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Comparison of Safflower Cultivation in Two Seasons in the South of Brazil

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Abstract

The objective of this work was to evaluate the production components, grain yield and safflower character correlations as a function of two sowing seasons (autumn and winter). Safflower culture was implanted in 2014 in a randomized complete block design with three replicates. The evaluation of safflower crop occurred in two seasons of the year, with the first growing season being characterized by sowing on April 30, 2014 (autumn), and the second growing season on July 30, 2014 (winter). The evaluations occur when the plants showed a 50% flowering and the following determination: plant height, number of branches per plant and chapters, stem diameter, dry weight of the stalk, dry mass of the branches dry mass of chapters and mass dry roots, grain yield, oil content and oil productivity. Growth stations were compared at 5% probability of error by the Student t test. For the study of correlations, Pearson's linear correlation coefficient matrix (r) was estimated between the characters by means of the Student's t-test, with a 5% probability of error. Except for the oil content and number of branches, safflower characters were benefited by early sowing in autumn. Safflower cultivated in autumn produced 3,820 kg ha^{-1} and in winter yielded 2,068 kg ha^{-1}. For the early cultivation of autumn, the characters have greater correlation, favored by the climatic conditions. Grain and oil productivity obtained correlation higher than 97% in both seasons.

Keywords: *Carthamus tinctorius* L., sowing time, yield

1. Introduction

The rise in concern for the preservation of the environment, together with the need to increase energy generation, results in the search for oleaginous alternatives to bioenergy production, such as safflower (*Carthamus tinctorius* L.) (Santos & Silva, 2015). Safflower is a crop with characteristics of easy adaptation to the Brazilian conditions, high potential of production and with satisfactory development in diverse types of soil (Santos et al., 2015).

For the species to stand out in the national scenario, an important component is the climate, because its variations can mean the difference between success and failure of a harvest (Barteko et al., 2010). The southern region of Brazil has large climatic variations, with climate that ranges from tropical to typical temperate, with hot summers, winter with sensitive temperature drop, the largest annual temperature range of the country and annual regular rainfall, which enables varied crop species (Wrege et al., 2009).

The development of safflower cultivation is influenced by the environmental conditions under which it is presented. The sowing season is an important factor that directly interferes with the agronomic characteristics and crop yield (Peixoto et al., 2008). Different research has shown the effects of sowing on yield, yield component and other agronomic characteristics of the crop (Mostafanezhad & Eivazi, 2010; Koutroubas et al., 2004). Late sowing may be responsible for the yield decline of safflower seeds, since the last flowering may not survive the high temperature and water deficit at the end of the season (Yau, 2007; Omidi & Sharifmoghadas, 2010). The plant's development period is directly linked to its productivity. Thus, late sowing will be responsible for acceleration in the maturation phase due to the shorter development period, which leads to decrease production (Tayebi et al., 2012). According to Si and Walton (2004), early sowing is associated with an early flowering cultivar allows higher productive performance.

Studies conducted in different localities have shown that safflower may be a winter or spring crop option in a place with mild temperatures, although its yield is better when sown in autumn (Koutroubas et al., 2004; Yau, 2007). The sowing in hot areas of the Mediterranean, such as California, cultivation is carried out in the spring avoiding excessive development, as it will lead to the production of low quality seeds (Kaffka & Kearney, 1998). Crops in central Italy, with low temperatures in the Mediterranean, have shown lower productivity, due to the low resistance of the species to low temperatures during its initial development (Salera, 1997). However, in southern Italy, a low temperature site, sowing in the autumn provided better yields than spring sowing (Corleto et al., 2001).

In view of the above, the objective of this research was to evaluate the components of production, grain yield and correlation of safflower characters as a function of two sowing seasons (autumn and winter) in southern Brazil.

2. Material and Methods

The cultivation of safflower was established in 2014 at the Centro de Desenvolvimento e Diffusion de Tecnologia (CEDETEC), Faculdade Assis Gurgacz (FAG), located in the municipality of Cascavel, PR, Brazil, whose geographical coordinates are 24°56′40″ S and 53°30′31″ W, with an average elevation of 715 m. The climate of the region is type Cfa, according to the Köppen classification, that is, temperate mesothermic superhumid, with moderate temperatures, well distributed rains and hot summer (Alvares et al., 2014). The soil of the experimental area was classified as Dystrophic Red Latosol (Santos et al., 2013).

The experimental design was a randomized complete block design, with three replicates, each block being divided into 5 plots, 5 meters by 4 meters, with a total area of 100 m² per block. The area of experimentation under no-tillage system for more than 20 years, with corn or soybean crops in the summer and oat or wheat crops in the autumn/winter seasons.

Soil chemical analysis showed in autumn, pH in $CaCl_2$ 0.01 M of 5.2, 38.2 g kg^{-1} of organic matter, 12.8 mg dm^{-3} of P ($Mehlich^{-1}$), 1.3 cmolc dm^{-3} of K, 4.6 cmolc dm^{-3} of Ca, 2.2 cmolc dm^{-3} of Mg, 14.3 cmolc dm^{-3} of CEC, and 59% of soil base saturation. In winter, it showed pH in $CaCl_2$ 0.01 M of 5.48, 46.48 g kg^{-1} of organic matter, 5.48 mg dm^{-3} of P ($Mehlich^{-1}$), 0.8 cmolc dm^{-3} of K, 4.5 cmolc dm^{-3} of Ca, 2.8 cmolc dm^{-3} of Mg, 13.3 cmolc dm^{-3} of CEC, and 61% of soil base saturation.

The evaluation of safflower crop was made with sowing in two seasons of the year, in the first plot sowing on April 30, 2014 (autumn) and the second plot sowing on July 30, 2014 (winter). The sowing was done manually, leaving 10 plants per linear meter after the thinning. Each evaluation plot consisted of four rows measuring 4 meters long.

When the plants showed 50% flowering, at 80 and 60 days after emergence for the first and second sowing seasons respectively, the height of plants was determined, measured with graduated tape measure, the distance between the soil level to the apex of in the plant, of six plants at random within each plot. The number of branches per plants and chapters was determined from this six plant. When the crop presented 50% of its flowering, six plants were randomly collected in each plot to measure the diameter of the stem, with a digital caliber we measure the basal region of the stem. This safflower plants were separated into stem, twigs, chapters and roots to determine the amount of dry matter by dried 338.15 K in a constant weight oven.

The harvest was made, at 160 and 140 days after the emergence in the first and second sowing seasons respectively. Yield was determined after manual threshing and cleaning the grain harvested from plants collected from a linear meter from each plot, with values expressed in kg ha^{-1}, correcting the moisture content to 12%. The mass of 1000 grains was performed by score sub samples of 100 grains per plot. The samples were weighed in precision scale with two decimal places, correcting the degree of humidity to 12%. The mass of 1000 grains was determined according to the Rules for Seed Analysis (Ministério da Agricultura, Pecuária e Abastecimento, 2009).

Oil content was determined from a TD-NMR in a SLK-SG-200 spectrometer (SpinLock Magnetic Resonance Solutions) at 571,3 K, equipped with a permanent magnet of 0.23 T (9 MHz for 1H) and a probe with 13 mm × 30 mm of useful area. We used the Condor IDE software with CPMG pulse sequence and Qdamper (Colnago et al., 2011), expressed on a dry basis (% DB).

Growth stations were compared at 5% probability of error by the Student t test. For the study of correlations, Pearson's linear correlation coefficient matrix (r) was estimated between the characters by means of the Student's t-test, with a 5% probability of error. Data from the two experiments were also submitted to principal component analysis (PCA). The Minitab 17 software (Minitab, Inc., State College PA, USA) was used to perform analysis of the results.

3. Results and Discussion

Safflower cultivated in the autumn period received about 1,170 mm of precipitation, which is above the winter precipitation (600 mm) and above the required amount throughout the cycle for optimal growth, since it is necessary values between 800 and 1,000 mm (Oyen & Umali, 2007). In addition, the cultivation in the autumn favored the crop due to the larger photoperiod and the long day favor and advances the plant cycle, since the solar interception is greater.

Except for the oil content (OIL) and number of branches (NG), the safflower characters were benefited by early sowing in autumn (Table 1). This is due to the lower effect of the environment in these characters, but also to due to the characteristics of the plant itself, as suggested by Brăileanu et al. (2013). The oil content in the present work is similar to the values of Elfadl et al. (2009), which varied from 19.0 to 26.1%.

Table 1. Safflower characters in autumn and winter crop

Season	AP	DC	CC	MSC	NG	MSG	NC	MSCA	PRO	TGW	OIL	PRO.O
Autumn	1.2 a	10.6 a	0.8 a	16.3 a	6.4 a	19.8 a	12.5 a	16.2 a	3820 a	68.7 a	23.5 a	907 a
Winter	0.7 b	8.3 b	0.5 b	7.7 b	6.8 a	5.9 b	9.3 b	6.2 b	2068 b	48.4 b	24.2 a	520 b

Note. Letters in the column indicate difference at 5% of probability of error by Student's t test. AP = Plant height, in cm; DC = stem diameter, in mm; CC = Length of stem in cm; MSC = Dry matter of stem, in g plant^{-1}. NG = Number of branches; MSG = Dry matter of branches, in g plant^{-1}; NC = Number of chapters; MSCA = Dry matter of chapters, in g plant^{-1}; PRO = Grain yield, in kg ha^{-1}; TGW = Weight of a thousand grains, in g plant^{-1}; OIL = oil content in %; PRO.O = Oil productivity, in kg ha^{-1}.

The safflower cultivated in autumn obtained better climatic conditions for the growth, flowering and filling of grains, thus, the accumulation of dry matter in the plant parts and in the chapters and the consequent productivity of grains was benefited by the early sowing. These results show that late sowing presents a significant decrease in these characters due to water deficit and high temperatures at the end of the cycle, which was also observed by Rao (1990), and Ashri (1975).

The water deficit has been pointed out as responsible for the reduction of safflower characters and grain yield (Lovelli et al., 2007), especially in the vegetative stage (Istanbulluoglu, 2009; Istanbulluoglu et al., 2009). Bellé et al. (2012) in Southern Brazil observed a lower accumulation of dry matter in spring-summer sowing in relation to autumn-winter, due to high evapotranspiration values. The results of this study are also agree with the results reported by Ghanbari-Odivi et al. (2013) in Iran, where higher productivity was observed with sowing in May (autumn) compared to January (winter). Positive results of autumn sowing are reported in the literature (Koutroubas et al., 2004; Yau, 2007).

Although contrasting with the environment, the average yield (2.068 kg ha^{-1}) observed in late winter cultivation in southern Brazil is between 1000-3300 kg ha^{-1} obtained in Pampa region of Argentina (Quiroga et al., 2001), in Potenza in Italy (Lovelli et al., 2007) and in Orissa in India (Kar et al., 2007).

The linear association of AP with the characters in autumn and winter, with the exception of CC, showed values of r of low magnitude, that is, the height of safflower plants is not associated with the production components (Tables 2 and 3). The highest correlation between AP and CC in winter is due to lower solar interception, which is reflected by the degree of intraspecific competition of plants.

Table 2. Pearson (r) linear correlation coefficients among the safflower characters in winter

Characters	AP	DC	CC	MSC	NG	MSG	NC	MSCA	PRO	TGW	OIL	PRO.O
AP	1	-0.12	0.69**	0.16	-0.27*	-0.17	-0.25	-0.24	0.19	0.10	0.06	0.15
DC	-0.12	1	-0.54**	0.76**	0.77**	0.87**	0.84**	0.82**	-0.24	0.13	-0.03	-0.22
CC	0.69**	-0.54**	1	-0.34*	-0.56**	-0.64**	-0.68**	-0.68**	0.15	-0.08	-0.02	0.11
MSC	0.16	0.76**	-0.34*	1	0.69**	0.82**	0.82**	0.76**	-0.19	0.08	-0.03	-0.18
NG	-0.27*	0.77**	-0.56**	0.69**	1	0.84**	0.86**	0.75**	-0.28*	0.03	-0.02	-0.25*
MSG	-0.17	0.87**	-0.64**	0.82**	0.84**	1	0.94**	0.92**	-0.29*	0.07	-0.05	-0.27*
NC	-0.25	0.84**	-0.68**	0.82**	0.86**	0.94**	1	0.91**	-0.22	0.13	-0.01	-0.20
MSCA	-0.24	0.82**	-0.68**	0.76**	0.75**	0.92**	0.91**	1	-0.25	0.08	-0.04	-0.22
PRO	0.19	-0.24	0.15	-0.19	-0.28*	-0.29*	-0.22	-0.25	1	0.26*	0.38**	0.98**
TGW	0.10	0.13	-0.08	0.08	0.03	0.07	0.13	0.08	0.26*	1	0.08	0.23
OIL	0.06	-0.03	-0.02	-0.03	-0.02	-0.05	-0.01	-0.04	0.38**	0.08	1	0.53**
PRO.O	0.15	-0.22	0.11	-0.18	-0.25*	-0.27*	-0.20	-0.22	0.98**	0.23	0.53**	1

Note. * Significant at 5% probability of error by Student's t-test, ** Significant at 1% probability of error by Student's t-test. Legend: AP = Height of plant, in cm; DC = stem diameter, in mm; CC = Length of stem in cm; MSC = Dry matter of stem, in g plant^{-1}. NG = Number of branches; MSG = Dry matter of branches, in g plant^{-1}; NC = Number of chapters; MSCA = Dry matter of chapters, in g plant^{-1}; PRO = Grain yield, in kg ha^{-1}; TGW = Weight of a thousand grains, in g plant^{-1}; OIL = oil content in %; PRO.O = Oil productivity, in kg ha^{-1}.

Table 3. Pearson (r) linear correlation coefficients among safflower characters in autumn

Characters	AP	DC	CC	MSC	NG	MSG	NC	MSCA	PRO	TGW	OIL	PRO.O
AP	1	0.44**	0.86**	0.48**	0.16	0.29*	0.39**	0.48**	0.42**	0.32*	0.36*	0.46**
DC	0.44**	1	0.32*	0.61**	0.54**	0.70**	0.65**	0.70**	0.19	0.08	-0.16	0.15
CC	0.86**	0.32*	1	0.42**	0.17	0.13	0.25*	0.36**	0.49**	0.27*	0.52**	0.54**
MSC	0.48**	0.61**	0.42**	1	0.45**	0.58**	0.44**	0.47**	0.24	0.14	0.02	0.23
NG	0.16	0.54**	0.17	0.45**	1	0.50**	0.68**	0.57**	-0.04	0.04	-0.01	-0.05
MSG	0.29*	0.70**	0.13	0.58**	0.50**	1	0.59**	0.64**	0.01	0.07	-0.30*	-0.03
NC	0.39**	0.65**	0.25*	0.44**	0.68**	0.59**	1	0.82**	-0.00	0.09	-0.07	-0.03
MSCA	0.48**	0.70**	0.36**	0.47**	0.57**	0.64**	0.82**	1	0.18	0.05	-0.06	0.15
PRO	0.42**	0.19	0.49**	0.24	-0.04	0.01	-0.00	0.18	1	0.02	0.41**	0.97**
TGW	0.31*	0.08	0.27*	0.14	0.04	0.07	0.09	0.05	0.02	1	0.26	0.06
OIL	0.36*	-0.16	0.52**	0.02	-0.01	-0.30*	-0.07	-0.06	0.41**	0.26	1	0.56**
PRO.O	0.46**	0.15	0.54**	0.23	-0.05	-0.03	-0.03	0.15	0.97**	0.06	0.56**	1

Note. * Significant at 5% probability of error by Student's t-test, ** Significant at 1% probability of error by Student's t-test. Legend: AP = Height of plant, in cm; DC = stem diameter, in mm; CC = Length of stem in cm; MSC = Dry matter of stem, in g plant^{-1}. NG = Number of branches; MSG = Dry matter of branches, in g plant^{-1}; NC = Number of chapters; MSCA = Dry matter of chapters, in g plant^{-1}; PRO = Grain yield, in kg ha^{-1}; TGW = Weight of a thousand grains, in g plant^{-1}; OIL = oil content in %; PRO.O = Oil productivity, in kg ha^{-1}.

The DC presented a higher degree of association in the autumn crop, whose higher r values were observed for MSG, NC and MSCA. However, independent of the season, there is a trend of association of DC with the characteristics related to the accumulation of dry matter in safflower plants. The lowest degrees of association in the winter are related to the decrease of the diameter of the stem and the smaller lengthening of the internodes due to the little solar radiation.

As the AP, the CC despite showing significant correlations is not associated with growth components and grain production. Grain production and vegetative growth have a high degree of competition for nutrients, but climatic characteristics also influence final grain production. In early planting, NG is related to MSG, NC and MSCA, this difference is due to the low compensatory capacity of the plants in the winter period, due to the smaller cycle and the photoperiod, which makes difficult the formation of rhymes and consequently of chapters.

In autumn and winter, MSC and MSG determined on flowering of safflower was associated with NC and MSCA until flowering, which is due to the transfer of the assimilates to the formation of biomass accumulation in the reproductive structures. Despite this, there was no association with grain yield at the end of the cycle. Thus, the accumulation of dry matter in the stem and branches is associated with the formation of chapters and consequently dry matter accumulation will not reflect higher grain yield. This is reflected in the non-existent association between the MSCA and the productive characters in both eras, and can be explained by the higher productive cycle of the safflower, being subject to abiotic stresses during the maturation phase.

The PRO.O constitutes a combination of PRO and OIL, thus follows a behavior similar to grain yield. Thus, as expected, grain yield and oil yield are highly associated with r of 0.97 and 0.98, since the oil content is limited by genetic factors characteristic of the plant. In this sense, the OIL character, although significant, in both stations presented r of 0.53 and 0.56, not being in association with the oil productivity. Koutroubas et al. (2009) observed that the classification among safflower genotypes for oil yield was similar to that of grain yield, because the oil yield was mainly determined by the latter. Omidi et al. (2012) also observed a high correlation between grain yield and oil content ($r = 0.90^{**}$).

Çamas et al. (2007), evaluating agronomic characteristics of the safflower cultivation in different conditions in the northern Turkey, found significant results for Pearson correlations for between grain yield with number of branches (0.49), grain weight (0.45), oil content (0.51) and oil yield (0.95), number of branches with oil content (0.34) and yield of oil (0.51), among number grains with grain weight (0.53), oil content (0.37) and oil yield (0.44), grain weight with oil content (0.29) and oil yield (0.39), oil content with oil yield (0.72). Vorpsi et al. (2010), evaluating the quality of safflower seeds cultivated in Albania, found significant relations for plant height with grain yield (0.60), oil yield (0.61), weight of chapters with grain weight (0.40), and oil yield (0.38), grain yield with oil yield (0.94).

The best behavior of the safflower characters in both seasons was that composed of three components, with 80 and 82% for autumn and winter, respectively (Table 4). The selection of the number of components was based on the principles suggested by Jolliffe (2002), that is, that the cumulative percentage of the total variance between 70 and 90% gives a reasonable idea of the representation of the original variance. It is observed that both in autumn and winter the three components explained a similar percentage of the variance of the variables, with 80 and 82% in autumn and winter respectively (Table 4).

Similarly, the first component explains 49% in the fall and 47% in the winter, although the score load indicates that the variability of the data is not explained by a single variable in the first component, that is, several components are responsible for determining variance of the data. In the second component, grain and oil productivity were highlighted in both seasons. In winter, due to the lower growth of the plant, the NG is an important factor, standing out in the second component. In autumn, due to the higher growth of safflower plants, plant height is an important variable, standing out in component three. On the other hand, due to lower productivity in winter, the oil content is a variable that explains the data variance and is important in component three.

Table 4. Matrix of factorial weight of autumn and winter safflower characters in the three main components selected

Characters	Autumn			Winter		
	PC1	PC2	PC3	PC1	PC2	PC3
AP	-0.12	-0.11	0.74	0.34	-0.24	-0.27
DC	0.36	-0.09	0.12	0.38	0.13	-0.04
CC	-0.29	0.07	0.49	0.24	-0.36	-0.30
MSC	0.33	-0.10	0.37	0.39	0.02	-0.12
NG	0.36	-0.04	-0.00	0.12	0.42	0.33
MSG	0.39	-0.06	0.07	0.37	0.21	-0.01
NC	0.39	-0.11	0.02	0.31	0.33	0.17
MSCA	0.38	-0.08	0.00	0.36	0.21	0.04
PRO	-0.16	-0.56	-0.05	0.22	-0.41	0.22
TGW	0.02	-0.30	0.09	0.20	-0.14	0.07
OIL	-0.04	-0.42	-0.12	-0.01	-0.19	0.70
PRO.O	-0.15	-0.58	-0.09	0.20	-0.41	0.33
Eigenvalue	58.7	22.7	14.7	57.4	29.1	12.7
% explained variance	49	19	0.1	47	24	10
% accumulated variance	49	67	80	47	72	82

Note. AP = Plant height, in cm; DC = stem diameter, in mm; CC = Length of stem in cm; MSC = Dry matter of stem, in g plant^{-1}. NG = Number of branches; MSG = Dry matter of branches, in g plant^{-1}; NC = Number of chapters; MSCA = Dry matter of chapters, in g plant^{-1}; PRO = Grain yield, in kg ha^{-1}; TGW = Weight of a thousand grains, in g plant^{-1}; OIL = oil content in %; PRO.O = Oil productivity, in kg ha^{-1}.

4. Conclusion

Except for the oil content and number of branches, the safflower characters were benefited by early sowing in autumn. Safflower cultivated in autumn in 2014 in southern Brazil produced 3,820 kg ha^{-1} and in winter produced 2,068 kg ha^{-1}.

At early autumn cultivation, the characters have more correlation, due to the climatic conditions. The yield of grains and oil has an association above 97% in both seasons.

The cultivation of safflower is extremely dependent on the climatic conditions, and it is not recommended to cultivate as a late crop (winter).

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