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Population Arrangement of Crambe Plants

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Abstract

Crambe (*Crambe abyssinica* Hochst) is an alternative raw material for biodiesel production. It is highly resistant to drought and has short growing cycle of 90 to 100 days. This work was conducted in Umuarama city, Parana State, Brazil, in Haplortox typical and aimed to study the effect of row spacing and population densities in the development of crambe in two growing seasons. The experimental design was a randomized block in a 3x3 factorial scheme with four replications. The treatments consisted of three row spacing (15, 30 and 45 cm) and three population densities (500 thousand, 750 thousand and 1 million plants per hectare). It was evaluated the thousand grain weight, oil content and grain yield. It can be concluded that high and low spacing plant population lead to smaller yields.

1. Introduction

Growing economic and environmental concerns, in addition to predictions that non-renewable energy reserves will be depleted in 50 years, have encouraged the search for new energy sources such as biofuels. Research shows the feasibility of using a liquid fuel that is biodegradable, non-toxic, and produced by raw materials (Pitol et al., 2010). The chemical reaction between vegetable oils (fats) and alcohol (ethanol or methanol) creates biodiesel. Currently the industry uses soybean oil as the main source of vegetable oil, followed by sunflower and tallow oils, though according Stachiw et al. (2016) new sources are being studied.

As well as being highly resistant to drought the crambe (*Crambe abyssinica* Hochst) plant species does well in both warm and cold soils, is resistant to pest and diseases and has an oil content of approximately 35% by mass, shelled (Pitol et al., 2010). Crambe is an annual upright plant with a height that ranges from 60 to 100 cm. It is grown in several regions of tropical and subtropical climates, with high resistance to water stress, especially in its vegetative stage, has better vegetative growth at temperatures ranging from 15-25 °C, with tolerance to higher temperatures, except while the plant is flowering (Silva et al., 2013).

Research conducted in the Umuarama-PR-Brazil indicates productivity between 1,000 and 2,000 kg ha^{-1}. In tests performed in the extraction of oil by means of crushing presses obtained yield 25 liters of oil per 100 kg of grains (Rogério et al., 2012).

Seeding rate is an important factor to be considered in the crop implantation to achieve satisfactory initial plant population and get consistent performance in the field (Stacciarini et al., 2010). The right combination of row spacing and plant density enables the best use of light, water and nutrients by plants (Martin et al., 2012). Braz and Rossetto (2009) reported that seeding rate can influence the establishment and growth of plants during their growth cycle.

The ideal arrangement of plants in the sowing area depends on the intrinsic characteristics of the variety, such as size, growth habit and plant architecture (Bezerra et al., 2009), as well as environmental conditions and management system (Bizinoto et al., 2010).

Kruger et al. (2014) working with genotypes canola (Hyola 432 and Hyola 61) and plant densities (20, 40, 60 and 80 plants m^{-2}), concluded the 0.40 m spacing employed provided no changes in grain yield in isolation.

Soratto et al. (2011) worked with row spacing of 45, 60, 75 and 90 cm and plant populations of 25,000, 40,000, 55,000 and 70,000 plants of castor bean per hectare, they found that increase in plant population, regardless of row spacing, the survival of plants decreased, stem diameter, number of racemes per plant and fruits per raceme. Higher yields of grain and oil cultivar FCA-PB were obtained with initial populations between 55,000 and 70,000 plants per hectare in row widths 0.45 to 0.75 m.

Albuquerque et al. (2011) worked with three row spacing of 50, 70 and 90 cm and three seeding rates of 100, 140 and 180 000 plants ha^{-1} of grain sorghum, in two growing seasons in the northern region of Minas Gerais. It was concluded that by reducing the spacing between rows the grains yield and panicles of sorghum was improved, regardless of plant population.

Debiasi et al. (2007) evaluated the influence of density of 30, 60 and 90 kg ha^{-1} of viable seeds and velocity (3.2, 5.3, 6.9 and 8.2 km h^{-1}) seeding in grain yield and components of the oat yield (*Avena strigosa* Schreb.), in the region of São Gabriel/RS, under conditions of intense grazing, observed fewer panicles per m^2 for densities of 30 and 60 kg ha^{-1}. The higher number of caryopsis per panicle offset this, so that higher yield grains were obtained in these densities. The densities did not significantly affect the 1000 caryopsis.

Given the recent interest in the species the current research about cultivation, liming and fertilization as well as spacing and population density is insufficient. Thus, this study aimed to verify the effect of row spacing and population densities on the development of crambe.

2. Methods

The experiment was conducted under field conditions, in Umuarama city, Parana State, Brazil, situated 53°18′ West longitude and 23°47′ South latitude and altitude 430 m. The climate is mesothermal humid subtropical (cfa). The soil is Oxisol dystrophic with a sandy texture (USDA, 1998).

Plots for each treatment consisted of six lines five meters in length, spaced according to each treatment, considered useful area four centerlines, ignoring 0.5 m at both ends.

Experimental design was a randomized block in a 3 × 3 factorial scheme with four replications. The treatments consisted of three spacing between rows (15, 30 and 45 cm) and three population densities (500, 750 and 1 million plants per hectare).

Sowing was performed manually in May 2012 and 2013, with crambe FMS-Brilhante. The grinding was done 20 days after sowing leaving in each treatment the number of plants per meter in accordance with the desired density.

Soil fertilization correction was performed according to indications Pitol et al. (2010). With nitrogen topdressing was performed at a dose of 60 kg ha^{-1} built next to the seeding line to 20 days after plant emergence, using as urea.

After completing the cycle of about 90 days, the crambe was manually harvested by cutting the shoots of the plants located in 0.5 m^2 area of each plot. Impurities were removed from the harvest thus leaving clean grains for later weighing and determination. The mass evaluated was 1,000 grains, and the oil content in the crambe seed was measured by the method of Silva et al. (2015). The data on productivity were converted to kg ha^{-1}, with correction for the 13% moisture.

Statistical analysis was performed followed by analysis of variance model, through Sisvar program using the 5% level of significance. The average of both factors was compared by Tukey test, with the same significance level (5%).

3. Results

The thousand-grain weight and oil content were not affected by treatments. It is inferred that the distribution of plants in the area not alters the density of the grains (Table 1).

Table 1. 1,000 grains mass (g), oil content (%) of crambe seeds under row spacing (cm) and plant population (1,000 plantas ha^{-1}). Umuarama, Paraná State, Brazil, 2012/13

Treatments	1,000 grains mass (g)		Oil content (%)	
	2012	2013	2012	2013
Row espacing (cm)				
15	8.39	7.89	30.35	31.01
30	7.92	7.94	30.65	32.72
45	8.46	8.16	31.52	31.50
Population (1000 pl ha^{-1})				
500	8.58	8.80	30.64	31.74
750	8.09	8.11	30.81	31.20
1000	8.09	8.10	31.07	31.09
F test				
Row espacing (R)	n.s.	n.s.	n.s.	n.s.
Population (P)	n.s.	n.s.	n.s.	n.s.
Interaction R*P	n.s.	n.s.	n.s.	n.s.
C.V. (%)	8.77	9.83	1.60	2.70

Note. Means followed by the same letter in the column and within each parameter and year, do not differ by Tukey test at 5 % level of probability. n.s. and * = not significative at 5% level of probability. C.V. = Coeficient of variant.

The interaction between the factors was significant as shown in Table 2, the average of the split between row spacing and plant population for grain yield variable.

Table 2. Deployment of meaningful engagement yield crambe grains (kg ha^{-1}) between row spacing (cm) and plant population (1,000 plantas ha^{-1}). Umuarama, Paraná State, Brazil, 2012/13

Population (1,000 pl ha^{-1})	Row spacing (cm)		
	15	30	45
2012			
500	1,963 A a	2,077 A a	953 B b
750	1,655 A a	1,325 A b	1,844 A a
1,000	1,752 A a	1,609 A ab	1,439 A ab
2013			
500	1,210 A a	1,324 A a	200 B b
750	902 A a	572 A b	1,091 A a
1,000	999 A a	856 A ab	686 A ab

Note. Means followed by the same letter, uppercase and lowercase on the line in the column, do not differ by Tukey test at 5% probability.

In the population of 500 thousand plants spaced 45 cm apart yield was the lowest. This increased spacing and lower density allows the plant to reach its maximum development potential, though the yield per area is small. Within the spacing 15 cm there was no difference in yield between the densities.

4. Discussion

Silva et al. (2013) observed that crambe oil content in seeds hardly has an influence on function of the environment. The rainfall conditions were atypical, with above average rainfall in the year of this experiment, potentially resulting in the lack of change in the thousand grain weight. Oil production values are close to the crop potential, according to Souza et al. (2009) and Rogério et al. (2012) that found that variation of 35 to 45% oil content.

Pitol et al. (2010) report that yield can be little affected by the spacing, as the plant species is able to compensate for low populations with significant branching. In canola, Kruger et al. (2014) working with genotypes (Hyola

432 and Hyola 61) and plant densities (20, 40, 60 and 80 plants m^{-2}), noted that in the cultivation of 0.40 m spacing the different densities employed provided no changes in grain yield in isolation. This supports the idea that in this species there is a strong phenotypic plasticity, allowing the offset of effects from low or high densities in crop condition.

Increased population density did not affect yield. Soratto et al. (2011) worked with row spacings and plant populations of castor bean, concluded in plant population, regardless of row spacing, the survival of plants decreased, stem diameter, number of racemes per plant and fruits per raceme.

Debiasi et al. (2007) also found that with the change in spacing oats was no change in yield. In the population density of 500 thousand plants the highest yield was achieved with 30 cm spacing between rows, and in the population density of 750 thousand plants there was increased yield at 45 cm spacing. Under these conditions there was a better distribution of plants in the area and therefore greater efficiency in the utilization of sunlight, water and nutrients (Ferrari et al., 2009).

Stacciarini et al. (2010), found that corn at low densities, a significant increase in yield with both the spacing reduction and the increase in population density. Albuquerque et al. (2011) reported an increase in sorghum yield due to the reduction of the spacing. Bezerra et al. (2009) and Bizinoto et al. (2010) report that alterations in plant yield is a function of adaptability to the environment.

Pitol et al. (2000) observed the effect of spacing and planting density on the crambe yield, cv. FMS Brilhante. The smallest gap while providing better closure of the crop and consequently greater ability to compete with weeds. In the second season, this spacing provided less grain yield due to increased shading and later plant lodging. In the present experiment there was good distribution of rainfall throughout the plant cycle, especially early in the development and flowering period, providing ideal conditions for its cultivation.

It can be concluded that both the 15 cm and the 45 cm spacing resulted in lower yields of crambe.

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