Factors related to the economic performance of wheat commercial fields[1]

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ABSTRACT

The variability of agronomic performance and of input use level of wheat commercial fields allows the identification of the factors with the greatest contribution to its economic performance. The objective of this work was to identify the main factors related to the variability of economic performance in wheat commercial fields in the Southern Region of Paraná State. The study was based on data from 65, 64 and 80 farms in 2013, 2014 and 2015, respectively. The variables evaluated were: costs of fertilizer, herbicide, insecticide, fungicide and seed; grain yield; and simplified gross margin (SGM). Data were subjected to Principal Components Analysis followed by Cluster Analysis. The variability of wheat economic performance was mainly related to grain yield, fertilizers cost and seed costs. Grain yield is one of the most important factors to determination of economic performance of wheat commercial fields in the studied region, and a greater investment in fertilizers and with seeds can decrease it. It must be considered that the cost reduction might be obtained with suitable management practices, and the contribution of items of cost analyzed to economic performance may be different in each cropping season probably due to variations of the cost profile and grain yield.

Keywords: *Triticum aestivum*; production cost; gross margin; multivariate; principal components.

INTRODUCTION

Wheat is the main winter crop in Southern Brazil with 1,7 million hectares planted, and the State of Paraná is the main wheat producer, responsible for about 50% of Brazilian production in the last decade (Conab, 2017). Wheat can compose different crop systems in this region, but the succession with soybean is the most important of them (Pires *et al*., 2016). Wheat cultivation has many technical and economic advantages for cropping systems as it provides a rational and efficient use of soil, resulting in less soil erosion (Canziani & Guimarães, 2009), summer crop weed control (Nichols *et al*., 2015), and a strategy to reduce farm operating costs (Baumgratz *et al*., 2017).

Regardless these advantages, in the last decade the wheat cultivated area in the South region varied from one year to another between an increase of 19% and decrease of 18% (Conab, 2017). The inherent risk for wheat farming is one cause of these variations, which is mainly related to oscillations of price and grain yield (Pereira *et al*., 2007). Excluding the price factor, the climatic conditions are one of the most important elements for wheat economic return, since they can significantly affect grain yield and influence costs and, consequently, determine the farmer's economic revenue. Besides, it can affect wheat technological quality and impact on the grain price (Wilson *et al*., 2018). This factor, linked with the high cost of inputs, places Brazil among the countries with the highest wheat production expenditure. In addition, wheat cultivation is unattractive because of the unsatisfactory insurance instruments, decapitalization or low investment capability, and unstable market (De Mori & Ignaczak, 2011).

Due to this high-risk scenario, the economic return of wheat farming depends on the management crop planning in order to reduce costs and ensure grain yield (Baumgratz

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et al., 2017). Few studies about this topic show that is possible to combine these conditions by adjusting inputs use level and management practices. The best economic performance has been obtained by farmers throughout an intermediate use of inputs (Nave *et al*., 2013). Furthermore, sowing date and cultivar selection are important strategies to maximize an economic gain, and a pesticide reduction could be possible without reducing farmers' income (Silva Neto *et al*., 2009; Jacquet *et al*., 2011).

The identification and hierarchization of limiting factors associated to a technical and economic performance are fundamental to fit strategies to increase economic return (Ribeiro & Raiher, 2013). Nevertheless, this information is scarce for wheat production in Brazil and it would contribute to an increase of farmers' income and make wheat a continually attractive option to crop systems in Southern Brazil. The variability of agronomic performance and of the input use level of wheat commercial fields allows the identification of the factors with the greatest contribution to its economic performance. The objective of this study was to identify the main factors related to the variability of economic performance in wheat commercial fields in the Southern Region of Paraná State.

MATERIAL AND METHODS

The study was based on data of wheat commercial fields owned by farmers who are associated with a cooperative situated in the Southern Region of Paraná State, whose area of activity comprises 115.000 hectares covering 14 cities. This region is composed by high yielding environments for winter crops due to both climate and edaphic potential and high input use (De Mori *et al*., 2016), reaching one of the highest rainfed wheat yields in Brazil. The climate of the region is classified as Cfb, in accordance with the Koeppen classification, and the predominant soil classes are Nitosols and Oxisol (Haplohumox) (Fontoura *et al*., 2015).

The farmer population considered in this study was of 151, 172, and 181 farmers, both individual farmers and family groups, in 2013, 2014 and 2015, respectively. The family groups corresponded to farmers, members of the same family that share land, machinery, and labor. Stratified random proportional sampling procedures were used according to strata defined based on grain yield obtained in each cropping season. The determination of strata was based on value variation around average using grain yield standard deviation in each cropping season. The determined strata were Superior Strata (SS), Inferior Strata (IS) and Medium Strata (MS). SS corresponded to wheat fields with grain yield superior to average added one standard deviation, while IS referred to wheat fields with grain yield inferior to average minus one standard deviation. MS corresponds to wheat fields with yield grains situated between average plus or minus one standard deviation. Sample size considered a margin of error of 10%, a confidence level of 95%, and a population heterogeneity of 50%. In 2013, 2014, and 2015 there were 65, 64, and 80 wheat commercial fields analyzed, respectively.

The data was obtained from the technical department of the cooperative and from its research foundation. Data about input costs, simplified gross margin (SGM) and grain yield were gotten from the cooperative database, and they were relative to each commercial field. Meteorological information was taken from Simepar's Forecast Station at Entre Rios-Guarapuava. The term SGM was adopted because gross margin was calculated considering only part of variable cost: seeds, fertilizers, and plant protection input.

The variables evaluated were: fertilizer (starter fertilization and nitrogen side dressing) costs; herbicide costs; insecticide costs; fungicide costs; seed costs; grain yield; and SGM. The costs with fertilizer, herbicide, insecticide, fungicide, and seeds correspond to the value per hectare paid by farmers for each item to the cooperative, and its sum was called field establishment and plant protection costs (FEPPC). SGM correspond to the difference between gross income, which considered wheat price and grain yield obtained, and FEPPC. The wheat price was the same for all commercial fields in each year. All values were corrected by IGP-M from January of each year to January 2018 (FGVDados, 2018).

Descriptive statistics were used to summarize the data of each variable, followed by analysis of variance and Tukey contrasts test. Subsequently, the data were standardized using Z-score (Hair *et al.*, 2009), and the multivariate analysis was performed in two stages, adapted from Ribeiro & Raiher (2013). First, the data were subjected to Principal Component Analysis (PCA), considering costs variables and grain yield as active ones to extract components, and SGM as supplementary variable, which in turn can have its variability explained by principal components with which they have correlation. This association allow the election of the most important variables (Del Pozo *et al*., 2014). The selection of the principal components (PC) considered the minimum cumulative explained variance of 70%.

In a second stage, all variables were used for commercial fields classification using agglomerative hierarchical clustering, considering the Euclidian distance as a measure of distance between two points and the Ward's method as a classification algorithm. This method permits the agglomeration of fields based on its similarity (Hair *et al.*, 2009). The R Program was used to process the analysis, using FactoMineR package for PCA, and the Cluster package for clustering analysis.

RESULTS AND DISCUSSION

In the three regarded cropping seasons, the fertilizers cost corresponded to 50% of FEPPC, while seed cost represented 22%, followed by fungicide cost (17%), herbicide (6%), and insecticide cost (2%) (Table 1). The FEPPC, gross income and SGM varied between years: the lowest FEPPC and the highest gross income and SGM in 2013; the highest FEPPC and the lowest gross income and SGM in 2015. The grain yield also varied between years, and 2013 stood out with an average of 4.186 kg ha^{-1}.

The fertilizer cost varied between years, with significant difference between 2014 and 2015 (Table 1). Herbicide costs did not vary in the period, whereas insecticide costs were superior in 2014 and in 2015. The highest expense with fungicide was in 2015, when it represented 20% of FEPPC. In 2014, these costs were intermediate in relation to other years, representing 16% of FEPPC, while in 2013 it was the lowest, reaching 14% of FEPPC. Seed costs also had significant variation, with the highest value in 2014.

Considering the variance of 70%, three PC were selected in each year (Table 2). In 2013, the first PC explained 37% of the variance and showed significant positive correlation with all variables related to costs, with the highest correlation with fertilizer cost (0.77). Besides, the first PC had a significant negative correlation with SGM, indicating that commercial fields with high costs, especially with fertilizers, obtained a lower economic return. The second PC showed a high positive correlation with grain yield (0.91) and SGM (0.74), while the third one did not show correlation with SGM. Thus, part of the variability of wheat economic performance was associated mainly with fertilizers cost and grain yield in 2013.

In 2014, the first PC explained 32% of the variance, with positive correlation with fertilizer, herbicide, insecticide, fungicide costs (0.84), and grain yield (0.72). The second and the third PC presented the highest correlation values with seed costs. However, there was no correlation between the first three PC and SGM, indicating that the economic performance variation could not be explained by studied variables.

In 2015, the first PC explained 32% of the variance, and had positive correlation with grain yield and with all variables related to costs, with the fungicide costs correlation of 0.75 standing out, but without correlation with SGM. On the other hand, the second and the third PC showed a significant correlation with SGM. The second one presented negative correlation with SGM (-0.37) and high positive correlation with seed costs (0.77), while the third showed a positive correlation with SGM (0.77) and grain yield (0.72). Therefore, in 2015 part of the SGM variability was explained mainly by seed costs and grain yield.

In 2013, the commercial fields were clustered into two groups (Table 3). Group 1 was formed by 31% of fields and was characterized by higher input costs, lower grain yield (3,618 kg ha^{-1}), and SGM of R$1,938.08. Group 2 obtained a productivity of 4,438 kg ha^{-1} and SGM of R$3,199.21 with a lower cost, expending 78%, 55% and 80% of the values invested in fertilizers, herbicides and insecticides in group 1, respectively. The results did not show a relationship between input cost and grain yield, otherwise commercial fields with high grain yields and lower cost obtained a better economic performance, according to PCA results.

In 2014, commercial fields were clustered into four groups (Table 3). Group 1, which comprised 16% of the commercial fields, reached the highest SGM, being 74% superior to average of groups 2, 3, and 4. Also, group 1 had a grain yield of 4,008 kg ha^{-1} and a lower investment in

Table 1: Means and standard deviations (SD) of field establishment and plant protection costs (FEPPC), simplified gross margin (SGM), and grain yield in wheat commercial fields, and yield potential in 2013, 2014, and 2015

Variable	2013		2014		2015	
	Mean	SD	Mean	SD	Mean	SD
Fertilizer costs[1]	926.27 ab[5]	255.36	862.62 b	202.84	988.31 a	240.86
Herbicide costs[1]	99.98 [ns]	56.80	107.48	71.13	109.56	57.48
Insecticide costs[1]	28.17 b	19.40	39.16 a	23.71	44.17 a	32.48
Fungicide costs[1]	243.72 c	81.10	312.67 b	110.43	402.08 a	144.41
Seed costs[1]	350.72 c	71.18	482.25 a	84.02	390.76 b	108.40
FEPPC[1]	1.648.88 c	360.72	1.804.50 b	304.73	1.934.89 a	384.15
Gross income[1]	4.460.05 a	678.94	2.757.90 b	346.40	2.206.76 c	484.74
SGM[1, 2]	2.811.17 a	780.25	951.00 b	351.35	271.87 c	550.22
Grain yield[3]	4.186 a	642	3.897 b	491	2.668 c	590
Yield potential[4]	7.068		4.864		3.681	

[1]R$ ha^{-1}. Values were corrected by IGP-M (FGVDados) from January of each year to January 2018. [2]Wheat price (R$ t^{-1}) corrected by IGP-M (FGVDados) for 2018 considered in SGM calculation: 2013 – R$1,065.34; 2014 – R$708.55; 2015 – R$827.09. [3]kg ha^{-1}. [4]Grain yield (kg ha^{-1}) obtained in experimental conditions. [5]Means followed by the same letter in the row are not significant different by the Tukey Contrasts (P<0,05). [ns]Non-significant difference.

fertilizers and fungicides, that corresponding to 66% and 78% of average value invested in another groups. Group 2, composed by 41% of fields, achieved grain yield of 4,037 kg ha^{-1} and SGM of R$947.08, and had the highest fungicide costs. Group 3, formed by eleven fields, obtained the lowest productivity (3,183 kg ha^{-1}), an intermediate input costs and SGM (R$649.85). Group 4, representing 26% of fields, had grain yield of 4,060 kg ha^{-1}, SGM of R$870.01 and the highest expense with seeds, which corresponded to 29% of FEPPC. It is important to highlight the observed for the groups 1, 2 and 4, that representing 83% of fields and obtained a similar grain yield with a different cost profile, which determined its SGM. This result might indicate differences in wheat crop management and on the production system one, what could have contributed to cost reduction and to increase the yield potential of fields.

In 2015, three groups were formed with great differences in SGM, varying between negative ones (-R$237.41) to R$923.32 (Table 3). Group 1, representing 60% of fields, obtained the lowest grain yield (2,408 kg ha^{-1}) and SGM of R$200.30, while Group 2, corresponding to 21% of fields, reached the highest productivity (3,359 kg ha^{-1}) and SGM (R$923.32). Group 3, formed by 19% of fields, adopted the highest investment in fertilizer, herbicides, fungicide and seeds, had grain yield of 2,714 kg ha^{-1} and a negative SGM of -R$237.41. Part of these results agree with PCA analysis, which indicated seed cost and grain yield and as the main factors related with SGM variability. It is worth noting the observed with Groups 1 and 2, that had a similar cost profile with an important difference in grain yield (951 kg ha^{-1}), which probably is related to choices adopted in the crop management as well.

Grain yield, fertilizers and seed costs were the main factors related to SGM variability in the studied period. Fertilizers represent the most important cost component for wheat production (Hirakuri, 2013), and its suitability based on agronomic parameters could have an important effect on its economic performance, as observed in cluster analysis as well (Tables 1, 2 and 3). The seed costs were the second principal one and it was important to SGM variability in 2015, probably because of the increase in sowing density or the adoption of cultivars of high seed

Table 2: Correlation coefficients between variables – field establishment and plant protection costs, simplified gross margin (SGM), and wheat grain yield – and principal components (PC) in 2013, 2014, and 2015

Variable	PC 1	PC 2	PC 3
	2013		
Fertilizer costs (R$ ha^{-1})	0.77 *	0.23	-0.07
Herbicide costs (R$ ha^{-1})	0.61 *	-0.39 *	-0.44 *
Insecticide costs (R$ ha^{-1})	0.68 *	0.33 *	-0.43 *
Fungicide costs (R$ ha^{-1})	0.65 *	0.04	0.42 *
Seed costs (R$ ha^{-1})	0.59 *	-0.16	0.60 *
Grain yield (kg ha^{-1})	-0.11	0.91 *	0.08
SGM (R$ ha^{-1})	-0.53 *	0.74 *	0.03
Cumulative explained variance (%)	37	56	72
	2014		
Fertilizer costs (R$ ha^{-1})	0.39 *	0.63 *	-0.37 *
Herbicide costs (R$ ha^{-1})	0.52 *	-0.49 *	-0.14
Insecticide costs (R$ ha^{-1})	0.51 *	-0.45 *	0.56 *
Fungicide costs (R$ ha^{-1})	0.84 *	-0.13	-0.24
Seed costs (R$ ha^{-1})	0.24	0.68 *	0.58 *
Grain yield (kg ha^{-1})	0.72 *	0.26 *	-0.002
SGM (R$ ha^{-1})	0.02	-0.10	0.14
Cumulative explained variance (%)	32	55	70
	2015		
Fertilizer costs (R$ ha^{-1})	0.53 *	0.50 *	-0.21
Herbicide costs (R$ ha^{-1})	0.62 *	-0.07	-0.46 *
Insecticide costs (R$ ha^{-1})	0.60 *	-0.58 *	0.22
Fungicide costs (R$ ha^{-1})	0.75 *	-0.12	-0.27 *
Seed costs (R$ ha^{-1})	0.32 *	0.77 *	0.29 *
Grain yield (kg ha^{-1})	0.52 *	-0.08	0.72 *
SGM (R$ ha^{-1})	-0.13	-0.37 *	0.77 *
Cumulative explained variance (%)	32	53	70

*Significant at 5% probability.

price. In addition to direct effect on economic performance, the use of high sowing may indirectly reduce income as a result of grain yield decrease caused by intraspecific competition and lodging (Fioreze & Rodrigues, 2014). Wheat grain yield explained part of SGM variability in two cropping seasons analyzed, similar to results found for sunflower economic performance in Paraná using the same methodology (Ribeiro & Raiher, 2013). Grain yield and price are decisive in determining gross income. Considering the impossibility of price control, grain yield is a key component to increase wheat economic performance.

The results did not show an association between commercial fields investment in FEPPC and grain yield, only with some cost items, especially fungicide cost (Tables 2 and 3). This reinforces the complexity of grain yield determination, which depends on factors that define, limit, reduce, and the level of intervention of the crop management on these factors (Loomis & Connor, 2002), and not about the level of inputs invested only. Moreover, considering the importance of cost benefit relationship, obtaining high grain yields based on a high input cost may not compensate the investment, reducing the economic revenue or turn it small (Baumgratz *et al*., 2017). It was showed in 2015, when a group of commercial fields with the highest cost and an intermediate grain yield had a negative SGM, while 60% of analyzed fields reached a small and positive SGM with a lower grain yield (Table 3). For this reason, the crop planning should consider the balance between production cost and productivity.

Also, the results did not presented relation between FEPPC and SGM, which are close to those obtained by Nave *et al*. (2013), where farmers with intermediate input levels got the highest gross margin. Our findings are also in agreement with other authors like Silva Neto *et al*. (2009), who used decision support models to different input levels in wheat crops, and Jacquet *et al*. (2011),

Table 3: Characterization of wheat commercial field groups according to field establishment and plant protection costs. simplified gross margin (SGM) and grain yield in 2013. 2014 and 2015

Variable	Group			
	2013			
			1	**2**
Fertilizer costs (R$ ha^{-1})*			1094.57	851.47
Herbicide costs (R$ ha^{-1})			144.13	80.37
Insecticide costs (R$ ha^{-1})			32.59	26.20
Fungicide costs (R$ ha^{-1})			272.64	230.88
Seed costs (R$ ha^{-1})			373.26	340.71
SGM (R$ ha^{-1})			1.938.08	3.199.21
Grain yield (kg ha^{-1})			3.618	4.438
Number of commercial fields			20	45
	2014			
	1	**2**	**3**	**4**
Fertilizer costs (R$ ha^{-1})	594.47	890.48	838.91	993.11
Herbicide costs (R$ ha^{-1})	75.29	151.23	68.57	84.70
Insecticide costs (R$ ha^{-1})	30.67	52.76	26.33	32.79
Fungicide costs (R$ ha^{-1})	233.05	371.01	241.42	316.39
Seed costs (R$ ha^{-1})	474.50	445.68	428.30	577.68
SGM (R$ ha^{-1})	1.430.10	947.08	649.85	870.01
Grain yield (kg ha^{-1})	4.008	4.037	3.183	4.060
Number of commercial fields	10	26	11	17
	2015			
		1	**2**	**3**
Fertilizer costs (R$ ha^{-1})		945.09	946.70	1.173.78
Herbicide costs (R$ ha^{-1})		87.85	120.77	166.34
Insecticide costs (R$ ha^{-1})		31.30	63.45	63.51
Fungicide costs (R$ ha^{-1})		347.99	350.58	633.56
Seed costs (R$ ha^{-1})		379.91	373.44	445.11
SGM (R$ ha^{-1})		200.30	923.32	-237.41
Grain yield (kg ha^{-1})		2.408	3.359	2.714
Number of commercial fields		48	17	15

*Values were corrected by IGP-M (FGVDados) to 2018.

who concluded that farmer's income could remain unchanged with pesticide reduction by 30%. Therefore, the results indicate that high use of inputs did not ensure high grain yield nor SGM, reinforcing the importance of a suitable crop management to achieve a better agronomic and economic return.

It must be considered the role of the management practices adopted during the cropping season and on the farm management system on cost reduction as well, as suggested to results observed on clustering analysis (Table 3). The use of integrated management practices can reduce costs due to rationalization of products use related to plant protection (Nichols *et al*., 2015; Shah *et al*., 2018), and other choices as sowing density can reduce seed costs, as discuss above. Furthermore, the farm management system, including crop rotation systems and soil and water conservation practices, for instance, can promote improvements on soil physico-chemical parameters, which might decrease the use of fertilizers, increment the crops yield potential, and contribute to weed and disease control too (Kumar *et al*., 2015).

The most important cost components related with field establishment and plant protection for SGM variability were different in each mentioned year. This result might be associated with environmental variation between years that can determine part of the management applied and, consequently, the costs. The grain yield of wheat commercial fields in 2013 and 2014 agree with the favorable environmental conditions in the region of Guarapuava for those years (Figure 1), especially 2013, with average of 4,186 and 3,897 kg ha^{-1}, respectively. In 2015, the wheat crop performance was inferior (2,668 kg ha^{-1}), concurring with the occurrence of El Niño phenomenon, with rainfall above average in September, October, and November (Figure 1). The yield potential in that period, estimated by experimental grain yield in the same region, indicates how severe the environmental limitation was (Table 1).

The correlations between El Niño and yield are consistently negative for wheat in the south of Brazil (Anderson *et al*., 2016). The high precipitation during wheat flowering seasons leads to a higher probability of Fusarium Head Blight (FHB) (*Fusarium graminearum*) occurrence, a fungal disease that attacks spikes and can cause severe losses on yield (Del Ponte *et al*., 2009). This situation may imply a rise in fungicide applications, increasing the fungicide cost and total cost and decreasing the economic performance (Tables 1 and 3). Besides, the high precipitation might increase nitrogen and other nutrients losses (Marschner & Rengel, 2012), and imply in reduction of wheat price due to mycotoxins levels (Wilson *et al*., 2018). Thus, under these conditions, there are many sources with potential to decrease the economic performance, which can cite low yield potential, lower price and high plant protection costs.

The results indicated that grain yield as an important element for the wheat economic performance, reinforcing the importance of using practices of crop integrated management to power grain yield at a low cost. Considering the field establishment and plant protection costs, the adjustment of fertilizers doses and plant density to crop conditions, and adoption of cultivars with good cost-benefit ratio, could contribute to reduce these input costs. The use of integrated management practices is an important strategy to decrease the use of chemical control of weeds, diseases and insects, and reduce costs as well. In the case of FHB disease, sowing date scheduling and selection of cultivars with the best reaction to this disease are fundamental. Improvements in application timing and spraying technology can contribute to the product efficiency use and the reduction of costs; using a disease model can help on the decision-making process. The consideration of these aspects has potential to increase the economic return of wheat fields contributing to maintain this crop on production systems in the Southern Region of Paraná State.

CONCLUSIONS

Grain yield is one of the most important factors on determination of economic performance in wheat commercial fields in the Southern Region of Paraná State. Besides, a greater investment in fertilizers and in seed can decrease it in this region.

It must be considered that the cost reduction is not related with input cost reduction only but could be obtained with management practices adopted during the cropping season and on the farm management system as well. Also, the contribution of costs related with field establishment and plant protection to the variability of economic performance may be different in each cropping season probably due to variations of the cost profile and grain yield.

The inclusion of all items of variable cost in the future studies can improve the discussion about factors related with wheat economic performance. Also, the method could be considered in studies for another wheat producer region and can contribute with information to decision-making process about both crop and inputs management.

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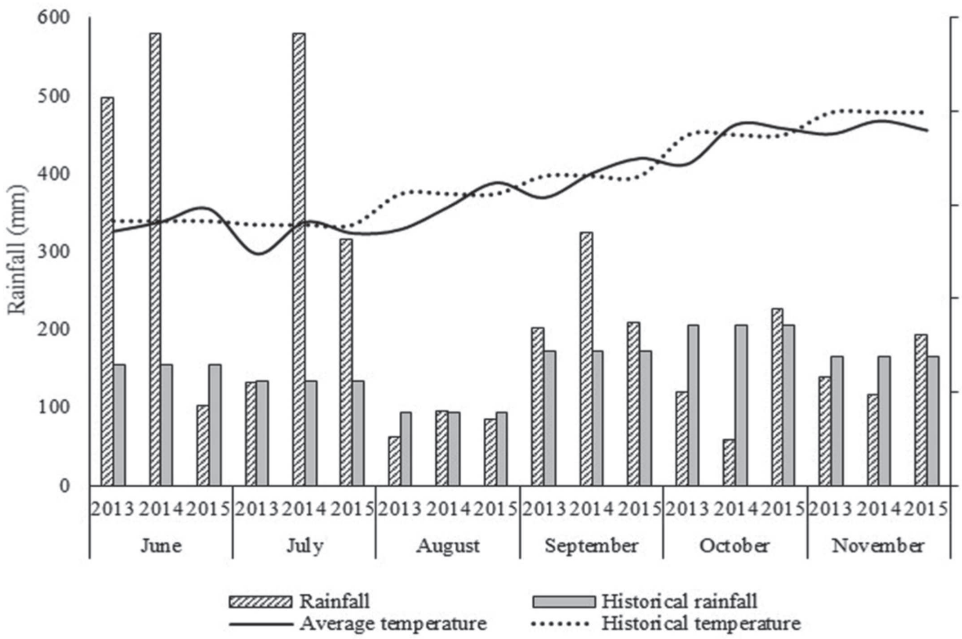

Figure 1: Rainfall and average temperature during the wheat cycle in 2013, 2014, and 2015, and historical average (1976-2015). Source: Simepar's Forecast Station at Entre Rios-Guarapuava.

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