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Short-term green manure effects on crambe yield and oil content

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Abstract

Crambe (*Crambe abyssinica* Hochst. ex R.E. Fries) is an oilseed crop that can be cultivated in tropical conditions and used for the production of industrial oil. While crambe is believed to be a suitable crop for no-tillage systems, identification of appropriate crop species to precede it is necessary to improve its grain yield and oil content. In this study, we aimed to assess the short-term effects of crop rotation on the grain yield and oil content of a crambe crop cultivated after spring-summer cover crops. The experiment was conducted on an Rhodic Hapludox soil in Santa Helena-PR, Brazil. The experimental design consisted of randomized blocks with four replications. The plots consisted of pearl millet (*Pennisetum glaucum*), grass brachiaria (*Brachiaria brizantha*), sorghum (*Sorghum bicolor*), sunn hemp (*Crotalaria juncea*) and a fallow area (spontaneous vegetation). Grain yield, oil content, and oil yield were measured. Crambe oil content was influenced by the cover crops. The use of crotalaria as predecessor species resulted in higher oil content, but the result did not differ from that observed in the fallow area. However, grain yield and oil content were benefited by the crotalaria cover crop in the short-term. Crambe looks promising as an alternative oilseed crop for South Brazil when seeded in autumn with crotalaria cover crop in Rhodic Hapludox.

Keywords: *Crambe abyssinica, Crotalaria juncea, Pennisetum glaucum, Brachiaria brizantha, Sorghum bicolor*.
Abbreviations: FMS_ Foundation Mato Grosso do Sul.

Introduction

Crambe (*Crambe abyssinica* Hochst. ex R.E. Fries) is a type of Brassica oilseed, which are the main sources of vegetable oil in semi-arid regions (Premi et al., 2013). As there is a need for plants with industrial potential, this species may be an alternative for cultivation in tropical regions, since it can be grown in rotation in idle areas with autumn-winter crops (Cattanêo et al., 2016). However, in no-tillage systems, owing to the residues left by antecedent species and subsequent utilization, it is necessary to investigate how crambe behaves under crop rotation. Studies have reported that Brassicas show lower yield when cultivated after grasses than when cultivated after legumes (Rathke et al., 2005). Legumes have the ability to fix atmospheric nitrogen and add it to the soil, and thus contribute to the nutrition of the subsequent crop because of nutrient cycling (Elfstrand et al., 2007; Werncke et al., 2014; Bassegio et al., 2015a) and the rapid release of N in the short term, which improves fertility (Astier et al., 2006). Furthermore, grasses have a high dry matter production potential (Crusciol et al., 2014), and their high C:N ratio slows down decomposition and increases the possibility of their use in warmer regions, especially in tropical regions. This process thus helps to prevent N loss via its persistence in soil and by absorption and immobilization of nutrients in the biomass. Crambe as a rotational crop has the ability to recycle and take advantage of residual nutrients from the preceding crop (Pitol, 2008). In Brazil, for example, crambe has been shown to respond favorably from residual fertilization of preceding soybeans (Bitencourt et al., 2016). In this regard, an ongoing process of soil nutrient recycling essentially transfers nutrients from waste predecessor species to newly planted crops (Lunelli et al., 2014). Given this evidence, it is important to examine the need for fertilization and the possible increase in fertilization in preceding crops to increase productivity in the crambe crop (Bitencourt et al., 2015). Several studies have been conducted on crop rotations between legumes and Brassica oilseeds such as mustard, rapeseed, and canola (Aulakh and Pasricha, 1998; Christen, 2001; Mohammadi and Rokhzadi, 2012); however, little is known about the use of the residues left by cover crops in rotations involving crambe as the main crop. Thus, in light of the limited scientific information and with the hypothesis that crop rotation with legumes can benefit crambe, in the present study, we aimed to assess the grain yield and oil content of a crambe crop after cultivation with short-term cover crops.

Results and discussion

Climatic conditions

Crambe cultivation with cover crops was affected by weather conditions (Figure 1). There was a larger volume of rainfall at the growth and flowering stages (472 mm) than at the formation and grain filling stages (62 mm). Moreover, temperatures below 0°C caused frost, and crambe is sensitive to low temperatures in certain phases (Pitol, 2008).

Grain yield

However, despite that damage to the crop due to the stress, crambe grain yield (Figure 2A) under crotalaria cover crops was within the expected yield potential (1000-1500 kg ha^{-1}) and it was similar to the results of by Viana et al. (2015). The highest grain yield under crotalaria cover crops was due to short-term intake of nutrients by this species, especially N, which resulted in better crop nutrition, because N is the most exported nutrient in the harvesting of crambe grains (Mauad et al., 2013); it was also due to the contribution to improvement of the physical conditions of the soil (Munoz-Carpena et al., 2008). These results are similar to those reported by Tomassoni et al. (2014), who observed short-term positive effects of crotalaria as a predecessor cover crop on nitrogen fertilization in crambe cultivation. Aulakh and Pasricha (1998), throughout four years of cultivation, observed that cowpea beans used as green manure in the absence of nitrogen fertilization increased *Brassica juncea* yield. Although other cover crops can accumulate dry matter and nutrients in tropical regions with warm weather, in the short term, the high nutrient release by crotalaria (mainly residual N) leads to higher grain yield, as reported previously (Balkcom and Reeves, 2005; Cherr et al., 2006; Schomberg et al., 2007).

Oil content

With respect to oil content (Figure 2B), the main determinant of crambe grains, we observed that among all cover crops, crotalaria provided the highest content (27%), but this result did not differ from that observed in the fallow areas (25%). According to Rathke et al. (2006), optimizing oil content involves balancing the synthesis of protein and crude oil in the grains, as well as energy and carbon dioxide (CO_2), as the management of N may affect oil synthesis.

Although low oil content was related to low grain yield, as was also observed by Santos et al. (2013) on crotalaria straw, in the short term, crotalaria led to satisfactory results; however, there are reports that high amounts of N do not influence or cause reduction in oil content in Brassica oilseeds (Hocking et al., 1997; Cheema et al., 2001; Grant et al., 2011). Mohammadi and Rokhzadi (2012) observed increased *Brassica napus* oil content in crop rotation with legumes. In contrast, Rathke et al. (2006) observed that cultivating rapeseed after barley in winter significantly increased oil content as compared to that upon rotation with peas.

Oil yield

The oil yield (Figure 2C) also benefited from rotation with crotalaria, as the supply of nutrients resulted in 295 kg of oil ha^{-1}. The crambe oil yield was similar to that observed by Santos et al. (2013) in tropical conditions. The results of this study are consistent with those of Aulakh and Pasricha (1998), who also found little effect of string beans on the oil content of *Brassica juncea*, but a significant increase in oil yield. Rathke et al. (2006) found that rapeseed, which is a winter crop, upon rotation with peas showed higher oil yield due to higher grain yield. This was also observed in the present study.

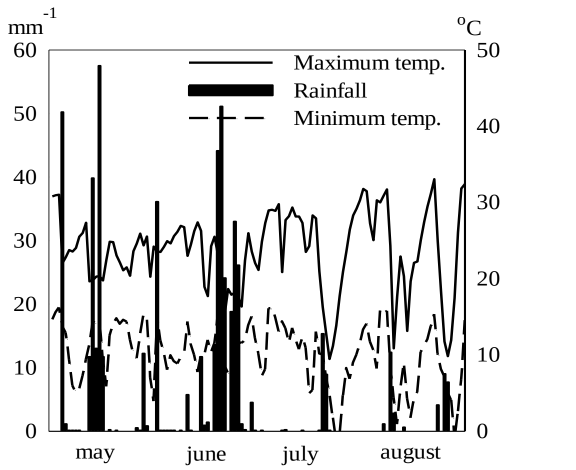

Fig 1. Maximum temperatures, minimum temperatures and rainfall during the experiment. Source: Meteorological Station of the Agronomic Institute of Paraná – IAPAR.

A correlation (r = 0.92, p <0.05) was observed between crambe oil content and grain yield (Figure 3A). Mohammadi and Rokhzadi (2012) also observed correlation (r = 0.78) between oil content and grain yield. The variation in oil content has genetic and biochemical limitations; thus, oil yield is further influenced by grain yield and, therefore, follows a nearly similar trend to grain yield (Premi et al., 2013), as observed in the present study (r = 0.99, p<0.001) (Figure 3B). Rosa (2013) analyzed the potential to decompress a latosol soil with cover crops, and found that crotalaria cover crops caused significant reduction in soil density in comparison to the fallow area, although this did not influence crambe grain yield or oil content. However, the author also observed a positive linear correlation between grain yield and oil content, which confirms the results obtained in the present study. Thus, in summary, we highlight the importance of using cover crops in planting systems, especially crotalaria, for the nutrition of crambe as the main crop. The rotation between cover crops and crambe can benefit the agricultural production system, as using crambe as the main species can also improve the physical properties of the soil (Dias et al., 2015), which is a feature of Brassicas (Chen and Weil, 2011; Chen et al., 2014). Moreover, as reported by Bassegio et al. (2015b), cover crops in rotation with crambe can also increase soil fertility in the short term.

Materials and Methods

Plant materials

The crambe (*Crambe abyssinica* Hochst. Former. RE Fries) cultivar was FMS–Brilhante originated FMS. Cover crops used for crop rotation were Pearl millet (*Pennisetum glaucum*), grass brachiaria (*Brachiaria brizantha*), sorghum (*Sorghum bicolor*) and sunn hemp (*Crotalaria juncea*).

Study site description

The experiment was carried out in Santa Helena, Paraná State, Brazil (24º57' S, 54°18' W, altitude of 282 m). The 30-year mean annual temperature is 22.1°C with a July minimum of 16.8°C and a January maximum of 27.6°C, and mean annual precipitation of 1,800 mm. The regional climate is relatively warm and wet. Rainfall and maximum and

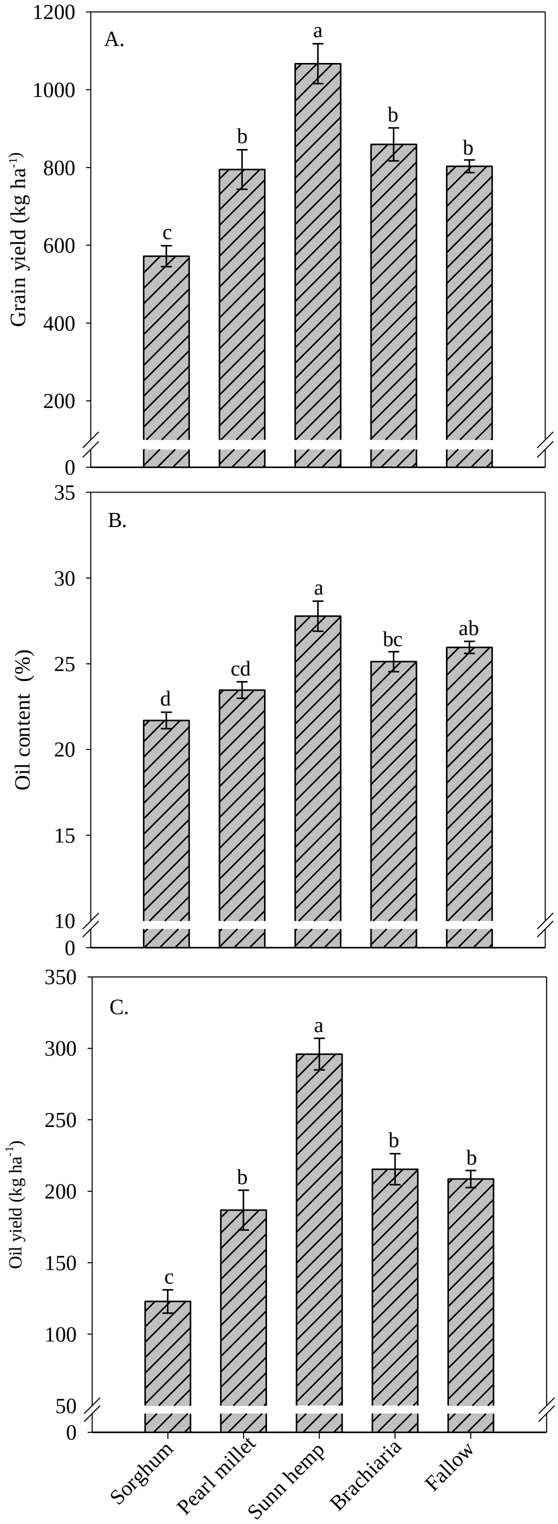

Fig 2. Grain yield (A), oil content (B) and oil yield (C) affected by cover crops. Different letters show significant differences (Tukey test, $p \leq 0.05$). Vertical bars show the standard error.

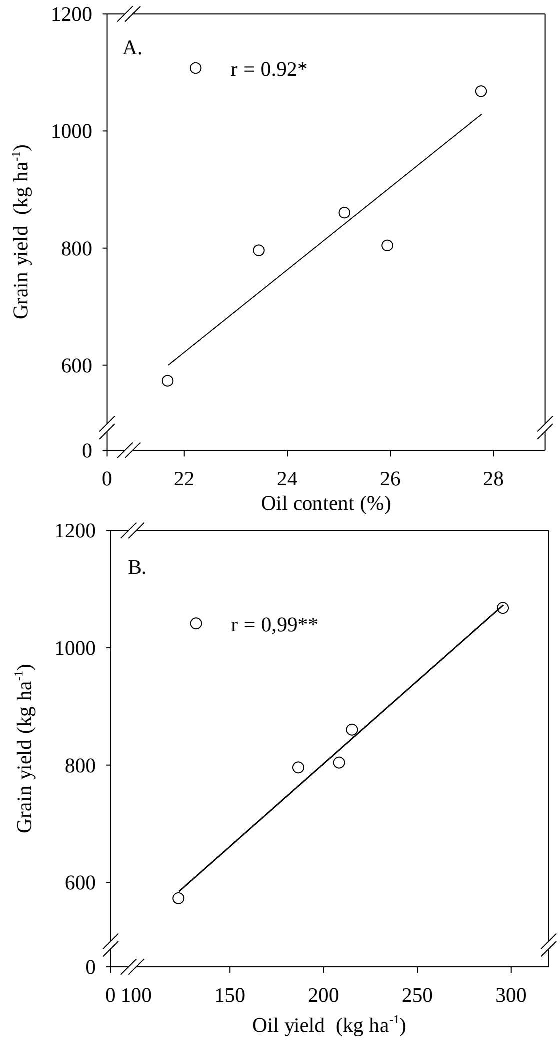

Fig 3. Correlation between oil content and grain yield (A) and oil yield and grain yield (B). *, ** significant at 5 % ($p \leq 0,05$) and 1 % ($p \leq 0,01$), respectively.

minimum temperatures recorded during the experiment are shown in Figure 1.

The soil was a Rhodic Hapludox (Soil Survey Staff, 2010), with 700, 150, and 150 g kg^{-1} of clay, silt and sand, respectively. Before starting the experiment, soil samples were taken from the surface layer (0–20 cm), air dried, sieved through a 2 mm mesh, and analyzed as in Embrapa (1997). Soil chemical analyses returned values of: pH in $CaCl_2$ (0.01 M) of 5.1; 14 g dm^{-3} of organic carbon; 21 mg dm^{-3} of P (Mehlich-1); 0.13 $cmol_c$ dm^{-3} of K^+; 6.07 $cmol_c$ dm^{-3} of Ca^{2+}; 2.50 $cmol_c$ dm^{-3} of Mg^{2+}; 12.98 $cmol_c$ dm^{-3} of cationic exchange capacity (CEC); and 67 % of soil base saturation.

Field management

The four experimental crop rotations and fallow were initially established on February 01, 2013. Cover crops were sown in 0.45 m spaced rows at densities of 20, 40, 15, and 20 kg seeds ha^{-1} of pearl millet, grass brachiaria, forage sorghum and sunn hemp, respectively.

Fertilization of cover crops was carried out by applying 100 kg ha^{-1} of 10-15-15 formulation at sowing. Seven days after the management of cover crops and spontaneous weed, in half of each experimental plot, crop residues were crushed into particles of approximately 50 to 70 mm long using a mechanical crusher of crop residues. Crambe was planted on May 10, 2013, in rows spaced 45 cm with a density of 20 seeds m^{-1}, fertilized with 10, 30 and 30 kg ha^{-1} of N, P_2O_5 and K_2O respectively, and applied in the seed furrows, as recommended by Pitol (2008). A total of 20 plots, 6.4 m wide × 6.0 m long.

Measurements

Grain yield (kg ha^{-1}) of crambe was determined in an area of 4.5 m^2 within each plot, becoming the two central lines. Grain yield were expressed corrected to 130 g kg^{-1} of moisture. The oil content of grains was determined by petroleum ether extraction and the results were expresssed as percentages (IAL, 1985). Oil yield (kg ha^{-1}) was calculated as the product of oil content and seed yield.

Statistical analysis

The experimental design consisted of randomized blocks with four replications. Original data were submitted to ANOVA and the results were compared using the Tukey's test ($p \leq 0.05$) and F test ($p \leq 0.05$), respectively.

Conclusion

Oil content is influenced by cover crops. Crotalaria as predecessor species resulted in higher oil content, but the result did not differ from that obtained in the fallow area. Crambe grain and oil yield is benefited by crotalaria cover crops. Green manure was shown to be as a good option for tropical climate change and crambe adaptation. Crambe looks promising as an alternative oilseed crop for South Brazil when seeded in autumn with crotalaria cover crop in short-term. However, it is necessary long-term studies to prove the effect of the other green manures (grasses).

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