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Sowing depth and loads on press wheels in emergence, growth, and yield of safflower

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Abstract

Safflower has recently been introduced to Brazil. This plant has attracted this view due to its properties and capacity to supply oil that can potentially be used both in the manufacture of biofuels and in the food industry. In order to contribute with studies for the viability of this crop in the country, which are still lacking in the management of seeding, the study aimed to assess the mechanization of seeding a safflower genotype in two seeding depths (4.5 and 6.5 cm) and three levels of loads applied to the wheels (117.7, 156.9, and 196.1N) in the emergence, growth, and grain yield. The experimental design of randomized complete block design arranged in factorial 2 × 3, with four replications. Seeding depth and loads on press wheels did not affect the emergence rate of safflower. The root length, plant height, stem diameter, and dry mass of the plant at 30 DAE were benefited by seeding in depth of 4.5 cm in relation to the depth of 6.5 cm. Higher grain yield was observed for loads of 196.1 N compared to the pressure of 117.7 N, with values of 725 and 443 kg ha^{-1}, respectively. Grain yield was 61% higher when seeding at a depth of 4.5 cm. Thus, the adjustment of the compactor wheels can influence in the safflower seeding process.

Keywords: seeder, precision seeding, energy crops.

Introduction

The safflower crop has been gaining more and more space and prominence in research around the world, both in the sphere of crops with energy potential, as well as in studies of oils for human nutrition (Olivo et al., 2020; Sarto et al., 2018). Safflower (*Carthamus tinctorius*) is a viable option for cultivation in regions with high-temperature winter droughts (Santos et al., 2017; Santos et al., 2018b). The properties of safflower oil are similar to those of other oils used for the production of biodiesel (Yesilyurt et al., 2020).

Recently, studies have been carried out in Brazil to evaluate the adaptation and determine the appropriate management so that the safflower, in addition to a new alternative for crop rotation, can become economically profitable between harvests or even in Brazilian harvests (Sampaio et al., 2016; Zanão Júnior et al., 2017; Santos et al., 2018a; Mazieiro et al., 2019). It is known that proper management is one of the elements that can most contribute to the success of a crop yield and can be defined at the very beginning of its implementation by the performance of mechanization during sowing. A careful seeding operation will avoid the emergence of future problems that can only be seen after the germination and development stages of the plants. If complications occur in these periods, they can hardly be corrected, as well as demand high costs and compromise yield (Modolo et al., 2007).

In the seeding operation, the performance of a seeder-fertilizer is influenced by all machine components and is not restricted to the feeder mechanism only. In this way, the regulation of the seeding depth, the type of loads on press wheels, among other components, as well as external variables, such as soil moisture and climatic conditions, can interfere with the performance of the seeding machines. Seed need optimum conditions of humidity and heat to germinate. For the emergence of the seedlings, factors such as the depth of seeding and the resistance of the soil layer above the seed are the variables that act simultaneously at the emergence stage (Cortez et al., 2006). Compacting wheels are devices that improve soil-seed contact by applying pressure exerted laterally and on the sowing line, causing light compaction and favoring seedling emergence (Modolo et al., 2010). The depth of seed deposition is another factor that can affect its germination, being conditioned by temperature, water content and soil type, among other factors (Silva et al., 2008).

Knowing the seedling emergence when selecting sowing depth and loads on press wheels is useful information for attaining an appropriate stand density and resultant optimum crop performance. We did not find previous reports on loads on press wheels in safflower sowing. Considering the scarcity of literature regarding the management of mechanized planting of

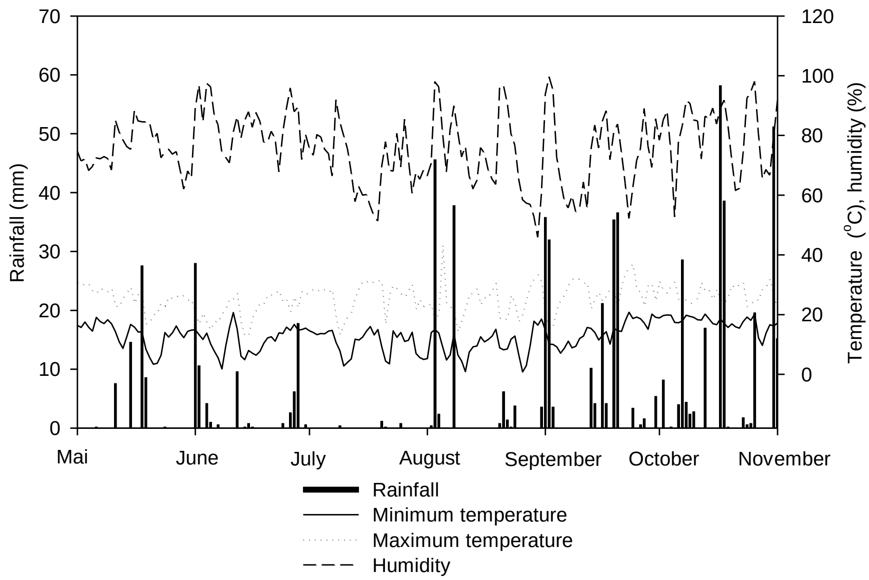

Figure 1. Rainfall, minimum and maximum temperature and humidity during the conduct of the experiment.

the safflower, the study aimed to assess emergency, growth, and grain yield parameters due to two seeding depths and three levels of loads on press wheels in the seeding operation.

Results and discussion

Emergence

No significant difference (P > 0.05) was observed between the seeding depth and loads on press wheels, as well as the interaction of factors for emergency assessments (Table 2). However, the emergency was low. The low emergency percentage rates that reduced the plant stand in this study can be attributed to problems in seed quality. Thus, the vigor of the seeds, an attribute that defines the establishment of rapid and uniform emergence rate of normal seedlings under diverse field conditions, may have contributed to the absence of statistical difference between treatments. The germination behavior of seeds in the field can be influenced by several factors that act simultaneously or separately during the germination process, such as luminosity, ideal temperature range, humidity, and oxygen availability (Seo et al., 2009). Typically, reports in the literature indicate the sensitivity of seedlings when submitted to increased seeding depth. Tanveer et al. (2012) found a reduction in the percentage of emergence rate from 72 to 35% with an increase in depth from 0 to 6 cm, respectively.

The emergence rate of the seedlings was not affected by the three loads on press wheels (Table 2). This may be due to soil moisture conditions and the no-till conditions, which facilitated the maintenance of high humidity in the compacted layer, reducing soil resistance and facilitating germination (Cortez et al., 2006). These results confirm those obtained by Grotta et al. (2007) for soybean cultivation due to seeding depths and vertical loads.

Growth

For the growth variables assessed at 30 DAE (root length, height, stem diameter, and dry mass of the plant), a significant difference (P < 0.05) was verified due to the seeding depth (Table 3). The root length, plant height, stem diameter, and dry plant mass were greater at a depth of 4.5 cm in relation to seeding depth of 6.5 cm. There was no interaction between seeding depth and loads on press wheels (Table 3).

No significant effect (P < 0.05) of the depths and loads on press wheels was verified for the variables analyzed in flowering, plant height, stem diameter, number of primary branches, and plants per meter, as well as by the interaction of the factors (Table 4).

Table 1. Granulometry and soil chemical properties before installation of the experiment.

Soil characteristics	Value
Sand (g kg^{-1})	200
Silt (g kg^{-1})	190
Clay (g kg^{-1})	610
pH	5.1
P (Mehlich-1) (mg kg^{-1})	35.2
H + Al ($cmol_c$ kg^{-1})	6.2
K ($cmol_c$ kg^{-1})	0.63
Ca ($cmol_c$ kg^{-1})	8.6
Mg ($cmol_c$ kg^{-1})	2.3
CEC ($cmol_c$ kg^{-1}) #	11.6
V (%)	65

#CEC: Cation exchange capacity.

Yield

Grain yield was significantly affected (P < 0.05) by the depths and pressures separately. Higher grain yield was obtained for 4.5 cm deep seeding with a yield of 868 kg ha^{-1} compared to 6.5 cm deep seeding (341 kg ha^{-1}). Regarding the loads on press wheels, higher grain yield was observed at a pressure of 196.1 N compared to the pressure of 117.7 N, with values of 725 and 443 kg ha^{-1}, respectively (Table 4). The visibility of the statistical difference in the grain yield variable concerning the seeding depth of 4.5 cm may be linked to the fact that this configuration

Table 2. Emergence speed index (ESI), mean time emergence (MTE), mean speed emergence (MSE) and emergence rate (E) of safflower according to seeding depths and loads applied to the wheels.

Variation sources	ESI (seeds d^{-1})	MTE (days)	MSE (days)	E (%)
Seeding depth (cm)				
4.5	0.81^{ns}	3.7	0.28	31.5
6.5	0.73	4.4	0.25	30.2
Loads on press wheels (N)				
117.7	0.74	4.3	0.24	30.7
156.9	0.82	3.9	0.28	32.2
196.1	0.76	3.9	0.27	29.6
F Test	——— P value ———			
Seeding depth (A)	0.2038#	0.1942	0.3757	0.5357
Loads on press wheels (B)	0.5132	0.6552	0.5180	0.6296
A × B	0.2471	0.1310	0.1060	0.6298
CV (%)	18.09	28.90	31.03	17.41

#p values less than 0.05 were considered statistically significant according to the Tukey test at 5% significance. ^{ns} not significant.

Table 3. Root length, plant height, stem diameter and dry mass (DM) at 30 DAE of safflower according to seeding depths and loads applied to the wheels.

Variation sources	Root length (cm)	Plant height (cm)	Stem diameter (mm)	DM (g)
Seeding depth (cm)				
4.5	10.2 a	18.1 a	6.1 a	1.93 a
6.5	9.2 b	15.6 b	5.4 b	1.38 b
Loads on press wheels (N)				
117.7	10.0^{ns}	17.3	5.9	1.81
156.9	9.7	16.5	5.7	1.61
196.1	9.3	16.8	5.7	1.55
F Test	——— P value ———			
Seeding depth (A)	0.0314#	0.0043	0.0033	0.0019
Loads on press wheels (B)	0.4558	0.7057	0.4947	0.3782
A × B	0.1257	0.7806	0.2131	0.9331
CV (%)	10.5	10.8	9.2	22.4

Means followed by the same letters in the column do not differ according to the Tukey test at 5% significance. #p values less than 0.05 were considered statistically significant according to the Tukey test at 5% significance. ^{ns} not significant.

of depth softened the effects of the low vigor of the seeds, identified in the emergency stage and promoted the growth of the seedlings. Lower seeding depths allow seedlings to emerge with less energy expenditure, resulting in stronger plants (Zuo et al., 2017). Thus, the results showed significant differences at 30 days after the stabilization of the emergence rate of the morphometric characteristics and dry mass contents of the plants (Table 3). After 30 days from the establishment of the crop, there was a higher accumulation of dry mass, which subsequently reflected in increased grain yield. The correlation between higher dry mass accumulation and increased grain yield was reported by Gomes et al. (2012) in the sunflower crop. Loads on press wheels affected significantly ($P < 0.05$) grain yield. A pressure of 196.1 N resulted in a higher grain yield (725 kg ha^{-1}) compared to a pressure of 117.7 N (443 kg ha^{-1}) (Table 4). The existence of a statistical difference in the grain yield variable may be related to the fact that higher loads imposed by the compacting wheel, according to the physical conditions and soil moisture at the time of seeding, favored the growth process of the safflower. The adequate compaction by the compacting wheels increases the permeability of the soil, maximizes the conduction of water and absorption of nutrients in the root zone (Gomez et al., 2002; Cortez et al., 2006). For the present study, it is assumed that the preparation system has mobilized the soil and superficially altered its structure, by fracturing the aggregates and developing pores. In a second moment, for the growth phases of safflower plants, the compaction exerted by the seeder on the highest load tension applied by the compacting wheels, favored the improvement of the previously unstructured soil structure, decreased excessive macroporosity and increased the density that under these conditions would affect the availability of water to the plants temporarily. Modolo et al. (2010) in a no-tillage system observed that different loads applied by the compactor wheel did not significantly influence the variables of the common bean. Our result may be due to the effect of the compacted wheel pressure on the soil overturned by the harrow.

Material and methods

Site description

The experiment was conducted at the Toledo, Paraná, Brazil (latitude 24°32’38”S, longitude 53°47’42”W and altitude of 550 m). The climate is considered Cfa (subtropical climate), with an

Table 4. Plant height, stem diameter, number of branches (NB), number of chapters (NC) and plants per meter at the stage of 50% of flowering and yield of safflower according to seeding depths and loads applied to the wheels.

Variation sources	Plant height (cm)	Stem diameter (mm)	NB (n.o)	NC (n.o)	Plants per m	Yield (kg ha^{-1})
Seeding depth (cm)						
4.5	134.4^{ns}	13.0	7.12	11.35	6.7	868 a
6.5	133.5	13.1	7.14	12.22	6.0	341 b
Loads on press wheels (N)						
117.7	134.3	13.1	7.03	12.41	5.6	443 b
156.9	133.2	12.9	6.93	10.41	6.5	645 ab
196.1	134.4	13.2	7.43	11.37	6.8	725 a
F Test	———— P value ————					
Seeding depth (A)	0.7039#	0.8925	0.9656	0.5598	0.2032	0.0002
Loads on press wheels (B)	0.9104	0.9257	0.6662	0.5533	0.2775	0.0355
A × B	0.0686	0.8229	0.6662	0.1945	0.7222	0.0948
CV (%)	4.54	10.43	16.65	30.21	24.40	45.6

Means followed by the same letters in the column do not differ according to the Tukey test at 5% significance. #p values less than 0.05 were considered statistically significant according to the Tukey test at 5% significance. ^{ns} not significant.

average annual rainfall above 1800 mm, but with no defined dry season and with the possibility of frost during the winter. The meteorological conditions during the experiment are presented in Fig. 1. The soil of the experimental area was classified as Oxisol (Soil Survey Staff, 2010). Table 1 shows the chemical characteristics of the soil for the experimental area at a depth of 0-20 cm.

Experimental setup

One month before the implementation of the experiment, a harrowing operation was performed to eliminate weeds and level the soil. The seeds were treated with Vitavax® Thiram 200SC fungicide at a dosage of 300 mL of the commercial product 100 kg^{-1} of seeds.

Seeding was performed on May 14, 2018, with relative air humidity at 76%, a maximum temperature of 27 ºC and no precipitation. In the seeding operation, the seeder-fertilizer (model IMASA 908), with 7 planting rows spaced 0.45 m. The seedling-fertilizer was driven by a New Holland® TL90 tractor, with 90 hp of power, mounted on the drawbar. The seeding speed kept the range of 5 km h^{-1}.

The mechanisms for opening seed grooves are of the double-disc type, and for fertilizer distribution, are of the machete type. The furrow covering body, loads on press wheels, consists of a system of two metal wheels coated with solid rubber with a "V" angle.

The regulation of the three loads on press wheels was manually operated by actuating the traction of a helical spring. The three loads on press wheels were determined by the relationship between the force applied on the ground and the contact area of the wheels. The seeding depth adjustment in this seeder is made by adjusting the depth limiter wheels in relation to the double grooving disc for seed deposition. The depth limiter wheels are moved in the vertical direction and adjusted by modifying the travel limiter stop. Both settings were modified row by row of the machine in each plot during the seeding operation.

The adjustment of the seed feeder was made by adjusting the transition of gears and drive-by traction tires. The feeder was assembled with discs adapted to the safflower culture and regulated to distribute 24 seeds per meter. For the base fertilization, a fertilizer formulated 10-15-15 (N-P-K) was used with a distribution of 300 kg ha^{-1} according to the indication of the need for fertilization of the crop and chemical analysis of the soil.

The experimental plots were constituted by 3 lines of 10 m, with spacing between lines of 0.45 m. A safflower genotype provided by the Instituto Matogrossense do algodão-IMAmt was used. The genotype has a germination percentage of 50%, according to previously performed laboratory analyses. The cycle lasted 160 days.

Treatments and experimental design

The experimental design of randomized complete block design (RCBD) arranged in factorial 2 × 3, with four replications. The treatments consisted of two seeding depths (4.5 and 6.5 cm) and three loads applied to the wheels (117.7, 156.9, and 196.1 N). The loads were defined according to the increase in tension of the spring system existing in the seed-fertilizer (Modolo et al., 2007). For the load of 117.7 N no spring compression force was used, only the wheel load; load 156.9 N was used the first compression adjustment of the spring; load 196.1 N was obtained with the second compression adjustment of the spring.

The chosen pressures were estimated by determining the loads exerted, measuring the mass of the loads on press wheels through a hook scale. The pressure was calculated by the contact area of press wheels with result in kgf cm^{-2} and converted into Newton.

Traits evaluated

For the determination of the IVE, we selected one meter of each plot for the accounting of the emergency. The seedlings were considered emerging from the moment they broke the soil surface when a cotyledon was visible from any angle. The monitoring was performed daily after the seeding date, to determine the beginning and end of the emergency (establishment of the emergency) for each treatment. Following the methodology proposed by Maguire (1962), this index is expressed in days^{-1} seed, according to Equation 1.

$$IVE = \frac{E_1}{N_1} + \frac{E_2}{N_2} + \ldots \frac{E_n}{N_n} \quad (1)$$

Where:
E_1, E_2... E_n: number of normal seedlings counted in the first, second, and last counts.
N_1, N_2... N_n: number of seeding days in the first, second, and last counting.
After the analysis of the emergency index, the average emergency time was calculated according to the methodology proposed by Labouriau and Valadares (1976), expressed as days^{-1}, according to Equation 2.

$$TMG = \frac{\sum n_i t_i}{\sum n_i} \quad (2)$$

Where:
n_i = number of seeds sprouting in the interval between each count;
t_i = time elapsed between the beginning of germination and the i-th count.

The average emergency speed was calculated after determining the average emergency time, expressed in days^{-1}, according to Equation 3.

$$AES = \frac{1}{t} \quad (3)$$

Where:
t = average emergency time.

For the emergence rate (E), the final count of the stand of emerged seedlings was performed, expressed in percentage (%), according to Equation 4.

$$E = \frac{\text{nº of emerging seeds}}{\text{total seeds}} \times 100$$

The height of plants was determined in two seasons, when the crop presented 30 days after the stabilization of the emergence rate and when it presented 50% of its flowering. With the aid of a graduated tape measure, the soil level was measured to the highest part of the plant in centimeters, from four random plants within each plot.
The diameter and length of the stem were measured when the crop presented 30 days after the stabilization of the emergence rate and when it presented 50% of its flowering, of four random plants of each plot. For the diameter, a digital pachymeter was used in the basal region of the stem, unit in millimeters, and the length of the stem (cm) with the aid of a graduated ruler. The number of primary branches per plant was quantified by randomly collecting four plants from each plot when the crop presented 50% of its flowering. The dry mass of plants was analyzed when the culture presented 30 days after the stabilization of the emergence rate of four random plants of each plot. The dry mass was made in an oven with forced air circulation at 65 ºC for 72 hours and then weighed using a precision scale.
The number of chapters per plant was determined when the crop reached full maturity of the chapters, from four to six random plants per plot, counting the total number of chapters per plant. The number of plants per meter was counted at the time of harvesting the chapters, and the number of total plants was counted in one random linear meter for each plot. The grain yield was estimated after the complete maturation of the chapters with manual collection and threshing of the capsules and cleaning of one square meter of grain from each plot. The samples were weighed using a precision scale, with four decimal places, adopting a standardized humidity degree of 13% and the calculation corrected to kg ha^{-1}.
The results obtained were submitted to analysis of variance (ANOVA) and the averages by the Tukey test at 5% probability of error using the SISVAR® software.

Conclusions

The emergence rate and final stand of safflower plants were not affected by the seeding depth and loads on press wheels. However, safflower seeding at a depth of 4.5 cm is indicated in relation to a depth of 6.5 cm, due to growth at 30 DAE and grain yield. The higher loads on press wheels of 196.1 N provided higher grain yield compared to 117.7 N. The adjustment of the wheels is an important factor in the process of safflower in Tillage System, which can affect the depth of sowing and safflower yield.

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