academicJournals

Vol. 13(12), pp. 1369-1373, 19 March, 2014
DOI: 10.5897/AJB2013.13593
ISSN 1684-5315

http://www.academicjournals.org/AJB

African Journal of Biotechnology

Full Length Research Paper

Fertigation of stillage in the culture of brown and golden linseed (*Linum usitatissimum*)

Paulo André Cremonez[1]*, Armin Feiden[1], Reginaldo Ferreira Santos[1], Joel Gustavo Teleken[2], Doglas Bassegio[1], Filipe Eliazar Cremonez[2], Henrique Bernardo Muriana[2] and Willian Cézar Nadaleti[1]

[1]University of West Paraná, Paraná, Brazil. Master in Agricultural Energy, Department of Agricultural Energy. Rua Universitária, 2069, CEP: 85.819-130, Bairro Faculdade, Cascavel – PR, Brazil.
[2]Federal Universityof Paraná (UFPR-Campus Palotina), R. Pioneiro, 2153, CEP: 85.950-000, Bairro Jardim Dallas, Palotina - PR, Brazil.

Received 23 December, 2013; Accepted 7 March, 2014

In Brazil, the stillage is mainly used in fertigation of sugarcane plantations, however, little is known about its effect on the nutritional supplementation and irrigation cultivation of linseed. Because of the shortage of work in the area, the present study aimed to evaluate the development of the culture of brown and golden linseed submitted to fertigation of stillage. The experiment was conducted in the field, at the Federal University of Paraná in Palotina/PR in the agricultural year of 2013, on a eutrophic Red Latosol. The adopted lineation was completely randomized in split plots, where the plots were composed by the two varieties (brown and gold), and the sub-plots by the ratios (100% stillage; 50% stillage and 50% water; 100% control water). Fertigation of stillage in the culture of brown and golden linseed presents positive results on plant height, dry and fresh weight, capsules number and productivity; except for the number of branches (100% is higher). It was observed that between the two varieties, the golden linseed showed better development with the applied treatment.

Key words: Fertigation, energy crops, agro industrial residues.

INTRODUCTION

Linseed (*Linum usitatissimum*) is the flax seed, commonly used in culinary and ingested with its husk. The earliest reports of the use of this oilseed are dated of the time of Mesopotamia. Its origin is Asian, though its consumption is worldwide, with common use mainly in Europe and North America (Bombo, 2006). Linseed is one of the most important cultivated plants worldwide in terms of vegetation cover and oil content. Its pie, byproduct of the oil extraction process, is very nutritious and can be used in animal feed. Furthermore, the linseed has high presence of lignans, especially secoisolariciresinol diglucoside (SDG), which are related to reduced risk of

*Corresponding author. E-mail: pa.cremonez@gmail.com.

cardiovascular diseases and are capable of inhibiting the development of diabetes, and are also important in the development of the central nervous system and important in the treatment of certain cancers (FAO, 2008; Oomah and Mazza, 1993; Westcott and Muir, 2003; Harbige et al., 2008).

The oilseed, among infinitude of functional foods, stands out for presenting one of the most interesting sources of essential fatty acids ω-3 and ω-6, besides several phenolic compounds, nutrients and fiber that act as antioxidants in the body (Mayes, 1994; Hall et al., 2006). There are two main varieties of linseed, the brown and the golden linseeds. Their seeds do not differ in their chemical composition in large proportions, since both have high levels of lignans and dietary fiber featuring more than 50% of phenolic in their composition. The golden linseed is better adapted to cold climates, having higher levels of protein in their composition when compared to brown linseed (Lima, 2008; Marques, 2008). In Brazil, the cultivation of linseed remains mainly in Rio Grande do Sul, being maintained by descendants of Polish and German immigrants. Linseed requires climates with relatively low temperatures for flowering, around 0 to -2°C. The plant does not require intensive cultivation and can be grown in crop rotation system on degraded lands in order to retrieve the soil depletion to erosion. Its planting usually occurs in the months of May and June (Soares et al., 2009; Vieira et al., 2012). The current national agriculture needs to adapt itself to new circumstances and complexities in an environment of extreme competitiveness, so that producers need to improve their techniques with better possible utilization of productive resources. Irrigation techniques are directly linked to agricultural production (Oliveira et al., 2012).

Fertigation is considered as fertilization technique using the water itself in order to bring nutrients to the soil. It can occur through the use of diluted commercial fertilizers or through the use of organic waste, and in large part; the technique is used in order to fertilize the soil efficiently and inexpensively, reducing the problem of proper treatment and disposal of nutrients (Dalri and Cruz, 2002). The stillage is a byproduct of the ethanol industry with dark brown color and high organic matter content (50 to 150 g L^{-1}), usually presenting relatively low pH values (3.5 to 5) (España-Gamboa et al., 2011; Waliszewski et al., 1997). Its generation shows the mean proportion of 13 L for each liter of ethanol produced (Carvalho and Silva, 2010).

According to data from the National Supply Company (Conab), in 2012, sugarcane production reached 490 million tons, and its expected growth of 7.2% for the coming years. Due to high production of waste in the production process of ethanol, several alternative designations of this material that are not harmful to the environment are studied. The first studies on fertigation of stillage in Brazil started in the 50s, becoming common in cane refineries. The process of fertigation with stillage is the infiltration of residue in the soil by irrigation channels, normally destined to sugarcane (Camargo et al., 2009). Its application decreases costs with chemical fertilizers and it is an alternative to the use of natural resources, avoiding the downloading of this material in rivers, while it is used on agricultural land (Laime et al., 2011; Gianchini and Ferraz, 2009). Diverging of studies that point the direct application of stillage related to salinization, leaching of metals presents in the soil to groundwater and changes in soil quality, studies developed by Penatti et al. (1999) show that volumes up to 300 m³/ha of stillage with the presence up to 4 kg of potassium per m³, do not alter the physicochemical and biological soil properties, regardless of their composition. When deposited on the soil, the stillage also ensures fertility due to the increased availability of some ions, increased cationic exchange capacity, increased water retention capacity and improvements in the physical structure of the soil. Due to its rich composition in nutrients, especially potassium, most Brazilian distilleries use this residue in fertigation of sugar cane plantations (Silva et al., 2007). From this information and due to the lack of studies focused on the study of fertigation of linseed, the present study aimed to evaluate the development of the culture of brown and golden linseed with stillage application in different proportions from the analysis of various parameters of plants.

MATERIALS AND METHODS

The experiment was conducted in the field during the period from May to September in the agricultural year of 2013, in the area of the Federal University of Paraná in Palotina/PR, located in the following coordinates: latitude 24°18' S, longitude 53º55' W and elevation of 310 m. The city has a eutrophic Red Latosol soil, with subtropical climate (Cfa), according to the Köppen classification, with no definite dry season. Its average annual temperatures vary between 17 and 19°C with hot summers and average rainfall well distributed throughout the year between 1,200 and 2,000 mm per year (IAPAR, 2006). The characterization of the soil where the experiment was carried out can be found in Table 1. The adopted lineation was completely randomized in split plots, where the plots were composed by the two varieties (brown and gold), and the sub-plots by the ratios (100% stillage; 50% stillage and 50% water; 100% control water). The plot was consisted by 9 rows of 5 m of length. The applications were performed every 4 days in volume of 8 L/m^2. The stillage used in the fertigation was from pilot plant of ethanol production, and must be fermented had only yeast *Saccharomyces cerevisiae* added, without addition of any additive of optimization process. The characterization of the stillage in nutrients can be found in Table 2.

According to Soares et al. (2009), the culture of linseed occurs in the fall, in the months of May and June and its harvesting in November, December and January. From these information, the linseed was planted at the beginning of May and harvested at the beginning of November, and the plants were harvested in the morning and after weighing the fresh weight of aerial portion and fresh weight of the root, the biomass was placed in a greenhouse with forced air circulation, with the temperature of 65°C ± 2 for determination of dry weight of aerial portion and dry weight of the

Table 1. Soil composition where the experiment was conducted.

Ca	Mg	K	Al (Cmolc/dm³)	H+Al (Cmolc/dm³)	Sum of bases	CCE	C	Microorganism (g/dm³)
5.67	1.84	0.72	0.00	4.28	8.23	12.51	20.74	35.67
Base Saturation (%)			**P**	**Fe**	**Mn**	**Cu**	**Zn**	**pH $CaCl_2$**
					mg/dm³			
65.8			12.96	18.48	146.38	8.86	5.01	5.10

CCE: Capacity of cations exchange.

Table 2. Characterization of the sugar kane stillage used in the linseed fertigation.

Nutrient	N	P	K	Ca	Mg	pH
	g/L					
	14.35	0.02	0.85	-	-	5.76

root. After this procedure, the samples were reweighed in a balance of semi-analytical accuracy. The greenhouse with forced air circulation step was repeated until constant weight was reached. Plant height, number of branches, number of capsules and productivity kg ha^{-1} were recorded. Statistical analysis (ANOVA) was performed using the statistical software ASSISTAT 7.6 beta and the comparison between treatment means was performed by applying the Tukey test at 1 and 5% probability and regression analysis at 1 and 5% probability.

RESULTS AND DISCUSSION

According to Table 3, the effect of varying the concentration of stillage in the analyzed variables can be verified. Fertigation with stillage influenced the components of linseed crop production. It could also be shown in Table 3 that the interaction between varieties and stillage concentration does not significantly interfere in fresh weight of the plant, and in the number of branches and capsules. From the unfolding of variables that showed interaction between the factors (Table 4), it can be observed that a significant difference between the grain productions of the two varieties of linseed with a higher productivity for the golden linseed where stillage was applied in proportions of 100%. Nevertheless, it is important to note that the brown linseed production increased by around 43% from the treatment without stillage to the treatment with 50% in waste composition, it could be a noted superior production of the golden linseed in these concentrations. From the unfolding of variables that showed interaction between factors (Table 4), it can be observed that plant height was positively influenced by the application of stillage. The concentrations (50 and 100%) did not differ between each other, regardless of variety. It can be observed that the fertigation with stillage positively influenced the dry matter production. The highest concentrations of stillage (50 and 100%) did not provide dry matter accumulation by the plant, regardless of the variety, the same was observed by irrigation only with water. The number of branches per plant (Table 4) followed the same pattern observed for plant dry matter, where the highest concentrations and only irrigation did not differ between cultivars. Productivity of the golden linseed (648.42 kg ha^{-1}) was superior to the brown cultivar (407.10 kg ha-^{1}) for the 100% fertigation concentration. When the linseed was subjected only to irrigation (0% stillage concentration), and it can be verified by superior results for the golden variety. De Paula et al. (1992) evaluated the production of onion crop with treatments with stillage, it was noted that the use of fertigation residue assured significant increase in vegetable production per unit area. The application of stillage from 200 to 400 m³/ha provides superior production of the pineapple culture, and the stillage replaces KCl as K source (De Paula et al., 1999). In works that evaluated the initial development of oilseed plants like groundnut, sunflower and castor bean, it was found that for the first two crops, the application of stillage was detrimental to emergence and seedling development, whereas for castor bean, the interference of stillage was positive in the variables that are related to seedling vigor (Ramos et al., 2008). Works of fertigation with stillage are commonly found for the sugar cane culture. In a study evaluating the production of sugar cane with fertigation of stillage, it was concluded that, concentrations at doses of 300 and 450 m³ ha^{-1}, the production of culms was increased, furthermore, doses of 300 m³ ha^{-1} provided better rooting in layer of 0.25 and 0.50 m deep (Medina et al., 2002). A work performed by Barbosa et al. (2012) using fertigation of stillage for sugar cane culture complementing the need for potassium; irrigation by surface drip also favored the production of culms. The same results are obtained in a study by Oliveira et al. (2009).

Barbosa et al. (2012) further states with experimentation that the use of fertigation of stillage on the sugar cane culture promotes alterations in the number of tillers and leaf area index, compared to non-irrigated cultivation, regardless of fertigation management. In the culture of cane, the stillage promotes reduction of sugar concentration; however it provides vigorous vegetative growth and

Table 3. Effect of the variation of stillage concentration on analyzed variables of golden and brown linseed.

Factor varieties	Height (cm)	Fresh weight (g)	Dry weight (cm)	Branch number	Capsule number	Productivity (Kg/ha)
Golden (A)	73.50[b]	14.45[a]	4.07[a]	3.96[a]	27.71[b]	383.64[b]
Brown (B)	79.42[a]	15.03[a]	3.91[a]	3.58[a]	36.25[a]	503.05[a]
Stillage (%)						
0	62.69[b]	7.92[b]	2.62[b]	3.19[b]	17.06[c]	363.88[c]
50	83.75[a]	17.01[a]	4.53[a]	3.94[ab]	31.19[b]	438.39[b]
100	82.94[a]	19.28[a]	4.77[a]	4.19[a]	47.688[a]	527.76[a]
CV %-A	8.47	25.40	21.95	21.02	26.11	7.98
CV %-B	8.70	31.62	23.78	26.91	33.61	5.95
Varieties	10.0162**	0.2857ns	0.2404ns	2.6872 ns	12.5571**	51.3021**
Vinasse	51.4310**	26.6035**	24.7753**	4.2081*	32.5462**	58.0631**
Int. AxB	4.3320*	1.1587ns	0.0129*	3.1561ns	3.3211ns	58.8071**

Averages in each column followed by the same letter do not differ significantly between each other by the Tukey test, at 5% probability. VC (%) = Variation coefficient. (**) = Significant at 1% probability. (*) = significant at 5% probability. (ns) = not significant.

Table 4. Unfolding of interaction for height, dry weight and productivity.

Linseed	0	50% Stillage	100% Stillage
Height (cm)			
Brown	55.75bB	83.13aA	81.63aA
Golden	69.63aB	84.38aA	84.25aA
Dry weight (g)			
Brown	2.67aB	4.62aA	4.81aA
Golden	2.57aB	4.44aA	4.73aA
Productivity (Kg/ha)			
Brown	271.14bC	472.67aA	407.10bB
Golden	456.61aB	404.12bB	648.42aA

Using small letters for columns and big letters for rows, averages followed by the same letter do not differ significantly between each other by the Tukey test, at 5% probability.

dry mass gain (Korndorfer, 1990). The stillage presents in its composition high concentrations of potassium. In a work by Rossetto et al. (2012), analyzing the influence of applying different levels of potassium in cultures of golden and brown linseed, it was proven that linseed shows significant response to treatments with macro-nutrient, and that the golden linseed obtained better performance. Corroborating with the data obtained in the study with the treatments of stillage, Turner (1987) states that potassium is an element that elevates the fiber content of linseed. Potassium is present in plants in concentrations near the nitrogen, and for a good development of the plant, potassium contents are between 2 and 5% of the dry weight, depending on each species. Potassium fertilization as well as phosphorus directly helps to increase the production of roots, flowers and leaves, besides affecting the production of active principles (Meurer, 1995; Bevilaqua et al., 2007). Lewis et al. (1991) also states that with certain levels of potassium, leaf area of different oilseed cultures is increased, as well as stem thickness, number of grains per spike and oil content. According to Khajani et al. (2012), combined applications of nitrogen, phosphorus and potassium bring positive impacts on production components of grain and on the linseed oil. Some cultivars of linseed, when treated with potassium fertilization, show resistance to diseases like fusarium.

Conclusion

With the present study, it can be concluded that fertigation of stillage in the culture of brown and golden linseed have significant positive results in all analyzed variables. It is important to point that between the two varieties, the golden linseed performed better in grain production than the brown linseed variety.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

Barbosa EAA, Arruda FB, Pires RCM, Da Silva TJA, Sakai E (2012). Cana-de-açúcar fertirrigada com vinhaça e adubos minerais via irrigação por gotejamento subsuperficial: Ciclo da cana-planta. Rev. Bras. Eng. Agríc. Ambient. 16(9):952-958.

Bevilaqua GAP, Schiedeck G, Schwengber JE (2007). Identificação e tecnologia de plantas medicinais da flora de clima temperado. Pelotas: Embrapa Clima Temperado. Color. (Embrapa Clima Temperado. Circular técnica, 61). p.32.

Bombo AJ (2006). Obtenção e caracterização nutricional de snacks de milho (Zeamays L.) e linhaça (Linum usitatissimun L.). Dissertação Mestrado, Faculdade de Saúde Pública, USP. São Paulo-SP. p. 97.

Camargo JA, Pereira N, Cabello PR, Teran FJC (2009). Viabilidade da aplicação do método respirométrico de Bartha para a análise da atividade microbiana de solos sob a aplicação de vinhaça. Eng. Ambient. 6:264–271.

Carvalho TC, Silva CL (2010). Redução da Quantidade de Vinhaça Através da Evaporação. Periódico Eletrônico Fórum Ambiental da Alta Paulista, 6:1-17.

CONAB – Companhia Nacional de Abastecimento (2012). Portal Brasil: Economia e Emprego. Disponível em: Acesso em: out/2013. <http://www.brasil.gov.br/economia-e-emprego>

Dalri AB, Cruz RL (2002). Efeito da freqüência de irrigação subsuperficial por gotejamento no desenvolvimento da cana-de-açúcar (Saccharum spp.). Irriga, Botucatu 7(1):29-34.

De Paula MB, Carvalho VD, Nogueira FD (1992). Efeitos da vinhaça na produção e qualidade da cebola em solos de baixo potencial de produtividade. Pesq. agrop. Bras. 27(3):389-393.

De Paula MB, Holanda FSR, Mesquita HA, Carvalho VD (1999). Uso da vinhaça no abacaxizeiro em solo de baixo potencial de produção. Pesq. agropec. bras. 34(7):1217-1222.

España-Gamboa E, Mijangos-Cortes J, Barahona-Perez L, Dominguez-Maldonado J, Hernández-Zarate G, Alzate-Gaviria L (2011). Vinasse: characterization and treatments. Waste Manage 29(12):1235-1250.

FAO (Food and Agriculture Organization of the United Nations): FAOSTAT, Domain ProdSTAT (2008). Disponível em: Acesso em: out/2013. <http://faostat.fao.org/site/636/default.aspx#ancor>

Gianchini CF, Ferraz MV (2009). Benefícios da utilização de vinhaça em terras de plantio de cana-de-açúcar. Revisão de Literatura. Rev. cient. electron. agron. 3:1-15.

Hall III C, Tulbek MC, Xu Y (2006). Flaxseed. In: Taylor, S. (Ed.), Advances in Food and Nutrition Research. Academic Press, San Diego, CA, USA, (Chapter 1) 51:1–97.

Harbige LS, Pinto E, Xiang M, Leach M, Sharief MK (2008).PUFA in the pathogenesis and treatment of patients with multiple sclerosis. Proc. Nutr. Soc. 67:21.

IAPAR – Instituto Agronômico do Paraná. Cartas Climáticas do Paraná (2006). Disponível em: Acesso em: ago/2013. http://www.iapar.br/modules/conteudo/conteudo.php?conteudo=856

Khajani FP, Irannezhad H, Majidian M, Oraki H (2012). Influence of different levels of nitrogen, phosphor us and potassium on yield and yield components of flax seed oil (*Linum usitatissimum* L.) variety Lirina. J. Med. Plan. Res. 6(6):1050-1054.

Korndorfer GH (1990). O potássio e a qualidade da cana-de-açúcar. Informações Agronômicas 49:1-3.

Laime EMO, Fernandes PD, Oliveira DCS, Freire EA (2011). Possibilidades tecnológicas para a destinação da vinhaça: uma revisão. R. Trop. Ci. Agr. Biol. 5(3):16–29.

Lewis DC, Potter TD, Weckert SE (1991).The effect of nitrogen, phosphorus and potassium fertilizer applications on the seed yield of sunflower (*Helianthus annuus* L.) grown on sandy soils and the prediction of phosphorus and potassium responses by soil tests. Nutr. Cycl. Agroecosys. 28(2):185-190.

Lima TL (2008). Avaliação dos efeitos da ingestão de semente de linhaça (Linum usitatissimum) em ratos wistar fêmeas. Tese (Monografia), Faculdade Assis Gurgacz, Cascavel. P. 14.

Marques AC (2008). Propriedades funcionais da linhaça (Linum usitatissimum L.) em diferentes condições de preparo e de uso em alimentos. Dissertação (Mestrado em Ciência e Tecnologia de Alimentos), Universidade Federal de Santa Maria, Rio Grande do Sul. p.115.

Mayes PA (1994). Lipídios de Importância Fisiológica. In: Harper: Bioquímica. São Paulo: Atheneu 7:142-154.

Medina CC, Neves CSVJ, Fonseca ICB, Torreti AF (2002). Crescimento radicular e produtividade de cana-de-açúcar em função de doses de vinhaça em fertirrigação. Semina: Ciências Agrárias 23(2):179-184.

Meurer EJ (1995). In: Gianello C, Biassini CA, Tedesco MJ. Princípio de Fertilidade de Solo. Porto Alegre, Editado pelos autores pp.121-134.

Oliveira EL, Andrade LAB, De Faria MA, Evangelista AWP, Morais AR (2009). Uso de vinhaça de alambique e nitrogênio em cana‑de‑açúcar irrigada e não irrigada. Pesq. agropec. bras. 44(11):1398-1403.

Oliveira MR de, Santo RF, Rosa HA, Werner O, Vieira MD, Delai JM (2012). Fertirrigação da cultura de linhaça *Linum usitatissimum*. Revista Brasileira de Energias Renováveis 1(1):22-32.

Oomah BD, Mazza G (1993). Flax seed proteins – a review. Food Chem. 48(2):109–114.

Penatti CP, Cambria S, Boni OS, Arruda FCO, Manoel LA (1999). Efeitos da aplicação da vinhaça e nitrogênio na soqueira da cana-de-açúcar. Boletim Técnico Coopersucar 44:32–38.

Ramos NP, Novo MCSS, Ungaro MRG, Do Lago AA, Marin GC (2008). Efeito da vinhaça no desenvolvimento inicial de girassol, mamona e amendoim em casa de vegetação. Bragantia 67(3):685-692.

Rossetto C, Santos RF, Souza SNM de, Dias PP, Klaus O (2012). Diferentes doses de Potássio na cultura da linhaça (*Linum usitatissimum* L.). Revista Brasileira de Energias Renováveis 1(3):98-105.

Silva MAS, Griebeler NP, Borges LC (2007). Uso de vinhaça e impactos nas propriedades do solo e lençol freático. Rev. bras. eng. agríc. ambient. 11(1):108–114.

Soares LL, Pacheco JT, Brito CM de, Troina A de A, Boaventura GT, Guzmán-Silva MA (2009). Avaliação dos efeitos da semente de linhaça quando utilizada como fonte de proteína nas fases de crescimento e manutenção em ratos. Rev. Nutr. 22(4):483-491.

Turner JA (1987). Linseed Law: A Handbook for Growers and Advisers. BASF UK Ltd., Suffolk. p. 356.

Vieira MD, Santos RF, Rosa HA,Werner OV, Delai JM, Oliveira MR (2012). Potássio (K) no cultivo da linhaça Linum usitatissimum. Revista Brasileira de Energias Renováveis 1(1):62-69.

Waliszewski KN, Romero A, Pardio VT (1997). Use of cane condensed molasses solubles in feeding broilers. Anim. Feed Sci. Technol. 67:253–258.

Westcott ND, Muir AD (2003). Flax seed lignan in disease prevention and health promotion. Phytochem. Rev. 2:401–417.