The potential role of spineless safflower (*Carthamus tinctorius* L. var. *inermis*) as fodder crop in central Italy

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Abstract

The present study aimed at assessing how nitrogen (N) fertilization affects nutritional characteristics of spineless safflower grown under Mediterranean conditions and evaluating a 2-days wilting treatment on moisture reduction and pH before ensiling. Spineless safflower, sown in November 2008, was grown in 3 m x 18 m plot (45 plants m^{-2}). A randomized complete block design (RCBD) one cultivar x four N-fertilization levels (N_0=0 kg/ha, land allocation, N_1=35 kg/ha, N_2=70 kg/ha, N_3=105 kg ha^{-1}) (3 replicates each level) was adopted. At mowing (May 2009, before blooming) the crop biomass production was recorded. Wilted plant material for each plot was collected and pH was measured. Dried and ground samples (1 mm mesh) were analyzed for crude protein (CP), lipids (EE), crude fibre (CF_{om}), neutral detergent fibre ($aNDF_{om}$), acid detergent fibre (ADF), lignin (ADL) and ash (ASH) content. All data were analyzed by ANOVA and differences among means were declared significant at P<0.05. Biomass production showed a N dose-dependent relationship [from N_0=1.80±0.29 to N_3=2.71±0.20 t ha^{-1} dry matter (DM), P<0.01]. N-fertilization significantly affected the CP content, with the highest values (17.52±0.26% DM) observed for the N3 fertilization level. The other nutritional characteristics (EE: 1.36±0.23% DM; CF_{om}: 41.70±3.65% DM; $aNDF_{om}$: 44.6±2.71% DM; ASH: 12.74±0.74% DM) were not or only slightly affected (ADF: 34.15±2.14%; ADL: 9.53±2.35) (P<0.05) by the N-fertilization. After the 2-day wilting treatment, the highest pH (5.99±0.08) was found for N_2 treatment, while the lowest one (5.85±0.06) was recorded for the N_0 level (P<0.01). The wilting treatment gave a sufficient moisture reduction, allowing satisfactory preservation of safflower by ensiling. Spineless safflower shows an interesting potential to be grown for ruminants feeding in Mediterranean area. N-fertilization plays an important role as far as productivity of safflower and its CP content are concerned. Further studies are in progress to fully characterize safflower as fresh and preserved forage resource for crop-livestock production systems in central Italy.

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Introduction

Safflower (*Carthamus tinctorius* L.) is cultivated for many purposes: its achenes are commonly used as birdseeds and for the extraction of edible or industrial oil; corollas can be used for dyeing fabrics as food colorings and cosmetics and in painting (Henry and Francis, 1996; Watanabe *et al*., 1997; Cho *et al*., 2000) or for producing medicines (Fatahi *et al*., 2008). Recently, spineless cultivars of safflower have been introduced that could be used as fodder (Leshem *et al*., 2001; Landau *et al*., 2004). Safflower is a very adaptable crop that can be sown in winter or spring in dryland or irrigated cropping systems. It has good drought, salt and heat tolerance (Zaman and Maiti, 1990; Welti *et al*., 1998), and its deep tap root enables it to use nutrients below the root zone of cereal crops, potentially reducing the rate of nitrogen (N) application. Growing safflower after a fertilized crop may remove N from the lower part of the soil profile and thus reduces the possibility of this soil-accumulated N to eventually reach the ground water. Cropping with safflower in rotation with other crops may have environmental benefits as well as saving on the costs of N fertilizers (Yau and Ryan, 2010). Since safflower is an under-researched crop, the relationship between safflower and N is poorly understood, with even contrasting reports on the optimal rate of N fertilization (Knowles and Miller, 1960; Cazzato *et al*., 1997). The high yields that can be obtained growing safflower as a fodder crop (Leshem *et al*., 2001) and the great adaptability of this plant to arid and semi-arid environments, provide many growers with an alternative crop option in rainfed cropping systems of the Mediterranean areas (Weinberg *et al*., 2002; Bar-Tal *et al*., 2008; Ghamarnia and Sepehri, 2010). The purpose of the present study was to assess the effect of nitrogen fertilization on yield and nutritional characteristic of safflower intended for ruminant feeding. Secondarily, the aim of this preliminary report was to evaluate the effect of a wilting treatment on characteristics of safflower with respect its possible use for silage production.

Materials and Methods

The study was carried out in Viterbo, central Italy (42° 26’ N, 12° 04’ E, altitude 310 m a.s.l), from 2008 to 2009 on a clayey soil. Soil properties are shown in Table 1. Spineless safflower was sown in November 2008 and was grown under rainfed conditions. Total precipitation recorded during the growing season (November 2008 to May 2009) was 657.6 mm (data obtained by the weather station of the Department of Crop Production, located 301 m a.s.l. at the geographical coordinates 42° 25´31.86´´ N, 12° 04´43.47´´E). However, most of the precipitation was recorded in winter and early spring. The experimental design was a randomized block with 3 replicates. The plots’ size (18 m × 3 m) was 54 m^2 and plant density was adjusted to 45 m^{-2}. Four nitrogen fertilization levels were applied at the beginning of the stem elongation stage (March 2009): N_0 = 0 kg ha^{-1} (residual soil fertility), N_1 = 35 kg N ha^{-1}, N_2 = 70 kg N ha^{-1}, N_3 = 105 kg N ha^{-1}. One mechanical weed control was performed after the fertilization by passing with a rotary hoes between the rows.

Plants were mown at the end of the branching stage, when the young buds appeared, and were left in the field for a 2-days wilting treatment in view of a possible use for ensiling trials. On each plot, a representative sample (approx. 6 kg) of fresh and wilted plant material was collected for the determination of the yields and chemical analysis. On wilted plant material (chopped at 2-3 cm length) pH was measured by means of a Crison micropH 2002 pH-meter (Crison Instruments SA, Alella, Barcelona, Spain). All dried plant samples (at 65°C for 48 h in a forced air oven) were ground (Retsch, Haan, Germany) to pass a 1 mm screen and analyzed for crude protein (CP) by distillation Kjeldal method, lipids (EE) by ether extraction, crude fibre (CF_{om}) and ash (ASH) according respectively to AOAC Official Methods 984.13 (A-D), 920.39, 978.10 and 942.05 (AOAC, 2006). Also, neutral detergent fibre ($aNDF_{om}$) was assayed according to the method of Mertens (2002), acid detergent fibre (ADF) was determined according to AOAC Official Method 973.18 (A-D) (AOAC, 2006) and lignin (ADL) was determined by sulphuric acid method (Robertson and Van Soest, 1981; AOAC, Official Method 973.18, A-D, 2006). Non-fibre carbohydrates (NFC) were calculated as [100 – (NDF + CP + EE + ASH)]. All data were subjected to the analysis of variance using STATISTICA 7.0 (StatSoft, Inc, Tulsa, OK, USA). Differences among means were compared by the Fisher LSD post-hoc test and declared significant at P<0.05.

Table 1. Soil chemical and physical properties.

Depth	Clay (%)	Silt (%)	Sand (%)	Total N (%)	OM (%)	pH
0-30 cm	45.20	24.50	30.08	0.16	2.13	7.33
31-60 cm	41.58	23.47	34.95	0.13	1.47	7.54

N, nitrogen; OM, organic matter.

Table 2. Yields, moisture content at mowing and dry matter content of wilted safflower grown under different level of nitrogen fertilization.

N-level	Yield (t ha^{-1})*	Yield (t ha^{-1})°	Moisture at mowing°	DM content after wilting
N_0	9.8±2.0B^c	1.8±0.3^{Bc}	0.81±0.02^b	0.36±0.01^A
N_1	13.9±3.3^b	2.3±0.5^{ab}	0.83±0.02^{ab}	0.31±0.01^B
N_2	14.6±3.2^b	2.1±0.5^{bc}	0.85±0.04^a	0.30±0.02^B
N_3	18.1±2.4^{Aa}	2.7±0.2^{Aa}	0.85±0.03^a	0.32±0.01^B

DM, dry matter; *Data (mean±s.d.) are expressed on wet weigh (WW) basis; °Data (mean±s.d.) are expressed on DM basis; $^{A,B-a,b}$Means with different superscripts are significantly different (P<0.01; P<0.05).

Results

At mowing, the biomass production (wet weight) was significantly affected (P<0.01) by nitrogen application passing from about 10 tons per hectare up to more than 18 tons per hectare, even if no statistical differences (P>0.05) were observed fertilizing either with 35 or 70 kg of nitrogen per ha (Table 2). Also, a direct relationship was observed between N-fertilization and dry matter (DM) yield (from N_0=1.80± 0.30 t ha^{-1} to N_3 = 2,71±0.20 t ha^{-1}; P<0.01) (Table 2). Plants showed a mean DM content of 16.5% just after mowing, even though the N_2 and N_3 fertilized ones had a higher (P<0.05) moisture content (85±4% and 85±3%, respectively) compared to the control (81±2%). After wilting, all N-treated samples showed a significant (P<0.01) lower DM value than the control (Table 2).

In view of silage-making trials, pH was determined on wilted plant samples. Overall, the highest N-treated plants (N_2 and N_3) showed a significant (P<0.01) higher pH values than the N_1 and N_0 treated ones (Figure 1). A slight, but significant difference (P<0.05), was also observed between treatments N_2 and N_3 (Figure 1). Looking at safflower as forage intended for ruminant feeding, no differences were observed among treatments as for the nutritional parameters EE, CF_{om}, $aNDF_{om}$, NFC and ASH and only for the N_2 treatment a higher content (P<0.05) of ADF and ADL was recorded (Table 3). Moreover, the N_3 treated plants showed a lower, though not significant (P>0.05), level of $aNDF_{om}$ (42.9±1.9%) compared with other treatments and control. At the same manner, a moderate but not significant (P>0.05) decrease of the NFC content was recorded for the N_3 samples (Table 3). As far as the crude protein content of spineless safflower is concerned, the N-treated plants showed a higher content compared with the control passing from about 11% DM to more than 17% (Figure 2). At the low (N_1) and medium (N_2) level of N-fertilization were not observed significant difference (P>0.05) in the CP content.

Discussions

As expected, the fresh biomass production of spineless safflower was affected by the nitrogen fertilization up to 105 kg ha^{-1} due to a combined effect of DM and water retention increase. In terms of DM

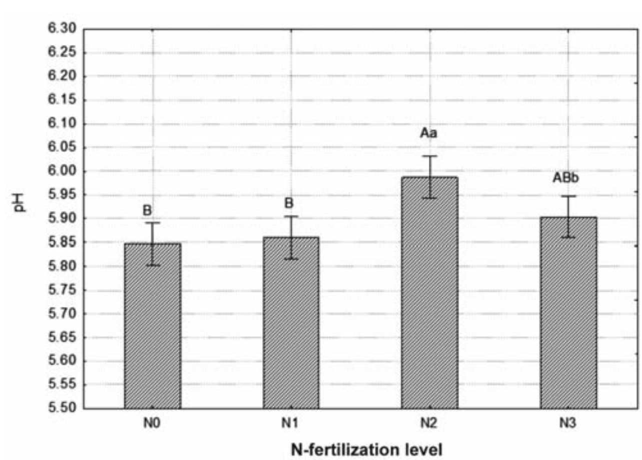

Figure 1. Level of pH of 2 days wilted safflower plants as affected by the nitrogen fertilization. Data are expressed as least square mean±SEM. $^{A,B-a,b}$Means with different superscripts are significantly different (P<0.01; P<0.05).

Table 3. Proximate chemical composition of spineless safflower grown under different level of nitrogen fertilization.

N-level	EE	CF_{om}	$aNDF_{om}$	ADF	ADL	ASH	NFC
N_0	1.3±0.2	43.8±4.7	45.9±1.7	34.4±1.4^b	9.4±1.6^b	13.2±0.6	28.3±1.5
N_1	1.4±0.3	42.1±3.5	44.7±3.9	33.7±1.8^b	7.4±1.9^b	12.7±0.4	25.8±4.6
N_2	1.3±0.2	39.8±3.0	45.1±2.5	35.4±2.3^a	11.7±1.8^a	12.7±1.1	24.8±3.3
N_3	1.4±0.3	41.2±2.7	42.9±1.9	33.1±2.7^b	9.6±2.4^b	12.4±0.3	25.8±0.6

Data (mean±s.d.) are expressed as % on dry matter (DM) basis; N, nitrogen; EE, ether extract; CF, crude fibre; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, lignin; NFC, non-fibre carbohydrates; ^{a,b}Means with different superscripts are significantly different (P<0.05).

yield, the highest value obtained (2.7±0.2 t ha^{-1}) fertilizing at 105 kgN ha^{-1} was lower than the yields reported by others (Smith, 1996; Leshem *et al*., 2000; Landau *et al*., 2007; Weimberg *et al*., 2007). As an example, Landau *et al*. (2007) in an experiment carried out in North Sardinia with spineless safflower intended for sheep grazing, obtained a DM yield of 5.02±0.68 t ha^{-1}. In such a situation, however, the trial was designed specifically for forage production with a seed rate of 43 kg ha^{-1}. In our study, originally conceived for seed and dye production and only secondarily for biomass production, the final plant density (45 m^{-2}) was equivalent to an estimated seed rate of about 20 kg ha^{-1}. Most probably, the low plant density used in our study was the main factor effecting the biomass production. As suggested by the results found in literature (Weinberg *et al*., 2007), an increased plant density combined with a higher nitrogen fertilization, could further improve the biomass production reaching DM yields comparable with those of many winter cereals (Smith, 1996). In intensive and semi-intensive livestock production systems, harvested forages are usually stored as hay and/or as silage. Ensiling is based on lactic acid fermentation under anaerobic conditions of almost any moist forages; this is less weather dependent than hay-making (Weinberg *et al.*, 2002).

At mowing, the moisture data for spineless safflower were found to be too high to guarantee correct ensiling, while the 2-days wilting treatment gave satisfactory results in terms of DM content, particularly for plants grown in N-fertilized plots having a mean DM content ranging from 30-32%. In fact, comparing safflower ensiled either at 41% DM or 29% DM, Weinberg *et al*. (2002) observed a faster pH decrease at 29% DM than the driest forage, even though better results, in terms of final pH in the ensiling process, were always obtained inoculating forages with *Lactobacillus plantarum* (3.3×10^5 UFC g^{-1}). These findings suggest that the 2-days wilting treatment of safflower up to about 30% DM, may be considered satisfactory to give good ensiling kinetics. Initial pH is another important parameter affecting the ensiling process. The pH of wilted safflower was found to be variable between 5.85 (N_0) and 5.98 (N_2), in line with data reported by others (Weinberg *et al*., 2002; 2007). In our study, nitrogen fertilization had a slight effect on nutritional characteristics, besides the CP content that was strongly nitrogen-dependent. In similar circumstances, Weinberg *et al*. (2007) did not find any statistically significant effect on NDF content of safflower grown under different N-fertilization treatments (0 vs. 300 kg ha^{-1}) while a significant effect was found on the ADF content. Overall, the nutritional characteristics were in line with data reported in literature for safflower (Landau *et al*., 2004; Weinberg *et al*., 2007) and are substantially comparable as for CP, lipids, NDF and ADF, with data found in literature (Martillotti *et al.*, 1996) for many common forage cereals (bromegrass resque, italian ryegrass, tall fesque, orchardgrass) and some forage legumes (alfalfa, sainfoin, squarroso clover and vetch). Safflower is known to contain a moderate amount of polyphenolic compounds, including tannins, which may improve the nutritional value of this species, especially as far as the protein metabolization in ruminants. As a matter of fact, moderate amounts of tannins in forages are able to partially protect dietary protein from microbial degradation in the rumen, increasing the absorption of amino acids from the small intestine (Waghorn, 1996) and improving animal performances such as milk production, wool growth and ovulation rate (Min and Hart, 2002) reducing, at the same time, both bloat risks and internal parasite burdens (Min *et al*., 2003). Tannins together with a good content of non-fibrous carbohydrates, may explain the good palatability shown by safflower (Dajue and Mündel, 1996) as well as by some legume forages (Jones *et al*., 1976). In conclusion, the preliminary results obtained indicate that the selection of spineless safflower used has an interesting nutritional value, which may be partially improved by the nitrogen fertilization. Moreover, wilted safflower characteristics allow satisfactory preservation by ensiling. Further studies are in progress to fully evaluate, both from agronomical and nutritional points of view, the potential of this species as forage crop for integrated crop-livestock production systems in central Italy.

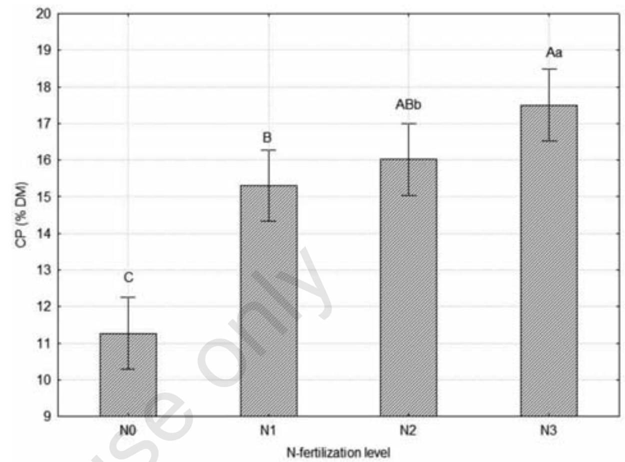

Figure 2. Crude protein content of 2-day wilted safflower plants as affected by the nitrogen fertilization. Data are expressed as least square mean±SEM. $^{A,B,C-a,b}$Means with different superscripts are significantly different (P<0.01; P<0.05).

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