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Leaf area response in dual purpose wheat submitted to different defoliation managements and seeding densities

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Abstract

The aim of this study was to assess the performance of leaf area during the development of dual purpose wheat genotypes when subjected to different seeding densities and defoliation managements. The experiment was conducted in 2014 growing season in experimental area belonging to the Breeding Lab and Plant Production of the Federal University of Santa Maria Campus Frederico Westphalen-RS. The experimental design was a randomized complete block in a factorial treatment design, as follows: five genotypes (BRS Figueira, BRS Guatambu, BRS Tarumã, BRS Umbu and BRS 277) × five seeding densities (75; 150; 225; 300; 375 plant m^{-2}) × four defoliation managements (without cut. one cut. two cuts and three cuts) arranged in three replications. The cuts were made when the plants reached 30 cm, leaving 10 cm for regrowth. Leaf area is influenced by defoliation management seeding densities and dual purpose wheat genotype. Increased in seeding density reduces leaf area in all genotypes. The larger leaf area at tillering was obtained at the density of 300 plant m^{-2} to management with three cuts for the genotypes BRS Tarumã, BRS Umbu, Guatambu BRS and BRS Figueira. The density of 300 plant m^{-2} provide increase on leaf area in flowering stage for BRS Umbu, BRS Guatambu and BRS 277 genotypes in all defoliation managements. Leaf area reduces in the grain filling when seeding density is increased for all defoliation managements in the genotypes BRS Tarumã, BRS Umbu and BRS 277.

Keywords: *Triticum aestivum* L., leaf area, managements.
Abbreviation: Plant m^{-2}_ Plants by square meters, LAT_Leaf area on tillering period, LAE_ leaf area on stem elongation, LAF_ leaf area at flowering, LAG_ leaf area in grain filling, cm^2_centímetro por metro quadrado, NPK_ nitrogen, phosphorus and potassium.

Introduction

Wheat (*Triticum aestivum* L.) is characterized as an annual-cycle Poaceae, considered a staple cereal in food and feed. Besides use in the form of grains, it can be used as fodder, making it possible to perform animal grazing or mechanical cutting of the foliar area during the vegetative stages and later to harvest the grains from the physiological maturation.Wheat genotypes used for dual purpose have specific morphological characteristics such as high dry matter production, grazing/ defoliation tolerance, high yield potential and long growing season (Carvalho et al., 2015). These features enable the farmer to maximize business efficiency; therefore, enables the production of grains beyond as a forage alternative in seasons where the available volume is low (Martin et al., 2010; Martin et al., 2013). In Rio Grande do Sul State, part of the cultivated area in winter is used for wheat seeding with main goal of grain production, which is benefited by the flour industry (Silva et al., 2015), cookies, pasta, as well as in feed form (Wesendonck et al., 2013). Brazilian production in last harvest was 5,534.9 ton, where the Rio Grande do Sul accounted for 1,464.2 tons grading as the second largest producer, behind only the Parana State who obtained production of 3,357.8 tons (Conab, 2015). However, in southern Brazil much of the cultivated area in the winter season remains fallow or is used for pasture seeding aiming forage for cattle, such as ryegrass (*Lolium multiflorum*), white clover (*Trifolium repens*) and oat (*Avena sativa*) (Martin et al., 2013). Forage production is dependent on leaf area, architecture and the number of leaves; thus, leaf area is an important trait for the choice of a wheat genotype with dual purpose. It is essential to understand the number of cuts that the genotype is able to deliver, as well as the magnitude production of green and dry matter. Thus, leaf area can be considered indicative for choosing the best management defoliation and cultivation techniques to be applied on dual purpose wheat genotypes. Management techniques such as seeding density, influence the forage production and defoliation management (Martin et al., 2010) as well as the number of cuts affects the grain production (Meinerz et al., 2011). Seeding density used in Rio Grande do Sul State to dual purpose wheat is between 350 to 400 plant per square meter (Martin et al., 2010).

There is need for studding the relationship between available genotypes to producers with the ideal number of cuts.
The aim of this study was to assess the performance of leaf area during the development of dual purpose wheat genotypes when subjected to different seeding densities and defoliation managements.

Results and Discussion

Three-way ANOVA reveled significant interaction between dual purpose wheat x seeding densities x defoliation managements to the traits LAT, LAE, LAF and LAG.
In leaves, the light energy is converted into chemical energy, providing the conversion of inorganic carbon into organic, which is used to provide the growth and development of wheat plants (Souza et al., 2013). In this species, the morphological structures and architecture of the leaves are closely related to the photosynthetically active leaf area index (Valério et al., 2009).

Leaf area on tillering period

Leaf area on tillering period (LAT) had a different behavior among dual purpose wheat genotypes cultivated in different seeding densities (Fig. 1). For BRS Umbu, BRS 277 and BRS Tarumã, increase in seeding density has reduced leaf area in defoliation managements. BRS Figueira genotype subjected to increase sowing density, has obtained increased leaf area. According to Martin et al. (2010), which evaluating the performance of wheat genotypes, has observed that seeding densities has provided to the BRS Umbu and BRS Tarumã, linear increase of biomass due to the increase of plants per area unit, especially in the absence of cuts. In BRS Figueira genotype, it was also observed increased biomass with the highest seeding density (Table 1).
The BRS 277 genotype without defoliation management has provided equal or superior magnitude than the other genotypes in all seeding densities. This genotype has high tillering potential (Meinerz et al., 2012), and is able to compensate the leaf area with number of tillers. BRS Tarumã has obtained superiority of LAT with densities of 75 plant m^{-2} and 150 plant m^{-2} in the managements with one and three cuts, respectively, and in the density of 225 plant m^{-2} on managements without cuts, with one and three cuts. The response to the restoration of leaf area is influenced by the high tillering potential (Meinerz et al., 2011).
The BRS Figueira genotype showed higher magnitude of LAT on densities of 300 e 375 plant m^{-2} when subjected to two and three cuts; as well as, BRS Umbu at the density of 75 plant m^{-2}. According to studies performed by Hastenpfluget al. (2011), these genotypes have high tillering capacityafter the realization of the cuts. For BRS Guatambu genotype, can be highlighted the magnitude of response on higher densities. Possibly the answer is linked to characteristic of this genotype in basically produce leaves in its main steam (Hastenpflug et al., 2011).
Regarding the response of cut management in each genotype, in the tillering period, BRS 277 without cut, showed LAT greater or equal to the others genotypes at the densities of 75, 150, 300 and 375 plant m^{-2} (Table 1). BRS Tarumã did not have its LAT affected as the number of cuts in density of 375 s m^{-2}, indicating that the farmer can make the number of cuts required. BRS Figueira and BRS Guatambu genotypes at the densities of 75 and 300 plant m^{-2}, has been increasing LAT when submitted to the defoliation managements; however, the response to defoliation is characteristic of each genotype (Hastenpflug et al., 2011).
Stem elongation in wheat is related to the action of gibberellin (Fioreze and Rodrigues, 2014), elongating the stem, influencing the number of tillers and leaf area. Fig. 2 shows the trend of LAE in defoliation managements in the respective seeding densities. The response of leaf area is influenced by tillering ability of each genotype (Valério et al., 2008; Hastenpflug et al., 2011). BRS Tarumã, BRS Umbu and BRS Figueira genotypes, has trend to maintain or reduce LAE with increasing of seeding densities.
BRS Guatambu genotype in management with three cuts tends to increase LAE with increased seeding density, inverse response compared to managements without cut and one cut, which reduces LAE as long as seeding density is increased. Regarding to BRS 277, with one defoliation management, tends to increase LAE at lower densities; but when subjected to two and three cuts, tends to decrease with increase in intermediate densities and higher densities. According to Bortoline et al. (2004), the response of winter cereals in dual purpose system subjected to cuts, is different regarding to dry matter after defoliation, being the result assigned to the regrowth capacity of each genotype.

Leaf area on elongation

Leaf area on stem elongation of BRS Tarumã has magnitude superior or equal to other genotypes with three cuts at the densities of 75 and 150 plant m^{-2} (Table 2). The restoration of plants after defoliation is influenced by remnant leaf area, due to a higher participation of leaf blades and greater leaf/stem ratio (Meinerz et al., 2012).
BRS Umbu in densities of 75 and 150 m^{-2} got equal or greater magnitude to other genotypes in managements without cuts and with two cuts. This genotype has a high proportion of leaf blades (Meinerz et al., 2011) and high tillering potential (Valerio et al., 2008). Regarding to BRS Figueira at the density of 75 plant m^{-2}, management with one cut showed higher LAE than the other genotypes; with two cuts at the density of 225 plant m^{-2}; and density of 300 plant m^{-2} in managements without cut, one cut and two cuts. Valério et al. (2008) observed in genotypes with high tillering potential which occurrence of variation in the production of tillers is not associated to seeding densities.
BRS Guatambu genotype showed equal or superior LAE than the other genotypes in densities of 150 s m^{-2} in managements without cut, one cut and two cuts; at the density of 225 plant m^{-2} in managements without cut and one cut; and at density of 300 and 375 plant m^{-2} without cut, one cut and three cuts. Regarding to BRS 277, we can highlight the management with one cut at the density of 150 plant m^{-2}, at the management with two cuts at densities of 75, 300 and 375 plant m^{-2} and management with three cuts at density of 375 plant m^{-2}. Meinerz et al. (2012) had found between the first and second defoliation, increase in the mass of fodder assigning this response to tillering ability of this genotype.
It is observed in Table 2 the magnitude of the behavior of genotypes between defoliation managements within the seeding densities. BRS Umbu genotype remained the same magnitude of LAE in all defoliation managements in the density of 225 plant m^{-2}; with a density of 75 plant m^{-2} in managements without cut, two and three cuts; and at the densities of 300 and 375 plant m^{-2} in management with

Table 1. Averages for interaction among dual purpose wheat genotypes x seeding densities x defoliation management for leaf area at tillering (LAT).

Genotypes	Density 75 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	31.4 b A	22.9 c B	22.6 ab B	22.2 a B
BRS Umbu	28.6 b A	23.3 c B	25.2 a AB	26.0 a AB
BRS Figueira	16.8 c B	23.6 c A	23.3 ab A	24.7 a A
BRS Guatambu	20.9 c B	32.5 b A	20.0 b BC	15.8 b C
BRS 277	45.1 a A	43.1 a A	23.3 ab B	22.7 a B
Genotypes	Density 150 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	20.6 ab C	29.7 a B	29.2 a B	34.6 a A
BRS Umbu	16.4 b C	30.7 a A	27.3 ab AB	23.8 b B
BRS Figueira	15.8 bc B	19.8 b B	19.2 c B	24.1 b A
BRS Guatambu	17.4 b B	15.4 c B	23.9 b A	16.8 c C
BRS 277	24.8 a A	26.5 a A	23.3 bc A	22.3 b A
Genotypes	Density 225 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	26.9 a A	29.6 a A	12.7 c B	27.5 a A
BRS Umbu	17.0 bc AB	16.2 c B	16.1 c B	21.0 b A
BRS Figueira	15.4 bc B	12.5 c B	24.8 ab A	15.5 c B
BRS Guatambu	20.1 abc C	23.1 a BC	27.4 a A	26.3 a AB
BRS 277	21.0 ab D	14.4 b C	32.1 a A	26.8 a B
Genotypes	Density 300 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	22.5 a A	14.9 b B	17.8 c B	13.9 b B
BRS Umbu	12.0 b B	21.3 a A	19.0 bc A	12.9 b B
BRS Figueira	20.1 ab C	23.1 a BC	27.4 a A	26.3 a AB
BRS Guatambu	16.1 b B	19.9 a AB	22.6 b A	23.8 a A
BRS 277	23.9 a AB	20.2 a B	20.4 bc B	25.8 a A
Genotypes	Density 375 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	19.8 c A	19.6 a A	20.5 b A	21.7 bc A
BRS Umbu	24.8 ab A	16.9 ab B	11.7 c C	11.5 d C
BRS Figueira	21.0 bc D	14.4 b C	32.1 a A	26.8 a B
BRS Guatambu	18.6 c B	20.2 ab B	12.5 c C	25.2 a A
BRS 277	28.9 a A	14.9 b B	16.0 c B	18.2 c B
CV(%)	12.15			

* Average followed by the same capital letter in line comparing defoliation managements. Do not differ statistically by Tukey test at 5% probability error.

** Means followed by the same letter in the column, comparing genotypes, do not differ statistically by Tukey test at 5% probability error.

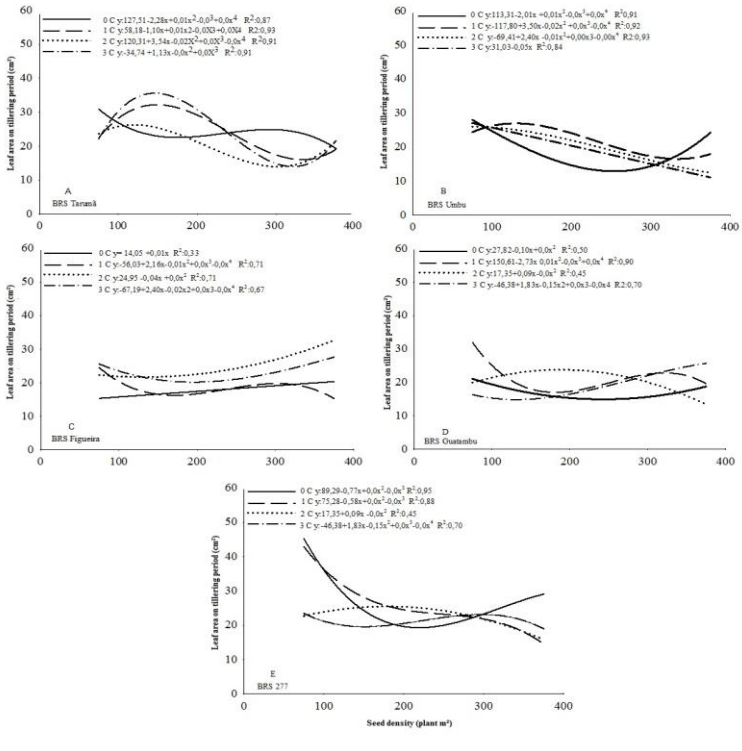

Fig 1. Regression curves for leaf area on tillering stage for interaction among dual purpose wheat genotypes x seeding densities x defoliation managements. A= BRS Tarumã. B= BRS Umbu. C= BRS Figueira. D= BRS Guatambu. E= BRS 277. Densities are 75, 150, 225, 300 e 375 plant m^{-2}. Defoliation managements are 0C = without cut; 1C = one cut; 2C = two cuts; and 3C = three cuts.

Table 2. Averages for interaction among dual purpose wheat genotypes x seeding densities x defoliation management for leaf area at steam elongation (LAE).

Genotypes	Density 75 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	81.0 c C	190.9 b B	227.4 a B	332.2 a A
BRS Umbu	243.2 a A	163.7 b B	224.6 a A	222.4 b A
BRS Figueira	145.6 b C	386.8 a A	214.7 a B	166.1 c C
BRS Guatambu	172.9 b A	63.2 c C	160.5 b AB	120.9 d B
BRS 277	163.9 b B	167.8 b B	239.4 a A	260.5 b A
Genotypes	Density 150 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	157.2 b A	148.7 b A	71.4 c B	183.4 a A
BRS Umbu	224.4 a A	113.9 b C	172.7 a B	153.4 ab BC
BRS Figueira	151.2 b A	158.3 b A	120.6 b A	156.1 ab A
BRS Guatambu	220.4 a A	249.4 a A	177.8 a B	119.6 b C
BRS 277	132.1 b B	256.5 a A	117.1 b B	123.8 b B
Genotypes	Density 225 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	129.7 c A	79.3 c B	148.8 bc A	109.9 c A
BRS Umbu	170.8 b A	144.6 ab A	165.4 b A	160.3 b A
BRS Figueira	210.0 ab B	136.8 b C	258.2 a A	195.8 b B
BRS Guatambu	218.1 a AB	180.6 a BC	155.1 bc C	246.6 a A
BRS 277	92.9 c AB	94 c AB	123.9 c A	73.1 c B
Genotypes	Density 300 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	51.2 b C	104.9 bc B	140.1 b AB	178.3 b A
BRS Umbu	72.2 b B	97.4 c B	93.5 c B	169.2 b A
BRS Figueira	143.8 a A	141.3 ab A	173.4 ab A	159.5 bc A
BRS Guatambu	131.3 a B	147.1 a B	147.4 b B	254.4 a A
BRS 277	66.8 b C	123.9 abc B	198.3 a A	120.6 c B
Genotypes	Density 375 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	100.7 c A	97.6 bc A	81.6 c AB	55.9 c B
BRS Umbu	152.8 b AB	135.9 ab B	69.0 c C	176.1 ab A
BRS Figueira	144.3 b A	159.9 a A	136.5 b A	139.3 b A
BRS Guatambu	325.6 a A	170.1 a B	156.6 b B	156 ab B
BRS 277	139.6 bc C	70.2 c D	263.9 a A	180.9 a B
CV(%)	15.52			

* Average followed by the same capital letter in line comparing defoliation managements. Do not differ statistically by Tukey test at 5% probability error.

** Means followed by the same letter in the column, comparing genotypes, do not differ statistically by Tukey test at 5% probability error.

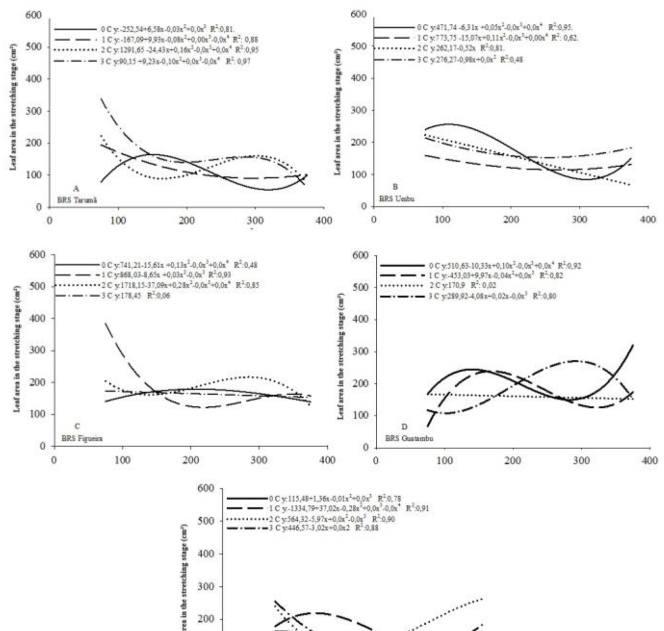

Fig 2. Regression curves for leaf area on stem elongation for interaction among dual purpose wheat genotypes x seeding densities x defoliation managements. A= BRS Tarumã. B= BRS Umbu. C= BRS Figueira. D= BRS Guatambu. E= BRS 277. Densities are 75, 150, 225, 300 e 375 plant m^{-2}. Defoliation managements are 0C = without cut; 1C = one cut; 2C = two cuts; and 3C = three cuts.

Table 3. Averages for interaction among dual purpose wheat genotypes x seeding densities x cutting management for leaf area at flowering stage (LAF).

Genotypes	Density 75 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	424.6 a A	137.7 b C	157.2 a C	255.3 a B
BRS Umbu	142.6 d A	147.1 ab A	160.1 a A	164.6 b A
BRS Figueira	241.4 c A	160.4 ab B	190.5 a B	106.1 c C
BRS Guatambu	343.9 b A	188.0 a B	173.1 a BC	135.6 bc C
BRS 277	151.3 d B	166.4 ab B	177.1 a B	254.5 a A
Genotypes	Density 150 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	225.2 c A	168.5 a B	140.6 a B	169.0 b B
BRS Umbu	150.4 d A	186.1 a A	141.2 a A	82.4 c B
BRS Figueira	322.3 b A	62.6 b C	152.8 a B	347.7 a A
BRS Guatambu	428.4 a A	154.8 a B	175.5 a B	168.0 b B
BRS 277	250.7 c A	170.6 a B	134.8 a B	156.5 b B
Genotypes	Density 225 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	149.6 c AB	137.9 ab B	186.6 b A	125.2 a B
BRS Umbu	321.3 a A	67.4 c C	81.4 c C	150.9 a B
BRS Figueira	159.2 c A	109.1 bc B	166.1 b A	170.2 a A
BRS Guatambu	241.5 b A	135.6 ab B	150.7 b B	145.8 a B
BRS 277	253.8 b B	181.2 a C	432.7 a A	125.5 a D
Genotypes	Density 300 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	436.2 b A	71.9 c C	125.2 b B	131.0 b B
BRS Umbu	97.8 d C	139.8 b C	364.3 a A	229.8 a B
BRS Figueira	369.2 c A	63.5 c C	117.9 b B	153.9 b B
BRS Guatambu	165.7 d A	152.4 b AB	119.4 b B	139.3 b AB
BRS 277	511.3 a A	340.3 a B	155.8 b C	160.6 b C
Genotypes	Density 375 plant m^{-2}			
	Defoliation managements			
	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
BRS Tarumã	252.2 a A	163.1 b B	154.8 a B	130.1 ab B
BRS Umbu	240.9 a A	148.9 b B	116.2 ab B	107.3 b B
BRS Figueira	148.4 b B	241.7 a A	143.5 ab B	140.2 ab B
BRS Guatambu	208.5 a B	256.2 a A	157.2 a C	168.2 a BC
BRS 277	144.6 b A	148.1 b A	104.9 b A	121.9 b A
CV(%)	15.57			

* Average followed by the same capital letter in line comparing defoliation managements. Do not differ statistically by Tukey test at 5% probability error.

** Means followed by the same letter in the column, comparing genotypes, do not differ statistically by Tukey test at 5% probability error.

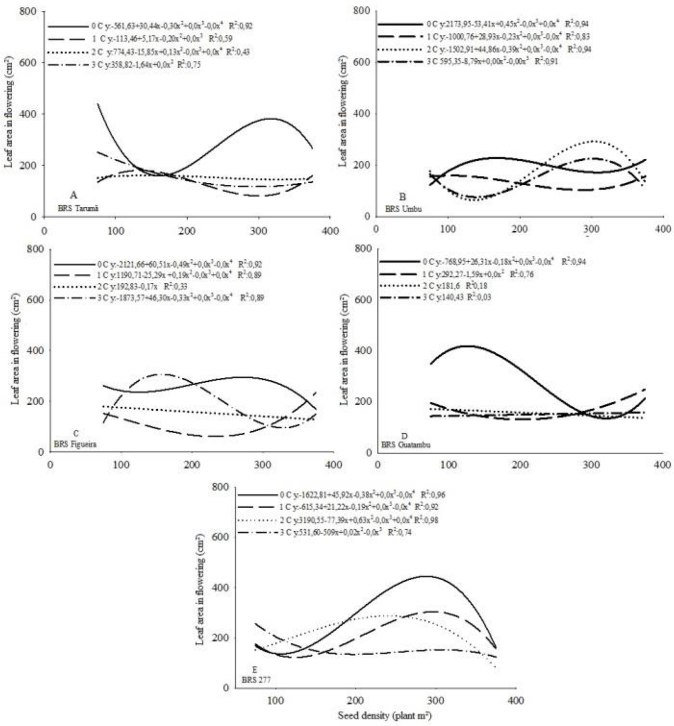

Fig 3. Regression curves for leaf area on flowering for interaction among dual purpose wheat genotypes x seeding densities x cutting managements. A= BRS Tarumã. B= BRS Umbu. C= BRS Figueira. D= BRS Guatambu. E= BRS 277. Densities are 75, 150, 225, 300 e 375 plant m^{-2}. Cutting managements are 0C = without cut; 1C = one cut; 2C = two cuts; and 3C = three cuts.

Table 4. Averages for interaction among dual purpose wheat genotypes x seeding densities x cutting management for leaf area at grain filing (LAG).

Genotypes	Without cut(cm^2)	One cut(cm^2)	Two cuts(cm^2)	Three cuts(cm^2)
	Density 75 plant m^{-2} – Defoliation managements			
BRS Tarumã	1355.2 a A	1241.1 a B	528.7 b C	324.2 c D
BRS Umbu	628.6 c B	976.4 b A	258.8 c C	322.7 c C
BRS Figueira	868.6 b A	753.8 c B	154. d D	561.2 b C
BRS Guatambu	393.8 d B	457.3 d B	470.8 b AB	552.3 b A
BRS 277	644.2 c B	842.1 c A	665.6 a B	767.3 a A
	Density 150 plant m^{-2} – Defoliation managements			
BRS Tarumã	750.2 a A	454.3 d B	543.0 a B	249.4 cd C
BRS Umbu	180.3 d C	331.8 e B	624.3 a A	161.3 c C
BRS Figueira	343.9 c C	1044.7 a A	434.8 b B	326.2 c C
BRS Guatambu	423.4 c B	647.5 c A	315.8 c C	567.1 a A
BRS 277	537.7 b B	767.8 b A	558.9 a B	359.9 b C
	Density 225 plant m^{-2} – Defoliation managements			
BRS Tarumã	541.7 a B	240.2 b B	722.5 a A	677.2 a A
BRS Umbu	423.6 b A	355.5 a A	188.5 c B	264.5 cd B
BRS Figueira	587.8 a A	376.8 a B	338.4 b B	558.3 b A
BRS Guatambu	315.7 c A	149.6 c B	350.1 b A	225.1 d B
BRS 277	283.1 c B	163.1 bc C	752.9 a A	318.8 c B
	Density 300 plant m^{-2} – Defoliation managements			
BRS Tarumã	854.3 a A	462.9 b C	747.8 a B	362.7 b D
BRS Umbu	269.3 d B	239.5 d B	476.6 b A	135.4 d C
BRS Figueira	560.5 b A	343.1 c B	148.8 d C	280.4 bc B
BRS Guatambu	466.7 c B	757.4 a A	338.1 c C	255.2 c C
BRS 277	147.6 e C	674.4 a A	338.7 c B	626.6 a A
	Density 375 plant m^{-2} – Defoliation managements			
BRS Tarumã	306.7 c A	351.6 c A	361.4 b A	80.5 c B
BRS Umbu	656.4 b A	540.5 b B	440.6 ab C	360.2 a C
BRS Figueira	351.9 d A	247.1 d B	248.9 c B	235.5 b B
BRS Guatambu	443.2 c B	627.6 b A	451.5 a B	353.2 a C
BRS 277	955.5a A	756.7 a B	455.7 a C	367.1 a C
CV(%)		11.74		

* Average followed by the same capital letter in line comparing defoliation managements. Do not differ statistically by Tukey test at 5% probability error.
** Means followed by the same letter in the column, comparing genotypes, do not differ statistically by Tukey test at 5% probability error.

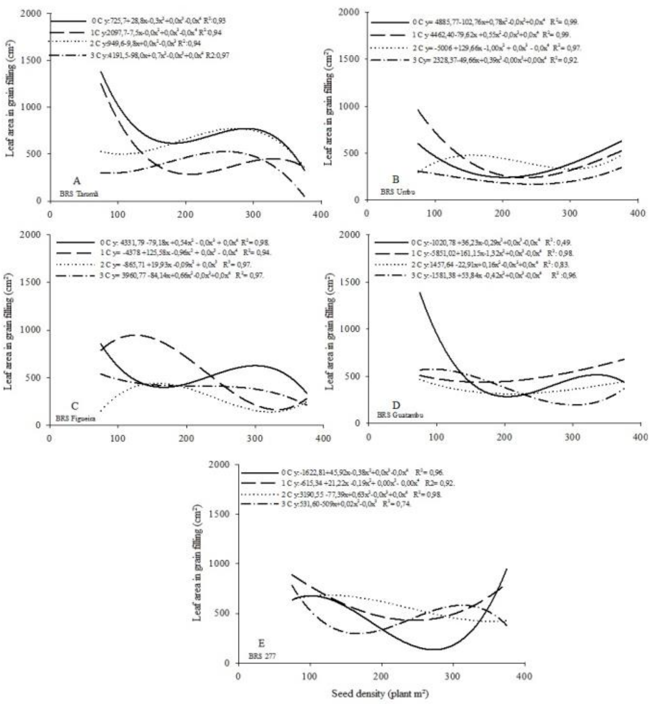

Fig 4. Regression curves for leaf area on grain filling for interaction among dual purpose wheat genotypes x seeding densities x cutting managements. A= BRS Tarumã. B= BRS Umbu. C= BRS Figueira. D= BRS Guatambu. E= BRS 277. Densities are 75, 150, 225, 300 e 375 plant m^{-2}. Cutting managements are 0C = without cut; 1C = one cut; 2C = two cuts; and 3C = three cuts.

three cuts. Possibly, the behavior of this genotype is related to the high tillering potential, regardless of seeding density (Valério et al., 2008).

Regarding to BRS Figueira, it can be observed the densities of 150; 300 and 375 plant m^{-2} where the same LAE on defoliation managements but at the densities of 75 and 225 plant m^{-2} management with one and two cuts obtained higher magnitude than the other managements. Possibly, this response is linked to higher regrowth capacity of plants (Bortoline et al., 2004), which favors the densities' response in defoliation managements.

Regarding to BRS Guatambu, it is observed that the management without cut shows magnitude of LAE greater or equal to other defoliation managements at the densities of 75, 150, 225 and 375 plant m^{-2}; and at the density of 300 plant m^{-2}on management with three cuts. This response may be related to the amount of leaves that this genotype has in its structure (Hastenpflug et al., 2011). Martin et al. (2010), has found at the management without cut and with one cut the occurrence of the greater height of plants and number of leaves in this genotype. Regarding to BRS 277 genotype, management with two cuts at the densities of 75; 225; 300 and 375 plant m^{-2} presented magnitude equal or superior than other managements; however, at the density of 150 plant m^{-2} higher magnitude of LAE was obtained in the management with one cut. According to Carvalho et al. (2015), dual purpose wheats shows tolerance to defoliation and proper recovery of leaf area according to the severity of the cuts.

Wheat productivity is associated with the accumulation of dry matter in pre anthesis (Fioreze and Rodrigues, 2014). At this stage, there is a direct effect of the accumulation of assimilates by photosynthetically active leaf area.

Leaf area at flowering

Leaf area at flowering (LAF), showed different behavior among genotypes and seeding densities at the different defoliation managements (Fig. 3). It is observed the trend of increasing the LAF for the BRS Tarumã genotype without cut in lower and higher seeding densities. The increase was also observed in BRS Umbu genotype, with higher plant densities in managements with two and three cuts, showing maintenance of LAF in managements without cut and with one cut. Possibly the leaf area increasing is linked to the higher number of leaves on the main stem or its greatest expansion of leaf blade (Walter et al., 2009).

Regarding to BRS 277 genotype, there is increase in magnitude of LAF in the management of two cuts and three cuts in higher densities, and at the management without cut in lower densities. The response goes against what happened with BRS Figueira and BRS Guatambu genotypes that tend to reduce the LAF with the increase in plant densities in the management of two cuts and without cut, respectively. The increase of seeding density increases the growth rate, resulting in increased leaf area, dry matter production, being the effects reduced during plant development (Abreu et al., 2002).

In Table 3, it is possible to observe the higher magnitude of the LAF in genotypes of seeding densities within the respective defoliation managements. This response is checked at BRS Tarumã in managements without cut, two and three cuts at the densities of 75 and 375 plant m^{-2}. This response may be due to the largest development cycle that provides greater time for leaves emergence (Martin et al., 2013).

In BRS Umbu genotype, it is observed the higher magnitude in management without cut at the densities of 225 and 375 plant m^{-2} and at the density of 300 plant m^{-2} in the managements with two and three cuts. The response of this genotype in higher plant densities may be related to loss of fertile tillers (Valério et al., 2008).

BRS Figueira genotype has obtained magnitude of LAF in the management with three cuts at the density of 150 plant m^{-2}, and the BRS Guatambu genotype at the density of 375 m^{-2} s in all defoliation managements. Silveira et al. (2010) had revealed optimal values of adaptability and stability with intermediate density, while higher densities are favorable for genotypes with low tillering potential.

Regarding to BRS 277 the magnitude of LAF is greater than or equal to the other genotypes with seeding densities of 75 and 225 plant m^{-2} in managements with one cut, two and three cuts; at the seeding density of 150 s m^{-2} with two cuts; and at the density of 300 plant m^{-2} in management without cut and one cut. According to Meinerz et al. (2012), this genotype has high tillering potential and leaf accumulation, which favors its defoliation management and arrangement of seeding density.

It is observed the effect between cuts within the sowing density for each genotype (Table 3). For genotype BRS Tarumã genotype obtained increase in LAF when subjected to management with two cuts at the density of 225 plant m^{-2}, but in the others plant densities when there was not cut. Meinerz et al. (2012) reported reduction in leaf accumulation of this genotype when subjected to greater number of cuts due to the change of relative allocation of assimilates caused by defoliation.

BRS Umbu genotype had not its LAF affected when subjected to defoliation management at the density of 75 plant m^{-2}; however, at the density of 150 plant m^{-2} obtained greater leaf area in managements without cut, one and two cuts; and at the density of 375 plant m^{-2} without cut. This response can be related to the high tillering potential, therefore, not dependent of seeding density (Valério et al., 2008).

BRS Figueira genotype obtained higher magnitude of LAF at the density of 150 plant m^{-2} in managements without cut and three cuts; at the density of 225 plant m^{-2} without cut, two and three cuts; and at the density of 375 plant m^{-2} in the management with one cut. The delay in leaf area recovery in the flowering stage is tied to high mortality of tillers after defoliation (Bortolini et al., 2004).

The tendency of the BRS Guatambu genotype shows the greatest magnitude of LAF in managements without cut. But at the density of 300 plant m^{-2} in managements with one and three cuts and at the density of 375 plant m^{-2} in the management with one cut. The response to high densities can be linked to greater plant height and the low response of leaf area after cuts (Martin et al., 2010).

BRS 277 genotype showed increased in LAF at the densities of 75 and 225 plant m^{-2} in management with three and two cuts, respectively; and at the density of 375 plant m^{-2} had not been influenced among defoliation managements, which enables the farmer to maximize its tillage with largest number of cuts. The high tillering potential (Meinerz et al., 2012) and regrowth capacity (Bortoline et al., 2004) may favor the response at the densities and defoliation managements.

Leaf area in grain filling

The larger number of leaves, within certain limits, offers necessary amounts of assimilates for grain filling. The loss of leaves close ear's wheat reduces the allocation of assimilates and yield of grains (Souza et al., 2013).

Leaf area in grain filling (LAG) had different behavior in defoliation managements within the plant densities. It is observed in fig. 4 that BRS Tarumã genotype there was a trend in reducing LAG in managements without cut and one cut with increasing in seeding density, but the managements of two and three cuts tend to increase LAG with increasing in seeding density. During plant development, photosynthetic activity per leaf area increases with leaves' age, up to its maximum expansion and decreasing up to senescence (Santos and Carlesso, 1998).

Regarding to BRS Figueira genotype, defoliation managements tend to reduce LAG with increasing in seeding density. BRS Guatambu in management with one cut tends to increase LAG, however, other defoliation managements had reduced LAG with increasing in seeding density. Martin et al. (2010), when comparing dual purpose wheat genotypes, found high forage production in this genotype using densities below 100 plant m^{-2}. Similar behavior has occurred in the BRS 277 genotype, which decreases leaf area with increased densities in defoliation managements. Excessive production of foliar blades causes self-shading, contributing to foliar senescence (Meinerz et al., 2012).

Leaf area on grain filling also had different magnitude between genotypes within seeding densities in their defoliation managements (Table 4). BRS Tarumã genotype showed magnitude of LAG greater than or equal with other genotypes at the density of 75 plant m^{-2} in managements without cut and one cut, and at the densities of 150, 225 and 300 plant m^{-2} in the managements without cut and two cuts. This genotype shows long cycle and has a higher final number of leaves, being this characteristic, essential to grain filling (Walter et al., 2009).

BRS Umbu genotype had a higher magnitude of LAG at the densities of 150 and 225 plant m^{-2} in managements with two and one cuts, respectively. Regarding to BRS Figueira at the densities of 150 and 225 plant m^{-2} in management with one cut. Similar than observed to BRS Guatambu at the densities of 300 and 375 plant m^{-2} in the managements with one and two cuts, respectively. Low response to LAG for defoliation managements, possibly be related to the number of issued tillers and lower survival rate (Valério et al. 2008).

BRS 277 stands out for having achieved greater magnitudes of LAG in all densities, being at the density of 75 plant m^{-2}, obtained higher magnitude with management of two and three cuts; at the density of 150 and 225 plant m^{-2} with two cuts; at the density of 300 plant m^{-2} with one and three cuts and at the density of 375 plant m^{-2} in all defoliation managements. This genotype has high tillering potential and leaf number (Meinerz et al., 2012), as well as adequate regrowth capacity (Bortoline et al., 2004). These characteristics favor its adaptation in different densities of sowing and defoliation managements.

Materials and Methods

Experimental conditions

The experiment was conducted in 2014 growing season in experimental area belonging to the Breeding Lab and Plant Production of the Federal University of Santa Maria Campus Frederico Westphalen-RS (S 27º39' and W 53º42' at 490 m.a.s.l.) The climate is characterized by Köppen as humid subtropical (*Cfa*), and soil classified as Oxisol.

Experimental design and genotypes used

The experimental design was a randomized complete block in a factorial treatment design, as follows: five genotypes (BRS Figueira, BRS Guatambu, BRS Tarumã, BRS Umbu and BRS 277) x five seeding densities (75; 150; 225; 300 and 375 plant m^{-2}) x four defoliation managements (without cut. one cut. two cuts and three cuts). Arranged in three replications. Both the cuts were manually made when the plants reached 30 cm, leaving 10 cm for regrowth (Carvalho et al., 2015).

Experimental units were composed of 12 rows of two meters in length, spaced by 0.17 meters. We used the direct seeding system, with manual seed deposition. Base fertilizer used was 200 kg ha^{-1} of 10-20-20 in NPK formulation. In coverage were applied 90 kg ha^{-1} of nitrogen (N) in the urea's form (45%) applied after the completion of each cut and parceled according to the managements. The control of insect pests and diseases was done preventively as recommendation.

The traits evaluated were

Assessments were based on methodology proposed by Martin et al. (2010), using the genotypes of the central lines of each experimental unit, despising 0.5 meters from each end. Traits were measured at tillering, flowering, stem elongation and grain filling, according to phenological scale described by Large (1954), in ten plants of each plot. Assessed traits were: leaf area on tillering (LAT) measured at tillering period; leaf area on stem elongation (LAE), measured when the plants were with the last-leaf sheath fully developed; leaf area at flowering (LAF) measured ten days after ear externalization; leaf area in grain filling (LAG). Leaf area in each assessment was determined with a portable leaf area meter (LiCor 3000 C). Results were expressed in cm^2.

Statistical analysis

Data were subjected to three-way ANOVA by F test at 5% probability. When interaction among dual-purpose wheat x sowing densities x defoliation managements was detected, it was compared its simple effects. For the qualitative factors, the traits were subjected to multiple comparison test (Tukey). For the quantitative factor, traits were subjected to linear regression, fitting the curve to the greater significant polinomy degree. Analyses were performed with Genes software (Cruz, 2013).

Conclusion

Leaf area is influenced by defoliation management seeding densities and dual purpose wheat genotype. In the tillering stage, increased in seeding density reduces leaf area in all genotypes. The larger leaf area at tillering is obtained at the density of 300 plant m^{-2} to management with three cuts for the genotypes BRS Tarumã, BRS Umbu, Guatambu BRS and BRS Figueira. The density of 300 plant m^{-2} s provide increase on leaf area in flowering stage for BRS Umbu, BRS Guatambu and BRS 277 genotypes in all defoliation managements.

Leaf area reduces in the grain filling when seeding density is increased for all defoliation managements in the genotypes BRS Tarumã, BRS Umbu and BRS 277.

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