Effects of Seeding Rates and Nitrogen Fertilization on Seed Yield, Seed Quality and Yield Components of False Flax (*Camelina sativa Crtz.*)

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Wirkung von Aussaatmenge und Stickstoffdüngung auf den Samenertrag, die Samenqualität und die Ertragskomponenten von Leindotter (*Camelina sativa Crtz.*)

1. Introduction

Triglyceride fats and oils fulfilled the needs of people for many centuries. Few oilseed crops such as flax and rape seed had been cultivated and grown for industrial use. Some other oilseed crops such as sunflower and soybeans have been utilized for both food and industrial applications. Surfactants, lubricants, coatings' color and plastics are some of vegetable oil products, which play a vital role in many industries. In addition to the existing industrial oil crops (rape, crambe, linseed etc.) there are numbers of uncultivated oil crops with highly yielding potentials and content of fats. These include false flax. Although linolenic acid content of false flax (35 to 40 %) is considerably less than that of linseed (60 to 70 %), it places this oil crop in the category of drying oils.

False flax is a member of the plant family *Brassicaceae*, which it relates to rape and mustard. This plant is one of the oldest oil crops in the temperate regions. It is native in south and south-west Asian countries. In the late 1930 some varieties of the genus *Camelina* had been grown on poor sandy soil in most parts of European countries, namely: Russia, Poland, Netherlands, Belgium etc., mainly to replace winter-killed rape (PLESSERS et al., 1962).

There is no clearly stated reason why the growing of false flax is declined in the Middle Age and thereafter. The incompetence with other fundamentally important oil crops and its very small size of seeds are probably the reasons for the decline in its cultivation (MIKUSCH, 1955; MARQUARD and KUHLMANN, 1986).

In recent years there had been made much interest in the possibility of finding new crops with high oil content for

Zusammenfassung

In 3-jährigen Versuchen wurden unter den Bedingungen eines lehmigen Sandbodens der Ertrag und die Bildung der Ertragskomponenten von Leindotter in Abhängigkeit von den Prüffaktoren Saatmenge und Stickstoffdüngung getestet. Die ermittelten Kornerträge variierten im Mittel der Varianten von 11,6 dt/ha im Jahr 1994 bis 18,0 dt/ha im Jahr 1995. Der Maximalertrag lag im Mittel aller Varianten bei 22,8 dt/ha (120 kg/ha N, 400 Samen/m^2). Die Realisierung der höchsten Aussaatmenge von 800 Samen/m^2 führte zu einer verringerten Ausprägung der Verzweigungszahl/Pflanze, der Schoten/Pflanze, der Samen/Schote und des Samengewichtes/Pflanze. Im Gegensatz zur Wirkung der Aussaatmengen bewirkten höhere Dosierungen an Stickstoff eine verbesserte Ausbildung des Ertrages und seiner Komponenten. Die Anwendung von 120 kg/ha N und die Aussaat von 400 keimfähigen Körnern/m^2 führten zum besten Ertragsergebnis und zu einem besseren Verhältnis zwischen den Ertragskomponenten. Weder die Aussaatmenge noch die N-Düngung bewirkten eine Beeinflussung des Tausendkorngewichtes. Der Ölgehalt des Leindotters variierte von 37 % bis 43 %. Innerhalb der Fettsäurenzusammensetzung betrug der Anteil der gesättigten Fettsäuren etwa 8 %. Von den ungesättigten Fettsäuren nahm die Linolensäure mit 35 % den größten Anteil ein.

Schlagworte: Leindotter, Camelina sativa, Samenertrag, Ertragskomponenten, Ölgehalt.

Summary

The influence of seeding rate and nitrogen fertilization on yield efficiency and formation of yield components of false flax was investigated over three years under loamy sand soil conditions. On average of all treatments ranges of yields were 11.6 dt/ha in the year 1994 to 18.0 dt/ha in the year 1995. The maximum yield of all treatments was 22.8 dt/ha (120 kg/ha nitrogen, 400 seeds/m²). The formation of the yield components branches/plant, pods/plant, seeds/pod and seed weight/plant was reduced by sowing the higher seeding rate of 800 seeds/m². In contrast to the effects of seeding rates, the yield elaboration and formation of its components are positively influenced by the higher doses of nitrogen fertilization. Application of 120 kg/ha nitrogen and sowing of 400 viable seeds per m² gave a better seed yield and a better proportion between the yield components. Seeding rate and nitrogen fertilizing didn't influence the thousand kernel weight. The oil content of false flax in the test ranged from 37 to 43 %. The amount of the saturated fatty acids in the fatty acid compositions comprises about 8 %. From all polyunsaturated fatty acids of false flax oil the linolenic acid has had the highest part with 35 %.

Key words: false flax, Camelina sativa, seed yield, yield components, oil content.

industrial applications. Because of its high content of linolenic fatty acid, the plant false flax is considered as one of the renewable resources of industrial row materials (BRAMM, 1993; SCHUSTER and FRIEDT, 1995).

Some agricultural and research institutes of Germany pay a close attention to develop new varieties of *Camelina* with a high seed and oil yield elaboration as well as with an improved seed and oil quality. In this case two cultivars of *Lindo* and *Soledo* (summer-forms) have been certified. The preliminary objectives of the study were to quantify the effects of different levels of seeding rates and nitrogen fertilization on the yield and its components of summer false flax under loamy sand soil conditions.

2. Materials and Methods

The field trial had been conducted in the periods of 1993–1995 on loamy sand soil. The field is characterized by annual temperature and rainfall of 8.6 °C and 595 mm, respectively. This field trial was prepared as two factorial block design with four replications (A*B-Bl, r=4). Seeds were sown on plots of 10 m² harvest area (1.25 m width x 8 m length). Sowing of seeds took place after a four year crop rotation with grass-legumes-mix. The soil received every year 80 kg/ha P_2O_5, 130 kg/ha K_2O and 40 kg/ha CaO before seeding.

The seed sowing activities were conducted every year in March (22. 3. 1993, 11. 3. 1994 and 13. 3. 1995). There were sown 200 (S_1), 400 (S_2) and 800 (S_3) seeds/m². Three different doses of nitrogen fertilization 0, (N_1), 60 (N_2) and 120 (N_3) kg/ha were applied immediately after sowing. The crop was treated against weed competition with 1.5 l/ha "Butisan S" (Metazachlor). Each year the crop was harvested in July (30. 7. 1993, 19. 7. 1994 and 27. 7. 1995). The oil content was analyzed both in 1993 and 1995. The laboratory analysis of fatty acid composition had been conducted only in 1993. The following plant characteristics are considered:

- yield performance under each treatment variables on 10 m² harvest area basis
- number of plant population per m², counted at harvesting time and
- yield components, determined from all uprooted plants on one meter row.

3. Results

The seed production efficiency of false flax is showed in Table 1. The dominating effect on seed yield is represented by the conditions of the year of cultivation. Because of better growing weather conditions, specially wet summer, the yield elaboration was reasonably better both in 1993 and 1995 than in 1994. About 4.7 and 6.5 dt/ha more seed yields had been gained in 1995 than 1993 and 1994, respectively.

The seed production is mainly influenced by the variation of seeding rates and nitrogen supplies. On averages of the 3 years the lowest and the highest yields lay among 8.2 and 19.5 dt/ha at 100 % DM. In each year and under each treatment variable on this loamy sand soil there were possibilities to harvest up to 22.8 dt/ha. The total mean yield of all years

Table 1: Effects of variations in level of nitrogen supply and sowing rates on seed yield (dt/ha = 100 % DM) of false flax
Tabelle 1: Einfluß variierter Stickstoffgaben und Saatmengen auf den Samenertrag (dt/ha TS) von Leindotter

Nitrogen level	0 kg/ha (N_1)			60 kg/ha (N_2)			120 kg/ha (N_3)			Mean
Seeding rates	S_1 200	S_2 400	S_3 800	S_1 200	S_2 400	S_3 800	S_1 200	S_2 400	S_3 800	dt/ha
1993	6.4	6.7	7.6	14.8	14.6	15.6	17.3	18.4	19.5	13.4
1994	5.8	7.0	9.0	10.8	13.9	13.6	10.7	16.0	17.5	11.6
1995	12.5	12.6	14.3	18.0	18.2	20.7	21.5	22.8	21.6	18.0
Mean	8.2	8.8	10.3	14.5	15.6	16.6	16.5	19.0	19.5	14.4
Rel. %	80	85	100	87	94	100	85	98	100	
Rel. %	50	46	53	88	82	85	100	100	100	

LSD. 5 % nitrogen/seed rate = 2.8 dt/ha

and all treatment factors was about 14.4 dt/ha. On average of all experiments the highest yield was achieved with the application of 120 kg/ha nitrogen (N_3) and with seeding rate of 800 seeds/m² (S_3). In comparing to the effects of N_2 x S_3-interaction, the actual yields showed on average a significant gain of 2.9 dt/ha for additional nitrogen N_3. Without nitrogen fertilizing (N_1) the yields reached only 46 to 53 % in comparison with N_3 (Table 1). An important effect of seeding rate is presented only on N_3-level. There has been observed a significant yield difference between the variants of S_1 and S_3 (3.0 dt/ha).

The formation of yield components depending on seeding rates is given in Table 2. Although in all three years the same amounts of seeding rates (200, 400 and 800 vigorous seeds/m²) were drilled, the establishment of the plant population (plants/m²) was not as high as expected. With respect to the drilled seeding rates the actual establishments of the plant population ranged from 90 to 302 plants/m² (rates of emergence = 45 to 38 %).

The variation in seeding rate is reflected mainly not only in the change in the number of plants per unit area, but also prevailed in the variation of the formation of yield and its components of each plant. In comparing with factor "nitrogen", there were indications that each additional seeding rate had an adverse effect on branches, pods and seed weight per plant as well as on seeds per pod, pods/m² and yield productivity (g/m²).

The onset and development of branches were affected directly by the plant densities. Higher plant densities tend to form some apical branches, whereas lower plant densities are liable to set basal branches. Increasing the seeding rate from S_1 to S_3 decreased the number of branches produced on each plant from 7.8 to 4.3. There was, however, a tendency to form more branches as the density of the plant decreased (Table 2).

The changes in the number of seeds per pod, in the seed weight per plant, in the pod production per plant or per unit area are also major factors which determine the relationship between seed production and plant density. The number of pods arising on each stem falls as the plant population rises.

Table 2: Effects of variations in the level of seeding rates on the formation of yield components of false flax (mean = 3 years)
Tabelle 2: Einfluß variierter Saatmengen auf die Bildung der Ertragskomponenten von Leindotter (Mittel aus 3 Jahren)

Treatment	Yield components							
Seeds/m²	Plants/ m²	Branches/ plant	Pods per		Seeds per pod	Seed weight g/plant	TSW (g)	Yield g/m²
			plant	m²				
200	90	7.8	287.6	21765	7.6	2.97	1.42	214.5
400	182	6.3	168.6	25160	7.1	1.79	1.46	246.6
800	302	4.3	98.7	25084	5.7	0.87	1.46	205.7
LSD. 5%	66.4	2.3	71.9	7378	1.6	1.1	0.06	61.7
Mean	191	6.1	185	24003	6.8	1.88	1.45	222.3

Table 3: Effects of variations in the level of nitrogen supplies on formation of yield components of false flax (mean = 3 years)
Tabelle 3: Einfluß variierter Stickstoffgaben auf die Bildung der Ertragskomponenten von Leindotter (Mittel aus 3 Jahren)

Treatment	Yield components							
Nitrogen kg/ha	Plants/ m^2	Branches/ plant	Pods per		Seeds/ pod	Seed weight g/plant	TSW (g)	Yield g/m^2
			plant	m^2				
0	90	4.6	110.9	18046	5.8	1.02	1.48	150.1
60	182	6.4	194.1	23360	7.1	1.98	1.41	224.8
120	302	7.3	249.9	30603	7.5	2.63	1.45	291.9
LSD. 5%	66.4	2.3	71.9	7378	1.6	1.1	0.06	61.7
Mean	191	6.1	185	24003	6.8	1.88	1.45	222.3

The loss in pods is balanced, however, by the gain of pod population on an area. The total number of pods per plant increased significantly from the less spacing (S_3) to the more spacing (S_1). On the other hand, the number of pods per unit area decreased as the space provided to the plant increased. The overalls mean of pods/plant were 185.

An increased number of plants affected not only the onset and development of branches and pods per plant, but also the number of seeds/pod and seed weight per plant. The number of seeds/pod increased significantly as the plant population per unit area decreased. On average of three seeding rates about 7 seeds/pod were developed. Because TSW is genetically fixed, it remains unaltered by the variation of seeding rates. The yield structure analysis shows that with the variation of the seeding rates (S_2), it was possible to harvest up to 247 g/m^2 of seed yield. Branches, pods and seed weight/plant and seeds per pod are consistently decreased by varying the seeding rates. It is also evident that the increase in seeding rate significantly decreased the yield of seed per unit area (Table 2).

The formation of yield components is not influenced only by the variation of seeding rates, but also by the variation of nitrogen supplies (Table 3). A supply of nitrogen stimulates the onset and the development of each component. The number of branches developed on a single plant increased significantly as the nitrogen doses increased. A higher level of nitrogen increases also the number of pods produced per stem and hence the number of pods per unit area. The number of branches, the number of pods and the seed weight per plant as well as the number of seeds per pod and the seed production per unit area are consistently changed by varying the supply of nitrogen.

Except the plant densities and TSW, all other components are significantly influenced by higher doses of nitrogen fertilization. The number of plants that reach maturity is not dependent on the level of nutrient supply. Since the TSW is genetically fixed, it was not influenced by variation of nitrogen supplies. With the variation of nitrogen doses it was possible to harvest up to 292 g/m^2 seed yield. In comparing with the nitrogen level N_2, the expected increase in yield from the additional nitrogen supply (N_3) was about 30 %.

The oil content and the compositions of the fatty acids of the variety "Lindo" are presented in Fig. 1 and in Table 4. On average of two years the variation of the oil content lies among 38 and 41 %. The variations of seeding rates and the year cycles have no significant effect on the oil content. A significant decline in percentage of oil was recorded as the level of nitrogen fertilizer increased (Fig. 1).

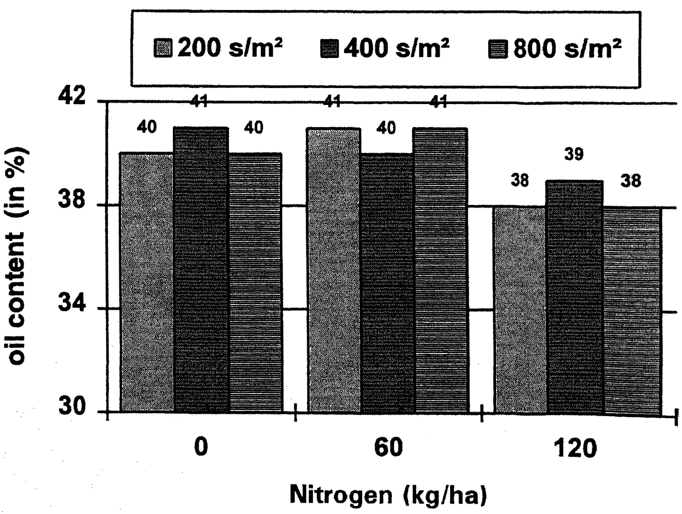

Figure 1: Oil content (in %) of false flax seeds cv. Lindo (mean: 1993 and 1995)
Abbildung 1: Ölgehalt (%) von Leindottersamen der Sorte Lindo (Mittel aus 1993 und 1995)

Table 4: Minimum, maximum and mean value of the oil content and its patterns of fatty acid composition of false flax (1993)
Tabelle 4: Minimum, Maximum und Mittelwert des Ölgehaltes und der Fettsäurenzusammensetzung von Leindotter (1993)

	Oil content %[1]	C16:0 %	C18:0 %	C18:1 %	C18:2 %	C18:3 %	C20:1 %	C22:1 %	Other %
Minimum	37.2	5.5	2.2	14.7	18.4	34.8	13.5	2.2	8.7
Maximum	43.2	5.6	2.4	15.3	18.7	36.3	14.0	2.3	5.4
Mean	39.7	5.6	2.4	15.0	18.5	35.5	13.8	2.3	6.9

[1] in dry matter of the seeds

The analysis of treatment variety samples in Gueterfelde showed that the oil content of false flax in the test ranged from 37.2 to 43.2 % at 100 % DM (Table 4). In considering of this percentage of false flax oil, saturated fatty acids are 7 to 8 % (palmitic and stearic acid, C 16:0 and C 18:0) and unsaturated fatty acids are 15 % oleic (C18:1), 19 % linoleic (C18:2), 36% linolenic (C18:3), 14 % eicosenic (C20:1) and very small amount (2.3 %) of erucic acids (C22:1).

4. Discussion

The summer form of the species *Camelina sativa* is characterized by its short period of maturity. Our research results confirmed that the duration of vegetation lasts within 100 to 110 days. The variation in plant height ranges 40 to 100 cm depending on growing conditions (HONERMEIER and AGEGNEHU, 1994; AGEGNEHU and HONERMEIER, 1993, 1995; HONERMEIER and AGEGNEHU, 1996).

False flax is an oil seed plant that merits serious consideration as a potential crop in temperate areas, because of its early maturity, high yield and oil content. Its production would require no special equipment beyond that used for cereals or for other oilseed crops. This important oil crop is supposed to be better grown on sandy soils with less water capacity and soil fertility, specially on areas which are unfit for the cultivation of rape seed (MAKOWSKI and KLOSTERMANN, 1995).

Several false flax varieties were tested in many European countries and in North America against seed yielding capacities with results similar to those reported in this paper. According to results from SEEHUBER and DAMBROTH (1983), SCHUSTER and FRIEDT (1995, 1996) and MERRIEN and CHATENET (1996) it is possible to harvest potentially 25 to 30 dt/ha. Although in mean of all the years under our soil and meteorological conditions only 14 dt/ha were harvested (Table 1). We have recorded within each experiment year up to 23 dt/ha (100 % DM). In other experiments we realized in 1993 on loamy soil the seed yields of false flax reached up to 31 dt/ha in the best treatment (120 kg/ha nitrogen) (HONERMEIER and AGEGNEHU, 1994). These results show in all that summer false flax is characterized by a high seed yield capacity. We suppose that the species *Camelina sativa* is able to realize the high yield capacity only under favorable soil and growing conditions.

With hybrid varieties of false flax, SEEHUBER and DAMBROTH (1983) had recorded a mean of about 54 branches and 95 pods per plant, 13 seeds per pods and 1.15 g 1000-seed weight. MIREK (1980) reported that about 10 to 22 seeds per pod could be formed. In our investigations, the number of branches per plant and seeds per pod were less than the reported figures. The number of pods per plant and the 1000-seed weight surpass the figures reported by the above authors (Table 2 and 3).

Because false flax partially compensates its yield efficiency by increasing the number of pods on each plant at lower population levels, reductions in seeding rate have often failed to alter seed yields. Similar investigation on linseed were conducted by BLACKMAN and BUNTING (1954) and ALBRECHTSEN and DYBING (1973), who have achieved similar results. Many of our present results with false flax hence support their conclusion in that pod production is the dominant factor influencing seed production.

False flax plants with nitrogen deficiency (N_1) are thin and very upright. The leaves are small and pale yellow-green. Ripening is premature and there are few pods and seed bearing branches. In this case it is evident that nitrogen is an important nutrient for a higher yielding performance of this oil plant. The influence of increased nitrogen fertilizing on seed yield of false flax showed similar reactions like in other species of Brassicaceae. We suppose that nitrogen requirement of false flax is probable higher than of linseed and similar like summer rape or summer mustard.

Variation in seeding rate had a pronounced effect on the number of pods produced by a plant. The false flax plant was able to compensate the yield differences of different plant population through the single yield component of pods per plant or per unit area. BRAMM (1993), GRAF and VETTER (1994) and SCHUSTER and FRIEDT (1995) suggested that a density of sowing of 400 vigorous seeds per m^2 and application of 120 to 130 kg/ha of nitrogen fertilization are most effective for maximum seed production. Our results support their conclusion.

ZUBR (1992) confirmed that the oil of false flax is characterized by a high content of polyunsaturated fatty acids amounting about 85 % and the content of essential fatty acids-linoleic (C18:2n-6) and alpha-linolenic (C18:3n-3) exceeds 50 % of the total. Our results are in good agreement with these results. False flax seed bears a greater resemblance to flax than to rape seed in fatty acid composition. It has 30 to 35 % less linolenic fatty acid than flax (60 to 70 %). It has also 14 % eicosenic fatty acid and small amounts of erucic acid of 2 %, while flax has none. It is mainly differing from rape seed in its low erucic and high linolenic acid content.

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