RELATIONSHIP BETWEEN FIBRE FLAX YIELD AND DIFFERENT FORMS OF NITROGEN IN THE SOIL
SAKARĪBA STARP LINU ŠĶIEDRU DAUDZUMU UN DAŽĀDĀM SLĀPEKĻA FORMĀM AUGSNĒ

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Abstract. *Research on fibre flax yield response to the amount of different nitrogen forms in the soil was carried out at the Upytė Research Station of the Lithuanian Institute of Agriculture (LIA). Humus content (as a source of nitrogen) (%), total nitrogen (%), ammonium nitrogen (NH_4^+) (mg kg^{-1}), nitrate nitrogen (NO_3^-) (mg kg^{-1}), total mineral nitrogen (N_{min}) (mg kg^{-1}) were measured in the soil samples collected from the plough layer, and the correlation between the mentioned - above soil variables and fibre flax yield was calculated. In most cases the relationships were weak but significant. Seed, stem, and long fibre yields responded to the soil nitrogen differently. The strongest correlation was established between flax yield and humus content.*

Keywords: *correlation, fibre flax, humus content, nitrogen, soil.*

Introduction

Safe and clean environment is of paramount importance for the existence of life on our planet. To minimize the hazardous effects of agricultural production on our natural environment we have to be environment-conscious while planning agricultural inputs, especially those of nitrogen. Our task was to study fibre flax yield as affected by different soil nitrogen forms so that we could predict and advocate rational use of fertilizers.

The first research findings on how flax responds to the soil agrochemical properties in Lithuania were reported in 1992-1996 [5, 6, 7, 8], where focus was placed on the effects of humus content on flax yield. Increasing humus content (up to 2.6 %) increased seed, stem, and long fibre yield.

Research carried out with fibre flax during 1995-1997 revealed a relatively strong relationship between fibre flax stem and long fibre yield and the content of mineral nitrogen in the soil plough layer [3].

Further studies were focused on the impact of some soil agrochemical properties on linseed yield, particularly the effects of humus, nitrate nitrogen, ammonium nitrogen, and total mineral nitrogen contents. Linseed seed yield was positively influenced by nitrate nitrogen and humus content and negatively – by the ammonium nitrogen in the soil. Stem yield for linseed increased with increasing contents of nitrate nitrogen, ammonium nitrogen, total mineral nitrogen and humus. Long fibre yield for linseed was positively influenced by increasing contents of nitrate nitrogen, total mineral nitrogen, and humus [9].

Materials and methods

The response of fibre flax yield to the amount of different forms of nitrogen in the soil was studied at the LIA"s Upytė Research Station. The trial was conducted on a sandy loam Eutri-Endohypogleyic Cambisol [1]. In 1996-1998 in the trial where different zinc sulphate rates (0.35-4 kg ha^{-1}) have been investigated soil samples taken from the 0-20 cm layer before flax sowing (in 84 trial plots each year) were assayed for contents of humus, total nitrogen, ammonium nitrogen (NH_4^+) mg kg^{-1}, nitrate nitrogen (NO_3^-) mg kg^{-1}, total mineral nitrogen (N_{min}) mg kg^{-1}, as wel as soil pH, content of P_2O_5 and K_2O. The content of P_2O_5 in the soil arable layer was 165-254 mg kg^{-1}, content of K_2O – 143-170 mg kg^{-1} (determined in A-L extraction), pH_{KCl} level – 7.3-7.5 (potenciometrically). Humus content was determined by Tyurin method,

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content of total nitrogen – by Kjeldahl method, content of nitrate nitrogen (NO_3) and content of ammonium nitrogen (NH_4) – in 1 N KCl extraction by calorimetrical method and content of total mineral nitrogen (N_{min}) – by adding up the amount of nitrate nitrogen and ammonium nitrogen.
$N_{15}P_{20}K_{60}$ before flax sowing have been applied. Flax cv. Baltučiai was sown by a sowing machine SNL-16 at a seed rate of 22 million viable seed per hectare with 10 cm row spacings. In the field rotation, flax followed winter wheat. Herbicide Valinate 0.3-0.4 l ha^{-1} was used to control broad-leaved weeds, herbicides Fusilade (2 l ha^{-1}) or Agile (1 l ha^{1}) – to control grasses. Insecticides Fastac (0.1 l ha^{-1}) and Decis (0.3 l ha^{-1}) were used to control flea-beetles. Flax was grown and the assessments were done following the standard methodology [11]. Flax was pulled at the stage of early yellow ripeness, threshed by a MS thresher, stems were retted in warm (33-37˚C) water, then were breaked up by a machine tool SMT-200, threshed by a MS thresher, fibre was hackled using combs number 9 and 13. Seed, stem and long fibre yield was established in the plots and the correlation between fibre flax yield and amount of different forms of nitrogen in the soil was calculated. More than 250 paired cases were used for the calculation of correlation.

Results and discussion

Variation of the contents of different nitrogen forms in the soil. Some authors report that the content of nitrate nitrogen or ammonium nitrogen depends on soil pH level. In acid soils the content of ammonium nitrogen is higher than that of nitrate nitrogen and in the soils having pH reaction close to neutral, the content of nitrate nitrogen is higher than that of ammonium nitrogen [3, 4, 10]. In our trials the soil was slightly alkaline and close to neutral reaction.
The content of nitrate nitrogen varied slightly in the plots and via time – from 5.10 to 7.32 mg kg^{-1}, but the content of ammonium nitrogen varied more markedly (especially in different years) – from 1.90 to 4.32 mg kg^{-1}. The content of total mineral nitrogen varied from 7.63 to 10.91 mg kg^{-1}. According to the grading system [2] tested soils could be described as having low amount of total nitrogen (up to 0.2 %). The amount of total nitrogen in the soil varied from 0.104 to 0.148 %. Humus content in the tested plots varied from 2.65 to 4.33 %, and tested soils could be described as having high or very high humus content [2].
Seed yield. The seed yield varied (from 625 to 1120 kg ha^{-1}) between plots and years, therefore a possibility to calculate the correlation occurred. Linear and quadratic correlations were calculated, but in most cases the quadratic correlation had higher probability level. In most cases the relationship between fibre flax seed yield and different soil nitrogen forms was weak, but significant at the 95 % probability level.
Flax seed yield was affected by the content of ammonium nitrogen and total mineral nitrogen, humus content and amount of total nitrogen in the soil and was not influenced by the content of nitrate nitrogen. The equations of correlation and their probability data are presented; "r / η" means coefficient of linear or quadratic correlation, "r_{95}/η_{95}" – statistically significant coefficient of linear or quadratic correlation at 95 % probability level. Statistically significant cases are presented in bold (Table 1).
Seed yield increased with an increase in ammonium nitrogen content from 1.90 to 4.32 mg kg^{-1} and the content of total mineral nitrogen increased from 7.63 to 10.91 mg kg^{-1}. Total nitrogen had different influence on flax seed yield. When the content of total nitrogen varied between 0.104-0.136 %, flax seed yield tended to decline. With an increase in the content of total nitrogen from 0.136 to 0.148 %, the seed yield increased. Seed yield was increasing until humus content had reached 4.06 %. From this point and onwards flax seed yield declined.
The strongest significant correlation (of the investigated nitrogen forms) showed ammonium nitrogen and humus.
Stem yield. The stem yield varied in the plots from 3191 to 7624 kg ha^{-1} (the main variation was found between years). Linear and quadratic correlations were calculated, and in most cases weak, but significant correlation was established (quadratic as well as linear correlations were found to be significant). Stem yield was not affected by the content of nitrate nitrogen (Table 2).
The changes in the content of ammonium nitrogen and in the content of total mineral nitrogen

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affected stem yield differently compared with seed yield. Stem yield decreased with an increase in ammonium nitrogen content from 1.90 to 4.32 mg kg^{-1} and the content of total mineral nitrogen increased from 7.63 to 10.91 mg kg^{-1}. The increase in the content of total mineral nitrogen from 0.104 to 0.148 % and the increase in humus content from 2.65 to 4.33 % had a positive effect on flax stem yield.

The strongest significant correlation (of all investigated nitrogen forms) exhibited ammonium nitrogen and total mineral nitrogen.

Table 1.

The influence of different soil nitrogen forms (x) on flax seed yield (y_1, kg ha^{-1})

N form (x)	x variation	Equation	r / η	r_{95}/ η_{95}
$N\text{-}NO_3$, mg kg^{-1}	6.21 ± 1.106	y_1= 955.52 – 15.39x	- 0.100	0.135
	6.21 ± 1.106	y_1= 969.66 – 19.77x + 0.3280x^2	0.100	0.135
$N\text{-}NH_4$, mg kg^{-1}	**3.11 ± 1.207**	**y_1= 761.84 + 31.60x**	**0.223**	**0.135**
	3.11 ± 1.207	**y_1= 686.24 + 67.70x – 3.2957x^2**	**0.234**	**0.135**
N_{min}, mg kg^{-1}	**9.27 ± 1.638**	**y_1= 720.18 + 15.09x**	**0.145**	**0.135**
	9.27 ± 1.638	**y_1= 770.66 + 5.10x + 0.4756x^2**	**0.146**	**0.135**
N_{total}, %	0.126 ± 0.0217	y_1= 875.81 – 125.34x	- 0.016	0.135
	0.126 ± 0.0217	**y_1= 1559.50 – 10585.74x + 38807.7895x^2**	**0.170**	**0.135**
Humus, %	**3.49 ± 0.838**	**y_1= 740.70 + 34.22x**	**0.168**	**0.135**
	3.49 ± 0.838	**y_1= 372.11 + 256.18x – 31.5254x^2**	**0.220**	**0.135**

Table 2.

The influence of different soil nitrogen forms (x) on flax stem yield (y_2, kg ha^{-1})

N form (x)	x variation	Equation	r / η	r_{95}/ η_{95}
$N\text{-}NO_3$, mg kg^{-1}	6.21 ± 1.106	y_2= 6020.75 – 88.96x	- 0.080	0.135
	6.21 ± 1.106	y_2= 7223.02 – 461.21x + 27.8837x^2	0.093	0.135
$N\text{-}NH_4$, mg kg^{-1}	**3.11 ± 1.207**	**y_2= 6485.27 – 327.11x**	**- 0.321**	**0.135**
	3.11 ± 1.207	**y_2= 8322.56 – 1204.60x + 80.0890x^2**	**0.399**	**0.135**
N_{min}, mg kg^{-1}	**9.27 ± 1.638**	**y_2= 7545.31 –224.06x**	**- 0.298**	**0.135**
	9.27 ± 1.638	**y_2= 8881.11 – 488.45x + 12.5854x^2**	**0.306**	**0.135**
N_{total}, %	0.126 ± 0.0217	**y_2= 4499.04 + 7701x**	**0.136**	**0.135**
	0.126 ± 0.0217	**y_2= 1556.17 + 52727.22x – 167044.7980x^2**	**0.169**	**0.135**
Humus, %	**3.49 ± 0.838**	**y_2= 4576.42 + 255.90x**	**0.174**	**0.135**
	3.49 ± 0.838	**y_2= 6261.35 – 758.72x + 144.1104x^2**	**0.196**	**0.135**

Long fibre yield. During the experimental years the yield of long fibre varied from 368 to 1595 kg ha^{-1}. The calculated quadratic and linear correlation was found to be significant at 95 % probability level. The relationship between long fibre yield and content of nitrate nitrogen, content of ammonium nitrogen and content of total mineral nitrogen, humus content in the soil was established. The amount of total nitrogen did not affect long fibre yield of flax. Long fibre yield decreased when the content of nitrate nitrogen rose from 5.10 to 7.32 mg kg^{-1}, the content of ammonium nitrogen rose from 1.90 to 4.32 mg $kg^{-1,}$ and the content of total mineral nitrogen rose from 7.63 to 10.91 mg kg^{-1}. Humus content had a positive effect on long fibre yield of flax. Long fibre yield increased with an increase in humus content from 2.65 to 4.33 %.

Humus content exhibited the strongest significant correlation (of the investigated nitrogen forms).

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Table 3.

The influence of different soil nitrogen forms (x) on long fibre yield of flax (y_3, kg ha^{-1})

N form (x)	x variation	Equation	r / η	r_{95}/ η_{95}
N-NO_3, mg kg^{-1}	6.21 ± 1.106	**y_3= 1422.89 – 78.09x**	**- 0.231**	**0.135**
	6.21 ± 1.106	**y_3= 1444.96 – 84.92x + 0.5118x^2**	**0.231**	**0.135**
N-NH_4, mg kg^{-1}	**3.11 ± 1.207**	**y_3= 133.47 – 62.80x**	**- 0.203**	**0.135**
	3.11 ± 1.207	**y_3= 1595.49 – 283.46x + 20.1398x^2**	**0.282**	**0.135**
N_{min}, mg kg^{-1}	**9.27 ± 1.638**	**y_3= 1534.95 – 64.38x**	**- 0.282**	**0.135**
	9.27 ± 1.638	**y_3= 2061.34 – 168.56x + 4.9594x^2**	**0.296**	**0.135**
N_{total}, %	0.126 ± 0.0217	y_3= 952.51 – 112.76x	- 0.006	0.135
	0.126 ± 0.0217	y_3= 935.50 + 147.40x – 965.2154x^2	0.007	0.135
Humus, %	**3.49 ± 0.838**	**y_3= 395.90 + 155.56x**	**0.348**	**0.135**
	3.49 ± 0.838	**y_3= 555.33 + 59.55x + 13.6360x^2**	**0.350**	**0.135**

Conclusions

In most cases the relationship between fibre flax yield and different soil nitrogen forms was weak, but significant at 95 % probability level.

In most cases the quadratic correlation had a higher significance level for seed yield and, while for stem and long fibre yield the quadratic as well as linear correlations were found to be significant.

Flax seed, stem and long fibre yield exhibited a different response to soil nitrogen. The changes in the content of ammonium nitrogen and in the content of total mineral nitrogen had the same effect on stem and long fibre yield, whereas they had a different effect on seed yield.

Flax seed and stem yield was not affected the by the content of nitrate nitrogen (when it varied from 5.10 to 7.32 mg kg^{-1}).

The correlation between long fibre yield and the content of total nitrogen (0.104 to 0.148 %) was not found.

Only increasing humus content (from 2.65 to 4.06 %) increased all three kinds of flax yield (seed, stem, and fibre).

The strongest significant correlation (of investigated nitrogen forms) for seed and stem yield exhibited ammonium nitrogen and total mineral nitrogen, for long fibre yield humus content.

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