EFFECT OF SOIL AND WEATHER CONDITIONS AND SOME AGRICULTURAL PRACTICES ON YIELD AND YIELD COMPONENTS IN LINSEED (*LINUM USITATISSIMUM* L.)*

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We investigated the effect of N-fertilization, sowing rates and soil-climatic conditions on yield and yield components of linseed varieties Atalante and Szegedi-30. Field experiments were carried out in 1994–1998 at localities of Troubsko near Brno and in Prague-Ruzyně, both situated in the sugar beet production region. The seed yield was significantly affected by site, year, N fertilization, sowing rate and variety. Average seed yields of dry matter ranged from 0.43 t.ha^{-1} (1994 – Troubsko) to 2.76 t.ha^{-1} (1998 – Prague-Ruzyně). N-fertilization before sowing (dose 30 kg.ha^{-1} of ammonia sulphate) increased seed yields in Ruzyně and Troubsko (in average of both sites) by 3.4% compared to non-fertilized control. The application of nitrogen during the vegetation period (30 kg.ha^{-1} in ammonia nitrate with limestone) resulted in the increase of seed yield by 2.4% compared to dose of 30 kg.ha^{-1} of ammonia sulphate. N fertilization in the total dose of 60 kg.ha^{-1} significantly increased, in the fertile soils at Ruzyně and Troubsko, the seed yields in the total average of both sites by 5.8% (0.1 t.ha^{-1}) in comparison with non-fertilized variants. The used N doses increased the seed yield more in treatment with higher sowing rates V_2 (500 germinable seeds per m^2) and, also generally in colder and wetter years. The number of capsules, thousand kernel weight and the number of seeds per plant were not significantly affected by nitrogen doses. The number of seeds and capsules per plant was significantly influenced by the year of growing and the sowing rates. Similarly, the average stem yield was significantly influenced by the year and sowing rates. Oil content of seeds varied between experimental years, but the composition of individual fatty acids was less variable. In both varieties the lowest oil content in seeds was observed in 1994 when the weather during seeds ripening (July, August) was very warm and dry. Linolenic acid was prevailed with more than 50% share in oil content in both varieties. During the whole experimental period the occurrence of diseases and pests was not important.

linseed; N-fertilization; sowing rates; seed yield; yield structure; oil content

INTRODUCTION

At present, winter rape is the most frequently grown oilseed crop in the Czech Republic. This development is due to the period in which the complex growing system was implemented. Simultaneously with this development, a greater attention has been recently paid also to spring oilseed crops. It is given by the fact that due to the foodstuff overproduction there is a greater interest in other plant species grown as technical crops or for further technical processing. One of the alternative plants, the growing of which is subsidised by the State, is also linseed. At present, about 2000 ha are harvested in the Czech Republic, the average yields in the periods 1999/2000 and 2000/2001 were 1.57 or 1.35 ton, respectively, of seed per hectare of linseed (according to the situation and prospect report of the Ministry of Agriculture).

The Research Institute of Crop Production in Prague-Ruzyně, together with the Forage Crop Research Institute, s.r.o., Troubsko, carried out experiments in the period 1994–1998 with linseed in field conditions, the field trials being mainly aimed, beside the comparison of linseed with some non-traditional oilseed crops, at observing the impact of soil and weather conditions, sowing rate and different N-fertilization on yields and yield structure of two selected linseed varieties.

MATERIAL AND METHODS

Field trials were carried out in the period 1994–1998 at two different sites (Troubsko near Brno, Prague-Ruzyně). Site conditions are given in Table 1.

The weather course in individual years and sites was evaluated using the system described by Kožnarová, Klabzuba (2002). In comparison with long term averages the year 1994 can be characterized by very warm and dry weather conditions during vegetation period and the year 1995 by relatively higher precipitations. The weather conditions of the other years were not substantially different from average course.

In the period of ripening of seed and stem the weather was very dry and warm in the years 1994 and 1995, and

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Table 1. Experimental site conditions

Experimental site	Troubsko (near Brno)	Prague-Ruzyně
Latitude	49°12'	50°04'
Longitude	16°37'	14°26'
Altitude (m)	270	350
Soil texture	loam	clay-loam
Great soil group	Luvic Chernozem	Orthic Luvisol
Average annual air temperature (°C)	8.4	8.2
Average annual precipitation sum (mm)	547	477
Agrochemical properties of topsoil:		
Humus content (%)	2.44	3.00
pH (KCl)	5.94	5.57
P content (Mehlich II, mg.kg^{-1} soil)	112.0	124.9
K content (Mehlich II, mg.kg^{-1} soil)	199.7	126.0

on contrary, wet and cold in 1996. In this period the course of temperatures and precipitation was close to average in the years 1997 and 1998. In 1999 the ripening of stem and seeds was affected by warm and dry weather conditions.

A cereal was the forecrop of linseed in both sites and in all years. Usual agricultural measures were applied when preparing the soil for linseed. In both sites, the forecrop was succeeded by stubble ploughing and mean ploughing (up to depth 22 cm). Usual pre-sowing preparation was done in spring. In autumn, P and K fertilization was applied every year in both sites – it was the same for all variants and the doses were 26 kg P per hectare in superphosphate and 50 kg K per hectare in potassium chloride. For N-fertilization, the following doses were chosen: N_0 – without N fertilization, N_1 – 30 kg.ha^{-1} (one dose in ammonia sulphate before sowing), N_2 – 60 kg.ha^{-1} (fertilization in two doses – 30 kg.ha^{-1} N in ammonia sulphate before sowing and 30 kg.ha^{-1} N in ammonia nitrate with limestone in the stage of quick growing of linseed).

Linseed was sown by Oyord sowing machine into rows in 125 mm spacing in two different sowing rates: V_1 – 250 germinable seeds per m^2 (about 17 kg.ha^{-1}), V_2 – 500 germinable seeds per m^2 (about 34 kg.ha^{-1}). Following varieties were introduced into the trials: Atalante (1994–1996 at the site Troubsko and 1994–98 at the site Ruzyně) and Szegedi-30 (1994–1998 at both sites). Atalante is a French medium early variety registered in the variety book of the Czech Republic since 1997. Szegedi-30 is a Hungarian medium early very plastic variety. Field trials had in three replications. The size of individual plots was 15 m^2. Herbicides recommended for linseed were used according to the weed infestation.

The following parameters were observed during the vegetation: health conditions, degree of pest and diseases infestation, plant density before the harvest. Seed and stem yields, the thousand seed weight (TSW), the duration of the vegetation period (from the sowing to the harvest), the number of capsules per plant and the plant height were also determined. The oil content in seeds and the proportion of individual fatty acid were established every year in individual varieties grown at the Ruzyně site. UNISTAT 5.0 package was used for statistical analyses of experimental data (LSD and mean squares).

RESULTS AND DISCUSSION

The oil content in seeds was variable in experimental years. The lowest content of oil in seeds was ascertained in both varieties in 1994, when the weather was very warm and dry during the ripening of seeds (July, August). Also the vegetation period of linseed was very short that year. The oil content in the Atalante variety was that year only 36.4% and in the Szegedi-30 variety was 34.5%. The highest oil content was ascertained in 1998, when it was 41.1% in the Atalante variety and up to 42.6% in the Szegedi-30 variety. In that year also the highest seed yields of the monitored period were obtained. The content of individual fatty acids varied in dependence on the year less that the oil content. In both varieties, linolenic acid prevailed in seeds (its content was much higher than 50% – Table 2). More than 10% of content had also oleic and linoleic acid. The used N-doses had not a statistically significant impact on the oil content in seeds. It can be said that, on average, a higher N-dose (60 kg.ha^{-1}) reduced the oil content by 2.1% compared to the non-fertilized variants. The fact that N-fertilization reduces the oil content in linseeds is mentioned also e.g. by Dubey et al. (1997).

Seed yield was significantly influenced by the site, the year of growing, fertilization, the sowing and the variety (Table 3). Seed yields ranged in average from 0.43 t.ha^{-1} calculated in dry mass in 1994 in the site of Troubsko up to 2.76 t.ha^{-1} in 1998 obtained at Ruzyně (Table 4). Also the length of the vegetation period was in different years largely influenced by the weather. The vegetation period in the dry and warm year 1994 was, from the

Table 2. The effect of nitrogen fertilization on content of oil (%) and composition of fatty acids (%) at Ruzyně site in the years 1994–1996

Variety	Fertilization	Oil content	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid
Atalante	N_0*	38.3	6.3	4.0	16.0	16.1	57.5
Szegedi-30	N_0	40.0	6.7	4.0	17.7	19.8	52.2
Average	N_0	39.1	6.5	4.0	16.9	17.9	54.9
Atalante	N_2**	38.0	5.9	4.0	15.7	16.3	58.0
Szegedi-30	N_2	38.6	6.0	3.8	16.4	19.2	54.6
Average	N_2	38.3	6.0	3.9	16.1	16.3	56.3

* no fertilization; ** 60 kg.ha^{-1} N

Table 3. ANOVA mean squares of different observed characters

Source of variability	Seed yield (t/ha)	Stem yield (t/ha)	Plant density (No/m^2)	Plant height (cm)	Thousand seed weight (g)	No. of seeds per plant (No/plant)	No. of capsules per plant (No/plant)
Site	3.641**	0.0282	9412.82**	157.034**	8.4120**	915.439	322.2561**
Year	6.859**	8.1145**	22280.3**	1342.74**	7.8970**	39004.72**	327.0426**
Fertilization	0.1279**	0.12226	83.540	40.4396*	0.0024	518.9251	10.32137
Sowing rate	0.2528**	4.4043**	1016611.5**	52.4507*	0.06771	26874.5**	435.7922**
Variety	1.2696**	0.3487	653.65	3.0467	1.2648**	1913.04	75.9002

* statistically significant influence ($P < 0.05$)
** statistically significant influence ($P < 0.01$)

Table 4. Average yields of seed dry matter (t.ha^{-1}) at two sites in the years 1994–1998

Variety	Year	Atalante	Szegedi 30
Site		Seed yield	Seed yield
Ruzyně	1994	1.296	1.102
	1995	1.187	0.823
	1996	2.168	1.809
	1997	1.849	1.584
	1998	2.757	2.605
Average	1994–1996	1.550	1.245
Average	1994–1998	1.851	1.585
Troubsko	1994	0.637	0.431
	1995	0.620	0.802
	1996	1.955	1.980
	1997	–	2.383
	1998	–	1.420
Average	1994–1996	1.071	1.071
Average	1994–1998	–	1.403

sowing to the harvest, only 119 days at Ruzyně and even 101 days at Troubsko. Vegetation was the longest period in 1996: 154 days at Ruzyně and 163 days at Troubsko. The difference in the length of the vegetation period between the mentioned years was 35 days at Ruzyně and even 60 days at Troubsko.

The impact of weather and by that the length of the vegetation period manifested itself by the seed yield. The difference in the seed yield in the mentioned years fluctuated on average of variants from 0.82 t.ha^{-1} to 2.76 t.ha^{-1} at Ruzyně and even from 0.43 t.ha^{-1} to 2.38 t.ha^{-1} at Troubsko. The average seed yield at Ruzyně, independently on the variety and the monitored indices, was, calculated in dry matter, in the monitored period (1994–1996) 1.40 t.ha^{-1}, at Troubsko 1.07 t.ha^{-1} (Table 4). At Ruzyně, the Atalante variety had higher yields in the monitored period. At Troubsko, both varieties gave in average nearly the same seed yields.

N fertilization in the total dose of 60 kg.ha^{-1} significantly increased, in the fertile soils at Ruzyně and Troubsko, the seed yields in the total average of both sites by 5.8% (0.1 t.ha^{-1}) in comparison with the non-fertilized variants (Tables 5, 6). The used N doses increased the seed yield more in treatment V_2 and, generally, also in colder and wetter years. No statistically significant difference was found in seed yields in comparison of the N_1 fertilization (30 kg.ha^{-1} before sowing) and the N_2 one (60 kg.ha^{-1} in two doses). It is generally not recommended to add nitrogen to flax after sowing because of its low effectiveness (Fábry et al., 1990). Also an additional N fertilization in our trials during the vegetation in the stage of quick linseed growing in a dose of 30 kg.ha^{-1} of N in ammonia nitrate with limestone increased in average the seed yield only by 2.4%. Lokot, Sadchenko (1995) consider in years with normal weather conditions the doses of 30 kg.ha^{-1} N to flax before sowing as sufficient. The dose of 30 kg.ha^{-1} N is recommended for the yield of linseed also by Dwivedi et al. (1994). Augustinussen (1992) indicates that the dose of 40 kg.ha^{-1} N was optimal for reaching the best total results as far as yields of both seeds and fibre are concerned.

With a higher sowing rate V_2 – 500 germinative seeds per m^2 higher yields of seeds, by 30% (0.42 t.ha^{-1} of dry

Table 5. Average seed and stem yields from different treatments on dry matter and other parameters observed at Ruzyně

Variant	N_0V_1	N_1V_1	N_2V_1	N_0V_2	N_1V_2	N_2V_2	Average	$LSD_{0.05}$
Seed yield (t.ha^{-1})	1.67	1.70	1.65	1.66	1.81	1.82	1.72	0.748
Stem yield (t.ha^{-1})	2.90	2.92	2.82	2.97	3.20	3.30	3.02	0.496
Thousand seed weight (g)	5.79	5.79	5.72	5.78	5.82	5.81	5.79	0.76
No. of capsules per plant	24.4	24.9	20.3	15.1	15.7	20.3	20.4	9.97
Plant height (cm)	57.7	61.1	58,0	54.3	58.0	60.3	58.4	10.84
Plant density (plants.m^{-2})	208	226	205	431	462	464	333	110.3
No. of seeds per plant	155	164	143	75	78	81	116	70.30

Nitrogen fertilization: N_0 – no fertilizing, N_1 – 30 kg.ha^{-1}, N_2 – 60 kg.ha^{-1}
V_1 – sowing rate of 250 germinable seeds per m^2 (17 kg.ha^{-1})
V_2 – sowing rate of 500 germinable seeds per m^2 (34 kg.ha^{-1})

Table 6. Average seed and stem yields from different treatments on dry matter and other parameters observed at Troubsko

Variant	N_0V_1	N_1V_1	N_2V_1	N_0V_2	N_1V_2	N_2V_2	Average	$LSD_{0.05}$
Seed yield (t.ha^{-1})	1.15	1.03	1.09	1.67	1.93	2.01	1.50	0.872
Stem yield (t.ha^{-1})	2.63	2.22	2.24	1.85	2.15	2.32	3.28	2.247
Thousand seed weight (g)	5.55	5.14	5.18	5.06	5.51	5.55	5.33	1.24
No. of capsules per plant	15.2	16.1	15.8	14,9	15.3	15.5	15.5	3.25
Plant height (cm)	65.6	62.3	62.9	61.7	65.6	66.1	64.0	16.14
Plant density (pieces.m^{-2})	254	226	234	496	499	499	368	31.7
No. of seeds per plant	77	89	84	150	144	157	117	53.9

mass), were found in comparison with the canopies founded with a lower sowing rate V_1 of 250 germinative seeds per m^2. From the point of view of yield level, our results showed that the sowing rate of about 250 germinative seeds per m^2 is too low. Diepenbrock et al. (1995) studied the yield stability of oilseed flax in trials in Germany and Switzerland. Besides others, they came to a conclusion that a sowing of 200 seeds per m^2 is connected with a significant yield instability and that a sowing of more than 800 seeds per m^2 also significantly reduces the yield of seeds. They recommend in their paper the sowing rate of 400 seeds per m^2. In farm practice in Czech, the sowing norm is recommended according to the type of soil and the altitude from 700 to 1000 seeds per m^2 (Štaud et al. 1996). Borm (1998) recommends 400 plants.m^2 as optimal for growing the McGregor variety in the Netherlands. The same number of plants is also recommended for the conditions of Spain by Alburquerque, Pascual-Villalobos (1996). For the conditions of Italy, Bonciarelli, Ciriciofolo (1997) recommend the sowing rate of 600–800 seeds per m^2.

Plant health of linseed crop was very satisfactory during the whole monitored period at both sites. During the whole experiment period, we did not find any stronger occurrence of diseases or pests.

The number of seeds and capsules per plat was statistically significantly influenced by the year of growing and by the used sowing rate. The yield of stems was significantly influenced by the year of growing and the sowing rate (Table 3). N-fertilization and selected variety did not significantly influence the stem yield. The used N doses did not significantly influence the number of capsules, the mass of thousand seeds and the number of seeds per plant in comparison with the non-fertilized variants. A similar conclusion was made also by Candrákova, Bakula (2001). Thousand seed weight was not significantly influenced by the density of the canopy in the trials. Similarly, Vender et al. (1995) found that the number of seeds in capsules and the thousand seed weight were not influenced by the density of the canopy. We have come to similar conclusions in our trials. Kurt (1996) indicates the presence of negative correlation between the number of capsules per plant and the number of seeds in a capsule and between the seed yield per plant and the thousand seed weight.

Our results showed that linseed can be successfully grown in the sugar beet growing region. Certain difficulties with reaching higher seed yields will appear in warm and dry summers.

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Vliv půdně-klimatických podmínek a některých agrotechnických opatření na výnosy a výnosové složky lnu olejného (*Linum usitatissimum* L.).

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V polních pokusech na dvou odlišných stanovištích zařazených do řepařské zemědělské výrobní oblasti v Troubsku u Brna a Praze-Ruzyni byl v letech 1994 až 1998 sledován vliv hnojení dusíkem, výsevku a půdně-klimatických podmínek na výnosy a výnosotvorné prvky dvou vybraných odrůd lnu olejného – Atalante a Szegedi-30. Výnos semene byl průkazně ovlivněn stanovištěm, rokem pěstování, hnojením, výsevkem i odrůdou. Výnosy semen přepočtené na sušinu kolísaly v průměru od 0,43 t.ha^{-1} v roce 1994 na stanovišti v Troubsku do 2,76 t.ha^{-1} v roce 1998 na stanovišti v Ruzyni. Hnojení dusíkem před setím (30 kg.ha^{-1} v síranu amonném) zvyšovalo v Ruzyni a Troubsku výnosy semene v průměru obou stanovišť o 3,4 % oproti nehnojeným variantám. Přihnojení dusíkem během vegetace ve fázi rychlého růstu lnu v dávce 30 kg.ha^{-1} N v ledku amonném s vápencem v průměru zvyšovalo výnos semene o dalších 2,4 % oproti nehnojeným variantám. Hnojení dusíkem na úrodných půdách v Ruzyni a Troubsku v celkové dávce 60 kg.ha^{-1} statisticky významně zvyšovalo výnos semene v celkovém průměru obou stanovišť o 5,8 % (0,1 t.ha^{-1}) v porovnání s nehnojenými variantami. Použité varianty hnojení dusíkem průkazně neovlivňovaly počet tobolek, HTS a počet semen na rostlinu. Počet semen a tobolek na rostlinu byl statisticky průkazně ovlivněn rokem pěstování a použitými výsevky. Podobně výnos stonků průkazně ovlivňovaly rok pěstování a výsevek. Obsah oleje v semenech kolísal v jednotlivých letech. Nejmenší procentuální zastoupení oleje v semenech bylo u obou odrůd zjištěno v roce 1994, kdy počasí v době dozrávání semen (červenec, srpen) bylo velmi teplé a suché. Obsah jednotlivých mastných kyselin kolísal vlivem ročníku méně, než tomu bylo u obsahu oleje. U obou odrůd převažovala v semenech kyselina linolenová, jejíž hodnoty překračovaly 50 % celkového podílu mastných kyselin. Během celého období sledování nebyl zjištěn silnější výskyt chorob nebo škůdců.

len olejný; hnojení dusíkem; výsevek; výnosy; struktura výnosu; olejnatost

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