The effect of nitrogen fertilization, sowing rates and site on yields and yield components of selected varieties of safflower (*Carthamus tinctorius* L.)

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ABSTRACT

Field trials were conducted at two sites Troubsko near Brno and Prague-Ruzyně in 1996–1999 with three varieties of safflower (Gila, CW-74, Sironaria). Three rates of nitrogen fertilization were used: N_0 = no fertilization, N_1 = 40 kg.ha^{-1}, N_2 = 80 kg.ha^{-1}. Sowing rates were 50 and 70 germinable seeds per m^2. The average values of oil content were highest in seeds of CW-74 variety (27.2%). Gila had on average the lowest oil content (24.5%). Linoleic acid was dominant in all three safflower varieties. Variation in content of linoleic acid in different years was not so high as in oil content. The highest average content of linoleic acid was found in Gila variety (81.2%), the lowest in Sironaria (77.4%). At Ruzyně average seed yield on dry basis was 2.7 t.ha^{-1} and average straw yield was 7.56 t.ha^{-1}. At Troubsko seed yield was 2.56 t.ha^{-1} and straw yield was 3.69 t.ha^{-1} (by 50% lower than at Ruzyně). The effect of year of growing and site on seed yields and on other parameters was highly significant. N fertilization increased safflower seed yield at Troubsko site only, where the dose of 40 kg.ha^{-1} N increased the yield by 0.08 t.ha^{-1} on average of years and the dose of 80 kg.ha^{-1} N increased the seed yield by 0.2 t.ha^{-1} in comparison with no nitrogen fertilization treatments. Increased N rates and especially higher plant density resulted in an increase in straw yields. Neither were thousand seed weight nor number of flower heads influenced significantly by different N rates or the above-mentioned differences in plant density.

Keywords: safflower; N fertilization; sowing rate; yields; yield structure

Developmental trends in neighbouring countries of Western Europe and in this country indicate that in European agriculture there exists overproduction in the plant production sector aimed at food supplies. Agriculture in Western countries has already suggested a new trend when besides traditional crops for food use alternative crops for non-food use start expanding. This trend must be accepted in the agriculture of Czech Republic too. Taking into account continuous development of agriculture we will have to adopt innovations that are more radical in a farming system. One of the possibilities is to grow alternative crops such as safflower.

Safflower production was tested in field conditions in the Research Institute of Crop Production at Prague-Ruzyně in cooperation with the Forage Crop Research Institute Troubsko. Field trials were conducted in 1996–1999 to study the effect of soil and climatic conditions, sowing rate and different N fertilization on yields and yield structure in three safflower varieties.

MATERIAL AND METHODS

Field trials were carried out at two different sites (Troubsko near Brno, Prague-Ruzyně) in 1996–1999. Site conditions at experimental localities are shown in Table 1. Weather conditions at both sites in the experimental period in comparison with long term average are shown in Tables 2 and 3.

Cultural practices

Grain crop was a forecrop for safflower at both sites and in all years of observation. Current cultural practices were used for soil preparation at both sites: Stubble breaking and medium-deep ploughing followed the forecrop harvest. Current seedbed preparation was applied in spring. Every year P and K fertilizing was applied at both sites in autumn: uniform application rates were used for all variants, amounting to 26 kg of P per ha as pure nutrients in superphosphate and 50 kg of K per ha in potassium salt. Nitrogen application rates were as follows: N_0 = no nitrogen fertilizing, N_1 = 40 kg.ha^{-1} (single dose of ammonium sulfate before sowing), N_2 = 80 kg.ha^{-1} (split doses = the first dose 40 kg.ha^{-1} ammonium sulfate before sowing and the second dose 40 kg.ha^{-1} ammonium nitrate with limestone at the beginning of elongation stage in safflower).

Safflower was planted with an Oyjord seeder into rows 250 mm in width using two sowing rates: V_1 = 50 germinable seed per m^2 (17 kg.ha^{-1}), V_2 = 70 germinable seeds per m^2 (24 kg.ha^{-1}). The varieties Gila, CW-74 (USA), Sironaria (Australia) were used. Field trials had three replications. The size of parcels was 15 m^2.

Table 1. Site conditions of experimental localities

Experimental site	Troubsko (near Brno)	Prague-Ruzyně
Latitude	49°12’	50°04’
Longitude	16°37’	14°26’
Height above sea level (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

The following parameters were investigated during growth: plant health, degree of pest attack and disease infection, and plant density before harvest. Seed and straw yields, thousand seed weight (TSW), duration of growing season (from planting to harvest), number of flower heads per plant, plant height were determined. Other parameters determined in the three varieties every year were seed oil content and composition of fatty acids. Least square difference (*LSD*) was used for the statistical processing of results.

RESULTS AND DISCUSSION

Oil content and contents of dominant fatty acids were investigated in all varieties at Ruzyně site in the years of

Table 2. Weather in the years 1996 to 1999 at site of Troubsko (deviations from 50 years average)

Year		Month
		Temperature
1996	normal	extraordinary cold – III, VII, IX, warm – V, VI
1997	normal	extraordinary cold – IV, cold – VII, warm – III, V, VI, very warm – VIII
1998	warm	warm – VII, very warm – VIII, extraordinary warm – IV, VI
1999	warm	warm – V, VI, VIII, extraordinary warm – III, IV, VII, IX
		Precipitation
1996	wet	extraordinary dry – VII, dry – III, wet – VI, very wet – IX, extraordinary wet – IV, VIII
1997	wet	extraordinary dry – VIII, very dry – III, IV, extraordinary wet – VII
1998	normal	extraordinary dry – V, dry – III, VIII, wet – VII, extraordinary wet – IX
1999	dry	extraordinary dry – VIII, dry – III, V, VII, IX, wet – IV, very wet – VI

Table 3. Weather in the years 1996 to 1999 at site of Prague-Ruzyně (deviations from 50 years average)

Year		Month
		Temperature
1996	normal	extraordinary cold – III, IX, very cold – VII, warm – VI, VIII, extraordinary warm – IV
1997	normal	extraordinary cold – IV, warm – V, very warm – VIII, extraordinary warm – III
1998	normal	very warm – VI, extraordinary warm – III, IV, V
1999	normal	very dry IV, extraordinary dry – III, V, VII, IX
		Precipitation
1996	normal	extraordinary dry – III, IV, wet – V, VI, VII, IX
1997	normal	extraordinary dry – V, IX, dry – VI, VIII, extraordinary wet – III, VII
1998	normal	extraordinary dry – IV, V, VIII, dry VII, extraordinary wet – VI, IX
1999	normal	extraordinary dry – VIII, very dry – IV, VI, dry – III, V, very wet – VII, IX

Table 4. Average contents of oil and fatty acids in seeds in three safflower varieties at Ruzyně site in the years 1996–1999

Variety	Oil content (%)	Palmitic acid (%)	Stearic acid (%)	Oleic acid (%)	Linoleic acid (%)
Gila	24.5	6.1	2.5	9.5	81.2
CW-74	27.2	6.2	2.4	9.2	80.4
Sironaria	25.9	7.8	3.2	10.9	77.4

observation (Table 4). Oleic acid is dominant in some safflower varieties, linoleic acid in others (Seehuber and Dambroth 1982, Nie et al. 1991, Mirza et al. 1998). In the three studied varieties of safflower, linoleic acid was dominant and the variations in its content were not so high as in oil content. The highest average values of this acid were determined in Gila (81.2%), the lowest in Sironaria (77.4%) – Table 4.

Oil content in the years of observation was variable, e.g. it ranged from 20.3% to 34.4% in the variety CW-74. Its seeds had the highest average content of oil (27.2%). The lowest average content of oil recorded in Gila (24.5%) over the years of study was higher than average values reported for the localities Suchdol and Tábor. Baranyk et al. (1995) reported average oil content of 21.7% in safflower seed from those localities. The effect of N fertilization on oil content in seeds was not significant. Zaman (1988) and Ekshinge et al. (1993) reached the highest oil content with N rate 60 kg.ha^{-1} for conditions of West Bengal or Parbhani.

The differences in early maturity between the three varieties were not large; they matured at all sites on about the same date. There were substantially larger differences in the average duration of growing season between the sites. The average growing season from planting to harvest for the years of observation was 142 days at Troubsko, where long-term temperatures are higher than at Ruzyně, where it was 168 days, i.e. almost by a month longer. The weather course in the individual years was different (Tables 2 and 3). The safflower growing season in 1996 was prolonged by generally colder and more rainy weather, by 36 days at Troubsko and by 24 days at Ruzyně in comparison with 1998. The year 1996 can be characterised in growing season by below-average temperatures and rainfall at both sites except the month of June in comparison with long-term averages.

Tables 5 and 6 show average seed and straw yields. Seed and straw yields were higher at Ruzyně for the years of observation than at Troubsko. They amounted to 2.7 t.ha^{-1} seed and 7.56 t.ha^{-1} straw on dry basis. Seed yields at Troubsko were on average lower by 5% and straw yields by almost 50% lower. Higher yields of seed and mainly of straw at Ruzyně were apparently influenced by a higher number of plants per plot: 70.7 plants per m^2 at Ruzyně versus 58.4 plants per m^2 at Troubsko (Tables 5 and 6). Among the parameters under study, the effects of year and site on seed and straw yields of safflower were significant while the effects of N fertilization or sowing rates were not significant. The other parameters under study were influenced highly significantly by year of growing and site.

Relatively high seed yields were obtained for a wide range of plant density from 50 to 80 plants per m^2 in dependence on site conditions. This finding may indicate large yield compensating ability of safflower. E.g. Singh and Singh (1989) reported an optimum density of 89 000 plants per ha to achieve the highest yield of safflower seed in the soil and climatic conditions of Punjab in India. Mane et al. (1990) obtained the highest yields of safflower seed for the plant density of 225 000 individuals per ha. Salera (1996) reported high yields of safflower seed for the plant density of 40 individuals per m^2 under Italian conditions (when the densities of 20, 30, 40 plants per m^2 were investigated).

The N rates, increase in sowing rates or their combinations did not affect significantly the seed yields at any site. Increased N rates and especially higher plant density resulted in an increase in straw yields. Different N rates increased the yield of safflower seed at Troubsko only, where the N rate of 40 kg.ha^{-1} increased the seed yield by 0.08 t.ha^{-1} on average and the split N rate of 80 kg.ha^{-1} by

Table 5. Seed and straw yields from the different variants on dry basis and other parameters investigated at Troubsko (average values of all varieties for the years of observation and $LSD_{0.05}$)

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})	2.4	2.48	2.59	2.54	2.60	2.74	2.56	0.264
Straw yield (t.ha^{-1})	3.49	3.56	3.58	3.79	3.79	3.9	3.69	17.151
Thousand seed weight (g)	29.77	29.80	29.81	29.90	29.94	29.88	29.85	2.183
No. of flower heads per plant	12.9	13.2	13.6	13.9	14.3	14.9	13.8	1.042
Plant height (cm)	90.9	92.1	92.9	91.3	91.9	94.1	92.2	9.487
Plant density (no.m^{-2})	47.4	48.7	49.6	67.1	67.9	69.9	58.4	1.344

N_0 = no fertilizing, N_1 = 40 kg.ha^{-1}, N_2 = 80 kg.ha^{-1}
V_1 = sowing rate of 50 germinable seeds per m^2 (17 kg.ha^{-1})
V_2 = sowing rate of 70 germinable seeds per m^2 (24 kg.ha^{-1})

Table 6. Seed and straw yields from the different variants on dry basis and other parameters investigated at Ruzyně (average values of all varieties for the years of observation and $LSD_{0.05}$)

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})	2.8	2.76	2.78	2.71	2.75	2.53	2.70	0.989
Straw yield (t.ha^{-1})	7.49	7.59	7.19	7.47	7.82	7.83	7.56	1.025
Thousand seed weight (g)	29.92	30.17	29.81	30.33	29.82	29.68	29.95	4.620
No. of flower heads per plant	10.6	11.3	10.4	10.1	10.7	12.9	11.0	6.879
Plant height (cm)	97.5	97.4	96.5	97.5	97.3	89.7	96.0	11.830
Plant density (no.m^{-2})	54.1	56.5	66.4	86.1	78.9	81.9	70.7	16.576

another 0.11 t.ha^{-1} (Table 5). The seed yield was not practically influenced by N fertilization at Ruzyně (Table 6). Singh et al. (1994) report 40 kg.ha^{-1} as an optimum N rate for safflower. German et al. (1988) included in their experiments eight levels of N fertilization from 20 to 80 kg.ha^{-1} in single or split doses. They drew a conclusion that the used N fertilization did not have any significant effect on seed yield.

Neither were thousand seed weight nor number of flower heads per plant considerably (significantly) influenced by different N fertilizing or differences in plant density. On the contrary, Salera (1996) stated that the highest plant density (40 plants per m^2) produced the highest number of seeds per m^2 that compensated lower seed weight, lower number of flower heads per plant and seeds per flower head more than sufficiently in comparison with lower densities (20, 30 plants per m^2). The highest thousand seed weight on average was determined in our trials in Gila (30.3 g), the lowest in CW-74 variety (28.5 g).

The chemical control of weeds in safflower crop has not been described in detail in this country. The well-closed canopy with early sowing is able to suppress weeds by its dense foliage. It is reported that herbicides can be applied to control dicotyledonous weeds similarly like in sunflower. The use of herbicides Furore Super (2 l.ha^{-1}), Targa Super 5 EC (1.5 l.ha^{-1}) or Fusilade Super (1 l.ha^{-1}) brought about good results in the control of monocotyledonous weeds in our experiments. Pre-emergence application of Treflan EC (1.5 l.ha^{-1}) and post-emergence spraying with Betanal Tandem (3 l.ha^{-1}) successfully controlled dicotyledonous weeds; Galant Super (0.7 l.ha^{-1}) was efficient in the control of barnyard grass. Pest attacks and disease infections of safflower are rare in this country, it is often ascribed to small safflower areas. Some foreign varieties are infected by torus rot in Southern Moravia. Scarce occurrence of some fungal diseases was observed at both sites under humid conditions in our experiments: gray mold *Botrytis cinerea* Pers.:Fr. and fungi of the genus *Alternaria* and *Fusarium*. Weak infection by safflower rust *Puccinia carthami* (Hutzelmann) Corda occurred at Ruzyně site almost every year.

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ABSTRAKT

Vliv hnojení dusíkem, výsevků a stanoviště na výnosy a výnosové prvky vybraných odrůd safloru (*Carthamus tinctorius* L.)

Polní pokusy probíhaly na dvou odlišných stanovištích v Troubsku u Brna a Praze-Ruzyni v letech 1996 až 1999 u tří vybraných odrůd safloru – světlice barvířské (Gila, CW-74, Sironaria). Pro hnojení dusíkem byly zvoleny tři stupně N_0 = bez hnojení dusíkem, N_1 = 40 kg.ha^{-1}, N_2 = 80 kg.ha^{-1}. Výsevky byly 50 a 70 klíčivých semen na m^2. V průměru nejvyšší obsah oleje vykazovala semena odrůdy CW-74 (27,2 %). Nejnižší obsah oleje v průměru pokusných let byl zjištěn u odrůdy Gila (24,5 %). U všech sledovaných odrůd safloru převažovala v semenech kyselina linolová, jejíž procentuální kolísání v jednotlivých letech nebylo tak vysoké v porovnání s kolísáním celkového obsahu oleje. Nejvyšší průměrné hodnoty této kyseliny jsme zjistili u odrůdy Gila (81,2 %), nejnižší u odrůdy Sironaria (77,4 %). V Ruzyni bylo v průměru dosaženo výnosu 2,7 t.ha^{-1} semene a 7,56 t.ha^{-1} slámy v přepočtu na sušinu. V Troubsku bylo v průměru dosaženo 2,56 t.ha^{-1} výnosu semene a 3,69 t.ha^{-1} (téměř o 50 % nižšího oproti Ruzyni) výnosu slámy. Rok pěstování a stanoviště vysoce průkazně ovlivňovaly výnosy semene i ostatní sledované ukazatele. Stupňované hnojení N zvyšovalo výnosy semene safloru pouze na stanovišti v Troubsku, kde dávka N 40 kg.ha^{-1} v průměru let zvyšovala výnos semene o 0,08 t.ha^{-1} a dávka N 80 kg.ha^{-1} o 0,2 t.ha^{-1} v porovnání s dusíkem nehnojenými variantami. Vyšší dávky N a zvláště vyšší počet rostlin se projevily spíš na zvýšení výnosů slámy. Hmotnost tisíce semen ani počet úborů na rostlinu nebyly rozdílným hnojením N ani výsevkem statisticky průkazně ovlivněny.

Klíčová slova: saflor; hnojení N; výsevek; výnosy; struktura výnosu

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