Macrothink Institute™

**Journal of Agricultural Studies**
ISSN 2166-0379
2019, Vol. 7, No. 4

# Physiological and Sanitary Quality of Safflower Seeds Under Different Seed Treatments

Janine Farias Menegaes (Corresponding author),

Department of Crop Science, Federal University of Santa Maria, Avenida Roraima, nº1000, Prédio 70, Bairro Camobi, Santa Maria, RS, Brazil. Tel: 55-55-991487031
E-mail: janine_rs@hotmail.com

Ubirajara Russi Nunes

Federal University of Santa Maria, Santa Maria, Brazil

Carla Medianeira Bertagnolli

Farroupilha Federal Institute, Júlio de Castilhos, Brazil

Marlove Fátima Brião Muniz, Rogério Antônio Bellé, Fernanda Alice Antonello Londero Backes

Federal University of Santa Maria, Santa Maria, Brazil

Received: Oct. 8, 2019 Accepted: Oct. 24, 2019 Published: Oct. 28, 2019

doi:10.5296/jas.v7i4.15563 URL: https://doi.org/10.5296/jas.v7i4.15563

**Abstract**

Safflower (*Carthamus tinctorius* L.) presents a high susceptibility for the attack of pathogens, resulting in low productivity of seeds. Thus, we aimed to evaluate the physiological and sanitary quality of safflower seeds submitted to different treatments. The experiment was conducted in the Floricultural Sector and in the Didactic and Seed Research Laboratory, in completely randomized design, with 4x9 (lots of seeds and treatment of seeds), with four repetitions. The lots of seeds were cultivated in the crop 2017/2018, the sowing occurred in the first fortnight of each season of the year (autumn, winter, spring and summer). After collected, the lots were stored in cold chamber with average degree of humidity of 9.0%. The treatments of seeds were constituted by: control, thermotherapy via humid heat,

thermotherapy via dry heat, *Trichoderma harzianum*, chemical fungicide with active ingredients of Carbendazim+Thiram, Metalaxyl-M+Fludioxonil and Carboxin+Thiram, vegetal extracts of *Dendranthema grandiflora* and of *Melia azedaeach*. We evaluated the seeds treated by the standard test of germination, length and mass of seedlings, emergence and sanity. We observed that all the tested treatments benefit the safflower culture, promoting improvement in its germination, with efficient establishment of seedlings in the field. At the same time that was carried out the infestation control of the pathogens on the same, among the treatments we highlight the chemical fungicide with active ingredient Carbendazim+Thiram.

**Keywords:** physiological characters, sanitory quality, Brazil

## 1. Introduction

The *Carthamus tinctorius* L. (safflower), belonging to Asteraceae family, originated in Asia. It is considered as one of the most antique agricultural cultures, and it is cultivated with different purposes of use, since culinary and textile coloring, medicinal oil and biodiesel extraction, to flower stems for ornamentation (Santos and Silva, 2015; Emongor and Oagile, 2017). The production of safflower was stagnated until the 70s, nevertheless, with the high demand of flower stems by Europe, as well as the consumption of medicinal and edible oils, and, mostly, for the biodiesel production, caused that the area and productivity of this culture double in less than 40 years (Hussain et al., 2015; Faostat, 2017).

Worldwide, the safflower is cultivated for production of seeds and, oil extraction in more than 60 countries, the seed productivity, in 2014, was of 882 kg $ha^{-1}$, in area of approximately one million of hectares. In productive volume, average data of crops from 2007 to 2012, the safflower was the eighth oleaginous culture (seeds) destined to biodiesel production at world level, and it is preceded by soybean (*Glycine max* L.), canola (*Brassica napus* L.), peanut (*Arachis hypogaea* L.), sunflower (*Helianthus annus* L.), sesame (*Sesamum indicum* L.), linseed (*Linum usitatissimum* L.) and castor bean (*Ricinus communis* L.) (Rai et al., 2016; Faostat, 2017).

In Brazil, the safflower cultivation is still incipient, however, promising and it is in experimental phase in different regions, with emphasis for the states of São Paulo, Mato Grosso, Goiás and Paraná. According to MAPA (Ministry of Agriculture, Livestock and Supply), in the year of 2012, the country imported the value of US$ 6.1 millions of "sunflower or safflower oils" (Brazil, 2013a), nevertheless, without percentage distinction among the species. In the 1990s, the safflower was introduced in the South region of the country as ornamental plant, in virtue of climate conditions, however, the great incidence of pathogens in all the productive cycle, had its cultivation reduced gradually (Santos and Silva, 2015; Sampaio et al., 2017). However, this species presents itself as an alternative of cultivation in the country, requiring economic-scientific investment for the increase of seed productivity, with phytosanitary quality.

The low productivity of safflower seeds is associated winth the high susceptibility to the attack of pathogens, and it can reduce the output of oil for biodiesel, in average of 75% (Ogut

and Oguz, 2006). The main phytopathogens that affect in the culture are: *Aspergillus* spp., *Botrytis* spp., *Cercospora* spp., *Cladosporium* spp., *Fusarium* spp., *Oidium* spp., *Penicillium* spp., *Phytophthora* spp., *Puccinia* spp., *Ramularia* spp., *Rhizoctinia* spp., *Rhizopus* spp. and *Sclerotinia* spp., among others (Garcia, 1999; Coronado, 2010; Emongor and Oagile, 2017).

The incidence of phytopathogens on the seeds can entail losses to the same and in the establishment of the plant stand in the field. This way, the treatment of seed is primordial in the agricultural management, and it is a technique of easy applicability and economically viable for the protection of seeds from the attack of pathogens presented in soil or transmitted via seed, for that there is no reduction of plant stand (Härter et al., 2014; Sharma et al., 2015).

Although in Brazil, the registration of products in MAPA seeking the treatment of seeds is elevated for agricultural species, there are no molecules of phytosanitary products registered for the safflower culture. In this context, the present work aimed to evaluate the physiological and sanitary quality of safflower seeds submitted to different treatments.

## 2. Material and Methods

The experiment was conducted in the period from May to August 2018, in the Floricultural Sector and in the Didactic and Seed Research Laboratory, both from the Phytotechny Department of Universidade Federal de Santa Maria (UFSM), located in Santa Maria, Rio Grande do Sul, Brazil (29 °43' S; 53 °43' W and altitude of 95m). In completely randomized design, in 4x9 factorial (four lots of seeds and nine treatments of seeds), with four replications.

The lots of safflower seeds (Lasting Orange cultivar) were collected in experimental area of Floricultural Sector, in the crop of 2017/2018. The sowing of the lots occurred in the first fortnight of each season of the year, characterizing the lots as:

**Lot 1:** planted in autumn (April 5$^{th}$, 2017) and collected 146 days after sowing (DAS);

**Lot 2:** planted in winter (July 5$^{th}$, 2017) and collected 127 DAS;

**Lot 3**: planted in spring (October 6$^{th}$, 2017) and collected 98 DAS;

**Lot 4:** planted in summer (December 22$^{nd}$, 2017) and collected 91 DAS. After collected, the seeds were stored in cold chamber (15 ºC and 40% UR) in Kraft paper bag (brown type of 1.0 kg), with average degree of 9.0%, until the execution of this experiment.

The treatment of seeds were constituted by

**Control Sample (Control**) without treatment;

**Physical treatment with thermotherapy via humid heat (PTH):** the seeds were packaged in glass Becker of 500 mL containing distilled water and this maintained in thermodigital water-bath device with water warmed at 45 ℃ 15 min$^{-1}$. Previously, the seeds were moistened in distilled unheated water, during one hour, for eliminating the air pockets between the superficial dead tissues, making it easy the conduction of heat in the seed tissues (Coutinho et al., 2007). After the thermotherapic treatment, the seeds were put to dry on towel-paper at

room temperature by the period of 24 h;

**Physical treatment with thermotherapy via dry heat (PTD):** the seeds were packaged in Kraft paper bags (brown type of 1.0 kg) and submitted to temperature 45 ℃ 24 $h^{-1}$, in greenhouse of forced circulation, for the procedure;

**Biological treatment with *Trichoderma harzianum* (BTT):** lineag ESALQ 1306 (TRICHODERMIL SC 1306®), toxicological classification III (moderately toxic), dose of 400 mL 100 $kg^{-1}$ of seeds;

**Chemical treatment with systemic fungicide (CTS):** right for treatment of seeds with active ingredient (i.a.) Carbendazim+Thiram (DEROSAL PLUS 500 SC®), toxicological classification III (moderately toxic), in dose of 200 mL 100 $kg^{-1}$ of seeds, having 30 and 70 g i.a., respectively, we used the recommended dose for the corn culture (*Zea mays* L.);

**Chemical treatment with contact fungicide (CCF):** right for treatment of seeds with i.a. Metalaxyl-M+Fludioxonil (MAXIM XL®), toxicological classification III (moderately toxic), in dose of 200 mL 100 $kg^{-1}$ of seeds, having 2 and 5 g i.a., respectively, we used the recommend doses for the cultures of sunflower and corn;

**Chemical treatment with systemic fungicide and of contact (CSC):** right for treatment of seeds with i.a. Carboxin+Thiram (VITAVAX-THIRAM 200 SC®), toxicological classification I (extremely toxic), in dose of 250 mL 100 $kg^{-1}$ of seeds, having 50 and 50 g i.a., respectively, we used the recommended dose for the corn culture;

**Treatment with aqueous vegetal extract (TAV):** in concentrated solution of 10% of Chrysanthemum leaf extract (*Dendranthema grandiflora* Tzvelev). The extract was prepared with collected leaves in the morning period, to avoid the dehydration, in the sequence the same were sanitized with three consecutive washings in running water. The sanitized leaves were blended with 100 mL of distilled water in concentration of 10% (10 g of fresh leaves at 100 $mL^{-1}$ distilled water). The extract obtained was stored, decanting it for 24 h in room temperature and with absence of light. After, the same were filtered separately in Wathman paper n.1, identified on the packages and stored.

**Treatment with dry macerated vegetal extract (TMV):** in concentration of 2.0 g dry macerated of cinnamon leaves (*Melia azedarach* L.) for one kilo of seeds. Dry extract was prepared with the leaves collected in the morning period, to avoid the dehydration, in the sequence the same were sanitized with three consecutive washings in running water. The sanitized leaves were dried in greenhouse of forced ventilation at 30 ℃ until the stabilization of dry mass (60 h), in the sequence the same were blended until they formed dust, after sieved (mesh 0.05 mm) were stored in Kraft paper bags to avoid the light passage.

For the application the treatments of chemical seeds and dry macerated, the products and the seeds were put in glass Becker of 500 mL, with addition of distilled water (with volume equivalent to 5% of total mass of seeds) and, with manual agitation for five minutes. For the control and physical treatment of seeds, the same procedure was adopted, however, only with distilled water. For the treatments of seeds, biological and aqueous, the same procedure was

adopted, however because they were liquid, it was not added to the seeds distilled water.

After the seeds were treated, we evaluated the quality of them using tests:

**Mass of one thousand seeds:** determined by the method by Brazil (2009a), with four repetitions.

**Degree of humidity of seeds:** determined by the method of greenhouse 105±3 ℃ for 24 h, using four repetitions of 5 g (adapted BRAZIL, 2009a).

**Germination standard test (GST) and germination speed index (IVG):** the seeds, with four repetitions of 50 units, were distributed in germination paper roll, moistened with distilled water in the proportion of 2.5 times the mass of dry paper. The rolls were maintained in BOD (Box Organism Development) type germinator, with photoperiod of 24 h (constant light) and temperature of 25±2 ℃ (Brazil, 2009a). The evaluations of germination were at four and at 14 DAS (days after sowing), and the results expressed in percentage of normal seedlings, abnormal seedlings (including the infested and damaged ones) and dead seeds. The IVG was carried out with daily evaluations according the methodology by Maguire (1962), we used as criteria of germination the stretching of primary root and emergence of cotyledons (Abud et al., 2010).

**Length and dry mass of seedling:** the seeds, with four repetitions of 20 units, were maintained under the same condition of GST, at four DAS, it was measured the length of aerial part and of rootlets of ten normal seedlings of each repetition, the results were expressed in centimeters (cm). In the sequence, we determined total dry mass by drying of the material in greenhouse of forced ventilation at 65±5 ℃ for 48 h, the results were expressed in mg $pl^{-1}$ (Nakagawa, 1999).

**Emergence in the field and emergence speed index (IVE):** the seeds, with four repetitions of 50 units, were distributed in lines of 1 m, spaced at 0.2 m and with depth of 0.03 m, final evaluation was performed at 14 DAS, with expressed results in emergence percentage of seedling. The IVE was carried out with daily evaluations according to the methodology by Maguire (1962), we used as criteria of emergence the complete development of cotyledons and epicotyl (Abud et al., 2010).

For the germination variables and emergence of seedlings in the field, we used as reference the Normative Instruction n.45/2013 of the sunflower culture, because they belong to the same botanical family of safflower (Asteraceae), and it is demanded values 65-70% (Brazil, 2013b).

**Sanity test:** the seeds, with four repetitions of 50 units, were distributed in transparent plastic boxes for germination under the sterilized paper substrate in autoclave and moistened with distilled water corresponding to 2.5 times the mass of dry paper. The seeds were maintained in freezer for 24 h at temperature of 06±1 ℃, in the sequence the seeds were conducted in BOD, where they remained for five days with photoperiod of 12 h of light and 12 h of darkness, at temperature of 20±2 ℃ (Brazil, 2009b). In the sequence, the seeds were evaluated in magnifying glass (microscope stereoscope) according to the morphological

characteristics of phytopathogens at level of genus, and the results expressed in percentage of infested seeds.

**Germination increment index at 14 DAS** (II.GER): it was determined by methodology adapted by Ahmad et al. (2012), expressed in Equation [II.GER=((GERts-GERt)/GERt)*100], in which: GERts: germination of treatment of seeds and GERt: germination of control treatment.

**Increment index and emergence of seedling in the field** (II.ESF): it was determined by methodology adapted by Ahmad et al. (2012), expressed in Equation [II.ESF=((ESFts-ESFt)/ESF t)*100], in which: ESFts: emergence of treatment of seeds and ESFt: germination of control treatment.

**Control index of total infested seeds** (IC.TIS): it was determined by methodology adapted by Ahmad et al. (2012), expressed in Equation [IC.TIS=((TISt-TISts)/TISt)*100], in which: TISts: infested seeds in the treatment of seeds and TISt: germination of control treatment.

The data expressed in percentage were transformed in arc-sine $\sqrt{x/100}$. The analysis of variance of data and the comparison of average by the test of Scott-Knott ($p<0.05$) were performed with the help of SISVAR program (Ferreira, 2014).

## 3. Results and Discussion

The mass results of one thousand seeds for the lots 1, 2, 3, and 4 of safflower seeds were of 38.8; 40.1, 39.9 and 41.0 g and the same presented initially, degrees of humidity of 8.35, 8.63, 8.60 and 8.82% respectively.

In germination at four DAS (we verified that the treatments of seeds promoted improvement in the germinability potential expression, highlighting the chemical treatment with systemic fungicide (CTS) with average of 51% for all the lots (Table 1).

Table 1. Germination at four and 14 DAS (days after seeding), emergence of seedlings in the field and total infested seeds of safflower submitted to different seeds treatment

| Lots of seeds | Treatments of seeds[A] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | PTH | PTD | BTT | CTS | CCF | CSC | TAV | TMV | Average |
| | Germination at four DAS (%) | | | | | | | | | |
| Lot 1 | 38 Cb* | 45 Ab | 42 Ab | 47 Aa | 51 Aa | 44 Ab | 46 Ab | 39 Bb | 39 Bb | 43 |
| Lot 2 | 39 Cb | 48 Aa | 47 Aa | 49 Aa | 50 Aa | 49 Aa | 49 Aa | 43 Ba | 43 Ba | 46 |
| Lot 3 | 40 Cb | 45 Bb | 43 Bb | 47 Aa | 51 Aa | 44 Bb | 47 Ab | 41 Ca | 41 Ca | 44 |
| Lot 4 | 43 Ca | 46 Bb | 43 Cb | 48 Ba | 52 Aa | 45 Cb | 48 Ba | 43 Ca | 43 Ca | 46 |
| Average | 40 | 46 | 44 | 48 | 51 | 46 | 47 | 41 | 42 | |
| CV (%) | 1.70 | | | | | | | | | |
| | Germination at 14 DAS (%) | | | | | | | | | |
| Lot 1 | 68 Dc* | 80 Bb | 76 Cc | 84 Bb | 91 Ab | 79 Cc | 83 Bc | 69 Dc | 71 Dc | 78 |
| Lot 2 | 70 Db | 85 Aa | 83 Ba | 87 Aa | 89 Ac | 87 Aa | 87 Aa | 76 Ca | 78 Ca | 82 |
| Lot 3 | 72 Db | 80 Cb | 76 Dc | 84 Bb | 91 Ab | 79 Cc | 83 Bc | 73 Db | 73 Db | 79 |
| Lot 4 | 76 Da | 81 Cb | 78 Cb | 86 Ba | 93 Aa | 81 Cb | 85 Bb | 77 Da | 77 Da | 81 |
| Average | 71 | 81 | 78 | 85 | 91 | 81 | 85 | 74 | 74 | |
| CV (%) | 1.60 | | | | | | | | | |
| | Emergence in the field (%) | | | | | | | | | |
| Lot 1 | 70 Dd* | 83 Bc | 79 Cb | 86 Bb | 93 Ab | 82 Bb | 86 Bb | 71 Dc | 72 Dd | 80 |
| Lot 2 | 72 Dc | 89 Aa | 86 Ba | 91 Aa | 92 Ab | 89 Aa | 89 Aa | 79 Ca | 81 Ca | 85 |
| Lot 3 | 75 Db | 83 Bc | 80 Cb | 88 Ba | 95 Aa | 81 Cb | 85 Bb | 75 Db | 76 Dc | 82 |
| Lot 4 | 79 Da | 85 Cb | 81 Db | 89 Ba | 94 Aa | 83 Cb | 88 Ba | 80 Da | 79 Db | 84 |
| Average | 74 | 85 | 81 | 88 | 94 | 84 | 87 | 76 | 77 | |
| CV (%) | 1.79 | | | | | | | | | |
| | Total infested seeds (%) | | | | | | | | | |
| Lot 1 | 46 Ac* | 13 Db | 25 Ca | 30 Bb | 0 Fb | 8 Da | 9 Db | 31 Bb | 29 Ba | 21 |
| Lot 2 | 55 Aa | 19 Da | 27 Ca | 30 Bb | 0 Fb | 6 Ea | 15 Da | 32 Bb | 33 Ba | 24 |
| Lot 3 | 49 Ab | 17 Da | 23 Ca | 33 Ba | 5 Ea | 6 Ea | 14 Da | 35 Ba | 32 Ba | 24 |
| Lot 4 | 41 Ad | 14 Db | 26 Ca | 34 Ba | 0 Fb | 5 Ea | 15 Da | 36 Ba | 23 Ca | 22 |
| Average | 48 | 16 | 25 | 32 | 1 | 6 | 13 | 34 | 29 | |
| CV (%) | 15.35 | | | | | | | | | |

[A] Control treatment (control; Control); Physical treatment with thermotherapy via humid heat (PTH); physical treatment with thermotherapy via dry heat (PTD); biological treatment with *Trichoderma harzianum* (BTT); chemical treatment with systemic fungicide (CTS); chemical treatment with contact fungicide (CCF); chemical treatment with systemic fungicide and of contact (CSC); treatment with aqueous vegetal extract (TAV) and treatment with dry macerated vegetal extract (TMV).

*Test of averages that are not followed by letter, uppercase in line and lowercase in column, differ by test of Scott-Knott ($p<0.05$). CV: coefficient of variation.

The initial physiological quality of lots 1, 2, 3 and 4 of seeds were of 68, 70, 72 and 76% for germination at 14 DAS and, of 70, 72, 75 and 79% of emergence of seedlings in the field, respectively, characterizing themselves as commercial lots according the standards of MAPA (Brazil, 2013b). We observed that the different treatments of seeds helped in the physiological potential expression of all the seeds, in which the germination and emergence of seedlings presented percentage values of inside and/or above the acceptable range by MAPA.

The physical treatments of seeds using different sources of heat helped in physiological potential expression of seeds with average of 81 and 78% for germination and, of 85 and 81% of emergence of seedlings in the field, for the treatments of thermotherapy via humid heat (PTH) and dry heat (PTD), respectively. Braga et al. (2010) and Gama et al. (2014) pointed that the use of thermotherapic methods are viable for the treatment of tomato seeds (*Solanum lycopersicum* L.) and fennel (*Foeniculum vulgare* Mill.), respectively and, with low environmental impact, offering an alternative to the use of chemical products. And the success of each method is in knowing an appropriate combination between temperature levels and heat exposure temperatures, what is the quality of the seeds submitted.

Medeiros et al. (2015), also, reported that the use of plant extracts with antimicrobial properties are ecological and promising alternatives for agriculture and of low environmental impact, observed for the pau-ferro forest species (*Caesalpinia ferrea* Mart. ex Tul.). Results of this work corroborated with the authors mentioned above, because the treatments with aqueous vegetal extract (TAV) with chrysanthemum leaves and dry macerated (TMV) with chinaberry leaves, also, were efficient in the promotion of physiological potential expression of safflower seeds, presenting germination average at four and 14 DAS and emergence superior to the average of the control treatment.

The biological treatment with *Trichoderma harzianum* (BTT) was efficient in physiological potential expression of safflower seeds, in emergence of seedlings in the field with average of 88% for all the lots, and this can be attributed to the positive interaction between the seed-fungus-soil system. Machado et al. (2015) point out the benefit of the use of *Trichoderma* for promotion of plant growth of cambara (*Gochnatia polymorpha* (Less.) Cabrera) and, that this promotion depends on the properties and action mechanisms of the organism with the environment.

The efficiency of the treatments of seeds using chemical fungicides with active ingredients of Carbendazim+Thiram (CTS), Metalaxyl-M+Fludioxonil (CCF) and Carboxin+Thiram (CSC) are proven both for the improvement of physiological potential expression as sanitary for the safflower seeds. Silva Neto et al. (2013) verified positive results in physiological potential of cowpea seeds (*Vigna unguiculata* L. Walp) treated with the same fungicides above mentioned.

The safflower seeds presented high incidence of phytopathogens with average of 48% of total infested seeds (TIS) in the sanity test for all the lots of seeds (Table 1). Nevertheless, we observed expressive reduction in the phytopathogens infestation in seeds according to the different treatments tested in this work, and this reduction is beneficial for the physiological and sanitary quality of safflower seeds. Flávio et al. (2014) report that the dissemination of phytopathogens via seed affects negatively the establishment of plant stand in the field, mostly its productivity.

The table 2 exposes the incidence of phytopathogens on the lots of safflower seeds average submitted to different treatments of seeds, and these ones did not differ significantly among the tested factors. This way, the individualized average test by treatment of seed is presented. The phytopathogens of greater incidence identified in the safflower seeds were the ones from

the genus *Aspergillius* spp., *Botrytis* spp., *Fusarium* spp., *Nigrospora* spp., *Penicillium* spp., *Rhizopus* spp. and *Sclerotinia* spp..

Girardi et al. (2013) working with the quality of safflower seeds collected in different periods of maturation, also verified high incidence of phytopathogens in these seeds, and *Aspergillus* spp., *Fusarium* spp. and *Penicillium* spp. are the most relevant ones. Reverberi et al. (2010) mentioned *Aspergillus* spp., *Fusarium* spp. and *Penicillium* spp. as the phytopathogens that contribute the most to the deterioration of seeds, in virtue of the production of mycotoxins on the same, depreciating its physiological quality.

Garcia (1999) reports that the main causers of damage to the safflower culture are the pathogens from the *Botryti*s spp. genus, because the presence of these pathogens in the flowering phase of safflower attack the ligules and host themselves inside the capitulum (inflorescence), depreciating the ornamental value of floral stems and impairing the germination of seeds, by shrinkage

The pathogens of *Nigrospora* spp., *Rhizopus* spp. and *Sclerotinia* spp. genus presented low percentage of incidences on the safflower seeds. Venturoso et al. (2015) verified that the pathogens of *Sclerotinia* spp. genus incident on the seeds of oleaginous cultures such as safflower, crambe (*Crambe abssynica* Hochs), sunflower, forage turnip (*Raphanus sativus* L.) and niger (*Guizotia abyssinica* L.f. Cass.), reduced the percentage and emergence speed of seedlings.

In the germination test we observed that the abnormal seedlings and dead seeds did not present statistical difference among the tested factors (Table 2). This indicates that the different treatments of seeds were effective in maintaining the physiological quality of seeds, without causing phytotoxic effect and damage to the membrane of the same. Marcos-Filho (2015a) report that the maintenance of the integrity of the membrane system is fundamental for the preservation of the vitality and viability of seeds, which will allow the process of germination in favorable environmental conditions.

We verified that there was no significant interaction of the tested factors for the plant biometric parameters (Table 2), with the germination speed index (IVG) and of emergence (IVE), length and root dry mass and aerial part. Marcos-Filho (2015b) point out that these biometric parameters are used as potential phytotoxic detectors of the effects of chemical products, such as fungicides, insecticides, among others that cause damage in plant growth and development.

This demonstrates that the safflower seeds when receiving different treatments did not suffer phytotoxic damage by the same, maintaining the physiological quality of seeds similar to the control treatment. The same author, also, reports that vigor tests considering speed index, length and dry mass of seedlings are important components of the seed performance, affecting directly the establishment of the plant stand in the field.

The similarities in the results of IVG and IVE indicate that the different treatments of seeds did not cause damage to the membranes permitting the physiological potential expression in favorable conditions of laboratory an in the field, respectively. Machado (2000) reports that

the treatment of seeds has as objective to ensure their physiological and sanitary quality, in a way that enables the germination and emergence processes. Marcos-Filho (2015a) exemplifies that the initial development of seedlings, specially, is expressed by the emergence rate (physiological potential) that can be related with the adaptation and interaction of seeds with the climate conditions to which they were exposed.

Table 2. *Aspergillius* spp. (ASP), *Botrytis* spp. (BOT), *Fusarium* spp. (FUS), *Nigrospora* spp. (NIG), *Penicillium* spp. (PEN), *Rhizopus* spp. (RIZ) and *Sclerotinia* spp. (SCL) incidents in seeds and abnormal seedlings (PAN), dead seeds (SEM), germination speed index (IVG) and of emergence (IVE), root length (CPR) and of aerial part (CPA) of seedlings, root dry mass (MSR) and of aerial part (MSA) of seedlings of safflower submitted to different seeds treatment

| Parameters | Treatments of seeds [A] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | PTH | PTD | BTT | CTS | CCF | CSC | TAV | TEVS | CV (%) |
| ASP (%) | 30 b* | 22 b | 14 c | 17 c | 6 d | 6 d | 0 e | 50 a | 55 a | 26.11 |
| BOT (%) | 5 b* | 3 b | 6 b | 0 c | 19 a | 19 a | 0 c | 7 b | 13 a | 16.40 |
| FUS (%) | 19 b* | 9 c | 29 a | 18 b | 0 d | 39 a | 7 c | 28 a | 0 d | 36.72 |
| NIG (%) | 13 a* | 17 a | 12 a | 17 a | 0 c | 0 c | 0 c | 15 a | 7 b | 16.84 |
| PEN (%) | 10 c* | 24 b | 23 b | 18 b | 0 d | 36 a | 13 c | 0 d | 18 b | 31.62 |
| RIZ (%) | 14 a* | 0 b | 0 b | 16 a | 0 b | 0 b | 0 b | 0 b | 0 b | 21.87 |
| SCL (%) | 9 c* | 25 b | 15 b | 14 b | 0 d | 0 d | 80 a | 0 d | 7 c | 38.28 |
| PAN (%) | 16 a* | 8 c | 12 b | 8 c | 2 d | 6 c | 12 b | 14 b | 18 a | 29.53 |
| SEM (%) | 13 a* | 11 a | 10 a | 7 b | 7 b | 13 a | 3 c | 12 a | 8 b | 30.19 |
| IVG (%) | 39.1 d* | 47.6 b | 40.6 c | 41.8 c | 43.0 c | 36.8 d | 43.3 c | 46.3 b | 51.1 a | 17.16 |
| IVE (%) | 18.7 c* | 21.3 b | 15.8 d | 14.9 d | 22.2 b | 14.8 d | 16.9 d | 22.3 b | 24.4 a | 17.31 |
| CPR (cm) | 4.5 c* | 4.9 b | 4.8 b | 4.5 c | 5.4 a | 5.4 a | 5.3 a | 5.0 b | 5.2 a | 25.79 |
| CPA (cm) | 0.8 c* | 1.3 b | 1.3 b | 1.2 b | 1.9 a | 1.0 c | 1.8 a | 0.9 c | 1.0 c | 44.60 |
| MSR (mg $pl^{-1}$) | 1.6* | 2.9 b | 3.4 a | 2.5 c | 2.1 c | 2.5 c | 2.7 b | 1.7 d | 1.8 d | 23.40 |
| MSA (mg $pl^{-1}$) | 8.0 b* | 7.3 c | 6.2 d | 7.6 c | 7.5 c | 8.1 b | 7.8 b | 9.9 a | 10.4 a | 22.99 |

[A] Control treatment (control; Control); physical treatment with thermotherapy via humid heat (PTH); physical treatment with thermotherapy via dry heat (PTD); biological treatment with *Trichoderma harzianum* (BTT); Chemical treatment with systemic fungicide (CTS); chemical treatment with contact fungicide com (CCF); chemical treatment with systemic fungicide and of contact (CSC); treatment with aqueous vegetal extract (TAV) and treatment with dry macerated vegetal extract (TMV).

*Test of averages are not followed by letter differ by the test of Scott-Knott ($p<0.05$) for the factor of treatment of seeds. CV: coefficient of variation.

The table 3 exposes the evaluation of germination increment indexes at 14 DAS (II.GER) and emergence of seedlings in the field (II.ESF) and the control index of total infested seeds (IC.TIS) promoted by the use of different treatments of seeds in relation to the control treatment that was positive with significant interaction for the tested factors. Medeiros et al. (2015) pointed out that, according to the efficiency of the fungal control promotes the

reduction of micoflora on the seeds, the physiological quality of the same is potentialized, increasing the germinative percentage both in conditions of laboratory and in the field, corroborating with the results of this work.

All the treatments of seeds tested in this work were efficient in the promotion of the physiological potential expression of safflower seeds in relation to the control treatment, as well as, in the sanitary quality, and all of them were efficient in pathogenic control on the same. Nabizadeh, Yousefi and Gerami (2012) point out that the use of treatment of safflower seeds has as objective to provide improvement in germination rate, as well as the uniformity of development and the time reduction of emergence in the field.

Table 3. Germination increment index (II.GER) and of emergence in the field (II.ESF) and index of total infested seeds of control (IC.TIS) of safflower submitted to different seeds treatment

| Lots of seeds | Treatments of seeds [A] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | PTH | PTD | BTT | CTS | CCF | CSC | TAV | TMV | Average |
| | II. GER (%) | | | | | | | | |
| Lot 1 | 18 Cb* | 12 Cb | 24 Ba | 34 Aa | 17 Cb | 23 Ba | 2 Da | 5 Db | 17 |
| Lot 2 | 22 Ba | 20 Ba | 25 Aa | 27 Ab | 25 Aa | 25 Aa | 9 Ca | 12 Ca | 21 |
| Lot 3 | 11 Bc | 5 Cc | 16 Bb | 26 Ab | 10 Bc | 16 Bb | 1 Ca | 1 Cb | 11 |
| Lot 4 | 7 Cd | 2 Dc | 12 Bc | 22 Ac | 6 Cc | 12 Bb | 1 Da | 0 Ec | 8 |
| Average | 14 | 10 | 19 | 27 | 15 | 19 | 3 | 4 | |
| CV (%) | 4.37 | | | | | | | | |
| | II.ESF (%) | | | | | | | | |
| Lot 1 | 19 Cb* | 13 Db | 23 Ba | 33 Aa | 18 Ca | 24 Ba | 1 Eb | 3 Eb | 17 |
| Lot 2 | 24 Aa | 20 Ba | 27 Aa | 29 Aa | 24 Aa | 24 Aa | 10 Ca | 13 Ca | 22 |
| Lot 3 | 11 Cc | 7 Dc | 17 Bb | 27 Aa | 8 Db | 14 Bb | 1 Eb | 1 Eb | 11 |
| Lot 4 | 7 Cc | 3 Dc | 13B b | 20 Ab | 5 Cb | 12 Bb | 2 Db | 1 Db | 8 |
| Average | 15 | 11 | 20 | 27 | 14 | 18 | 3 | 4 | |
| CV (%) | 4.64 | | | | | | | | |
| | IC.SIT (%) | | | | | | | | |
| Lot 1 | 71 Ca* | 45 Db | 34 Eb | 100 Aa | 84 Bb | 80 Ba | 31 Eb | 36 Eb | 60 |
| Lot 2 | 63 Cb | 47 Db | 40 Da | 100 Aa | 88 Ba | 70 Cb | 39 Da | 40 Da | 61 |
| Lot 3 | 65 Bb | 54 Ca | 30 Db | 90 Ab | 87 Aa | 71 Bb | 27 Dc | 33 Db | 57 |
| Lot 4 | 66 Cb | 37 Dc | 13 c | 100 Aa | 87 Ba | 64 Cc | 7 Ed | 41 Da | 52 |
| Average | 66 | 46 | 29 | 97 | 86 | 71 | 26 | 37 | |
| CV (%) | 3.52 | | | | | | | | |

[A] Physical treatment with thermotherapy via humid heat (PTH); physical treatment with thermotherapy via dry heat (PTD); biológical treatment with *Trichoderma harzianum* (BTT); chemical treatment with systemic fungicide (CTS); chemical treatment with contact fungicide (CCF); chemical treatment with systemic fungicide and of contact (CSC); treatment with aqueous vegetal extract (TAV) and treatment with dry macerated vegetal extract (TMV).

* Test of averages that are no followed by letter, uppercase in line and lower case in column, differ by test of Scott-Knott ($p<0.05$). CV: coefficient of variation.

We verified that the chemical treatment with CTS systemic fungicide was the one that promoted the most II.GER, II.ESF and IC.DIT in average percentages of 27, 27 and 97%, respectively, for all the lots of safflower seeds, in relation to the control treatment. Vechiato and Parisi (2013) reported the importance of sanitary quality of seeds for the formation of plant stand, because the infestations of pathogenic fungus associated to seeds in the field cause rottenness, leaf spots and damage still in plant stage.

We observed that all the treatments presented positive results for the sanitary quality, and the physical, biological treatment of seeds, and with vegetal extracts, an alternative of use to chemical products, with efficiency. Sharma et al. (2015) reported that the different forms of treatment of seeds increased the precision and efficacy of culture establishment in the field, having a fundamental role in sustainable agricultural production and that this cannot be ignored.

## 4. Conclusion

The different treatments of safflower seeds were efficient in the infestation control of phytopathogens on the seeds, promoting also an increasing in its potential of germination and emergence of seedlings in the field. Among the tested treatments, we highlight the chemical fungicide (CTS) with active ingredient Carbendazim+Thiram.

## Acknowledgements

To Coordination for the Improvement of Higher Education Personnel (CAPES) by the incentive and financing of this work and to Postgraduate Program in Agronomy from Federal University of Santa Maria (UFSM).

## References

Abud, H. F., Gonçalves, N. R., Reis, E. G. E., Gallão, M. I., & Innecco, R. (2010). Morfologia de sementes e plântulas de cártamos. *Revista Ciência Agronômica*, *41*(2), 259-265. https://doi.org/10.1590/S1806-66902010000200013

Ahmad, I., Akhtar, M. J., Zahir, Z. A., & Jamil, A. (2012). Effect of cadmium on seed germination and seedling growth of four wheat (*Triticum aestivum* L.) cultivars. *Pakistan Journal of Botany*, *44*(5), 1569-1574.

Braga, M. P., Olinda, R. A., Homma, S. K., & Dias, C. T. S. (2010). Relações entre tratamento térmico, germinação, vigor e sanidade de sementes de tomate. *Revista Brasileira de Sementes*, *32*(1), 101-110. https://doi.org/10.1590/S0101-31222010000100012

Brazil. (2009a). Ministério da Agricultura, Pecuária e Abastecimento. *Regras para Análise de Sementes*. Brasília: MAPA, 395p.

Brazil. (2009b). Ministério da Agricultura, Pecuária e Abastecimento. *Manual de Análise Sanitária de Sementes*. Brasília: MAPA, 200p.

Brazil. (2013a). *Intercâmbio comercial do agronegócio - principais mercados de destino*. Brasília: Ministério da Agricultura, Pecuária e Abastecimento. 449p.

Brazil. (2013b). Ministério da Agricultura, Pecuária e Abastecimento. *Instrução Normativa n. 45*. Brasília. MAPA. 38p.

Coronado, L. M. (2010). *El cultivo del cártamo* (*Carthamus tinctorius* L.) *en México*. Ciudade Obregon: SGI. 96p.

Coutinho, W. M., Silva-Mann, R., Vieira, M. G. G. C., Machado, C. F., & Machado, J. C. (2007). Qualidade sanitária e fisiológica de sementes de milho submetidas à termoterapia e condicionamento fisiológico. *Fitopatologia Brasileira, 32*(6), 458-4654. https://doi.org/10.1590/S0100-41582007000600002

Emongor, V., & Oagile, O. (2017). *Safflower production*. Botswana: The Regional Universities Forum for Capacity Building in Agriculture - RUFORUM. 67p.

Faostat. (2017). Food and Agriculture Organization of the United Nations Statistics Division. *Crops: Safflower*. 2017. Disponível em: <http://faostat3.fao.org/browse/Q/QC/E>. Acesso em: 20 mar. 2018.

Ferreira, D. F. (2014). Sisvar: A guide for its bootstrap procedures in multiple comparisons. *Ciência e Agrotecnologia, 38*(2), 109-112. https://doi.org/10.1590/S1413-70542014000200001

Flávio, N. S. D. S., Sales, N. L. P., Aquino, C. F., Soares, E. P. S., Aquino, L. F. S., & Catão, H. C. R. M. (2014). Qualidade sanitária e fisiológica de sementes de sorgo tratadas com extratos aquosos e óleos essenciais. *Semina: Ciências Agrárias, 35*(1), 7-20. https://doi.org/10.5433/1679-0359.2014v35n1p7

Gama, J. S. N., Neto, A. C. A., Bruno, R. L. A., Pereira Júnior, L. R., & Medeiros, J. G. F. (2014). Thermotherapy in treating fennel seeds (Foeniculum vulgare Mill.): effects on health and physiological quality. *Revista Ciência Agronômica, 45*(4), 842-849. https://doi.org/10.1590/S1806-66902014000400023

Garcia, A. G. (1999). *Cultivos herbaceos extensivos*. Barcelona: Ed. Mundi-Prensa. 779p.

Girardi, L. B., Bellé, R. A., Lazarotto, M., Michelon, S., Girardi, B. A., & Muniz, M. F. B. (2013). Qualidade de sementes de cártamo colhidas em diferentes períodos de maturação. *Revista Acadêmica de Ciências Agrárias e Ambiental, 11*(1), S67-S73. https://doi.org/10.7213/academica.10.S01.AO08

Härter, L. S. H., Deuner, C., Meneghello, G. E., & Villela, F. A. (2014). Salinidade e desempenho fisiológico de sementes e plântulas de mogango. *Horticultura Brasileira, 32*(1), 80-85. https://doi.org/10.1590/S0102-05362014000100013

Hussain, M. I., Lyra, D. A., Farooq, M., Nikoloudakis, N., & Khalid, N. (2015). Salt and drought stresses in safflower: a review. *Agronomy for Sustainable Development, 34*(4), 1-32. https://doi.org/10.1007/s13593-015-0344-8

Machado, D. F. M., Tavares, A. P., Lopes, S. J., & Silva, A. C. F. (2015). *Trichoderma* spp. na emergência e crescimento de mudas de cambará (*Gochnatia polymorpha* (Less.) Cabrera). *Revista Árvore*, *39*(1), 167-176. https://doi.org/10.1590/0100-67622015000100016

Machado, J. C. (2000). Tratamento de sementes no controle de doenças. Lavras: UFLA, 138p.

Maguire, J. D. (1962). Speed of germination aid in selection and evaluation for seedling emergence and vigor. *Crop Science*, *2*(2), 176-177. https://doi.org/10.2135/cropsci1962.0011183X000200020033x

Marcos-Filho, J. (2015a). Fisiologia de sementes de plantas cultivadas. ABRATES: Londrina, 650p.

Marcos-Filho, J. (2015b). Review: Seed vigor testing: an overview of the past, present and future perspective. *Scientia Agricola*, *72*(4), 363-374. https://doi.org/10.1590/0103-9016-2015-0007

Medeiros, J. G. F., Araújoneto, A. C., Silva, E. C., Huang, M. F. N., & Nascimento, L. C. (2015). Qualidade sanitária de sementes de *Caesalpinia ferrea*: incidência de fungos, controle e efeitos na qualidade fisiológica com o uso de extratos vegetais. *Floresta*, *45*(1), 163-174. https://doi.org/10.5380/rf.v45i1.34074

Nabizadeh, E., Yousefi, F., & Gerami, F. (2012). Osmopriming effects on safflower (*Carthamus tinctorius* L.) seed germination and seedling growth. *European Journal of Experimental Biology*, *2*(3), 623-630.

Nakagawa, J. (1999). *Testes de vigor baseados na avaliação das plântulas*. In: Krzyzanoswki, F. C., Vieira, R. D. & França Neto. J. B. Vigor de sementes: conceitos e testes. Londrina: ABRATES. 218p.

Ogut, H., & Oguz, H. (2006). Biodiesel: Third Millennium Fuel. Nobel Publication, n.745, 55- 60.

Rai, S. K., Charak, D., & Bharat, R. (2016). Scenario of oilseed crops across the globe. *Plant Archives*, *16*(1), 125-132.

Reverberi, M., Ricelli, A., Zjalic, S., Fabbri, A. A., & Fanelli, C. (2010). Natural functions of mycotoxins and control of their biosynthesis in fungi. *Applied Microbiology and Biotechnology*, *87*(3), 899-911. https://doi.org/10.1007/s00253-010-2657-5

Sampaio, M. C., Santos, R. F., Bassegio, D., Vasconselos, E. S., Silveira, L., Lenz, N. B. G., … Toku, L. K. (2017). Effect of plant density on oil yield of safflower. *African Journal of Agricultural Research*, *12*(25), 2147-2152. https://doi.org/10.5897/AJAR2016.11370

Santos, R. F., & Silva, M. A. (2015). *Carthamus tinctorius* L.: Uma alternativa de cultivo para o Brasil. *Acta Iguazu*, *4*(1), 26-35.

Sharma, K. K., U.S. Singh, U. S., Sharma, P., Kumar, A., & Sharma, L. (2015). Seed treatments for sustainable agriculture - A review. *Journal of Applied and Natural Science*,

*7*(1), 521- 539. https://doi.org/10.31018/jans.v7i1.641

Silva Neto, M. L., Smiderle, O. J., Silva, K., Fernandes Junior, P. I., Xavier, G. R., & Zilli, J. E. (2013). Compatibilidade do tratamento de sementes de feijao-caupi com fungicidas e inoculação com estirpes de *Bradyrhizobium. Pesquisa Agropecuária Brasileira*, *48*(1), 80-87. https://doi.org/10.1590/S0100-204X2013000100011

Vechiato, M. H., & Parisi, J. J. D. (2013). Importância da qualidade sanitária de sementes de florestais na produção de mudas. *Biológico, 75*(1), 27-32.

Venturoso, L. R., Bacchi, L. M. A., Gavassoni, W. L., Venturoso, L. A. C., Pontin, B. C. A., & Reis, G. F. (2015). Inoculação de *Sclerotinia sclerotiorum* em sementes de oleaginosas: transmissão e seus efeitos sobre a emergência de plantas. *Ciência Rural, 45*(5), 788-793. https://doi.org/10.1590/0103-8478cr20140374