticale growing season, N_{min} content at the 0-40 cm soil layer from which plants utilize nutrients most intensively at the beginning of the growing season varied within 38.0-55.2 kg ha^{-1} range, at low or moderate variation (V = 87-17.3 %). Having added up N_{min} present at 0-40 and 40-60 cm soil layers, it was noted that in different years it varied within 55-70 kg ha^{-1} range, (V = 7.3-10.9 %). The distribution of N_{min} content in the soil profile was as follows: at the 0-40 cm depth on average 68-78 %, at the 40-60 cm depth 22-32 % of the total N_{min} content in the 0-60 cm depth.

Experimental design: 1. Not fertilized ($N_0 P_0 K_0$)/ 2. $P_{60}K_{60}$ (background F)/ 3. N_{60} in spring (BBCH 25-29)/ 4. F+N_{30} in autumn +N_{60} in spring (BBCH 25-29)/ 5. F+ N_{60} in spring (BBCH 25-29)/ 6. F+ N_{90} in spring (BBCH 25-29)/ 7. F+ N_{60} in spring (BBCH 25-29) + N_{30} at the beginning of booting (BBCH 30-32)/ 8. F+ N_{120} in spring (BBCH 25-29)/ 9. F+ N_{90} in spring (BBCH 25-29) + N_{30} at the beginning of booting (BBCH 30-32). Treatments 2 and 4-11 received the same phosphorus and potassium fertilization level – $P_{60}K_{60}$.

Meteorological conditions was differed between the experimental years. Of the five experimental years, two were extremely dry and warmer than usual, three years were normally wet. Statistical grain yield data processing was done using analysis of variance. Correlations between grain yield, yield increase in different expressions and nitrogen fertilizer rates and mineral nitrogen were determined and regression equations were calculated following the directions in special literature (Tarakanovas *et al*., 2003). Symbols used in the paper: * and ** statistically significant at 95 % and 99 % probability level; LSD_{05} – least significant difference at 95% probability level.

Results of research. Nitrogen fertilizer efficacy during 2001-2004 was sufficiently high and grain yield increases through its application were statistically significant (Table 1). The data averaged over the five experimental years suggest that triticale grown without fertilizers produced a grain yield of 5.86 t ha^{-1}, and a yield increase of 19.5-24.0 % resulting from nitrogen fertilization was obtained, compared with the check treatment.

1. The effect of fertilization and fungicides on grain yield t ha^{-1} (15% moisture) and protein content in the grain

Treatment	Grain yield							Protein content %
	Year					Mean.		
	2000	2001	2002	2003	2004	t ha^{-1}	relative values	
Without fertilizers	8.34	3.86	7.30	4.01	5.78	5.86	100	10,3
$P_{60}K_{60}$ (background F)	8.59	4.46	7.32	3.94	4.73	5.81	99.1	10,1
N_{60} in spring	8.58	5.76	8.13	4.93	7.46	6.97	119.0	11,0
F+ N_{30} in autumn + N_{60} in spring	8.53	5.85	7.64	5.84	7.53	7.08	1208	11,2
F+ N_{60} in spring	8.66	6.15	7.76	5.14	7.31	7.00	119.5	11,2
F+ N_{90} in spring	8.56	6.08	8.01	5.92	7.87	7.29	124.4	11,4
F+ N_{60} in spring + N_{30} at beginning of booting (BBCH 30-32)	8.20	5.95	8.04	5.79	8.20	7.24	123.5	11,4
F+ N_{120} in spring	7.89	6.,08	7.73	6.27	7.99	7.19	122.7	12,1
F+ N_{90} in spring + N_{30} at beginning of booting (BBCH 30-32)	7.81	6.28	7.99	5.78	8.46	7.26	124.0	11,9
LSD_{05}	0.676	0.447	0.839	0.669	0.962	0.727		0,826

The variation in protein content dependent on the weather during the growing season and fertilization level. The investigation showed that with increase of nitrogen rates the content of protein in grain tended to increase.

Yield increases on the background of PK, that resulted from single spring-applied nitrogen rates 60, 90 and 120 kg ha^{-1} were different during the experimental years and varied substantially – the variation in different fertilization levels was as high as 81-88 %. In 2001 and in 2002, which was especially warm it increased with a nitrogen rate up to 90 kg ha^{-1}. In 2003 and 2004 nitrogen fertilizers were the most effective – with increasing single rate to 120 kg ha^{-1}, the yield increased. Averaged data indicate that nitrogen rates of 60, 90 and 120 kg ha^{-1} gave grain yield increases of 1.20 ± 0.447 t ha^{-1}, 1.49 ± 0.540 t ha^{-1} and 1.52±0.602 t ha^{-1}, respectively.

Having estimated nitrogen fertilizer efficacy, expressed as kg grain per 1 kg of fertilizer nitrogen, it was found that with nitrogen rates of 60, 90 and 120 kg ha^{-1} applied to triticale, 1 kg of fertilizer nitrogen gave on average 19.9 ± 7.46 kg, 16.5 ± 6.00 kg and 12.7 ± 5.02 kg grain, respectively.

The correlations between winter triticale yield and nitrogen fertilizer rates are presented in Table 2. The strength of correlation varied from weak and statistically insignificant at 95 % probability level (η = 0.35, in 2002) to strong and significant at the highest 99 % probability level (η = 0.92, in 2001). In separate experimental years nitrogen fertilizers were responsible for 13 to 84 % yield data variation. However, the data averaged over the 5 experimental years show that only 11 % yield variation was related to nitrogen fertilizer rate.

2. Correlation coefficients between the yield (y, t ha^{-1}) and nitrogen fertilizer rate (x_1, kg ha^{-1}) and total contents of nitrogen present in the soil and applied with fertilizer (x_2 and x_3, kg ha^{-1})

Year	Correlation coefficients		
	η x_1 – nitrogen fertilizer rate	r x_2 – sum of N-NO_3 and fertilizer nitrogen at the 0-60 cm soil layer	r x_3 – sum of N min and fertilizer nitrogen at the 0-60 cm soil layer
2000	0.50*	0.05	0.04
2001	0.92**	0.88**	0.87**
2002	0.35	0.49	0.49
2003	0.73**	0.96**	0.97**
2004	0.75**	0.94**	0.93**
Avg. over 5 yrs.	0.32**	0.31*	0.31*

While calculating the dependence of nitrogen fertilizer efficacy on nitrogen content in the soil and nitrogen fertilizer rate, we took nitrate and mineral nitrogen content present at the 0-60 cm depth, as the most appropriate indicator that defines nitrogen abundance in the soil, since at the beginning of the growing season, before the main spring fertilization, a large part of mineral nitrogen present in the soil (about 30 %) was found at the 40-60 cm depth. The data from 2001-2004 period indicate that similar yield correlation in terms of strength and significance, was determined when adding up both nitrate and mineral nitrogen content with fertilizer nitrogen content. The correlation was moderate or strong, in 60 % of the cases tested – statistically significant at 99 % probability level. During the experimental period, the sum of $N\text{-}NO_3$ and N_{min} and nitrogen applied with fertilizers present at the 0-60 cm soil layer determined from 24 to 88 % and from 24 to 93 % of the yield, respectively. The data averaged over the 5 experimental years show that the correlation between the yield and total soil mineral nitrogen forms and fertilizer nitrogen content was weak but statistically significant (r = 0.31*).

In plant nutrition diagnostics tests nitrogen fertilizer efficacy is defined by yield increase or calculated figure – percentage yield. It is calculated by dividing the yield of each experimental plot by the highest yield obtained in the experiment. The correlation of winter triticale separate year's and percentage yield with soil nitrogen – nitrate and mineral present at the 0-40 and 0-60 cm depth was determined (Table 3). In most cases the correlation between the mentioned indicators was best described by a parabola of the second degree, however, the correlation was significant not in all the cases studied. The contents of both $N\text{-}NO_3$ and N_{min} at the 0-40 cm soil depth correlated very similarly with percentage yield, the correlation ranged from moderate to strong. At the 0-60 cm depth, percentage yield correlated stronger with soil N_{min} than with $N\text{-}NO_3$, but it was statistically significant only in 40 % of cases. The data from 5 experimental years suggest that average percentage yield correlations with soil nitrogen were most often represented by a linear equation, indicating an inverse moderately strong correlation (r = –0.50-0.51) which was significant only in half of the cases.

Extra fertilization of winter triticale with N_{30} rate in the middle of booting stage, when at the beginning of the growing season 60 and 90 kg ha^{-1} rates of nitrogen had been applied, gave a low and insignificant yield increase in most cases. In 2003 and 2004 extra fertilization for N_{60} – applied triticale was slightly more effective – the grain yield was by 0.65 and 0.89 t ha^{-1} higher compared with the treatments fertilized once at N_{60} and the yield increase was significant at a slightly lower than 95 % probability level. Additionally applied N_{30} rate for triticale fertilized with N_{90} in spring was ineffective, since in the experimental years with considerable moisture deficit grain tended to dry and maturity was accelerated, therefore additionally applied nitrogen remained unutilised.

3. The relationship between percentage yield (y) and N min and $N\text{-}NO_3$ at the 0-40 and 0-60 cm soil layers

Year	Denomination of trait x	Equation	r/ η	dxy	F_{Fisher}
2000	$N\text{-}NO_3$ 0-40 cm	$y = -25.28+1.4134x-0.0191x^2$	0.63	0.40	3.3
2001		$y = -3.07+0.3016x-0.0056x^2$	0.70*	0.50	6.4
2002		$y = -3.86+0.4495x-0.0103x^2$	0.64	0.41	4.9
2003		$y = -1.68+0.2165x-0.0044x^2$	0.84*	0.71	7.4
2004		$y = 2.18-0.0513x$	0.71*	0.50	9.4
Avg. over 5 yrs.		$y = -1.78-0.0523x+0.0007x^2$	0.54	0.29	2.8
2000	$N\text{-}NO_3$ 0-60 cm	$y = -2.69+0.1888x-0.0024x^2$	0.61	0.37	1.5
2001		$y = -3.40+0.1728x-0.0017x^2$	0.38	0.14	0.1
2002		$y = -4.57+0.3499x-0.0054x^2$	0.65*	0.42	5.8
2003		$y = -3.43+0.2273x-0.0029 x^2$	0.79*	0.62	5.6
2004		$y = 2.32-0.0415x$	0.61*	0.38	5.4
Avg. over 5 yrs.		$y = 1.28-0.0099x$	0.50**	0.23	15.9
2000	N min 0- 40 cm	$y = -2.74+0.01640x-0.0018x^2$	0.70*	0.49	5.5
2001		$y = -42.00+1.5463x-0.0139 x^2$	0.55	0.30	2.3
2002		$y = -7.41+0.4367x-0.0056x^2$	0.51	0.26	1v3
2003		$y = -13.57+0.6851x-0.0081x^2$	0.90**	0.81	17.7
2004		$y = 10.35-0.3734x+0.036x^2$	0.47	0.22	0.6
Avg. over 5 yrs.		$y = 1.34-0.0096x$	0.50**	0.25	17.7
2000	N min 0-60 cm	$y = -5.39+0.2004x-0.0016x^2$	0.69	0.47	5.0
2001		$y = -50.49+1.4507x-0.0102x^2$	0.57	0.33	3.2
2002		$y = -16.09+0.6058x-0.0053x^2$	0.72*	0.52	8.7
2003		$y = -14.61+0.4950x-0.0039x^2$	0.84*	0.71	10.9
2004		$y = 9.96-0.2679x+0.0020x^2$	0.39	0.15	0.4
Avg. over 5 yrs.		$y = 1.54-0.0101x$	0.51	0.26	18.6

Conclusions. 1. Nitrogen fertilizers were effective for winter triticale and significantly increased grain yield by on average 19.5-24.0 %. Averaged data suggest that on PK background, N_{60}, N_{90} and N_{120} gave a grain yield increase of 1.20 ± 0.447 t ha^{-1}, 1.49 ± 0.540 t ha^{-1} and 1.52 ± 0.602 t ha^{-1}. Additional winter triticale fertilization was effective in normally wet years; dry weather in separate experimental years was unfavourable for the uptake of additionally applied fertilizer nitrogen.

2. Having estimated the dependence of winter triticale grain yield on nitrogen fertilizer rates, in most cases – five out of six we determined statistically significant, moderately strong or strong correlation ($\eta = 0.50^{*}-0.92^{**}$), nitrogen fertilizers determined 13-84 % grain yield variation.

3. The relationship between winter triticale yield and total nitrogen fertilizer and nitrate ($N-NO_3$) and mineral nitrogen (N_{min}) content at the 0-60 cm soil depth was identified. In terms of strength and significance, the correlations differed little when comparing nitrate and mineral nitrogen and in 60 % of the cases studied were statistically significant at 99 % probability level.

References

1. Alaru M., Laur Ű, Jaama E. (2003) Influence of nitrogen and weather conditions on the grain quality of winter triticale, Agronomy Research, 1(1), 3-10.

2. Булавина Т. М. (1993) Технология производства зерна озимого тритикале *Dar Belarusi* // Автореф. дисс. на соиск.уч. степ. с.-х. наук. Жодино, 29 с.

3. Cimrin K., Bozkurt M., Sekeroglu N. (2004) Effect of nitrogen fertilization on protein yield and nutrient uptake in some triticale genotypes, Journal of Agronomy, 3 (4), 268-272.

4. Malecka I., Blecharczyk A., Sawinska Z. (2004) Wplyw sposobow uprawy roli i nawoženia azotem na plonovanie pszenžyta ozimego, Ann. Univ. M. Curie –Skladovska, E, 59 (1), 259-267.

5. Mikulionienė S., Stankevičius R. (2002) Žolinių pašarų konservantų ir siloso cheminė sudėtis, maistinė vertė ir virškinamumas, Veterinarija ir zootechnika, 18 (40), 94-100.

6. Mut Z., Sezer I., Gulumser A. (2005) Effect of different sowing rates and nitrogen levels on grain yield, yield components and some quality traits of triticale, Asian Journal of Plant Sciences, 4 (5), 533-539.

7. Paponov I. A., Lebedinskai S., Koshkin E.I. (1999) Growth analysis of solution culture – grown winter rye, wheat ant triticale at different relative rates of nitrogen supply, Ann. of Bot., 84, 467-473.

8. Petraitis V., Maikštėnienė S. (2002) Žieminiai ir vasariniai kvietrugiai, 63.

9. Seguchi M., Ishihara C., Yoshino Y. et al. (2000) Breadmaking properties of triticale flour with wheat flour and relationship to amylase activity, Journal of the Science of Food and Agriculture, 64 (4), 582-586.

10. Tarakanovas P., Raudonius S. (2003) Agronominių tyrimų duomenų statistinė analizė taikant kompiuterines programas ANOVA, STAT iš paketo «Selekcija», 60.