

# Agronomic Performance of Wheat Cultivars Under Different Sowing Densities in Southern Brazil

## ABSTRACT

Sowing density is one of the management techniques that most influence wheat crops. This management practice may affect the plant productive behavior, leading to changes in tillers growth, and also interferes with the plant architecture by influencing solar radiation uptake by the plant canopy, the production components and grain yield. This work aimed to assess the agronomic performance of two wheat cultivars (low tillering and high tillering) under influence of four sowing densities. The experiment was conducted in field conditions from July to November 2017. The experimental design consisted of randomized blocks with split-plots and five replicates. The factors consisted of two wheat cultivars in main plot (TBIO Sossego and TBIO Toruk), subjected to four different sowing densities as split plot (208; 312; 416 and 500 viable seeds  $m^{-2}$ ). The morphological characteristics, measured by optical sensors, production components and grain yield were assessed. Among the assessed traits, only the stem diameter was affected by sowing density. The highest plant height, peduncle length, flag leaf length were found in cultivar Sossego, whereas the largest stem diameter was observed in cultivar Toruk. Relative chlorophyll content and NDVI were higher in cultivar Sossego. The cultivar Sossego showed superior agronomic performance than Toruk, differing in  $673 \text{ kg ha}^{-1}$ . Suboptimal sowing densities promote a decrease in the productive performance of wheat and under conditions of rainfall limitation, genetic potential of reduced tillering and sowing densities above the recommended ones are more efficient.

*Keywords: Triticum aestivum; tillering; crop management.*

## 1. INTRODUCTION

Maximization of wheat production has been of vital importance to Brazil from the point of view of self-sufficiency in cereal grains production [1]. The country is the fourth consumer of cereal grains in the world with per capita consumption of  $53 \text{ kg year}^{-1}$ . However, Brazilian production of grains is around six million tons, not sufficient to meet the domestic demand. Most of the country's total demand is imported, making Brazil the second largest importer of wheat and its byproducts in 2012, with average annual imports of six million tons during the 2005 decade [2].

Wheat yield potential is a characteristic controlled by complex and quantitative mechanisms, since the direct and indirect physiological interferences triggered by the gene expression that affect final grains yield are controlled by various genes of small individual effect [3]. Valério et al. [4] further concludes that, in addition to the gene effect, the yield components may respond differently to different environmental conditions. In this context, an optimal use of the cropland and field conditions are strategies that aim to increase grain yields, so that the interaction of wheat genotypes with different environmental conditions and crop management would be beneficial [1]. Among the crop management methods that most influence the crop outcomes is sowing density, which has a direct influence on tillers growth and effectiveness, but the tillering capacity is associated with environmental factors and the tillering potential of wheat genotypes [4]. There is a great diversity in the genotypes tillering

Comment [P1]: Revise; e.g. sub-plots

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34 pattern, which makes more difficult to decide on the most appropriate sowing density for  
35 each cultivar. Furthermore, this characteristic may have a direct influence on yield  
36 components. So, knowledge on the compensatory effect of yield components as a function  
37 of wheat tillering is crucial when technical management recommendations aiming to  
38 approximate grain yield to the potential yield of each cultivar [5] are considered. As a rule,  
39 the low productivity of Brazilian wheat crops is associated with a small number of fertile  
40 tillers in final grains production [6].

41 Currently, in the microregion 1 (cold and humid) in southern Brazil, sowing density ranges  
42 from 250 to 400 of viable seeds per square meter, considering the cultivars cycle, dual  
43 purpose cropping (grazing and grains harvesting) and sowing time. However, this technical  
44 recommendation of the Brazilian Commission of Wheat and Triticale Research (*Comissão*  
45 *Brasileira de Pesquisa de Trigo e Triticale*) [7] does not consider different tillering behaviors  
46 (tillers emergence and survival), the components of each cultivar yield and different  
47 cultivation environments, which indicates lack of information for more precise technical  
48 recommendations.

49 In Brazil, one of the requirements to register a cultivar in the National Cultivars Registration  
50 is to demonstrate its cultivation and use value through tests conducted according to pre-  
51 established criteria. According to the Ministry of Agriculture and Food Supply [8], Cultivation  
52 and Use Value refers to the intrinsic combined value of the cultivar's agronomic properties  
53 and its use in agricultural, industrial, commercial and/or consumption activities. Thus, data  
54 on grain yields, its behavior against pests and diseases, regions of adaptation and other  
55 factors that indicate the cultivar's marketable importance must be recorded.

56 Currently, occurrence of diseases in wheat crops is caused by pathogens of different  
57 characteristics, and the genetic improvement of resistant or tolerant cultivars is the most  
58 effective way to reduce economic losses [9]. Therefore, genotypes with different behaviors  
59 have been frequently launched in triticale growing regions, which makes that decisions on  
60 the most suitable management methods for each cultivar lack clarity. Thus, this work aimed  
61 to assess the agronomic performance of two wheat cultivars held in the private domain and  
62 recently launched, under the influence of suboptimal, optimal and supraoptimal sowing  
63 densities.  
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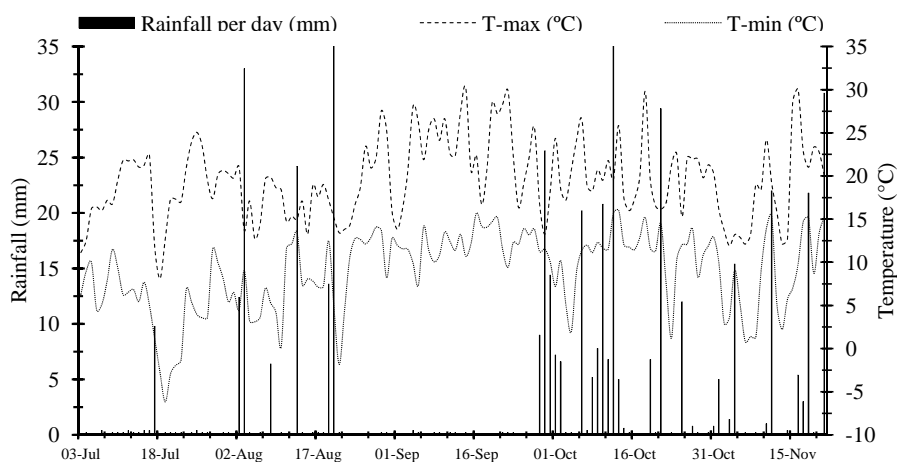
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## 65 2. MATERIAL AND METHODS

### 66 2.1 Site of assay

67  
68 The experiment was conducted from July to November 2017 in the agricultural and livestock  
69 experimental area of the Federal University of Santa Catarina, in the municipality of  
70 Curitiba, state of Santa Catarina, Brazil. The city is located at an altitude of 987 m  
71 between geographic coordinates 27°16'44" S latitude and 50°34'57" W longitude, with an  
72 annual mean temperature of 16.5 °C and annual precipitation around 1500 mm [10]. The soil  
73 is classified as Cambissolo Haplico with typical clay texture (550g kg<sup>-1</sup> of clay). Figure 1  
74 shows the maximum and minimum temperatures and precipitation rates during the  
75 experiment.

76



**Fig. 1. The rainfall, maximum and minimum temperatures from sowing to harvest of two wheat cultivars. Curitibanos, State of Santa Catarina, 2017 growing season. Source: Agroclimatic report EPAGRI/CIRAM.**

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## 82 2.2 Experimental design and management practices

83 The experiments were conducted in a randomized blocks design with split-plots and five  
 84 replicates. The cultivars TBIO Toruk (high tillering) and TBIO Sossego (low tillering),  
 85 launched in 2014 and 2016, respectively, were assessed in the main plot. The planting  
 86 density indicated for both cultivars, according to the breeder, is 300 and 330 plants  $m^{-2}$ ,  
 87 respectively. Both genotypes were subjected to four sowing densities of viable seeds  $m^{-2}$  in  
 88 split plot, namely: 208 (suboptimal); 312 and 416 (optimal) and 500 (supraoptimal). Prior to  
 89 sowing, a germination test was conducted in laboratory for both cultivars to obtain the  
 90 germination rate to adjust the number of seeds for each plant density. Before implementing  
 91 the experiment, soil was sampled at 0-20 cm depth, and the soil test indicated the following  
 92 results: organic matter = 3.3%; P= 13.1  $mg\ dm^{-3}$ ; K= 74  $mg\ dm^{-3}$ ; pH ( $H_2O$ ) 6.7; CEC = 20.5  
 93  $cmolc\ dm^{-3}$ . Correction of pH and fertilization were performed according to the  
 94 recommendations of the Commission of Soil Chemistry and Fertility (*Comissão de Química*  
 95 *e Fertilidade do Solo*) [11] for wheat crops for estimated grain yields of 5 tons  $ha^{-1}$ .

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96 Sowing was performed on July 03, 2017 using a seed drill (Embrapa-Semeato, model  
 97 Sêmína) under no-till system. Each experimental unit consisted of five rows with 5 meters in  
 98 length, spaced 0.2 m between rows and 0.5 m between plots. It was considered three  
 99 central rows with four linear meters, disregarding two side rows and 0.5 m at the end of each  
 100 row.

## 101 2.3 Weeds, diseases and pests managements

102 Weeds control was made ten days prior to the implementation of the experiment with pre  
 103 sowing application of glyphosate (Roundup® 3 L  $ha^{-1}$ ), and application of paraquat  
 104 (Gramoxone® 1.5 L  $ha^{-1}$ ) soon after sowing. Postemergence control was made with  
 105 applications of iodosulfuron-methyl (Hussar® 100 g  $ha^{-1}$ ) on Aug. 28, 2017 when weeds had

106 2-4 leaves, and with clodinafop-propargyl (Topik® 0.2 L ha<sup>-1</sup>) on Sept. 04, 2017, when  
107 weeds exhibited 1-2 leaves. All herbicides were applied sequentially as its recommended  
108 dose for the weed development and specie.

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109 Diseases control was performed with sequential applications of propiconazole (Tilt® 0.5 L  
110 ha<sup>-1</sup>) on Sept. 04, 2017, when the first symptoms of leaf fungal diseases were visible on the  
111 plant, and applications with tebuconazole (Folicur® 0.75 L ha<sup>-1</sup>) on Oct. 03, 2017. Pest  
112 control was performed with sequential applications of beta-cyfluthrin + imidacloprid  
113 (Connect® 0.5 L ha<sup>-1</sup>) on Aug. 28 and Oct. 03, 2017.

Comment [P11]: revise; e.g tebuconazole (Folicur® 0.75 L ha<sup>-1</sup>) was applied on Oct.03, 2017.

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## 115 2.4 Evaluated traits

116 Relative chlorophyll content (RCC) and the normalized difference vegetation index (NDVI)  
117 were determined on field at the growth stage 59 (end of ear formation) of the Zadoks growth  
118 scale [12] by reading the leaf blade of flag leaf and the leaf bellow of flag leaf (leaf<sup>-1</sup>) of ten  
119 plants at each experimental unit using a portable chlorophyll meter (Falker, model Clorofilog  
120 CFL 1030), and NDVI was read with a portable sensor (PlantPen NDVI-300). The peduncle  
121 length (PL), plant height (PH), flag leaf length (FLL), stem diameter (SD), number of grains  
122 per ear (NGE), number of spikelets per ear (NSE), number of grains per spikelet (NGS) were  
123 quantified by harvesting all plants in 30 cm rows of each experimental unit. From this  
124 sample, a subsample of 15 stems was randomly collected, among them stems and tillers,  
125 and with a graduated ruler the PL, PH, FLL were measured, and SD with a pachymeter, and  
126 the number of total spikelets on 15 stems were counted. Finally, after manual threshing, the  
127 Number of Total Grains from 15 stems (NTG15) were obtained. The morphometric traits and  
128 NSE were obtained from the average of 15 stems. The NGE and NGS were obtained from  
129  $NGE = NTG15/15$  and  $NGS = NSS/NGE$  ratios. The considered area was harvested manually  
130 on Nov. 21, 2017. After harvesting, the harvest index (HI) was obtained, which corresponds  
131 to the ratio of grain yield dry weight (GY) to plant total dry weight (TDW); therefore,  
132  $HI = GY/TDW \times 100$ . The hectoliter weight (HW) was determined using a DallaMolle scale  
133 with results expressed in kg hL<sup>-1</sup>. The Thousand grain weight (TGW) was obtained by the  
134 average of 8 x 100 grains as following the method described on the Rules for Seeds  
135 Analysis [13]. The percentage of grains with size larger than 1.75 mm ( $G > 1.75$ ), subsample  
136 of 250g of grains from each experimental unit was sieved at a 1.75 x 20 mm mesh sieve.

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Comment [P14]: revise; e.g. measuring PL, PH and FLL using/with a graduated ruler

137 Grain yield (GY) was determined by harvesting the considered area of each experimental  
138 unit following the wheat tracks. Yield was estimated in kg ha<sup>-1</sup>, adjusted to 13% moisture  
139 standard. The adjusted weight was obtained by the following equation: production from each  
140 plot \* [(100-RM)/(100-13)], where RM is the real moisture of the grains at the harvesting  
141 time, and 13 is the moisture standard. This real moisture was obtained by drying the grains  
142 in oven at 65 °C to constant weight, starting from an initial wet weight of 100g impurities-free  
143 grains. The moisture content expressed on a wet basis was determined by the following  
144 equation:  $M\% = [100 * (GW - GD)/GW]$ , where GW = grains wet weight, GD= grains dry weight.

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## 146 2.5 Statistical Analysis

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148 Data were subjected to analysis of variance by F test ( $P = 0.05$ ). When significant variances  
149 were found, the means of the qualitative factor were compared using the Tukey probability  
150 test ( $P = 0.05$ ). Regression analysis was applied for the quantitative factor. Pearson's  
151 correlation was measured between all variables in the overall mean of all experimental units  
152 and for each sowing density.

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### 3. RESULTS

#### 3.1 Morphometric and physiological traits

157 There was a significant effect of the cultivars on the morphometric variables (Table 1). The  
158 longest peduncle length, plants height and flag leaf length were found for the cultivar  
159 Sossego, whereas the greatest stem diameter was found for cultivar Toruk.

160 Cultivar Sossego exhibited the longest mean length of peduncle, measuring 29.11 cm in the  
161 comparison with cultivar Toruk, which exhibited a peduncle length of 20.28 cm (Figure 2a).  
162 When the mean sowing densities for this same dependent variable were compared, the  
163 variation between the extreme values was 0.6 cm only, which generated a nonsignificant  
164 angular coefficient for this factor, corroborating the low variance value (Table 1), showing  
165 that the population density had little influence on the plants' peduncle length. The plant  
166 height of cultivar Sossego was 19.75 cm higher than the Toruk cultivar, and the flag leaf  
167 length of Sossego cultivar was 2.83 cm higher than the Toruk cultivar (Figure 2b and 2c).

168 Relative chlorophyll content (RCC) and NDVI were affected only by the cultivar factor (Table  
169 1). The RCC of cultivar Sossego was about 12% higher than cultivar Toruk at the reading  
170 time (Figure 3a), while cultivar Sossego exhibited 0.25 units of NDVI higher in the mean  
171 values of its experimental units (Figure 3b).

172 Regarding the stem diameter, cultivar Toruk had a mean diameter of 3.03 mm in its  
173 experimental units, while cultivar Sossego had a mean stem diameter of 2.90 mm (Figure  
174 2d). The sowing density factor affected the stem diameter with 10% significance probability  
175 level. The mean sowing densities in the experimental units indicated adjustment for the  
176 quadratic function with significant parameters (Figure 2e). The largest stem diameter was  
177 found in the suboptimal density, showing a downward behavior for sowing densities close to  
178 the optimal density, from which an upward behavior is observed.

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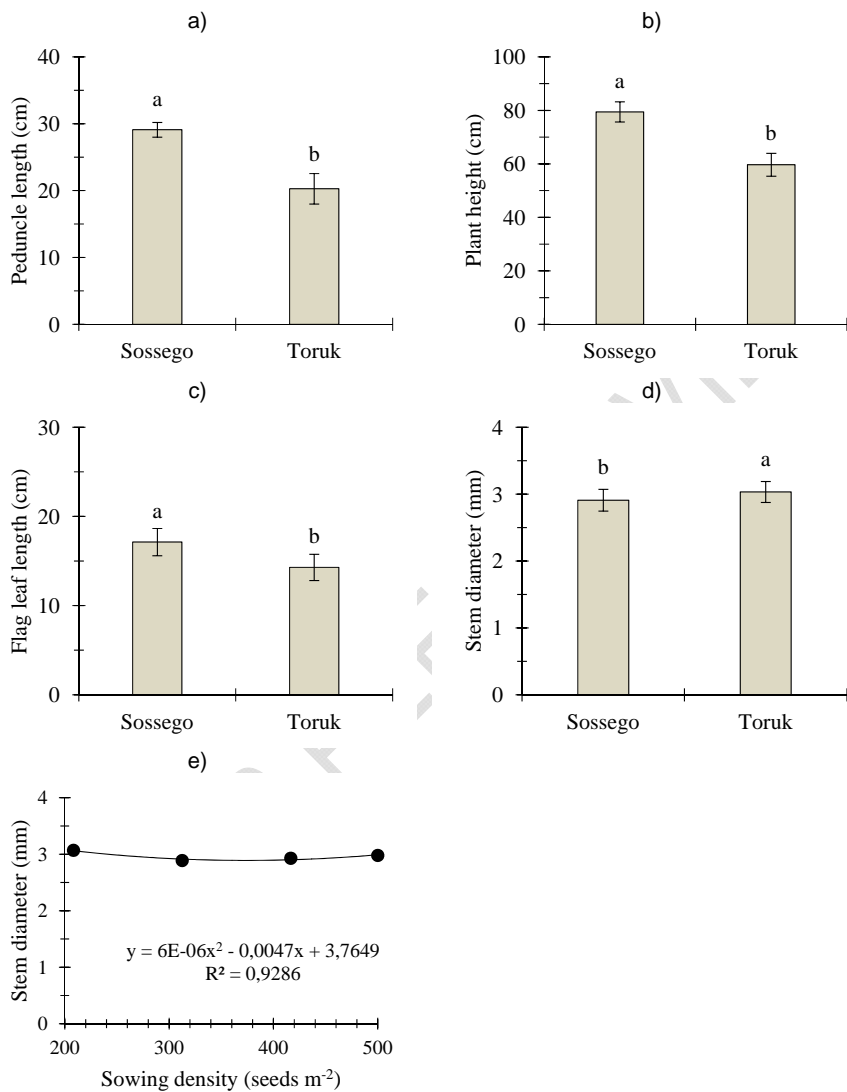
180 **Table 1. Summary of the analysis of variance, mean square and significance for plant**  
181 **height (PH), stem diameter (SD), peduncle length (PL), flag leaf length (FLL), relative**  
182 **chlorophyll content (RCC) and normalized difference vegetation index (NDVI).**

| SOV                 | PH        | SD    | PL       | FLL     | RCC      | NDVI  |
|---------------------|-----------|-------|----------|---------|----------|-------|
| Block               | 24.55     | 0.01  | 3.48     | 2.68    | 35.96    | 0.58* |
| Cultivar (C)        | 3901.41** | 0.15* | 779.45** | 80.56** | 365.23** | 0.65* |
| Error 1             | 3.50      | 0.01  | 2.42     | 2.25    | 17.62    | 0.06  |
| Density (D)         | 7.70      | 0.05  | 0.80     | 1.55    | 12.29    | 0.32  |
| C x D               | 5.30      | 0.02  | 1.71     | 0.70    | 20.37    | 0.20  |
| Error 2             | 19.29     | 0.02  | 3.78     | 2.48    | 12.06    | 0.25  |
| CV (%) <sup>1</sup> | 2.69      | 4.71  | 6.31     | 9.56    | 8.53     | 3.71  |
| CV (%) <sup>2</sup> | 6.31      | 5.28  | 7.88     | 10.02   | 7.05     | 7.02  |
| Main                | 69.56     | 2.97  | 24.69    | 15.71   | 49.23    | 7.13  |

183 \* and \*\*: significant by F-test F at 5 and 1%, respectively. <sup>1</sup> coefficient of variation for main  
184 plot; <sup>2</sup> coefficient of variation for split plot. SOV, source of variation.

185

Comment [P15]: and



188 **Fig. 2. Single effect of peduncle length (a), plant height (b), flag leaf length (c), stem**  
 189 **diameter (d) of two wheat cultivars; “Toruk” and “Sossego” and stem diameter as**  
 190 **function of four sowing densities (e). Curitibaanos, Brazil, 2017 growing season.**  
 191 **Vertical bars are standard deviation of mean.**

193 **3.2 Productive and qualitative characteristics of grains**

194 The factor levels under study did not have a significant effect on the yield components,  
 195 harvest index and grains size larger than 1.75 mm. However, there was a significant  
 196 variance between the means of the cultivars for grains yield and hectoliter weight (Table 2),  
 197 and a significant angular coefficient was obtained with a significance probability level of 10%  
 198 for sowing densities with adjustment of the increasing linear function in grains yield (Figure  
 199 3d).

200 The cultivar Sossego obtained grain yield of 4527 kg ha<sup>-1</sup> and cultivar Toruk obtained  
 201 3853.61 kg ha<sup>-1</sup> (Figure 3c). The significant coefficient showed that the increase in sowing  
 202 density promoted an estimated increase of 193 kg ha<sup>-1</sup> in grain yield (Figure 3e). However, a  
 203 higher number of seeds would be needed to estimate the point of maximum yield under the  
 204 same conditions. The mean value of the cultivars grown at the suboptimal density was 480  
 205 kg ha<sup>-1</sup> lower than the overall mean of the experiment, which aggravates when compared to  
 206 a density of 312 seeds m<sup>-2</sup>. The highest grain yield was achieved at density of 312 seeds m<sup>-2</sup>,  
 207 where a decrease of 715 kg ha<sup>-1</sup> was found, while the mean value of the experimental  
 208 units with supraoptimal density was 205 kg ha<sup>-1</sup> higher than the overall mean, and a  
 209 decrease of only 28 kg ha<sup>-1</sup> was observed when compared to a density of 312 seeds m<sup>-2</sup>.  
 210 This fact indicates that densities below the recommended values may be important from the  
 211 point of view of productive potential. Such relationship is still clear when the mean values of  
 212 the two cultivars grown with suboptimal density are observed, in which a decrease over 900  
 213 kg ha<sup>-1</sup> of Toruk grains compared to Sossego. Cultivar Sossego, although showing more  
 214 potential, had its GY reduced to more than 500 kg ha<sup>-1</sup> as density was reduced from 312 to  
 215 208 seeds m<sup>-2</sup>.

216 HW was dependent on the cultivar factor (Table 2). Cultivar Sossego exhibited a mean value  
 217 in its experimental units of 79.63 kg hL<sup>-1</sup> while for cultivar Toruk a mean value of 77.47 kg  
 218 hL<sup>-1</sup> was observed (Figure 3d).

219 **Table 2. Summary of the analysis of variance, mean square and significance for grain**  
 220 **yield (GY) thousand grain weight (TGW), number of spikelet per spike (NSS), number of**  
 221 **grains per spike (NGS), number of grains per spikelet (NGSS), harvest index (HI), sieve**  
 222 **grains higher than 1,75mm (G>1.75) and hectoliter weight (HW).**

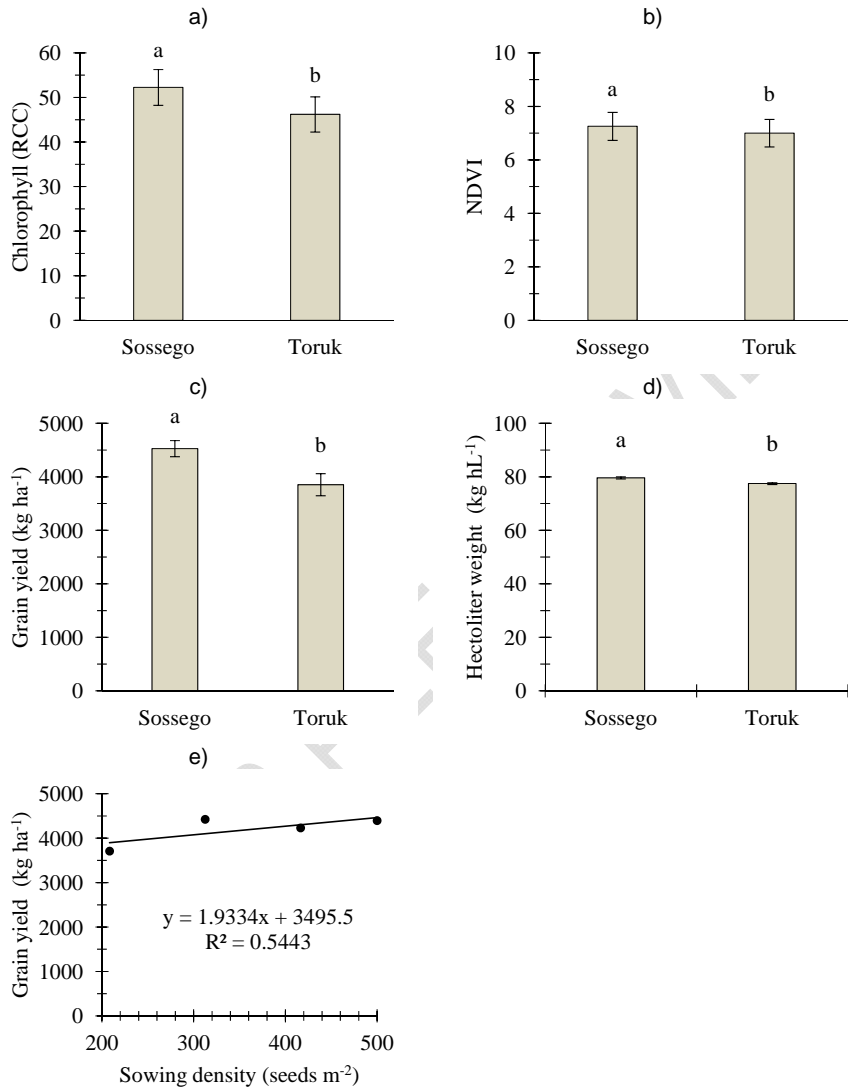
| SOV                 | GY          | TGW   | NSS   | NGS   | NGSS | HI    | G>1,75 | HW     |
|---------------------|-------------|-------|-------|-------|------|-------|--------|--------|
| Block               | 1637188.61  | 3.76  | 1.83* | 12.93 | 0.00 | 10.20 | 3.59   | 0.25   |
| Cultivar (C)        | 4535067.59* | 36.29 | 1.49  | 2.40  | 0.00 | 72.19 | 14.73  | 46.31* |
| Error 1             | 372550.59   | 5.50  | 0.25  | 2.97  | 0.00 | 31.79 | 3.48   | 3.42   |
| Density (D)         | 1100480.09* | 3.59  | 3.28  | 35.46 | 0.03 | 82.40 | 9.12   | 3.45   |
| C x D               | 149080.09   | 4.19  | 1.41  | 31.61 | 0.07 | 4.20  | 7.99   | 0.79   |
| Error 2             | 538458.88   | 3.52  | 1.13  | 14.09 | 0.03 | 31.70 | 4.73   | 2.79   |
| CV (%) <sup>1</sup> | 14.57       | 6.01  | 3.48  | 5.83  | 4.79 | 13.26 | 1.91   | 2.36   |
| CV (%) <sup>2</sup> | 17.51       | 4.80  | 7.40  | 12.68 | 9.71 | 13.24 | 2.22   | 2.13   |
| Main                | 4190.32     | 39.06 | 14.40 | 29.59 | 2.05 | 42.51 | 97.86  | 78.55  |

223 \* and \*\*: significant by F-test F at 5% and 1%, respectively. <sup>1</sup> coefficient of variation for main  
 224 plot; <sup>2</sup> coefficient of variation for split plot. SOV, source of variation.

Comment [P16]: spikelet

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227 **Fig. 3. Single effect of relative chlorophyll content (a), normalized difference**  
 228 **vegetation index (NDVI) (b), grain yield (c), hectoliter weight (d) of two wheat cultivars;**  
 229 **“Toruk” and “Sossego” and grain yield as function of four sowing densities (e).**  
 230 **Curitibanos, Brazil, 2017 growing season. Vertical bars are standard deviation of**  
 231 **mean.**

233 **4. DISCUSSION**

234

235 **4.1 Morphometric and physiological characters**

236

237 Espindula et al. [14] mentions that the peduncle is the structure that contributes most to  
238 plant height growth; however, for plants height it was found that when the cultivars were  
239 compared for different sowing densities, there was more variability in the differences  
240 between the cultivars for this variable, but which did not extrapolate the MSD (minimum  
241 significant difference). Thus, this fact indicates that sowing density may result in a higher  
242 contribution to internodes on the stem base than to the peduncle length in the composition of  
243 the total height of wheat plants. The peduncle length and plant height are traits that are  
244 indicated to assist in the indirect selection of genotypes, since they can diminish the risk of  
245 lodging by increasing the plant resistance to this phenomenon [14]. In this study, there was  
246 no occurrence of strong winds and prolonged periods of rain, especially during the  
247 reproductive period, which minimizes lodging occurrences. Rainfall during the growing  
248 period was of 477.8 mm, but there was a poor distribution of rainfall with long periods of low  
249 precipitation, which contributed to the soil dryness (Figure 1) and, as a consequence, the  
250 plants grew less.

**Comment [P19]:** revise; e.g. It has been mentioned that the peduncle is the structure that contributes most to plant height growth [14]

251 The flag leaf length (FLL) in this study corroborates finding of Fioreze & Rodrigues [15], who  
252 worked with an increased number of wheat plants in the cultivation line and found that the  
253 flag leaf length was not affected by sowing density. However, these authors reported a  
254 decrease in the flag leaf dry matter accumulation. Abichou et al. [16] reports that the  
255 senescence of wheat tiller is a gradual process in which the stoppage of leaf extension  
256 precedes the gradual senescence of the leaves. Therefore, decreases and / or stagnation in  
257 FLL may be indicative that certain tillers will not become effective, succumbing to the course  
258 of the cycle.

**Comment [P20]:** revise; e.g. with other findings [15]

**Comment [P21]:** revise; e.g. It was reported that the senescence of wheat tiller is a gradual process in which the stoppage of leaf extension precedes the gradual senescence of the leaves [16]

259 Grains development is dependent on carbohydrate accumulation in the stems during the  
260 pre-anthesis stage and afterwards. In post-anthesis, this dependence lies on the carbon  
261 assimilation rate, which is associated with the flag leaf. Because the flag leaf is the youngest  
262 leaf, it is photosynthetically more active and does not have its growth constrained by self-  
263 shading; therefore, it is physiologically more important than other leaves. Piana et al. [17]  
264 corroborates this assertion and infers that the genetic improvement prioritized genotypes  
265 with more upright leaves since they can adapt to greater plant densities per area, which  
266 contributes to solar radiation absorption efficiency. Therefore, high densities of plants with  
267 compact architecture may contribute to a higher efficiency of natural resources and  
268 potentiate grains yield. Domiciano et al. [18] reaffirms the importance of leaves at the upper  
269 portion of the stem and recognizes that the pre-anthesis reserve accumulation is an  
270 important source of carbon for grains filling under water stress or phytopathological stress.  
271 Such assertion has a direct relation with the behavior observed in the cultivars of this study,  
272 which clearly showed that a higher plant stature, as identified in the morphological traits of  
273 cultivar Sossego, and the water deficit that was imposed to the experiment, especially during  
274 the early stages of the experiment, influenced final grain yield.

**Comment [P22]:** add citation for the sentences

**Comment [P23]:** Revise citation; check previous comments

**Comment [P24]:** Revise citation; check previous comments

275 An increased sowing density causes more competition between plants in the cultivation line  
276 and affects tillering adversely. Thus, the behavior of the stem diameter is a clear reflection of  
277 competition. When spacing between the cultivation lines is enlarged, thus enhancing the  
278 tillering potential, there is more area for nutrients uptake, whereas with increased densities  
279 and reduced nutrients uptake, there is an upward behavior reflected on the stem diameter  
280 due to a lower tillering potential. According to Fonseca et al. [19], the plant has the capacity  
281 to use the nutrient reserves stored on the stems for grains filling in conditions of limited

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**Comment [P26]:** behaviour

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282 carbohydrate sources. Thus, by observing other morphometric traits, it can be seen that  
283 cultivar Toruk exhibited a lower height, which indicates that this characteristic may have  
284 culminated in a lower performance. Furthermore, in addition to the peduncle and plants  
285 height, the stem diameter is a characteristic that must be considered with regard to plants  
286 lodging resistance, since such resistance is a function of the tissues thickening level at the  
287 base of the plant and inversely proportional to its height [20]. However, cultivar Toruk  
288 showed to be more stable for this variable, considering that the deviations in all densities in  
289 relation to the cultivar overall mean were lower when compared to cultivar Sossego.

290 Relative chlorophyll content may be an indicator of sunlight energy conversion into chemical  
291 energy, i.e., of photo-assimilates accumulation [21]. For wheat cultivation, NDVI can be a  
292 reference on biophysical characteristics (total fresh mass, leaf dry mass and leaf area index)  
293 with more correlation in the post-anthesis stages, besides representing the duration of the  
294 photosynthesis activity during the cycle and being correlated with grains yield [22].  
295 Indirectly, this index can also be correlated with nutritional status, diseases infestation and  
296 leaf senescence from chloroses, also being an effective tool in nitrogen fertilization at a  
297 variable rate [23].

298 The two portable meters used in this study express measures based on absorbance and  
299 reflectance correlations. In the case of this study, since the measures were read at the same  
300 day in all experimental units, although the breeder of both cultivars classify them as medium-  
301 cycle cultivars, cultivar Toruk clearly showed a cycle advance at the time, since its leaves  
302 had already turned yellow, therefore with lower chlorophyll and NDVI levels. According to  
303 Zucareli et al. [24], genotypes that require a lower accumulated heat sum remain less time in  
304 the field, as they complete their cycle more quickly. However, Lyra et al. [25] mention that  
305 the cycle may be longer when plants suffer water stress and, as a consequence, the  
306 accumulated heat sum is higher when compared to a cycle without restrictions. Considering  
307 that both cultivars are of medium cycle, the RCC and NDVI analysis suggests that these  
308 cultivars have different accumulated heat sums and/or respond differently to temporary  
309 water deficit, considering that at the third phase of the initial cycle both cultivars  
310 experimented low rainfalls (Figure 1).

#### 311 4.2 Productive and qualitative characteristics of grains

312 The upward behavior in grains yield with increased sowing density was not observed by  
313 Fioreze & Rodrigues [26]. These authors observed a decreasing GY relationship with an  
314 increasing number of plants in the cultivation line. According to these authors, the adverse  
315 response to individual components as a function of an increased number of plants derives  
316 from dry matter accumulation in the pre-anthesis stage, due to interspecific competition  
317 between plants, and the accumulation of dry matter is one of the factors that contribute to  
318 GY. However, the authors used complementary irrigation, which may have contributed to  
319 more accumulation of dry matter at lower densities and full irrigation is the best management  
320 practices for better growth and to attain maximum grain yield [27]. However, Zhang et al.  
321 [28] observed that the dry mass accumulation during late stages (flowering to maturity) are  
322 more stable under water-saving management conditions.

323 In the case of this study, in which cultivation was under natural rain conditions, there was a  
324 long period of low precipitation rates, particularly during the pre-anthesis phase (Figure 1),  
325 and this fact caused a reduction in biomass accumulation, making that the compensation of  
326 this factor was achieved by the greater number of plants in the crop line. This situation can  
327 also be observed in the HI, where in the average of the experimental units of 208 seeds m<sup>-2</sup>  
328 there was a decrease of HI when compared to the other sowing density conditions. This  
329 behavior was also observed in corn by Sangoi et al. [29], who report that there was an

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330 increase in yield due to the increase in plant density in the crop year with water restriction,  
331 making the contribution of tillers to yield decrease. Also, the long period of water deficit may  
332 have caused a higher tillers mortality, particularly of those that emerged late, in addition to  
333 the fact that wheat cultivars with reduced tillering potential stand out in conditions where  
334 water is a limiting factor [30], like observed to cultivar Sossego. Santos et al. [31] found that  
335 in water deficit conditions, there is a reduced number of effective tillers due to low  
336 emergence or early abortion of the tillers and reports that such reduction may result from the  
337 plant need to diminish the leaf area, increasing senescence and causing the tillers death.  
338 Reductions in grain yield due to low densities can be attenuated due to the regular  
339 distribution of rainfall, which reduces the role of tillering as a compensatory trait to yield [32].  
340 Valério et al. [4] also concludes that genotypes with low tillering potential express more  
341 effect on grains yield as a function of increased sowing density, which was also observed in  
342 cultivar Sossego, which has less tillering potential than Toruk and exceeded the grains yield  
343 of the latter.

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344 Regarding hectoliter weight (HW), Stefen et al. [33] found that his measure is correlated with  
345 the grain size and protein content and that higher grains weight makes that higher HW  
346 values be achieved. Moreover, since HW is a weight to volume ratio, this may be also an  
347 indirect indicator of milling yield, and due the fact that it correlates positively with protein  
348 content, wheat lots with lower HW may produce flour with lower breadmaking quality. From  
349 this perspective, it was found that the TGW of cultivar Sossego reached 38.1 g whereas  
350 Toruk reached 40.0 g, and when productivity is considered, Sossego showed highest grain  
351 yield. Since the NGS averages were practically the same, this suggests that the grains of  
352 cultivar Sossego may have a higher bulk density compared to Toruk, and that this cultivar  
353 has smaller grain sizes, as reported by TGW, which culminates in a larger specific surface  
354 area, contributing to higher HW. A lower bulk density may also result in less flour yield per  
355 ton of processed wheat, which, consequently, requires a greater storage volume. According  
356 to Normative Instruction 38/2010, which sets technical regulation for wheat in Brazil [34], HW  
357 is a requirement that classifies wheat types for flour, and the minimum HWs for wheat types  
358 1, 2 and 3 are 78, 75 and 72, respectively. Thus, since cultivar Toruk was at the threshold of  
359 legislation for type 1, only cultivar Sossego fell into this category, although both are  
360 appropriate for milling aiming flour for bread.

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### 361 4.3 Correlation study

362 Pearson correlation between all variables in the overall average of all experimental units and  
363 for each sowing density (Table 3) was tested to check for general and specific relations  
364 between the variables as a function of plants population, particularly the contributions of  
365 each variable on grain yield. It was found that in fact the morphometric traits had a higher  
366 correlation coefficient with yield, especially at suboptimal density, whereas on the overall  
367 mean of plants populations this effect diminished. This key trait favored the accumulation of  
368 dry matter, contributing to a higher sink/source ratio for the grains, given that the suboptimal  
369 density caused the greater amount of tillers death, leading to a greater dependence of the  
370 main stem on grain yield and, consequently, a lower phenotypic plasticity as a result of the  
371 decreased plants population.

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372 According to Gondim et al. [35], a stress situation in wheat crops may cause changes in the  
373 redistribution of photosynthates and the sink/source balance, and changes in these patterns  
374 may lead to a compensation or yield losses. From this perspective, what was found in this  
375 study is that the higher degree of positive linear association between the morphometric  
376 variables and grain yield suggests that there was a greater remobilization of stem  
377 assimilates to the grains, especially at lower densities. This fact is also clear from the  
378 perspective of cultivars, in which cultivar Sossego exhibited a higher stature compared to

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379 cultivar Toruk, which also led to a greater dry mass accumulation with an effect on final grain  
380 yield.

381 In addition to this fact, the greater tillering potential of cultivar Toruk associated with water  
382 deficit, resulted in tillers abortion, which are more sensitive regarding the main stems, with a  
383 positive impact on the productive performance of this cultivar. Thus, supraoptimal density  
384 eventually promoted a compensation due to the deleterious effects of water deficit on the  
385 overall densities average. Supraoptimal densities contribute to maximizing the yield potential  
386 of low-tillering cultivars, while suboptimal densities maximize the yield potential of high-  
387 tillering cultivars [4]. What was found in this study is that this relation can be affected by  
388 abiotic factors (low rainfall), contributing to reduce the yield potential of cultivar Toruk (high  
389 tillering) at suboptimal plant density.

390 Valério et al. [4] confirmed this interaction between environment and sowing density  
391 regarding wheat grain yields and highlights the importance of having an optimal stand and  
392 the need for recommendations based on a period of more than a year and for specific sites.  
393 Particularly in production systems that depend on regular rainfalls, this fact becomes even  
394 clearer, considering that the temporary water deficit imposed on the third phase of the initial  
395 wheat cycle in this study altered the grain yield dynamics as result of sowing density, as  
396 observed in the comparison of the yield data of this study with those found by Fioreze &  
397 Rodrigues [26]. Furthermore, drought stress in preharvest caused decrease (16,3%) on  
398 grain yield [36].

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399 **Table 3. Pearson correlation among the studied variables grain yield (GY), a thousand**  
400 **grains weight (TGW), number of spikelets per spike (NSS), number of grains per spike**  
401 **(NGS), number of grains per spikelets (NGSS), harvest index (HI), grains higher than**  
402 **1.75 mm (G>1.75), hectoliter weight (HW), peduncle length (PL), plant height (PH), flag**  
403 **leaf length (FLL), stem diameter (SD), relative chlorophyll content (RCC) and**  
404 **normalized difference vegetation index (NDVI) among all experimental traits and**  
405 **within four seeding densities.**

| All experimental traits (all densities) |                    |                     |                    |                    |                    |                    |                    |                    |                     |                     |                    |                    |       |      |
|---|--------------------|---------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|---------------------|---------------------|--------------------|--------------------|-------|------|
|   | GY                 | TGW                 | NSS                | NGS                | NGSS               | HI                 | G>1.75             | HW                 | PL                  | PH                  | FLL                | SD                 | RCC   | NDVI |
| GY                                      | 1                  |                     |                    |                    |                    |                    |                    |                    |                     |                     |                    |                    |       |      |
| TGW                                     | 0,50*              | 1                   |                    |                    |                    |                    |                    |                    |                     |                     |                    |                    |       |      |
| NSS                                     | 0,61*              | 0,59*               | 1                  |                    |                    |                    |                    |                    |                     |                     |                    |                    |       |      |
| NGS                                     | 0,54*              | 0,62*               | 0,90*              | 1                  |                    |                    |                    |                    |                     |                     |                    |                    |       |      |
| NGSS                                    | 0,58*              | 0,71*               | 0,80*              | 0,88*              | 1                  |                    |                    |                    |                     |                     |                    |                    |       |      |
| HI                                      | 0,50*              | 0,64*               | 0,40*              | 0,35*              | 0,50*              | 1                  |                    |                    |                     |                     |                    |                    |       |      |
| G>1.75                                  | 0,59*              | 0,36*               | 0,25 <sup>ns</sup> | 0,27 <sup>ns</sup> | 0,32*              | 0,41*              | 1                  |                    |                     |                     |                    |                    |       |      |
| HW                                      | 0,74*              | 0,21 <sup>ns</sup>  | 0,55*              | 0,47*              | 0,50*              | 0,41*              | 0,43*              | 1                  |                     |                     |                    |                    |       |      |
| PL                                      | 0,64*              | -0,15 <sup>ns</sup> | 0,42*              | 0,33*              | 0,24 <sup>ns</sup> | 0,00 <sup>ns</sup> | 0,47*              | 0,76*              | 1                   |                     |                    |                    |       |      |
| PH                                      | 0,64*              | -0,17 <sup>ns</sup> | 0,41*              | 0,32*              | 0,25 <sup>ns</sup> | 0,02 <sup>ns</sup> | 0,44*              | 0,75*              | 0,98*               | 1                   |                    |                    |       |      |
| FLL                                     | 0,74*              | 0,14 <sup>ns</sup>  | 0,64*              | 0,50*              | 0,47*              | 0,21 <sup>ns</sup> | 0,49*              | 0,79*              | 0,87*               | 0,85*               | 1                  |                    |       |      |
| SD                                      | 0,28 <sup>ns</sup> | 0,67*               | 0,66*              | 0,78*              | 0,79*              | 0,53*              | 0,14 <sup>ns</sup> | 0,34*              | -0,10 <sup>ns</sup> | -0,10 <sup>ns</sup> | 0,18 <sup>ns</sup> | 1                  |       |      |
| RCC                                     | 0,67*              | 0,08 <sup>ns</sup>  | 0,48*              | 0,35*              | 0,31*              | 0,36*              | 0,56*              | 0,72*              | 0,75*               | 0,75*               | 0,79*              | 0,17 <sup>ns</sup> | 1     |      |
| NDVI                                    | 0,73*              | 0,42*               | 0,46*              | 0,34*              | 0,40*              | 0,58*              | 0,59*              | 0,67*              | 0,48*               | 0,46*               | 0,60*              | 0,36*              | 0,79* | 1    |
| 208 seeds/m <sup>2</sup>                |                    |                     |                    |                    |                    |                    |                    |                    |                     |                     |                    |                    |       |      |
|   | GY                 | TGW                 | NSS                | NGS                | NGSS               | HI                 | G>1.75             | HW                 | PL                  | PH                  | FLL                | SD                 | RCC   | NDVI |
| GY                                      | 1                  |                     |                    |                    |                    |                    |                    |                    |                     |                     |                    |                    |       |      |
| TGW                                     | 0,70*              | 1                   |                    |                    |                    |                    |                    |                    |                     |                     |                    |                    |       |      |
| NSS                                     | 0,94*              | 0,68*               | 1                  |                    |                    |                    |                    |                    |                     |                     |                    |                    |       |      |
| NGS                                     | 0,92*              | 0,63*               | 0,94*              | 1                  |                    |                    |                    |                    |                     |                     |                    |                    |       |      |
| NGSS                                    | 0,87*              | 0,90*               | 0,89*              | 0,80*              | 1                  |                    |                    |                    |                     |                     |                    |                    |       |      |
| HI                                      | 0,47 <sup>ns</sup> | 0,88*               | 0,57 <sup>ns</sup> | 0,52 <sup>ns</sup> | 0,81*              | 1                  |                    |                    |                     |                     |                    |                    |       |      |
| G>1.75                                  | 0,80*              | 0,68*               | 0,68*              | 0,81*              | 0,69*              | 0,47 <sup>ns</sup> | 1                  |                    |                     |                     |                    |                    |       |      |
| HW                                      | 0,96*              | 0,71*               | 0,98*              | 0,95*              | 0,86*              | 0,53 <sup>ns</sup> | 0,77*              | 1                  |                     |                     |                    |                    |       |      |
| PL                                      | 0,88*              | 0,31 <sup>ns</sup>  | 0,83*              | 0,89*              | 0,58 <sup>ns</sup> | 0,12 <sup>ns</sup> | 0,72*              | 0,86*              | 1                   |                     |                    |                    |       |      |
| PH                                      | 0,87*              | 0,28 <sup>ns</sup>  | 0,83*              | 0,88*              | 0,57 <sup>ns</sup> | 0,10 <sup>ns</sup> | 0,68*              | 0,84*              | 1,00*               | 1                   |                    |                    |       |      |
| FLL                                     | 0,92*              | 0,57 <sup>ns</sup>  | 0,90*              | 0,94*              | 0,71*              | 0,37 <sup>ns</sup> | 0,75*              | 0,94*              | 0,88*               | 0,87*               | 1                  |                    |       |      |
| SD                                      | 0,41 <sup>ns</sup> | 0,84*               | 0,54 <sup>ns</sup> | 0,44 <sup>ns</sup> | 0,66*              | 0,79*              | 0,43 <sup>ns</sup> | 0,55 <sup>ns</sup> | 0,07 <sup>ns</sup>  | 0,05 <sup>ns</sup>  | 0,42 <sup>ns</sup> | 1                  |       |      |

|                          | RCC                | NDVI                | 312 seeds/m <sup>2</sup> |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
|--------------------------|--------------------|---------------------|--------------------------|---------------------|---------------------|---------------------|--------------------|---------------------|---------------------|---------------------|--------------------|---------------------|--------------------|------|-----|------|
|                          |                    |                     | GY                       | TGW                 | NSS                 | NGS                 | NGSS               | HI                  | G>1.75              | HW                  | PL                 | PH                  | FLL                | SD   | RCC | NDVI |
| RCC                      | 0.75*              | 0.72*               | 0.83*                    | 0.80*               | 0.72*               | 0.57 <sup>ns</sup>  | 0.75*              | 0.86*               | 0.61 <sup>ns</sup>  | 0.59 <sup>ns</sup>  | 0.80*              | 0.79*               | 1                  |      |     |      |
| NDVI                     | 0.65*              | 0.72*               | 0.78*                    | 0.69*               | 0.70*               | 0.60 <sup>ns</sup>  | 0.59 <sup>ns</sup> | 0.80*               | 0.47 <sup>ns</sup>  | 0.45 <sup>ns</sup>  | 0.69*              | 0.87*               | 0.97*              | 1    |     |      |
| 312 seeds/m <sup>2</sup> |                    |                     |                          |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
|                          | GY                 | TGW                 | NSS                      | NGS                 | NGSS                | HI                  | G>1.75             | HW                  | PL                  | PH                  | FLL                | SD                  | RCC                | NDVI |     |      |
| GY                       | 1                  |                     |                          |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| TGW                      | 0.61               | 1                   |                          |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| NSS                      | 0.98*              | 0.55 <sup>ns</sup>  | 1                        |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| NGS                      | 0.97*              | 0.66*               | 0.94*                    | 1                   |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| NGSS                     | 0.91*              | 0.83*               | 0.85*                    | 0.89*               | 1                   |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| HI                       | 0.65*              | 0.85*               | 0.66*                    | 0.72*               | 0.74*               | 1                   |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| G>1.75                   | 0.90*              | 0.80*               | 0.87*                    | 0.91*               | 0.91*               | 0.83*               | 1                  |                     |                     |                     |                    |                     |                    |      |     |      |
| HW                       | 0.81*              | 0.33 <sup>ns</sup>  | 0.84*                    | 0.75*               | 0.73*               | 0.43 <sup>ns</sup>  | 0.59 <sup>ns</sup> | 1                   |                     |                     |                    |                     |                    |      |     |      |
| PL                       | 0.61*              | -0.22 <sup>ns</sup> | 0.65*                    | 0.50 <sup>ns</sup>  | 0.29 <sup>ns</sup>  | -0.07 <sup>ns</sup> | 0.30 <sup>ns</sup> | 0.58 <sup>ns</sup>  | 1                   |                     |                    |                     |                    |      |     |      |
| PH                       | 0.55 <sup>ns</sup> | -0.30 <sup>ns</sup> | 0.58 <sup>ns</sup>       | 0.43 <sup>ns</sup>  | 0.23 <sup>ns</sup>  | -0.17 <sup>ns</sup> | 0.23 <sup>ns</sup> | 0.59 <sup>ns</sup>  | 0.98*               | 1                   |                    |                     |                    |      |     |      |
| FLL                      | 0.78*              | 0.15 <sup>ns</sup>  | 0.82*                    | 0.63*               | 0.57 <sup>ns</sup>  | 0.20 <sup>ns</sup>  | 0.54 <sup>ns</sup> | 0.72*               | 0.87*               | 0.82*               | 1                  |                     |                    |      |     |      |
| SD                       | 0.66*              | 0.77*               | 0.65*                    | 0.72*               | 0.78*               | 0.87*               | 0.72*              | 0.67*               | -0.07 <sup>ns</sup> | -0.12 <sup>ns</sup> | 0.19 <sup>ns</sup> | 1                   |                    |      |     |      |
| RCC                      | 0.67*              | -0.13 <sup>ns</sup> | 0.69*                    | 0.59 <sup>ns</sup>  | 0.36 <sup>ns</sup>  | 0.07 <sup>ns</sup>  | 0.41 <sup>ns</sup> | 0.57 <sup>ns</sup>  | 0.97*               | 0.93*               | 0.85*              | 0.02 <sup>ns</sup>  | 1                  |      |     |      |
| NDVI                     | 0.86*              | 0.13 <sup>ns</sup>  | 0.87*                    | 0.80*               | 0.60 <sup>ns</sup>  | 0.29 <sup>ns</sup>  | 0.64*              | 0.76*               | 0.90*               | 0.87*               | 0.86*              | 0.31 <sup>ns</sup>  | 0.92*              | 1    |     |      |
| 416 seeds/m <sup>2</sup> |                    |                     |                          |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
|                          | GY                 | TGW                 | NSS                      | NGS                 | NGSS                | HI                  | G>1.75             | HW                  | PL                  | PH                  | FLL                | SD                  | RCC                | NDVI |     |      |
| GY                       | 1                  |                     |                          |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| TGW                      | 0.30 <sup>ns</sup> | 1                   |                          |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| NSS                      | 0.68*              | 0.74*               | 1                        |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| NGS                      | 0.30 <sup>ns</sup> | 0.90*               | 0.75*                    | 1                   |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| NGSS                     | 0.35 <sup>ns</sup> | 0.96*               | 0.79*                    | 0.93*               | 1                   |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| HI                       | 0.57 <sup>ns</sup> | 0.70*               | 0.90*                    | 0.75*               | 0.74*               | 1                   |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| G>1.75                   | 0.88*              | 0.39 <sup>ns</sup>  | 0.84*                    | 0.43 <sup>ns</sup>  | 0.44 <sup>ns</sup>  | 0.75*               | 1                  |                     |                     |                     |                    |                     |                    |      |     |      |
| HW                       | 0.81*              | -0.05 <sup>ns</sup> | 0.37 <sup>ns</sup>       | -0.16 <sup>ns</sup> | -0.09 <sup>ns</sup> | 0.35 <sup>ns</sup>  | 0.71*              | 1                   |                     |                     |                    |                     |                    |      |     |      |
| PL                       | 0.66*              | -0.43 <sup>ns</sup> | 0.11 <sup>ns</sup>       | -0.47 <sup>ns</sup> | -0.41 <sup>ns</sup> | 0.09 <sup>ns</sup>  | 0.55 <sup>ns</sup> | 0.91*               | 1                   |                     |                    |                     |                    |      |     |      |
| PH                       | 0.75*              | -0.32 <sup>ns</sup> | 0.30 <sup>ns</sup>       | -0.28 <sup>ns</sup> | -0.27 <sup>ns</sup> | 0.26 <sup>ns</sup>  | 0.70*              | 0.89*               | 0.96*               | 1                   |                    |                     |                    |      |     |      |
| FLL                      | 0.71*              | -0.17 <sup>ns</sup> | 0.45 <sup>ns</sup>       | -0.20 <sup>ns</sup> | -0.11 <sup>ns</sup> | 0.37 <sup>ns</sup>  | 0.70*              | 0.82*               | 0.87*               | 0.91*               | 1                  |                     |                    |      |     |      |
| SD                       | 0.08 <sup>ns</sup> | 0.87*               | 0.58 <sup>ns</sup>       | 0.95*               | 0.85*               | 0.67*               | 0.22 <sup>ns</sup> | -0.27 <sup>ns</sup> | -0.60 <sup>ns</sup> | -0.45 <sup>ns</sup> | -0.39              | 1                   |                    |      |     |      |
| RCC                      | 0.77*              | -0.27 <sup>ns</sup> | 0.39 <sup>ns</sup>       | -0.21 <sup>ns</sup> | -0.18 <sup>ns</sup> | 0.28 <sup>ns</sup>  | 0.73*              | 0.80*               | 0.90*               | 0.97*               | 0.94*              | -0.42 <sup>ns</sup> | 1                  |      |     |      |
| NDVI                     | 0.90*              | 0.33 <sup>ns</sup>  | 0.60 <sup>ns</sup>       | 0.19 <sup>ns</sup>  | 0.29 <sup>ns</sup>  | 0.54 <sup>ns</sup>  | 0.81*              | 0.91*               | 0.69*               | 0.70*               | 0.69*              | 0.04 <sup>ns</sup>  | 0.65*              | 1    |     |      |
| 500 seeds/m <sup>2</sup> |                    |                     |                          |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
|                          | GY                 | TGW                 | NSS                      | NGS                 | NGSS                | HI                  | G>1.75             | HW                  | PL                  | PH                  | FLL                | SD                  | RCC                | NDVI |     |      |
| GY                       | 1                  |                     |                          |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| TGW                      | 0.57 <sup>ns</sup> | 1                   |                          |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| NSS                      | 0.89*              | 0.73*               | 1                        |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| NGS                      | 0.94*              | 0.67*               | 0.94*                    | 1                   |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| NGSS                     | 0.93*              | 0.57 <sup>ns</sup>  | 0.87*                    | 0.95*               | 1                   |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| HI                       | 0.53 <sup>ns</sup> | 0.88*               | 0.78*                    | 0.67*               | 0.54 <sup>ns</sup>  | 1                   |                    |                     |                     |                     |                    |                     |                    |      |     |      |
| G>1.75                   | 0.92*              | 0.40 <sup>ns</sup>  | 0.72*                    | 0.86*               | 0.89*               | 0.36 <sup>ns</sup>  | 1                  |                     |                     |                     |                    |                     |                    |      |     |      |
| HW                       | 0.78*              | 0.32 <sup>ns</sup>  | 0.62*                    | 0.76*               | 0.84*               | 0.38 <sup>ns</sup>  | 0.70*              | 1                   |                     |                     |                    |                     |                    |      |     |      |
| PL                       | 0.62*              | -0.18 <sup>ns</sup> | 0.26 <sup>ns</sup>       | 0.49 <sup>ns</sup>  | 0.62*               | -0.21 <sup>ns</sup> | 0.69*              | 0.78*               | 1                   |                     |                    |                     |                    |      |     |      |
| PH                       | 0.56 <sup>ns</sup> | -0.23 <sup>ns</sup> | 0.21 <sup>ns</sup>       | 0.42 <sup>ns</sup>  | 0.56 <sup>ns</sup>  | -0.22 <sup>ns</sup> | 0.62*              | 0.79*               | 0.99*               | 1                   |                    |                     |                    |      |     |      |
| FLL                      | 0.87*              | 0.20 <sup>ns</sup>  | 0.62*                    | 0.78*               | 0.89*               | 0.15 <sup>ns</sup>  | 0.88*              | 0.87*               | 0.90*               | 0.86*               | 1                  |                     |                    |      |     |      |
| SD                       | 0.77*              | 0.81*               | 0.91*                    | 0.86*               | 0.79*               | 0.89*               | 0.67*              | 0.58 <sup>ns</sup>  | 0.11 <sup>ns</sup>  | 0.08 <sup>ns</sup>  | 0.48 <sup>ns</sup> | 1                   |                    |      |     |      |
| RCC                      | 0.72*              | 0.11 <sup>ns</sup>  | 0.53 <sup>ns</sup>       | 0.62*               | 0.68*               | 0.28 <sup>ns</sup>  | 0.66*              | 0.88*               | 0.78*               | 0.81*               | 0.80*              | 0.41 <sup>ns</sup>  | 1                  |      |     |      |
| NDVI                     | 0.77*              | 0.80*               | 0.92*                    | 0.84*               | 0.73*               | 0.92*               | 0.62*              | 0.52 <sup>ns</sup>  | 0.08 <sup>ns</sup>  | 0.04 <sup>ns</sup>  | 0.44 <sup>ns</sup> | 0.91*               | 0.51 <sup>ns</sup> | 1    |     |      |
| Color key                |                    |                     |                          |                     |                     |                     |                    |                     |                     |                     |                    |                     |                    |      |     |      |
|                          | <0,59              |                     | 0,6 - 0,69               |                     |                     | 0,7 - 0,79          |                    |                     | 0,8 - 0,89          |                     |                    | 0,9 - 1             |                    |      |     |      |

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#### 4. CONCLUSION

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Cultivar Sossego exhibited a better agronomic performance compared to cultivar Toruk independent of sowing density.

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Sowing density affects the stem diameter and causes a decrease of this structure, a result of the plants competition into row particularly on tillerest cultivar as Toruk.

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Suboptimal sowing densities affect the productive performance of wheat cultivars and, under conditions where rainfall is a limiting factor, reduced tillering potential and supraoptimal sowing densities are more efficient and needed to achieve highest grain yield. **Further**

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417 research can be given to wheat plant grown under stressed-factors such drought or heat  
418 stress wheat plant densities are changed on basis to low or higher tillering potential.

Comment [P48]: Revise

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