academicJournals

Vol. 11(38), pp. 3690-3695, 22 September, 016
DOI: 10.5897/AJAR2016.11469
Article Number: 2CFC80660625
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Assessment of a crambe (*Crambe abyssinica* Hochst) crop under no-tillage in different sowing dates

Reginaldo Ferreira Santos[1], Octavio Henrique Viana[1], Luciene Kazue Tokura[1]*, Deonir Secco[1], Cristiano Fernando Lewandoski[1], Paulo de Lima Bueno[1], Oswaldo Hideo Ando Junior[1], Maritane Prior[2] and Helton José Alves[3]

[1]UNIOESTE – State University of Western Paraná – Graduation Program, Master's in Engineering in Energy in Agriculture, Rua Universitária, 2069, CEP: 85.819-130 Bairro Faculdade, Cascavel, Paraná, Brazil.
[2]State University of Western Paraná - Graduation Program, Master's in Engineering Agriculture, Cascavel, Paraná, Brazil.
[3]UFPR-Federal University of Paraná - Graduation Program, Master's in Bioenergy, Palotina, Paraná, Brazil.

Received 22 July, 2016; Accepted 17 August, 2016

Crambe (*Crambe abyssinica* Hoschst) is a winter oilseed crop with yield potential of 1500 kg ha^{-1}. It is indicated for crop rotation systems and tolerates moderate frost. However, crambe presents thermal and water limitations that influence sowing dates since it needs water at blooming and at least 200 mm rainfall until it reaches the flowering stage. This study aimed to assess the performance of a crambe crop in different sowing dates. The experiment was conducted on the experimental farm of Assis Gurgacz College (Faculdade Assis Gurgacz – FAG) Cascavel – Paraná, at an altitude of 700 m, within latitudes 24°56'25.39" S and 24°56'45.39" S and longitudes 53°30'9.89" W and 53°31'17.01" W. The experimental design consisted of randomized blocks with three sowing dates (April, June and July) and five replications. Phenometric parameters such as plant height, dry mass, plants per meter, grain yield and mass of 1000 grains were assessed and data were subjected to Tukey's test at 5% probability. Phenometric variables were influenced by sowing dates. Degree days and rainfall influenced the results. April has proven to be the best month for sowing.

Key words: Winter oilseed crop, cycle, development, production, *Crambe abyssinica* Hoschst.

INTRODUCTION

Crambe (*Crambe abyssinica* Hochst) is an oilseed native to the Mediterranean area from Ethiopia to Tanzania that is tamed and adapted to dry and cold areas of that region. It is a winter species sown after the harvest of soybean from March to May, with total oil content of 26 - 38% (Pitol, 2008). Therefore, crambe has stood out as an alternative to be used in biodiesel processing and as a provider of feedstock for insulating fluids used in high voltage electric equipment (Laghetti, 1995; Lazzeri et al., 1997; Souza et al., 2009).

Crambe also presents low incidence of pests due to the presence of glucosinolate, and reduction of diseases in dry weather (Pitol et al., 2010). Its yield potential ranges from 1,000 to 1,500 kg ha^{-1} and it is sensitive to strong

*Corresponding author. E-mail: lucienetokura@gmail.com.

frosts during the seedling and flowering stages. Crambe has a short growing season as it blooms at 35 days after sowing (DAS) and can be harvested at 90 DAS, depending on the maturation of plants (Pitol, 2008; Carneiro et al., 2009; Falasca et al., 2010). It can also be used in crop rotation systems as an alternative for soil cover in no-tillage, with sowing densities that ranges from 12 to 15 kg ha^{-1} (Pitol, 2008).

Despite showing good adaptation and use of no-tillage, initially expansion was not successful in mass production for ground cover. However, since its inclusion in the country, it showed good yield potential of grain and oil, stimulating the creation of a single cultivar available in Brazil, Brilhante FMS. With the creation of PNPB, National Program for Biodiesel Production and Use, intensified its cultivation, mostly in the Midwest and South of the country (Pitol et al., 2010).

In order to determine the most adequate sowing date in each region, water restrictions and temperature must be taken into account (Pitol et al., 2010). Water conditions and solar radiation levels are important factors in the development of a plant, but even when such factors are ideal, plant growth may be affected by temperatures that differ from those tolerated by it (Went, 1953). Plant development can be influenced by the interaction between photoperiod and temperature, sowing date and latitude (Wallis et al., 1981).

As reported by Falasca et al. (2010), ideal temperature for crambe development during the vegetative phase ranges from 15 to 25°C and plants can tolerate up to -6°C for a few hours without suffering significant damage (Fowler, 1991). Its thermal needs were defined with approximately 1350°C degree days accumulated between sowing and physiological maturation, considering temperatures above 2.5°C for the sum (Kmec et al., 1998).

Crambe demands good soil humidity for germination and plant establishment, as well as rainfall between 150 and 200 mm until reaching the flowering stage. After this period, absence of rain prevents the occurrence of diseases (Graser, 1996; Pitol et al., 2010).

According to Pereira et al. (1992), the interaction between species and sowing dates has been an important tool for researchers to assess and improve the agronomic capability of tropical leguminous plants. Thus, acquiring information on the climatic requirements of plants allows the execution of a crop cycle planning in order to define the best sowing dates in locations where cultivation does not take place but meets climatic requirements (Pilau et al., 2011). Therefore, this work aimed to assess the development of a crambe crop under no-tillage on three sowing dates.

MATERIALS AND METHODS

The experiment was carried out in 2012 on the experimental farm of Assis Gurgacz College – (Faculdade Assis Gurgacz – FAG), located in the city of Cascavel – Paraná, at an altitude of 700 m, within latitudes 24°56’25.39” S and 24°56’45.39” S and longitudes 53°30'9.89" W and 53°31'17.01" W. Local climate is classified as subtropical Cfa, according to Köppen’s classification, with average annual rainfall over 1800 mm with no defined dry season and possibility of frosts during winter.

The experiment area was cultivated under no tillage for more than 20 years, with soybean or maize in summer crops and wheat or oat in fall/winter crops. Soil is classified as eutroferric Red Latosol – (LVef - Oxisol) with clayey texture (EMBRAPA, 2006). Soil was sampled from 0 to 0.02 m depth and taken to a soil analysis laboratory. Table 1 presents the results of the chemical features analysis. Accumulated rainfall, sum of degree days and sowing period cycles are presented in Table 2.

Figure 1 depicts levels of rainfall as well as minimum and maximum air temperature during crambe development under different sowing dates. Weeds in the area were desiccated with glyphosate herbicide in the rate of 2.5 L ha^{-1} before sowing. Sowing of crambe cultivar FMS Brilhante, developed by Fundação MS was performed on three different dates (23/04/2012, 14/06/2012 and 19/07/2012) in no-tillage system, with a tractor and a seeder/fertilizer set at a depth of 0.03 m, with inter-row spacing of 0.45 m, no base and cover fertilization, and seed density of 12 kg ha^{-1}.

The occurrence of pests and diseases was monitored during the entire crop cycle. On the eleventh day after sowing, 0.2 L.ha^{-1} of Lambda-cyhalothrin + Thiamethoxam insecticide, was applied with the aid of a 20 L knapsack sprayer to effectively control *Diabrotica speciosa* (Germar).

Others weed controls was made according to the needs and technical recommendation of culture. The experimental design consisted of randomized 4 x 5 m blocks. Seeds were sown on three different dates (April, June and July) and each treatment had five replications. The following phenometric features were assessed during crambe cycle:

Plant height

Assessment under all sowing dates was performed during flowering stage. Five plants were randomly collected from each plot and measured from ground level to their apex with a graduated ruler (Jasper, 2009).

Plant dry mass

Plants were dried up at 65°C for 72 h in oven with air recirculation and weighed in a precision balance. After determining dry mass in grams (g), data were converted into kg ha^{-1} (Freitas, 2010).

Plants per meter

The number of plants per meter was counted during harvest with the aid of a 5-m measuring tape. Measurement was randomly performed in each experimental unit.

Grain yield

Samples were collected from each unit by using a wooden frame measuring 1 m^2. All plants within the frame were collected. Grains were manually removed from plants and put in empty fertilizer bags. Later, grains were cleaned with the aid of sieves. Humidity was determined by drying grains in oven at 110°C for 24 h. The material was then weighed on an analytical balance for the obtainment of grain mass data (BRASIL, 1992).

Table 1. Chemical features of soil samples collected from 0 to 0.02 m depth in the experiment area.

Soil attributes	$cmol_c\ dm^{-3}$	Reading
Calcium (Ca^{+2})	5.39	High
Magnesium (Mg^{2+})	2.30	High
Potassium (K^+)	0.30	Medium
Aluminum (Al^{+3})	0.00	Low
H + Aluminum ($H^+ + Al^{3+}$)	5.76	High
Sum of bases (S)	7.99	High
CEC (T)	13.75	High
	$g\ dm^{-3}$	
Carbon (C)	27.12	High
Organic matter (OM)	46.65	High
	%	
Base saturation (V)	58.11	Medium
	$mg\ dm^{-3}$	
Phosphorus (P)	7.50	High
pH $CaCl_2$ (0.01 mol L^{-1})	5.20	

Source: EMBRAPA (2009).

Table 2. Sowing period cycles, sum of degree days and accumulated rainfall.

Cycle (days)	Degree days (°C)	Rainfall (mm)
125	1070.00	468.9
103	941.15	186.2
78	893.55	145.7

Mass of 1000 grains

After determining grain yield, 100 grains per sample were counted and weighed, and the results were multiplied by 10 (BRASIL, 1992). Weights were corrected to standard humidity of 13%. Data obtained were subjected to analysis of variance (ANOVA) and means comparison by Tukey's test at 5% significance in ASSISTAT software.

RESULTS AND DISCUSSION

Results of the analysis of variance and mean comparison by Tukey's test at 5% significance of plant height (H), dry mass (DM), number of plants per meter (P/M), mass of 1000 grains (MTG) and grain yield under different sowing dates are shown in Table 3.

All variables were significantly influenced by sowing dates. The coefficient of variation (CV) of all variables remained homogeneous according to classification proposed by Gomes and Garcia (2002). Plant height and number of plants per meter had homogeneous CV with low dispersion. Mass of 1000 grains and yield had coefficient of variation with medium dispersion. Dry mass presented CV with high dispersion, however, it presented the highest variability among data classified as heterogeneous CV.

Plant height

There was significant statistical difference at 1% probability. The highest increase was observed in the crop sown in July, with an average height of 111.92 cm. Similar data were observed by Barbisan et al. (2009), who studied the influence of different sowing dates on canola plant height. The results also match those obtained by Barni et al. (1995) and Capone et al. (2012), in an experiment on sunflowers.

Plant dry mass

This variable was influenced by the sowing date. The highest average dry mass yield of 14.47 t ha^{-1} was achieved when sowing was performed in April. Moreover, under the conditions in which this experiment was carried out, early sowing resulted in higher dry mass yield.

Barbosa et al. (2011) achieved higher dry mass yield when performing sowing with cover plants in two different dates (March and April). Dry mass is important because it is used as straw in no tillage, protecting the soil from the impact of raindrops that cause erosion (Rangel et al., 2003).

Plants per meter

Sowing in April and June resulted in 35.6 and 35.2 plants per meter respectively. These results differ statistically from the sowing performed in July (30.8 plants per meter). The difference in July can be because of rainfall inferior to 5 mm until the seventh day after sowing, which may have contributed to a decrease in the final plant density.

Grain yield

This variable was influenced by the sowing date. Highest average grain yield was achieved with sowing in April (1892.18 kg ha^{-1}). The lowest yield occurred with sowing in July (530.73 kg ha^{-1}). This difference represents a reduction of 71.95%.

The same happened in experiments conducted by Pitol et al. (2010) in different locations in the state of Mato Grosso do Sul, in which sowing performed in April resulted in higher yield than that performed in May. There was also a decrease in yield with late sowing in studies carried out in the states of Goiás and Mato Grosso (Pitol et al., 2010).

When choosing sowing dates, environmental factors such as temperature, soil humidity and photoperiod, which interact with plants and cause variations in their characteristics, such as productivity were taken into

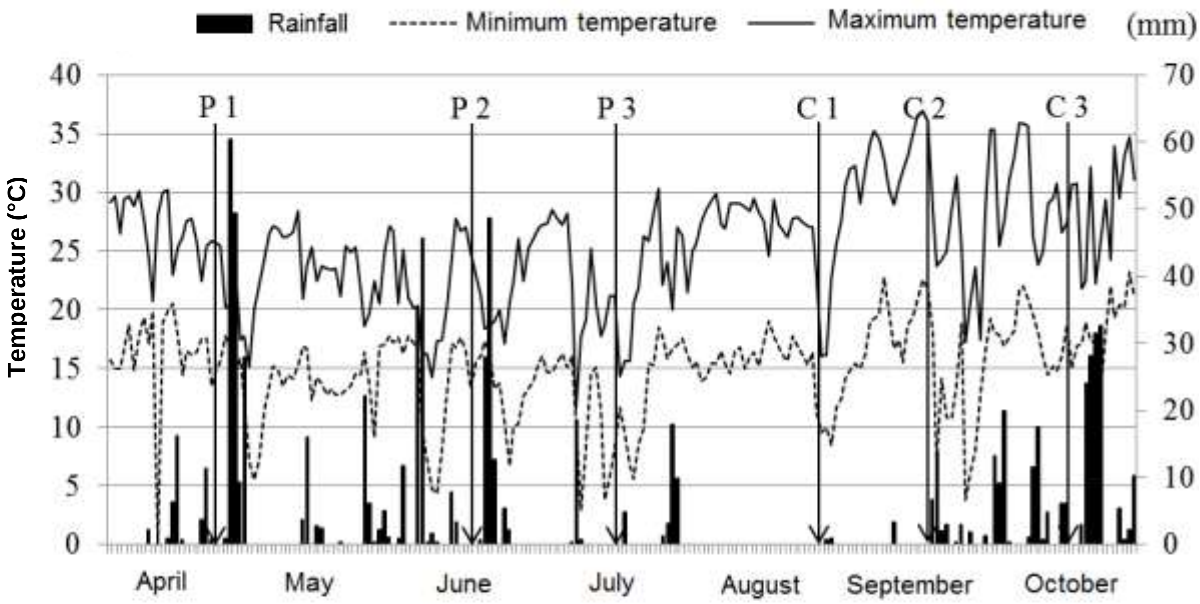

Figure 1. Minimum and maximum air temperature and rainfall during crambe development under three different sowing dates in Cascavel, PR, 2012. P1: Sowing in April; P2: Sowing in June; P3: Sowing in July; C1: Harvest in August; C2: Harvest in September; C3: Harvest in October.

Table 3. Analysis of variance of the crambe crop regarding plant height (H), dry mass (DM), number of plants per meter (P/M), mass of 1000 grains (MTG) and crambe yield under different sowing dates.

Sowing dates	Variables				
	H (cm)	DM (t ha^{-1})	P/M	MTG (g)	Yield (kg ha^{-1})
April	97.94^{b}	14.47^{a}	35.6^{a}	7.82^{a}	1892.18^{a}
June	111.92^{a}	6.61^{b}	35.2^{a}	7.64^{ab}	1350.72^{b}
July	65.04^{c}	4.09^{b}	30.8^{b}	6.33^{b}	530.73^{c}
F	278.01**	30.00**	6.00*	6.05*	42.99**
CV (%)	3.52	26.35	7.90	10.22	18.97
MSD	5.83	3.99	4.88	1.34	436.83

**Significant at 1% probability ($p < 0.01$); *significant at 5% probability ($0.01 =< p < 0.05$). ns: non-significant ($p >= 0.05$). CV: Coefficient of variation. MSD: minimum significant difference.

account (Peixoto et al., 2000).

Mass of 1000 grains

The sowing date influenced this variable. Sowing performed in April resulted in the highest average among treatments (7.82 g). As stated by Guarienti et al. (2004), temperature favors a higher number of days with green plants, helps in photosynthesis and grain filling and subsequently increases their weight. Thermal sum presented higher value of degree days when sowing was performed in April, with 1070°C. Table 2 shows the relationship between sowing dates and degree days. Toebe et al. (2010) considered the minimum temperature of 2.5°C and obtained results from 1165.3 to 1175.8°C between crambe emergence and senescence. In an experiment on crambe carried out in Rio Grande do Sul, the authors obtained an average of 690.64°C between plant emergence and maturation, based on the minimum basal temperature of 9.5°C (Pilau et al., 2011).

Gilmore Jr and Rogers (1958) reported that the thermal sum is obtained by the sum of temperature during plant cycle, considering minimum basal temperature. Such parameter is relevant once basal temperature controls plant growth and development. It is important to highlight the influence of the degree days level on crambe productivity and development, mainly when sown in July, which present the lowest sum of temperature and lower values as compared to other sowings regarding all variables analyzed.

Throughout the study, there was large rainfall variability. With sowing in April, there were 468.9 mm of rainfall during crambe development; in other months, rainfall was much lower. In June, rainfall was 186.2 and 145.7 mm in July (Figure 1). As rainfall in April was the most elevated, there was a considerable incidence of diseases during that period. During the month of June, there was a total rainfall of 186.2 mm concentrated between sowing and flowering. According to Pitol et al. (2010), crambe demands 150 to 200 mm of water until its complete flowering.

During the third month of sowing, July, total rainfall was inferior to the minimum demanded by crambe. The concentration of rains occurred only during flowering and graining. Pitol et al. (2010) also state that after sowing, crambe needs at least 50 mm of water in order to develop and in this study, the rainfall that occurred during germination was lower than 10 mm, it might have contributed to the low results of the variables analyzed.

CONAB (2012) reports that Brazilian regions that obtained the best yields of vegetal species were the ones in which climatic conditions were favorable, however, regions that presented low rainfall levels had inferior yield in comparison with previous harvests. Another relevant factor presented in Table 2 shows the cycle difference with different sowing dates. The cycle started in April had 125 days, whereas the ones started in June and July had 103 and 78 days, respectively. Such variation must be highlighted to affect the planning of agricultural harvests.

In the area of Maracaju-MS, where temperatures are elevated, the plant presents a cycle of 90 days, according to Pitol et al. (2010). Pilau et al. (2011) in a study conducted in 2009 and 2010 observed different cycles ranging from 77 to 136 days. According to the authors, air temperature was responsible for the variation in the development cycle. Thus, cycles under higher average temperature showed decreased plant development time, whereas inferior average temperature values extended the cycle.

Sowing performed in April had the lowest average temperature (18.8°C) during the 125 days of development cycle. Sowing in July presented the highest average temperature (22.0°C) during the 78 days between crambe planting and harvest. These data match those obtained by Pilau et al. (2011).

In general, the assessed variables in the three sowing dates were affected by rainfall and degree days. In the first period, rainfall contributed to the high incidence of diseases. As for the sowing performed in July, the low sum of degree days and rainfall affected the results negatively. Elevated average temperatures contributed to earlier cycles.

Conclusion

Different sowing dates affected the phenometric variables assessed. Rainfall and sum of degree days were the factors that most influenced the results of different sowing dates. April is proven to be the best period for sowing.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank Copel Distribuição S/A, which by means of Program P&D PROJECT PD-2866-0258/2011 – “Assessment of crambe oil as insulating fluid in converters and agro-industrial crop development”, provided resources for the progress of this research; Assis Gurgacz College – FAG for providing the location and supporting the development of this research; State University of West Paraná - UNIOESTE and the Post-graduation Program of Energy in Agriculture for their facilities, opportunity and support given.

REFERENCES

Barbisan F, Dapper F, Graminho D, Lajus CR (2009). Efeito de diferentes épocas de semeadura sobre a ontogenia e a produtividade de canola (Brassica napus l. var. oleifera) em rondinha, RS. UNOCHAPECÓ. Disponível em: https://www.unochapeco.edu.br/static/files/trabalhos-anais/Pesquisa/Ci%C3%AAncias%20Ambientais/Fausto%20Barbisan.pdf Acesso em 15 mai 2011.

Barbosa CEM, Lazarini E, Picoli PRF, Ferrari S (2011). Determinação da massa seca teor de nutrientes e cobertura do solo de espécies semeadas no outono-inverno. Rev. Bras. Ciênc. Agrár. 6:265-272.

Barni NA, Berlato MA, Santos AO, Sartori G (1995). Análise de crescimento do girassol em resposta a cultivares, níveis de adubação e épocas de semeadura. Pesqui. Agropecu. Gaúcha 1:167-184.

BRASIL (1992). Regras para análise de sementes. Ministério da Agricultura. Brasília: Departamento Nacional de Produção Vegetal 365p.

Capone A, Barros HB, Santos ERdos, Ferraz EdeC, Santos AF dos, Fidelis RR (2012). Influência de diferentes épocas de semeadura no desempenho agronômico de cultivares de girassol no Cerrado Tocantinense. Biosci. J. 28:136-144.

Carneiro SMTPG, Romano E, Marianowski T, Oliveira JP, Garbim THS, Araujo PM (2009). Ocorrência de Alternaria brassicicola em crambe (*Crambe abyssinica*) no estado do Paraná. Summa Phytopathol. 35:154-154.

COMPANHIA NACIONAL DE ABASTECIMENTO (CONAB) (2012). Acompanhamento de safra brasileira: grãos, décimo segundo levantamento. Companha Nacional de Abastecimento. Brasília: CONAB.

EMBRAPA (EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA) (2006). Sistema brasileiro de classificação de solos, Centro Nacional de Pesquisa de Solos, 2 ed. Rio de Janeiro.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (2009). Manual de análises químicas de solos, plantas e fertilizantes, EMBRAPA Informação Tecnológica, 2 ed. Brasília.

Falasca SL, Lamas MC, Carballo SM, Anschau A (2010). *Crambe* *abyssinica*: An almost unknown crop with a promissory future to produce biodiesel in Argentina. Int. J. Hydrogen Energy 35:5808-5812.

Fowler JL (1991). Interaction of salinity and temperature on the germination of crambe. Agron. J. 83:169-172.

Freitas MEE (2010). Comportamento agronômico da cultura do crambe (*Crambe abyssinica* Hoechst) em função do manejo empregado. (Dissertação de Mestrado). Programa de Pós-Graduação em Agronomia – Produção Vegetal. Universidade Federal da Grande Dourados: UFGD. Dourados, 42p.

Gilmore Jr EC, Rogers JS (1958). Heat units as a method of measuring maturity in corn. Agron. J. 50:611-615.

Glaser LK (1996). Crambe: An economic assessment of feasibility of providing multipleperil crop insurance. Economic Research Service of the Risk Management. Estados Unidos: Agency. Federal Crop Insurance Corporation. Disponivel em: < http://www.rma.usda.gov/pilots/feasible/pdf/crambe.pdf> Acesso em: 09 nov. 2011.

Gomes FP, Garcia CH (2002). Estatística aplicada a experimentos agronômicos e florestais - Exposição com exemplos e orientações para uso de aplicativos. Biblioteca de ciências agrárias Luiz de Queiroz. v.1. Piracicaba: FEALQ 309 p.

Guarienti EM, Ciacco CF, Cunha GR (2004). Influência das temperaturas mínima e máxima em características de qualidade industrial e em rendimento de grãos de trigo. Ciência Tecnologia Alimentos 24:505-515.

Jasper SP (2009). Cultura do Crambe (*Crambe abyssinica* Hochst): Avaliação energética, de custo de produção e produtividade em sistema de plantio direto. 103p. Tese (Doutorado). Faculdade de Ciências Agronômicas do Campus de Botucatu: UNESP. Botucatu.

Kmec P, Weiss MJ, Milbrath LR, Schatz BG, Hanzel J, Hanson BK, Eriksmoen ED (1998). Growth analysis of crambe. Crop Sci. 38:108-112.

Laghetti G, Piergiovanni AR, Perrino P (1995). Yield and oil quality in selected lines of *Crambe abyssinica* Hochst. X R.E. Fries and *C. hispanica* L. grown in Italy. Industrial crops and products, 4, 203-212.

Lazzeri L, De Mattei F, Bucelli F, Palmieri S (1997). Crambe oil – a potencial new hidraulic oil and quenchant. Ind. Lubrication Tribol. 49:71-77.

Peixoto CP, Camara GMS, Martins MC, Marchiori S, Guerzoni RA, Mattiazi P (2000). Épocas de semeadura e densidade de plantas de soja: I. Componentes da produção e rendimento de grãos. Sci. Agric. 57:89-96.

Pereira J, Burle ML, Resck DVS (1992). Adubos verdes e sua utilização no Cerrado. In: SIMPÓSIO SOBRE MANEJO E CONSERVAÇÃO DO SOLO NO CERRADO, 1990, Goiânia. Anais. Campinas: Fundação Cargill. pp. 140-154.

Pilau FG, Battisti R, Somavilla L, Schwerz L (2011). Temperatura basal, duração do ciclo e constante térmica para a cultura do crambe. Bragantia 70:958-964.

Pitol C (2008). Cultura do Crambe. Tecnologia e Produção: Milho Safrinha e Culturas de Inverno. Maracaju: Fundação MS. Disponível em: <http://www. fundacaoms.org.br/request.php?51> Acesso em: 06 de fev. 2011.

Pitol C, Broch DL, Roscoe R (2010). Tecnologia e produção: crambe. Maracaju: Fundação MS. 60 p.

Rangel LEP, Lamas FM, Staut LA, Menezes VL (2003). Avaliação da produção de matéria seca de coberturas vegetais para o plantio Direto do algodoeiro no cerrado do Mato Grosso. Embrapa Algodão. Campina Grande. Disponível em: <http://www.cnpa.embrapa.br/produtos/algodao/publicacoes/.../306.pdf>. Acesso em: 15 nov 2012.

Souza ADV, Fávaro SP, Ítavo LC, Roscoe R (2009). Caracterização química de sementes e tortas de pinhão-manso, nabo-forrageiro e crambe. Pesqui. Agropecu. Bras. 44:1328-1335.

Toebe M, Lopes SJ, Storck L, Silveira TR, Milani M, Casarotto G (2010). Estimativa de plastocrono em crambe. Ciênc. Rural 40:793-799.

Wallis ES, Saxena KB, Byth DE (1981). Flowering responses of thirty-seven early maturing lines of pigeonpea. In: INTERNATIONAL WORKSHOP ON PIGEONPEAS, Patancheru. Proceedings… Patancheru : ICRISAT. 2:143-150.

Went FW (1953). The Effect of temperature on plant growth. Ann. Rev. Plant Physiol. 4:347-362.