AGRONOMY SCIENCE AND BIOTECHNOLOGY

RESEARCH ARTICLE

Edaphoclimatic variables in determining flaxseed yield

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ABSTRACT

Flaxseed is an oil plant, belonging to the Linaceae family, of an autogamous species. The objective of this work is to evaluate grain yield through edaphoclimatic variables, which are descriptive of field, soil and climate in relation to the production of the line in the state of Rio Grande do Sul. The trial was carried out at the Regional Institute of Rural Development (IRDeR), belonging to the Regional University of the Northwest of the state of Rio Grande do Sul (Unijuí); the experimental design used was that of randomized blocks, organized in a factorial scheme of 5 application moments x 5 doses of nitrogen in 3 replications, totaling 75 experimental units. The traits evaluated were grain yield in relation to the soil, climate and field attributes. Grain yield is directly and indirectly influenced by base saturation at pH 7.0 and soil compaction, and also by the maximum temperature and minimum temperature. The condition of the climate during the culture cycle influences the components of the grain yield of flaxseed. The maximum and minimum temperature were negatively related to flaxseed grain yield under the conditions of the study. The Track Analyses allowed us to visualize the contribution of both chemical and physical attributes to the final production. Higher values of base saturation enhance flaxseed grain yield. Variables number of capsules, number of capsules that formed grains, number of grains per plant, population, and mass of grains per plant were the variables that determined grain yield.

Keywords: *Linum usitatissimmum*, soil attributes, oil production, meteorological variables, Pearson correlation, predictor model.

INTRODUCTION

With the current growth of the human population and the difficult expansion of new arable areas, it becomes necessary to use managements more efficiently, expanding production in the same area. This issue has been widely discussed in the agricultural sector in the current years in our region and in other parts of the country, considering the different types of farmers and production systems practiced in their production units. The productions carried out can be destined for multiple uses, such as for human and animal food, and oil extraction. Considering the culture of flaxseed (*Linum usitatissimmum*) and the products that can be obtained, in addition to the different cultural practices to which it can be subjected and the different soil and climate conditions in which it can be grown, it is necessary to qualify the existing knowledge in terms of soil fertility management and also in terms of efficiency of use of resources used in cultivation systems that include the flaxseed culture. This oilseed has a promising future in the use of energy for the production of biofuels.

Studies have shown that flaxseed seeds provide various benefits to the human body and protective health effects (Oomah and Mazza, 200). Its cultivation is carried out mainly in Argentina, the United States, Canada, Russia, Ukraine and Brazil (Novello et al., 2012). In Brazil, flaxseed has been grown in the state of Santa Catarina since the seventeenth century, and over the years the cultivation was introduced in the states of São Paulo, Paraná and Rio Grande do Sul. There is a greater demand on the consumer market than production itself for the use of food intended for both industry and animal feed. Thus, it is necessary to realize a viable production, in addition to the practices adjusted to the cultivation, in order to maximize the production of flaxseed. According to Rossetto (2012), the flaxseed plant is fully exploited by the industry: oil is extracted from its seed, used in food, medicine, cosmetic and textile industries such as clothing and linen production. From this culture, resins, varnishes, dyes and paints can be manufactured, and foods, too.

Flaxseed responds positively to nitrogen (N) fertilization, but the overall response is lower than that observed in traditional crops such as wheat; however, the application of nitrogen fertilizers is necessary to improve the yield of seeds and grains. Therefore, the objective of this study is to evaluate grain yield through edaphoclimatic variables, that is, those descriptive of field, soil and climate in relation to the production of flaxseed (*Linum usitatissimum*) in the state of Rio Grande do Sul.

MATERIAL AND METHODS

The trial was developed in the experimental area of the Regional Institute of Rural Development (IRDeR), which is part of the Regional University of the Northwest of the Brazilian State of Rio Grande do Sul (UNIJUÍ), geographically located within the municipality of Augusto Pestana (RS), 28° 26’ 20’ S and 54° 00’ 23', at an altitude of 301 metres. The soil of the experimental area is classified as typical dystroferric Red Latosol (Santos et al., 2018), which is characterized as a deep soil with excellent porosity, enabling good root development. According to Köppen, the climate is characterized as CFA (humid subtropical), which is characterized by the occurrence of hot summers and without prolonged droughts, cold and humid winters, with frequent occurrence of frosts. The average annual rainfall is around 1600 millimeters, and the highest rainfall is in the winter period.

The experimental design used was that of randomized blocks, organized in a factorial scheme of 5 application moments x 5 doses of nitrogen in 3 replications, totaling 75 experimental units. Therefore, the treatments were distributed in five different nitrogen application times, defined in days after sowing (0, 10, 30, 60 and 90 days after sowing), associated with five different nitrogen doses (0, 30, 60, 90 and 120 kg ha-1), which corresponded, respectively, to 0, 67, 133, 200 and 267 kg ha-1 of urea, 45% nitrogen applied as a cover. The genotype of flaxseed used to conduct the trial was the cultivar of registration IJUÍ 001 which is characterized by brown seed coloring and a cycle of approximately 160 days. The sowing took place on May 15, 2020 with a Seeder, using the spacing of 0.18 meters between lines and a density of 50 kg ha^{-1}, equivalent to approximately 150 linear seeds. The sowing was carried out in an area prepared in the direct sowing system, where silage corn was the predecessor crop.

Seventeen sowing lines with 6 meters of length constituted the experimental units, totaling an area of approximately 18 m^2, and for the evaluations a useful area of 10 m^2 was considered. The other culture treatments, as well as the control of weeds, pest insects and diseases were standardized for all treatments. Thus, the management of weeds was carried out through two applications of the Iodosulfurom-methyl herbicide at a dose of 100 g ha^{-1}. Two applications of insecticide Diflubenzurom at a dose of 100 ml ha^{-1} and two applications of Zeta-Cypermethrin at a dose of 50 ml ha-1 were used for the management of pest insects. In the useful area of each experimental unit the following were measured: plant height (PH, cm) and height of the insertion of the first capsule (HIFC, cm). Subsequently, ten representative plants were removed from the experimental unit and were submitted to the evaluations. Thus, the analyzed variables were: number of basal branches (NBB, pc), steam diameter (SD mm), number of stem branches (NSB, unit), number of productive branches (NPB, unit), number of capsules (NCAP, unit), mass of the capsules (MCP, g), number of capsules that have formed grains (NCFG, unit), number of capsules that did not form grains, (NCNFG, unit), number of grains per plant (NGP, unit), mass of grains per plant (MGP, g), mass of a thousand grains (MTG, g), and grain yield (GY, kg ha^{-1}).

Meteorological data were collected to characterize each application moment, such as maximum temperature conditions (MXT), minimum temperature (MMT), relative humidity (RH), rainfal (RF) and thermal range (TR); they were obtained through the IRDeR weather station. At this stage, a soil analysis was also carried out, in which the variables described in the field were aluminum (AL), clay (CL), calcium (CA), soil class (SCLA), soil compaction (SC), cation exchange capacity (CEC), copper (CU), potential acidity (H+Al), potassium (K), magnesium (MG), manganese (MN), organic matter (OM), phosphorus (P), pH, sulfur (S), aluminum saturation (alsat), base saturation (BS), SMP index and zinc (ZN).

The data obtained were submitted to the assumptions of the statistical model, normality and homogeneity of residual variances, additivity of the model. Subsequently, the descriptive analysis and the analysis of variance at 5% probability were performed by the F test. The mean effects were identified through the descriptive trends as well as the linear relationships of grain yield x descriptive of soil, field and climate. In order to understand the trend of the linear association among the variables, the linear correlation with significance based on the T-test was applied at 5% probability. In order to understand the trend of the linear association among the variables, the linear correlation with significance based on the T-test was applied at 5% probability (Pelegrin et al., 2020). All statistical analyses were performed by the RStudio software, using the Ggplot2, Metan, Agricolae and Exp. Des. Pt. packages.

RESULTS AND DISCUSSION

To understand the results, a study of the cultivation history of the area was carried out first. Thus, crop management was evidenced in a period of 23 years of direct sowing, with soybean being the most cultivated crop in the summer, showing 78.26% of the entire period, that is, 18 years. Corn for grain represented 13.04%, being cultivated in the summer for 3 years. Corn for silage was grown for only 1 year in this area, representing 4.34%. Some winter crops expressed minimum values of 4.34%; each crop was grown for only one year; they were wheat, oat grain, fallow, vetch+oat. The intercropped silage represented 12.60%, and was cultivated for 3 years; as for oat pasture and oat silage, they were cultivated for 2 years, representing 8.69%.

Soil components, temperature and air relative humidity are factors that exert a great influence on the development and physiology of the flaxseed culture. Furthermore, the reduced spacing between rows is responsible for enhancing the linseed grain yield (Muraro et al., 2018). These factors cause effects on production capacity, oil content in the grains and quality. Table 1 shows the manifestation of meteorological phenomena, soil components and flaxseed yield during the crop development cycle in the 2020 harvest, in Augusto Pestana, RS. Relating the descriptive components of the soil (Table 1), aluminum has a low value of 0.41 cmol-dm3, but its variation is from 0.10 cmol-dm3 to 0.70 cmol-dm3, having a 0.60 cmol-dm3 interval between samples. Its CV is high, around 45.9%, the standard error of the mean has a minimum variance from 0.40 to 0.41, meaning 0.02. Clay has an average value of 57.8%, but its variation ranges from 50% to 62%, having 12% among the samples. In relation to CV, it is small, since it is around 5.6%. The standard error of the mean shows a small variation from 56 to 58, which means 0.38. For variable calcium, its mean is 4.55 cmol-dm3, ranging from 3.90 cmol-dm3 to 5.80 cmol-dm3, having a 1.90 cmol-dm3 variation. The CV is 11.26% and the standard error of the mean is 0.06.

Variable soil compaction is found with an average of 2385.07 kPa, its variation ranging from 1586.36 KPA to 2785.42 KPA. The CV is 13.87%, being an average value and the standard error of the mean is 38.18. The CEC pH 7 by bases has an average of 12.29 cmol-dm3, and an oscillation between the maximum and minimum from 15.70 cmol-dm3 to 10.10 cmol-dm3. The CV is average with a value of 13.14%. The standard error is low, 0.19. Copper has an average value of 6.83 mg-dm3, its maximum and minimum range from 9 mg-dm3 to 5 mg-dm3. In relation to the CV, 16.30% is the average value. The standard error of the mean is low, around 0.13. Potassium has a mean value of 159.65 mg dm-3, ranging from 87.00 mg dm-3 to 290.00 mg dm-3. The CV is average, 30.94%. The standard error is 5.70, an average value for this variable. Mg has a mean value of 2.45 mg dm-3, ranging from 2.10 mg dm-3 to 3.30 mg dm-3. Its CV is 15.10%, being an average value. The standard error is low, 0.04. For Mn, the mean is 47.57 mg dm-3, ranging between the maximum and minimum from 25.40 mg dm-3 to 71.50 mg dm-3. The CV is an average value of 26.43%. The standard error is 1.45. Organic matter is at a low value of 2.80%, ranging from 2.10% to 3.20%. In relation to the CV, it is low, since it is 9.76%. The standard error of the average mean is 0.03. Phosphorus is 22.86, ranging from 14.30 to 53.70 of the average. The CV is 40.40%. The standard error of the mean is 1.07, a low value.

For pH, it has an average value of 5.07, and its variation is from 4.80 to 5.60 on average. The CV is low, 3.58%. The standard error of the mean is 0.02, a low value. Sulfur has an average value of 8.35%, and an oscillation from 1.60% to 13.60% of the average. The CV is 47.80%, considerably median. The standard error of the mean is low, around 0.46%. The saturation per aluminum is at an average value of 5.45%, the maximum and the minimum range from 1.00% to 9.90%. The CV is 50.33%. The average standard error is low, 0.32%. The base saturation is at an average of 60.70%, with an oscillation from 50.50% to 72.60% of the average. The CV is 10.62%. The standard error of the mean is 0.74%, which is low. The SMP index has an average value of 5.93, ranging between the maximum and the minimum from 5.60 to 6.40. The CV is 3.84%, a low value. The standard error of the mean is only 0.03%. Zinc has an average value of 2.26, oscillating between maximum and minimum from 1.50 to 4.40 of the average. The CV is 28.14% and the standard error of the mean is low, 0.07%.

Table 1. Descriptive analyses of soil attributes. Aluminum (Al), clay (CL), calcium (Ca), soil class (SCLA), soil compaction (SC), cation exchange capacity (CEC), copper (Cu), hydrogen+aluminum ratio (HAL), potassium (K), magnesium (Mg), manganese (Mn), organic matter (OM), phosphorus (P), hydrogen-ionic potential (pH), sulfur (S), aluminum saturation (ALSAT), base saturation (BS), SNMP index, zinc (ZN), temperature range (TR), relative humidity (RH), rainfall (RF), maximum temperature (MXT), minimum temperature (MMT), the height of the insertion of the first capsule (AIPC), plant height (PH), the cycle (CYCLE), stem diameter (SD) mass of grain per plant (MGP), mass of a thousand seeds (MTS), number of capsules (NCAP), number of capsules that form grains (NCFG), number of grains per plant (NGP), number of base branches (NBB), number of stem branches (NSB), number of branches per plant (NBP), population (POP), and grain yield (GY).

Variable	Coefficient of variation	Maximum	Mean	Median	Minimum	Standard Deviation	Standard error of the mean	Confidence interval
HIFC	8.84	82.50	70.25	71.00	53.00	6.21	0.72	1.43
PH	8.78	95.50	79.73	79.50	65.00	7.00	0.81	1.61
CYCLE	1.95	171.00	168.76	171.00	164.00	3.29	0.38	0.76
RD	18.63	2.86	2.01	2.01	1.29	0.37	0.04	0.09
MGP	22.66	0.48	0.30	0.29	0.17	0.07	0.01	0.02
MMS	2.58	5.82	5.47	5.48	5.13	0.14	0.02	0.03
NCAP	18.91	12.25	8.51	8.60	5.40	1.61	0.19	0.37
NCFG	17.15	11.20	7.57	7.50	4.75	1.30	0.15	0.30
NGP	21.95	81.40	53.00	50.80	32.00	11.63	1.34	2.68
NBB	26.95	2.00	1.30	1.20	1.00	0.35	0.04	0.08
NSB	11.95	5.40	4.14	4.20	3.00	0.49	0.06	0.11
NPB	17.25	8.50	6.01	6.00	3.25	1.04	0.12	0.24
POP	16.28	11.76	8.16	8.10	5.82	1.33	0.15	0.31
GY	22.04	3401.69	2251.25	2204.35	1204.23	496.19	57.29	114.16
PH	14.19	13.91	12.19	12.69	8.33	1.73	0.20	0.40
RH	31.81	85.60	57.94	53.14	16.88	18.43	2.13	4.24
RF	31.58	2653.70	1802.90	1738.60	523.00	569.30	65.74	130.98
MMT	10.40	28.30	25.93	26.65	18.06	2.70	0.31	0.62
MXT	14.67	18.17	13.74	14.01	9.73	2.02	0.23	0.46
Al	45.92	0.70	0.41	0.40	0.10	0.19	0.02	0.04
CL	5.64	62.00	57.80	57.00	50.00	3.26	0.38	0.75
Ca	11.26	5.80	4.55	4.40	3.90	0.51	0.06	0.12
SCLA	23.77	2.00	1.77	2.00	1.00	0.42	0.05	0.10
SC	13.87	2785.42	2384.07	2414.63	1586.36	330.69	38.18	76.08
CEC	13.14	15.70	12.29	11.80	10.10	1.62	0.19	0.37
Cu	16.30	9.00	6.83	6.70	5.00	1.11	0.13	0.26
HAL	24.99	6.90	4.90	4.90	2.80	1.22	0.14	0.28
K	30.94	290.00	159.65	166.00	87.00	49.39	5.70	11.36
Mg	15.10	3.30	2.45	2.30	2.10	0.37	0.04	0.09
Mn	26.43	71.50	47.57	44.30	25.40	12.57	1.45	2.89
OM	9.76	3.20	2.80	2.90	2.10	0.27	0.03	0.06
P	40.40	53.70	22.86	21.50	14.30	9.24	1.07	2.13
PH	3.58	5.60	5.07	5.00	4.80	0.18	0.02	0.04
S	47.80	13.60	8.35	8.40	1.60	3.99	0.46	0.92
SAL	50.33	9.90	5.45	5.20	1.00	2.74	0.32	0.63
BS	10.62	72.60	60.70	60.00	50.50	6.45	0.74	1.48
SMP	3.84	6.40	5.93	5.90	5.60	0.23	0.03	0.05
Zn	28.14	4.40	2.26	2.00	1.50	0.64	0.07	0.15

Describing the climate attributes, the thermal range obtained an average of 12.19, ranging from 8.33 to 13.91 between the maximum and the minimum. Its CV is

14.19%, while the standard error is a low value of 0.20%. The relative humidity is on average 57.94 UR, ranging from 16.88 to 85.60. The CV has a value of 31.81%, the standard error of the mean is 2.13. The average rainfall during the crop cycle was 1802.90 mm, ranging from the minimum of 523.00 mm to the maximum of 2653.70 mm. The CV is 31.58%. The standard error of the mean is 65.74. The maximum temperature has an average of 25.93 ºC, ranging from 18.06 ºC to 28.30 ºC. In relation to the CV, it was 10.40%, and its standard error is 0.31. The mean value of the minimum temperature is 13.74 ºC, ranging from 9.73 ºC to 18.17 ºC. The CV represents a value of 14.67% and the standard error of the mean is 0.23. High temperatures during the flowering season, on average 32ºC, reduce plant growth, seed size and oil content, as well as quality (Floss, 1983). According to the same author, temperatures below-1ºC in the reproductive period cause significant losses in production.

Regarding the descriptive field analyses, the height of the insertion of the first capsule has a mean value of 70.25, ranging from the maximum and minimum from 53.00 to 82.50. The CV is 8.84%, considered an average value. And the standard error is low, 0.72. For plant height, an average value of 79.73 is found, ranging from 65.00 to 95.50 to maximum and the minimum. The CV is median, 8.78%, and the standard error of the mean is low, 0.81, reports that the final height of the plants in 2014, for Brown flaxseed, was 83.2 cm, and for Golden flaxseed it was 76.8 cm, with thermal accumulation of 1223, 8 ºC day. In the following year, the height for Brown flaxseed was 86.0 cm, while for Golden flaxseed it was 84.7 cm, with thermal accumulation of 1241.7 ºC day. It is concluded that the height of the year 2015 was higher and this can justify that a higher incidence of solar radiation can cause plant elongation.

The average cycle is 168.76 days, but it has an oscillation from 164 to 171 days. The CV is 1.95% and the standard error is 0.38, both low values. The flaxseed plant cycle consists of a vegetative period of 60-80 days, a flowering period of 25-40 days and a maturation period of 40-60 days. High temperatures, diseases and water stress can interfere with any of these developmental periods. For stem diameter, its average is 2.01, ranging from 1.29 to 2.86 between the maximum and minimum. The CV has an average value of 18.63 % and the standard error of the mean is low, 0.04. The mass of grains per plant has an average value of 0.29, ranging from 0.17 to 0.48. The CV is 22.66%, considered an average value. The standard error is low, 0.01. For variable mass of one thousand seeds, the average is 5.47, ranging from 5.13 to 5.82 between the sample. The CV is 2.58% and the standard error 0.02, considered a low value for both analyses. Regarding the number of capsules, it has an average value of 8.51, ranging from 5.40 to 12.25. The CV is 18.91% and the standard error is 0.19, considered a low value. The number of capsules that form grains has an average of 7.57, ranging from 4.75 to 11.20 of the average. The CV is an average of 17.15% and the standard error of the mean is 0.15. For variable number of grains per plant the average is 53.00, ranging from 32.00 to 81.40. The CV is an average of 21.95% and the standard error is 1.34, a low value. Reported that under controlled conditions with flaxseed plants, it seems that during the formation/maturation phase high temperatures reduce the number of seeds per capsule and the weight of grains, decreasing the quality and yield of the oil.

Regarding the number of branches in the base, it has an average value of 1.30, ranging from 1.00 to 2.00. The CV is 26.95% and the standard error is low, 0.04. The number of branches on the stem has an average of 4.14, ranging from 3.00 to 5.40. The CV is 11.95%, considered an average value, and the standard error is 0.06, considered to be a low value. The number of branches per plant has an average value of 6.01, ranging from 3.25 to 8.50. The CV is 17.25%, in relation to the standard error is at a low value of 0.12. For the plant population, it has an average of 8.16, ranging from 5.82 to 11.76. The CV is 16.28% and the standard error is 0.15, a low value. The grain yield of flaxseed is, on average, 1.5 T há-1 (Oliveira et al, 2012). The grain yield of this trial was 2251.25 kg/ha ranging from 1204.23 kg/ha to 3401.69 kg/ha, a very significant result in relation to the work of Oliveira (2015). The CV is 22.04% and the standard error is 57.29, considering average values for both analyses.

Discussing the Pearson's linear correlation to soil effects related to yield (Figure 1): through this analysis, the correlations between the tested variables can be identified, so that the correlation values vary from -1(strong and negative correlation) to 1(strong and positive correlation) and 0 when there is no correlation (Loro et al., 2021).

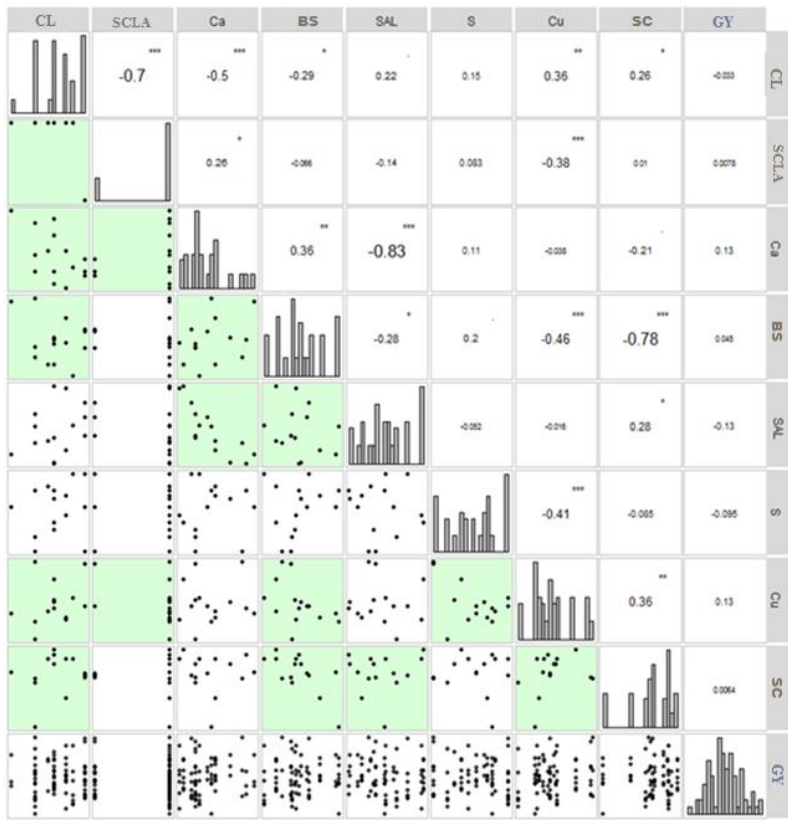

Figure 1. Pearson’s linear correlation for soil effects related to yield (Pearson’s linear correlation coefficients (n=1000) significant at 5.00% probability of error. CL: clay; SCLA: soil class; Ca: calcium; BS: base saturation; ALSAT: aluminum saturation; S: sulfur; Cu: copper; SC: soil compaction; and GY: grain yield).

Therefore, for the conditions of the present experiment, it is observed on soil descriptions, soil compaction is minimally correlated with clay (r= 0.26), aluminum saturation (r= 0.28), copper (r= 0.36) and a strong negative correlation with base saturation (r= -0.78). Copper was related to clay (r= 0.36), soil class (R= -0.38), base saturation (r= -0.46) and sulfur (r= -0.41). Aluminum saturation was significantly related to calcium (r=-0.83) and with lower intensity to base saturation (r= -0.28). The base saturation variable was significantly related to clay (r= -0.29) and calcium (r= 0.3), but with low significance in both. Calcium is strongly related to clay (r= -0.50) and with little significance to the soil class (r= 0.26). Soil class is strongly related to clay (r= -0.70).

In the Pearson’s linear correlation, for the effects of climate-related yield (Figure

2), it can be seen that grain yield is minimally related with minimum temperature (r= -0,23) and maximum temperature (r= -0,25), the height of the plant is related positively with minimum temperature (r=0,66); the minimum temperature is correlated positively with rainfall (r=0,44) and maximum temperature (r=0,77). And the maximum temperature significantly relates to rainfall (r= 0.58). Stanck (2018) reports that high temperatures around 32ºC impair the flowering and filling of grains, causing reductions in differentiation processes, oil content in the grains and size, thus decreasing their quality. In an analysis of Pearson's linear correlation for traits of yield components related to yield (Figure 3), it is noticed that grain yield was positively related to variables number of capsules (r= 0.65), number of capsules that form grains (r= 0.67), number of grains per plant (r= 0.73), population (r= 0.33) and mass of one thousand grains per plant (r= 0.67). According to Antonelli et al. (2015), grain yield is directly related to plant height (PH), number and capsules (NCAP) and mass of grains per plant (MGP). In soybeans, Follmann et al. (2018), showed that plant height and mass of one hundred grains exhibit a positive correlation with grain yield.

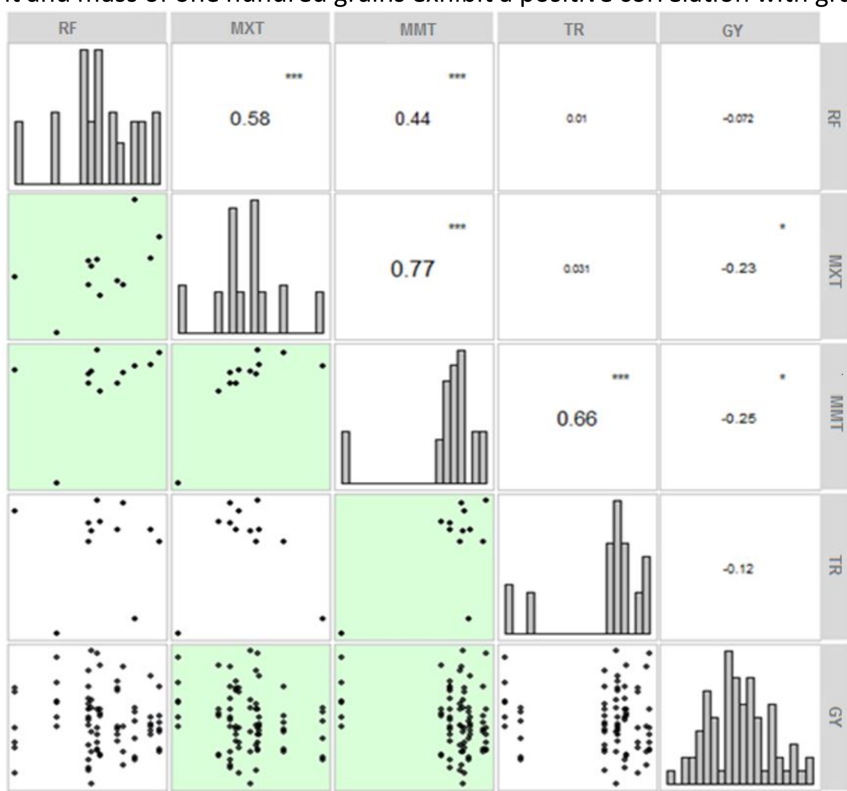

Figure 2. Pearson’s linear correlation for climate effects related to yield (Pearson’s linear correlation coefficients (n=1000) significant at 5.00% probability of error. TR: thermal range; RF: rainfall; MXT: maximum temperature; MMT: minimum temperature; and GY: grain yield).

The mass of one thousand grains per plant is positively related to the number of capsules (r= 0.83), number of capsules that format grains (r= 0.80) and number of grains per capsules (r= 0.92), that is, this interaction indicates that with the increase in the number of capsules that formed grains, the number of grains per plant increased, and consequently the mass of grains per plant, raising grain yield. The number of grains per plant correlated positively with the number of capsules (r= 0.79) and the number of capsules that form grains (r= 0.83). Carvalho et al., (2017), showed similar results in soybean, where the number of pods and grain mass promote grain yield. Variable number of capsules that form grains correlated with the number of capsules (r= 0.83). The height of flaxseed plants is positively correlated with the height of the insertion of the first capsule (r= 0.74), that is, larger plants tend to have the height of the insertion of the first capsule higher.

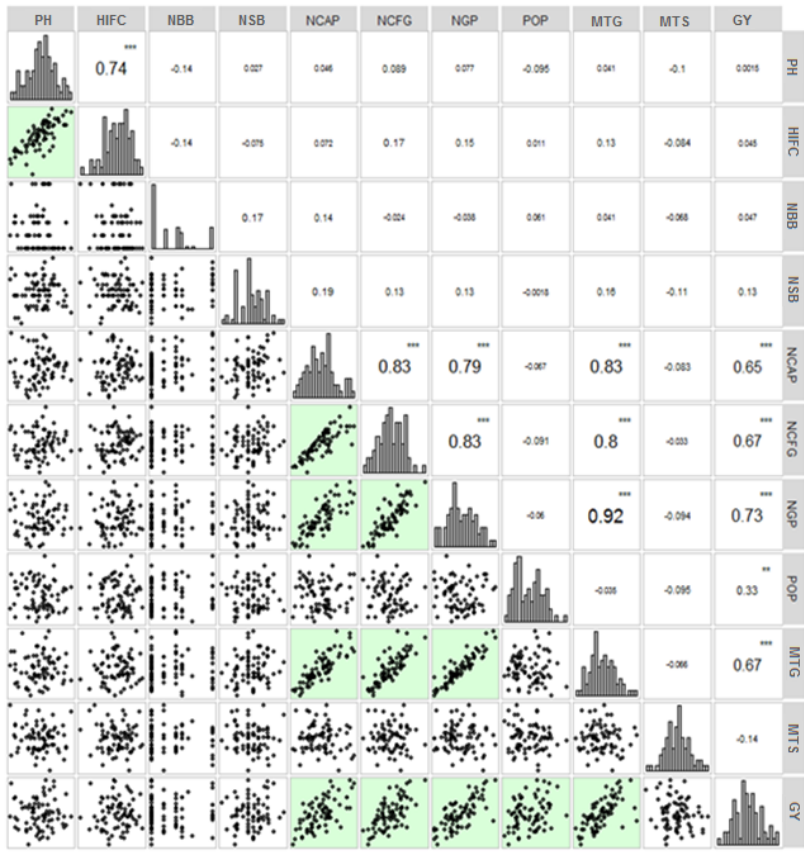

Figure 3. Pearson's linear correlation for yield component traits related to yield (Pearson's linear correlation coefficients (n=1000) significant at 5.00% probability of error. PH: plant height; HIFC: height of the insertion of the first capsule; NBB: number of basal branches; NSB: number of steam branches; NCAP: number of capsules; NCFG: number of capsules that form the grains; NGP: number of grains per plant; POP: population; MTG: mass of a thousand grains per plant; MTS: mass of a thousand seeds GY: grain yield).

The predictor model (Table 2) was established in order to present which traits determine grain yield in the flaxseed culture. Estimates for the dependent character of the yield components is determined by the number of capsules, number of grains per plant and population. The climate prediction is determined by the maximum air temperature, and for soil it is defined according to the SMP index, potassium and base saturation. Therefore, this joint action, that is, when there is a lower air temperature, together with high fertility and soil structuring, there is an increase in the yield of the components, NCAP, NGP and POP, which will result in higher grain yield.

Table 2. Grain yield (GY) predictor model for soil, climate and yield components.

Dependent character for grain yield

Climate	GY = 3453,14 - 46,34 (Maximum air temperature)
Soil	GY = 6366.003 - 1058.816 (SMP) - 1.851 (K) + 40.140 (SB)
Performance components	GY = 812,42 + 68,21 (NCAP) + 24,81 (NGP) + 143,16 (POP)

For the field Track Analysis (Figure 4), it can be observed that the variable of interest is grain yield (GY), where the contribution of five variables is defined, which are mass of one thousand seeds (MTS), number of capsules (NCAP), number of stem branches (NSB), number of capsules that form grains (NCFG) and population (POP). Of these, the variables that contributed the most to GY were NCFG (0.45) and NCAP (0.28), while the other variables had a lower weight for GY. Variable NRH positively influenced the NCFG (0.05), and NCAP (0.05), positively affecting GY. This leads to infer that when there is an adequate plant population per meter, this will optimize the branching per meter, contributing to a greater number of capsules that form grains, being greater the number of seeds per plant, consequently greater grain weight, optimizing a higher yield of grains per hectare.

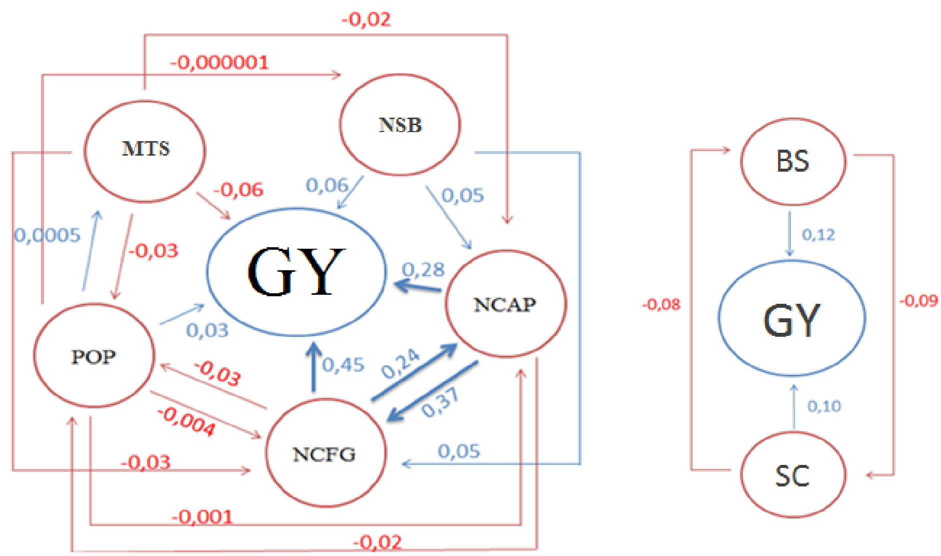

Figure 4: Track Analysis for field effects. Grain yield (GY), number of steam branches (NSB), number of capsules (NCAP), number of capsules that formed grains (NCFG), population (POP), mass of one thousand seeds (MTS). Track Analysis for soil effects. Grain yield (GY), soil compaction (SC), base saturation (BS).

For the soil Track Analysis, it is noted that variable grain yield (GY) is defined by the contribution of base saturation (BS) and soil compaction (SC). The SC presents a direct contribution in relation to the variable of interest GY (0.10) and indirect negative (-0.08) for BS. Variable BS contributes directly (0.12) to GY, and indirectly negative to SC (-0.09). This indicates that soil compaction limits the availability of the main chemical nutrients, Ca, Cu, K, Mg, Mn, P, S, Zi (SB), influencing grain yield (GY), in the same way for base saturation, even contributing directly, it is indirectly limited by the physical trait (SC).

CONCLUSIONS

The condition of the climate during the culture cycle influences the components of the grain yield of flaxseed. The maximum and minimum temperature were negatively related to flaxseed grain yield under the conditions of the study.

The Track Analyses allowed to visualize the contribution of both chemical and physical attributes to the final production. Higher values of base saturation enhance flaxseed grain yield.

Variables number of capsules, number of capsules that formed grains, number of grains per plant, population, and mass of grains per plant were the variables that determined grain yield.

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