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Economic recommendations for reseeding wheat crops

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ABSTRACT. There are several factors that may compromise the initial establishment of wheat crops, reduce the plant populations, and consequently affect yield components and grain yield. The objective of this study was to produce reseeding recommendations for wheat crops affected by reduced plant stands based on an economic analysis of the yield cost and the expectation of financial return. Experiments were conducted during two agricultural years (2011 and 2012) in the Experimental da Coxilha area, which belongs to the Department of Plant Science of Universidade Federal de Santa Maria, in the state of Rio Grande do Sul (Brazil). Random removals of wheat plants were undertaken, corresponding to 0, 20, 40, and 60% of the initial population of plants for the following cultivars: Fundacep Horizonte, Marfim, Fundacep Campo Real, Mirante and Quartzo. The characteristics that were evaluated included the number of plants and ears, as well as the grain yield. The Fundacep Horizonte, Marfim and Fundacep Campo Real cultivars were stable and able to compensate for losses caused by reductions in the plant stands. The yield production of Mirante and Quartz cultivars was dependent on the number of established plants and therefore relied on good establishment of the initial crop and no subsequent losses. Thus, the findings of this study indicate that the Mirante and Quartz cultivars do not compensate for reductions in plant populations and need to be reseeded if the number of plants is not appropriate. In such cases, the economic viability of reseeding can be quantified. In contrast, the Fundacep Horizonte, Marfim, and Fundacep Campo Real cultivars are more stable, and reseeding is not economically justified at these locations.

Keywords: *Triticum aestivum* L., economic analysis, plants stand.

Indicação econômica de ressemeadura na cultura do trigo

RESUMO. A redução da população de plantas de trigo ocorre por diversos fatores, os quais podem comprometer o estabelecimento inicial da cultura e consequentemente afetar os componentes de rendimento e a produtividade de grãos. O objetivo do presente trabalho foi de realizar uma análise econômica com ênfase na indicação de ressemeadura de trigo em função da redução aleatória do estande de plantas, do custo de produção e da expectativa de retorno financeiro. Foram conduzidos experimentos em dois anos agrícolas (2011 e 2012), na área Experimental da Coxilha, pertencente ao Departamento de Fitotecnia da Universidade Federal de Santa Maria, RS (Brasil). Efetuaram-se retiradas aleatórias de plantas de trigo, correspondendo a 0, 20, 40 e 60% da população inicial das cultivares Horizonte, Marfim, Campo Real, Mirante e Quartzo. As características avaliadas foram o número de plantas, espigas e produtividade de grãos. Verificou-se que as cultivares Horizonte, Marfim e Campo Real demonstraram ser estáveis e capazes de compensar perdas causadas pela redução do estande de plantas. A produção de grãos das cultivares Mirante e Quartzo são dependentes do número de plantas estabelecidas, devendo-se assim garantir um bom estabelecimento da lavoura para que não hajam prejuízos. Portanto, as cultivares Mirante e Quartzo não compensam a redução na população de plantas, necessitando ser ressemeadas caso o número de plantas não seja adequado. Nesses casos, a viabilidade econômica pode ser verificada. Enquanto que as cultivares Horizonte, Marfim e Campo Real são mais estáveis não sendo recomendado a ressemeadura devido a inviabilidade econômica.

Palavras-chave: *Triticum aestivum* L., análise econômica, estande de plantas.

Introduction

In extreme situations, a decision is required regarding the option to carry out wheat reseeding due to the low potential of the installed crop. However, the farmer must be aware of crop and government restrictions (in the case of farmers in the USA), related to crop insurance and herbicide handling.

Productive potential is maximized when all biotic and abiotic conditions are favorable (Guarienti, Ciacco, Cunha, Del Duca, & Camargo, 2005). Crop husbandry aims to establish an appropriate plant population, which is crucial for determining the productive potential of the crop (Benin et al., 2012). Differences in plant genetics, weather, and husbandry practices are crucial factors that affect the quality of grains (Franceschi, Benin, Guarienti, Marchioro, & Martin, 2009) and crop health (Noori & Shahrokhi, 2012). The wheat yield depends directly on the yield components, which are represented by the plant population, the number of ears per area, the number of spikelets per ear, the number of grains per ear, and the thousand grain weights (Vesohoski, Marchioro, Franco, & Cantelle, 2011).

Reductions in wheat plant stands can be caused by several factors, the main factors being related to plant health, climate, seed quality, sowing, and soil characteristics. Losses due to a reduction in the number of plants, tillers, and ears can occur from insect attacks (Peruzzo, Salvador, Pereira, Bertollo, & Tonello, 2007), competition from weeds (Agostinetto, Rigoli, Schaedler, Tironi, & Santos, 2008), and diseases that affect the emergence and establishment of healthy seedlings (Garcia Júnior, Vechiato, Menten, & Lima, 2008). The choice of cultivar and seed lot contributes to the agronomic characteristics of the stand (Felício et al., 2006). The use of quality seeds, which are free of pathogens that create economic risk (Brennan, Warham, & Byerlee, 1992), improves the likelihood that the optimal number of seedlings will survive (Boligon, Lúcio, Lopes, Cargnelutti Filho, & Garcia, 2011). The quality of the sowing operation is also important. Thus, the depth of sowing and appropriate spacing and density need to be determined (Valério et al., 2009). Soil characteristics are another crucial factor that affect the establishment of crops. Thus, chemical conditions must be optimized (Freitas et al., 2000), physical conditions, which are related to soil compaction and water infiltration, should be checked, and issues should be rectified (Bonini, Secco, Santos, Reinert, & Reichert, 2011).

Crop productivity is directly affected by the spacing between plants and rows of plants and the plant density (Kolb, Gallandt, & Mallory, 2012). When problems affecting crop establishment occur, reducing the expected population of plants, there are plant mechanisms that can compensate for these stand flaws. The main compensation mechanism is the growth of new tillers, which contributes to a greater number of ears per area. The reduction in plant density and the resultant decrease in competition from plants increases tillering because more light (Almeida, Sangoi, Trentin, & Gálio, 2002), water, and nutrients are available to each plant. Another compensatory mechanism for plant stand failures in the case of genotypes with reduced tillering potential is the formation of larger ears with a higher numbers of spikelets and a higher grain yield per plant (Valério et al., 2008). These compensatory mechanisms reduce plant stand losses but offer only a partial compensation.

The balance between the numbers of plants and tillers and the ability to compensate with regard to the components of yield, cost of production, and financial return are distinct elements in the yield process and are indispensable to the decision making process for farmers. In this context, the aim of this study was to perform an economic analysis of reseeding recommendations for wheat losses due to the random reduction of plants, based on the yield cost and the expected financial return for the yield.

Material and methods

Two agricultural experiments were conducted in 2011 and 2012 in the Experimental da Coxilha area belonging to the Department of Plant Science of Universidade Federal de Santa Maria, Santa Maria, Brazil (29º 43´ 04''S, 53º 44' 01''E). This area is at an altitude of 116 m and has a flat topography. Santa Maria is located in the Central Depression of Rio Grande do Sul State and, according to the Köppen classification, has a mesothermal and humid climate, which is defined as the fundamental Cfa type and is characterized as humid subtropical, with hot summers and no dry season. The annual average temperature is 19.1ºC, and the average annual rainfall is 1712.4 mm, which is distributed throughout the year (Heldwein, Buriol, & Streck, 2009). The soil in the experimental area is classified as a dystrophic Alfisol, with a sandy texture that belongs to the mapping unit of São Pedro (Streck et al., 2002). The soil analysis reports for both years are shown in Table 1.

A randomized block experimental design was used with the treatments arranged in split plots and with four replications. The main plots were cultivars, and the subplots included a random reduction of plants in the stand (0, 20, 40, and 60%)

Table 1. Soil certificate of analysis for the experimental area in 2011 and 2012.

Year	pH H_2O	Ca	Mg	Al	H+Al	CTC ef.	Saturation (%)		SMP
	1:01			cmolc dm^{-3}			Al	Bases	
2011	5	8.3	3	0.7	7.7	12.3	5.7	59.9	5.5
2012	4,8	5.7	2.7	1.5	10.9	10	15	44	5.2
	% M.O.	%Argila	Texture	S	P-Mehlich	P-resin	K	CTC pH7	
	----- m/v -----				----- mg dm^{-3} -----		---- cmolc dm^{-3} ----		---mg dm^{-3}---
2011	2.8	27.0	3.0	16.3	18.9	X	0.225	19.3	
2012	2.4	24.0	3.0	X	12.6	X	0.153	19.4	
	Cu	Zn	B	Fe	Mn	Na	Ca/Mg	(Ca+Mg)/K	
			----- mg dm^{-3} -----						
2011	0.90	1.50	0.60	X	X	X	2.7	50.40	
2012	X	X	X	X	X	X	2.1	54.7	

In 2011, the wheat cultivars Fundacep Horizonte, Marfim, Mirante, and Quartzo were used. The experimental unit was eleven rows, spaced 0.2 m apart and 4.5 m long, for a total area of 9.90 m^2. The usable area of the plot included nine rows that were 3.5 m in length, for a total area of 6.3 m^2. In 2012, Fundacep Campo Real, Fundacep Horizonte, Mirante, and Quartzo cultivars were used, with spaces of 0.2 m between rows. The experimental plots consisted of ten rows that were 3 m long, for a total area of 6 m^2. The usable area of the plot included eight rows that were 2 m in length, for an area of 3.2 m^2. In both years, sowing occurred during the first fortnight of June and aimed to produce a population of 350 plants m^{-2}. In 2011, the plots were manually sown, whereas in 2012, they were mechanically sown using an Imasa® PHS 125 seeder. To control for weeds, pests, and diseases, crop husbandry was performed according to the recommendations of the Comissão Brasileira de Pesquisa de Trigo e Triticale (Brazilian Research Committee of Wheat and Triticale) (Cooperativa Central de Pesquisa Agrícola [COODETEC], 2011).

The base and coverage fertilizations were based on the soil analysis results for the respective years. The base fertilization in 2011 and 2012 was 350 kg of commercial fertilizer at 05:20:20 NPK per hectare. In 2011, the coverage fertilization was a nitrogen application prior to full tillering on July 15 at a dose of 80 kg urea per hectare. In 2012, the coverage fertilization was three applications of nitrogen (urea at a dose of 80 kg per hectare), the first before tillering on July 3, the second during tillering on July 13, and the third during the stalk elongation stage on August 14.

The removal of plants was based on a random plan produced using a list of random numbers that were in proportion to the desired reduction. Plant removal occurred before tillering (July 6, 2011 and July 1, 2012). In each row of subplots, the plants were numbered, and the plants with a number corresponding to the table of random numbers generated in Excel were manually removed. To reduce the number of plants per plot (2011), the total number of plants in each of the rows (11) was initially considered, where each plant received an ordinal number from 1 to n. Subsequently, for each of the rows, lists of random numbers with a uniform distribution were generated {528 lists [11 rows x 4 cultivars x 3 plant reductions (20, 40, and 60%) x 4 blocks]}, corresponding to the number of plants that should be removed from the field under the proposed reductions. Each plant in the listing was manually removed, and the same procedure was repeated in 2012.

After the random removals, the number of the remaining plants, the number of ears (at anthesis), and the grain yield were evaluated in the field. The plants that remained in the plots were manually and randomly counted. In this evaluation, the number of plants in one linear meter from the fifth sowing row was counted. Likewise, the number of ears per linear meter was also manually counted.

After determining productivity, statistical analyses were performed by applying the assumptions of the mathematical model used by Martin and Storck (2008). Then, the data were reviewed by analysis of variance using SOC software (Empresa Brasileira de Pesquisa Agroecuária [EMBRAPA], 1997).

The economic analysis included the cultivar yield, the possible variation in wheat price, the production costs, the implementation costs, the reseeding costs, and the costs of conducting the experiment. The effects of local conditions were also taken into account. Prices were calculated in Brazilian Reals (R$) and then converted to U.S. dollars using a value of R$ 2.2231 for each US$. This value was obtained from the Brazilian Central Bank on July 10, 2014. Thus, for each cultivar studied, the yield, revenue, and profit were determined, and the revenue and profits were estimated for a cultivar if reseeding was undertaken. A quadratic equation was developed based on the information obtained, which allowed the balance point for yield to be ascertained without reseeding and determined when it was appropriate to reseed. The values attributed to the production costs are shown in Table 2.

Results and discussion

The variations in the number of plants (NP) in 2011 for each treatment and cultivar, were assessed (Figure 1a). In 2012, there was a significant interaction between the cultivars and the number of plants (Figure 1b). This result was due to mechanized sowing, which caused variations in plant populations due to the different seed sizes of the cultivars. Reduction in the plant stand stimulates the remaining components of the crop yield, which offsets the decline in population; however, this is dependent on genetic and environmental characteristics (Silveira et al., 2010).

Recommendations for reseeding were based on the price being paid per bushel of wheat.

In 2011, there was a significant interaction between the number of ears and cultivar (Figure 1c). However, the random reduction did not affect the number of ears produced by three of the cultivars (Fundacep Horizonte, Quartzo, and Marfim). For these cultivars, it was not possible to determine a regression equation for the number of ears. However, Mirante presented a different behavior.

Table 2. Yield costs (US$) for 2011 and 2012.

	2011					2012				
Description		Horizonte	Marfim	Mirante	Quartzo		Horizonte	Campo Real	Mirante	Quartzo
	V.U.	Value	Value	Value	Value	V.U.	Value	Value	Value	Value
A- Operations US$ ha^{-1}										
A.1. Soil conservation										
Maintenance of terraces	37.17	7.44	7.44	7.44	7.44	37.17	7.44	7.44	7.44	7.44
A.2. Tillage										
Desiccation	43.17	9.50	9.50	9.50	9.50	43.17	9.50	9.50	9.50	9.50
A.3. Planting										
Planting	59.52	42.26	42.26	42.26	42.26	59.52	42.26	42.26	42.26	42.26
Physical work	1.81	0.54	0.54	0.54	0.54	1.81	0.54	0.54	0.54	0.54
Internal transport	24.34	4.15	4.15	4.15	4.15	24.34	4.15	4.15	4.15	4.15
A.4. Cultivation										
Topdressing	16.13	4.84	4.84	4.84	4.84	16.13	4.84	4.84	4.84	4.84
Application of pesticides	43.17	37.99	37.99	37.99	37.99	43.17	37.99	37.99	37.99	37.99
Physical work	1.81	0.66	0.66	0.66	0.66	1.81	0.66	0.66	0.66	0.66
Internal transport	24.34	4.85	4.85	4.85	4.85	24.34	4.85	4.85	4.85	4.85
A.5. Harvest										
Mechanical harvesting	100.85	60.51	60.51	60.51	60.51	100.85	60.51	60.51	60.51	60.51
Physical work	1.81	0.72	0.72	0.72	0.72	1.81	0.72	0.72	0.72	0.72
Internal transport	24.34	1.22	1.22	1.22	1.22	24.34	1.22	1.22	1.22	1.22
Subtotal A		174.70	174.70	174.70	174.70	0.00	174.70	174.70	174.70	174.70
B- inputs US$ ton^{-1} US$ L^{-1} US$ kg^{-1}										
B.1. Fertilizers / Correction										
Urea	404.84	32.39	32.39	32.39	32.39	404.84	97.16	97.16	97.16	97.16
05-20-20	494.80	173.18	173.18	173.18	173.18	494.80	173.18	173.18	173.18	173.18
B.2. Seeds/Mat. Planting										
Seeds	0.45	54.95	58.09	65.93	54.95	0.45	54.95	47.23	65.93	54.95
Insecticide TS	71.41	21.78	22.99	26.14	21.78	71.41	25.71	22.50	31.42	25.71
Fungicide TS	23.84	7.27	7.68	8.73	7.27	23.84	5.72	5.01	6.91	5.72
B.3. Agrochemicals										
Fungicides	25.21	37.82	37.82	37.82	37.82	25.21	80.48	80.48	80.48	80.48
Herbicides	236.67	32.14	32.14	32.14	32.14	236.67	32.14	32.14	32.14	32.14
Insecticides	18.34	18.34	18.34	18.34	18.34	18.34	18.34	18.34	18.34	18.34
Other products	2.47	2.47	2.47	2.47	2.47					
Subtotal B		382.72	388.22	400.62	382.72		487.68	476.04	505.58	487.68
C- Administration US$ ha^{-1}										
M.O. Administrative	8.72	8.72	8.72	8.72	8.72	8.72	8.72	8.72	8.72	8.72
Technical Assistance	6.97	6.97	6.97	6.97	6.97	6.97	6.97	6.97	6.97	6.97
Accounting / office	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49
Electricity / telephone	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49
Conservation and depreciation of improvements	5.11	5.11	5.11	5.11	5.11	5.11	5.11	5.11	5.11	5.11
Travels	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26
Taxes and fees	0.01	10.76	10.76	10.76	10.76	0.01	10.76	10.76	10.76	10.76
Subtotal C		40.79	40.79	40.79	40.79		40.79	40.79	40.79	40.79
D- Postharvest US$ ha^{-1}										
Transport to warehouse	2.36	5.67	5.67	5.67	5.67	2.36	5.67	5.67	5.67	5.67
Reception, drying, cleaning	7.50	17.99	17.99	17.99	17.99	7.50	17.99	17.99	17.99	17.99
Storage (1 month)	2.40	5.76	5.76	5.76	5.76	2.40	5.76	5.76	5.76	5.76
Administrative fee	0.99	2.38	2.38	2.38	2.38	0.99	2.38	2.38	2.38	2.38
Subtotal D		31.79	31.79	31.79	31.79		31.79	31.79	31.79	31.79
Total cost (US$ ha^{-1})	508.63	630.01	635.50	647.90	630.01	508.63	734.97	723.32	752.86	734.97

The number of ears (m^{-2}), which was affected by the different plant reduction treatments, fit an equation of the third degree, where it was found that plant reductions up to 25% could be offset, but higher rates of reduction affected the yield of fertile ears. In 2012, there was a negative linear trend in the number of ears (m^{-2}) and the plant reduction treatments in the stands (Figure 1d). This trend was the same for all of the cultivars assessed in the experiment, and there was no significant interaction between cultivars.

Maintenance of the number of ears per area is due to compensatory mechanisms that increase tiller production. This behavior is common in wheat genotypes with high germination rates and high initial establishment capacities (Alves, Mundstock, & Medeiros, 2005). The formation of larger ears with greater numbers of spikelets and higher grain weights per ear is an additional compensatory mechanism in plant stands that is exhibited by cultivars with low tillering potentials (Valério et al., 2008).

In both years, there was a yield interaction between the cultivars and the reduction treatments. In 2011, the Fundacep Horizonte and Marfim yields were consistent, which means that they were not affected by the reduction in plant numbers and that there was therefore no adjustment in the regression equation (Figure 1e). Mirante and Quartzo cultivars showed yield sensitivity to the random reductions in plant numbers. The Mirante cultivar showed a drop in linear productivity due to a reduction in the number of plants. This meant that a first-degree equation could be composed, which allowed for a recommendation for reseeding to be made. The third degree equation was adjusted to account for the variation in the productivity of Quartzo. Reductions of 10–20% caused significant drops in yield but the stands had the capacity to compensate for yield losses.

In 2012, the Fundacep Campo Real and Fundacep Horizonte cultivars had consistent grain yields in relation to the reduction in plant numbers (Figure 1f), which did not fit any regression equation. This meant that a reseeding recommendation for these cultivars could not be made. However, the reduction in plant population affected the yields of Mirante and Quartzo cultivars, which showed a linear decrease in productivity. The performances of these cultivars were adjusted to the first-degree equation, which made it possible to make a recommendation for reseeding when a drop in productivity occurred. Silva et al. (2011) found that some cultivars that were under different environmental conditions or subject to different sowing times were highly stable and had wide adaptability and high grain yields. This indicates that they have mechanisms to compensate for the reduction in plant populations, such as increased numbers of ears, spikelets, and grains per area, as well as larger grain weights (Vesohoski, Marchioro, Franco, & Cantelle, 2011).

After assessing the productivity achieved by the different cultivars subjected to plant reduction treatments over two years, it is possible to say that the Fundacep Horizonte, Marfim, and Fundacep Campo Real cultivars can effectively offset plant population losses because they have an efficient compensation mechanism for yield, which means that there is no need for reseeding. The ability to offset potential production losses is increased by the lower levels of plant competition caused by the reduction in population density, which improves the growth of new tillers through the increased interception of radiation (Almeida et al., 2002) and the increased absorption of water and nutrients. The choice of cultivar should be made under the same performance criteria, with respect to how well it responds to changes in the production environment. The reduction in yield can be suppressed if specific cultivars that have a wide adaptability and good specificity are used for each environment (Carvalho et al., 2002).

The yield performances of the Quartzo and Mirante cultivars were significantly affected by the reduction in plant numbers. The performance of Mirante was similar in both years, with a linear reduction in productivity due to the reduction in its population. The Quartzo yields, which, despite being affected by the population reduction in 2011, were adjusted to a quadratic function in 2011 and a linear function in 2012. Thus, it is possible to say that the Mirante and Quartzo cultivars are technologically better crops and that the possibility of failures in the stand is low. This means that these cultivars require higher quality seeds (Valério et al., 2009) and that greater attention must be paid to their husbandry (Benin et al., 2012). Regardless of how much the reduction in productivity is affected, the recommendations for reseeding both cultivars can be assessed in terms of grain yield and the amount paid per bushel of wheat.

Due to the sensitivity displayed by the Quartzo and Mirante cultivars, the size of the reduction in the plant stands has become a viable determinant for the recommendation for reseeding when seeking greater profitability. The variability in grain yields reflects the percentage reduction in plant numbers and the market price of wheat required before reseeding is recommended. Reseeding a wheat crop becomes a suitable solution for better financial return in areas with damaged initial stands. However, reseeding also increases production costs. Therefore, the decision to reseed should take into consideration the recommended sowing period, which depends on the cultivar cycle and the region where wheat is produced. The conditions must be suitable for reseeding because the date when the seeding is performed is directly related to the expectation of financial return (Royer et al., 2005). The decision making on the alternatives to be followed takes into account the issues of higher profitability and lower risk (Ambrosi, Santos, Fontaneli, & Zoldan, et al., 2001). The production breakeven level depends directly upon the amount paid per bushel of wheat, which, when the Brazilian economy was opened up, was primarily affected by international factors (Souza & Stülp, 2005).

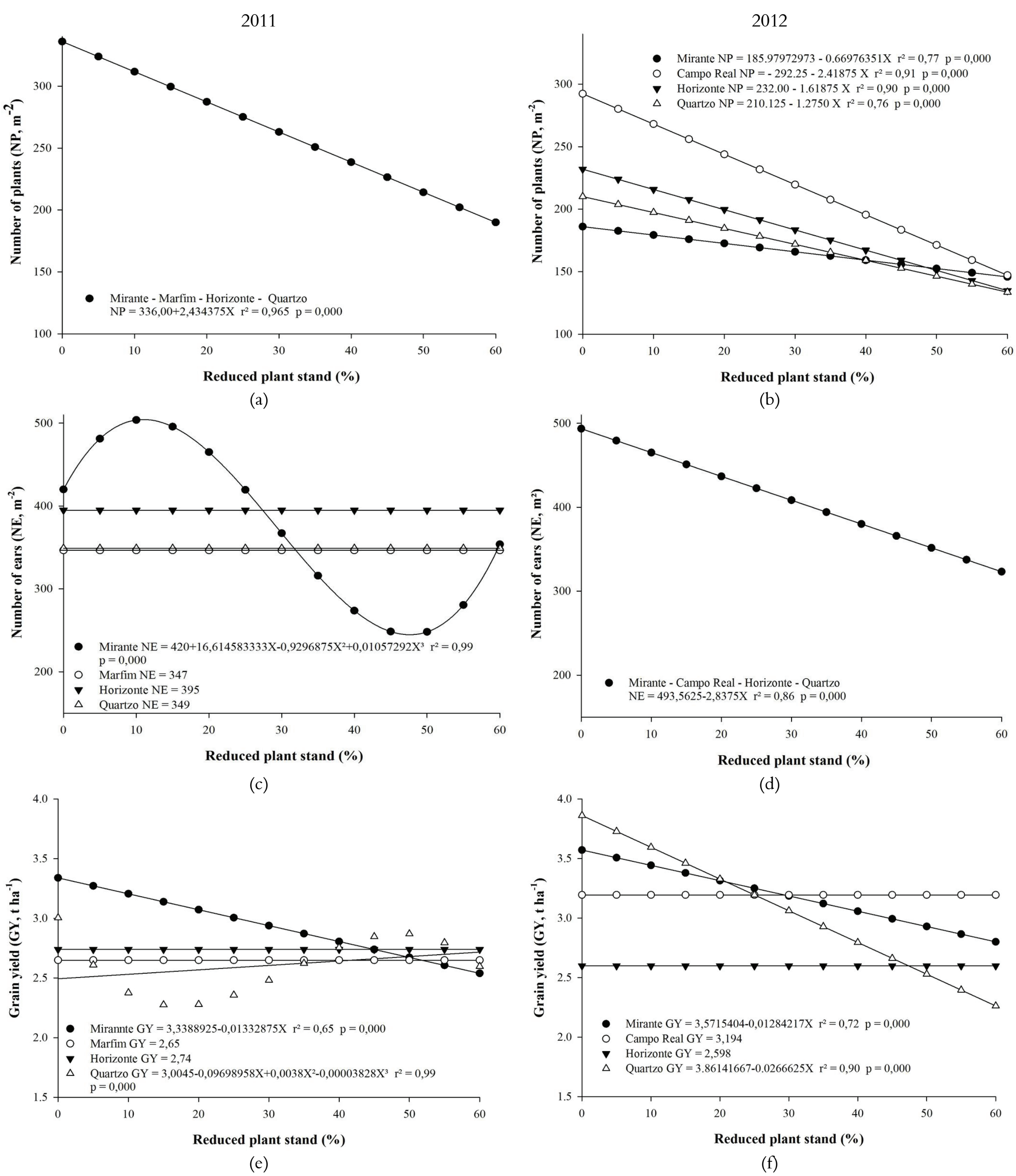
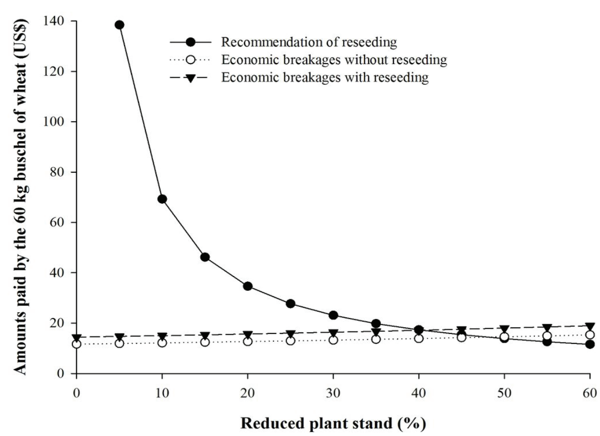


Figure 1. Assessed characteristics: Variation in the number of plants (Pl, m^2) (a, b), the number of ears (NE, m^2) (c, d), and the grain yield (GY, t ha^{-1}) (e, f) when the stand reductions (%) were applied.

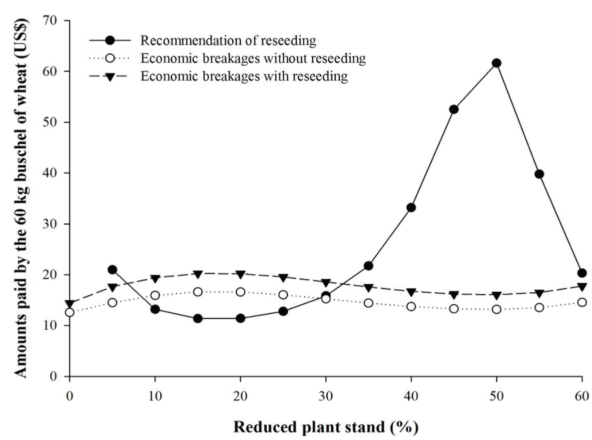
In 2011, due to the linear decrease in the grain yield of Mirante, it appears that the greater the reduction in plant population, the lower the market price paid per bushel of wheat, which affects the reseeding recommendation (Figure 2a). The production costs of this cultivar were linear and increased due to the reduction in plant population. Without reseeding, the breakeven level to cover costs ranged from 11.64 to 15.31 US$ bsh^{-1}. When reseeding occurred, this parameter varied between 14.40 and 18.94 US$ bsh^{-1}. Similarly, in 2012, the production costs for this cultivar, due to the reduction in plant numbers, also increased in a linear manner. Without reseeding, the breakeven level for yield ranged from 12.34 to 15.74 US$ bsh^{-1}, and if reseeding occurred, it ranged from 14.74 to 18.80 US$ bsh^{-1}. The decision to reseed was again associated with a reduction in the price paid for wheat and the lowest percentage number of plants in the field (Figure 2c). Thus, there is wide variation in the economic analysis, but it is recommended that reseeding be performed when there is a crop reduction of 5% and the price of wheat is 133.46 US$ bsh^{-1}, as well as when there is a 60% reduction in plant numbers and the price of wheat is 11.12 US$ bsh^{-1}. In these cases, reseeding is necessary, as greater profitability will be generated, thus contributing to sustainable agricultural production (Gitti, Arf, Melero, Rodrigues, & Tarsitano, 2012).

Quartzo showed uneven behavior over the 2 years. In 2011, the cultivar did not show a gradual decrease in productivity due to the reduction in plant numbers. The grain yield curve related to the decrease in plant population showed a decline in productivity from 0 to 15% when there was a reduction in the plant numbers. Therefore, there is a recovery in the productive potential in stands with 20 to 50% plant reduction, but the grain yield falls when there are greater decreases in the plant population (Figure 2b).

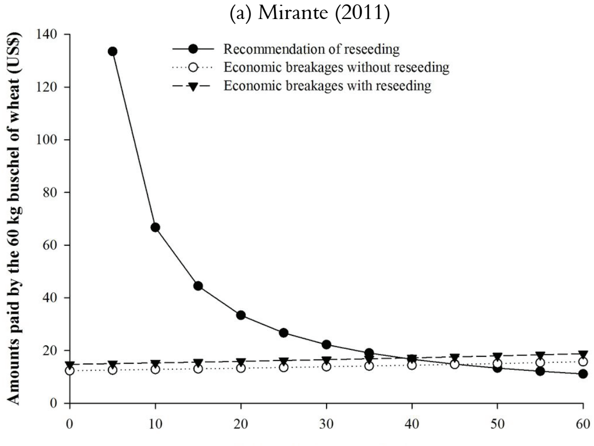
The breakeven variation did not increase and was linear. Therefore, the cost of production without reseeding ranged from 12.58 US$ bsh^{-1} with 0% plant reduction and reached a maximum of 16.61 US$ bsh^{-1} at 15% reduction in the population but then fell to 14.40 US$ bsh^{-1} in the stand with the highest plant reduction percentage.



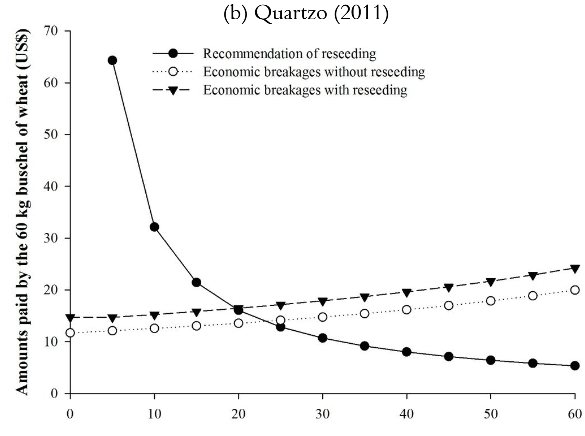
(a) Mirante (2011)



(b) Quartzo (2011)



(c) Mirante (2012)



(d) Quartzo (2012)

Figure 2. Economic analysis: Amounts paid are shown according to 60 kg bushels of wheat (US$) to facilitate the recommendation for reseeding. The economic breakages with and without reseeding due to the random reduction in plant number are also shown.

If reseeding was undertaken, the highest breakeven level occurred with a 15% reduction in stand numbers (20.25 US$ bsh^{-1}), and the minimum occurred with 0% stand reduction (14.40 US$ bsh^{-1}). Due to the unusual behavior shown by the cultivar, the recommendation for reseeding most likely occurs with a 15% random reduction in plants and when the amount paid for wheat exceeds 11.36 US$ bsh^{-1}.

In 2012, Quartzo again proved to be responsive to reductions in the plant population. However, the variation in grain yield decreased in a linear manner (Figure 2d). Due to declining productivity, there is a greater recommendation for reseeding in stands with large reductions in plant population. Seeding is recommended for wheat with a 60% drop in the plant population of when the market price of wheat exceeds 5.35 US$ bsh^{-1}. However, the price that makes this recommendation viable is modified as a function of the plant population and reaches 64.29 US$ bsh^{-1} with a 5% reduction in the stand. The performance evaluation of this cultivar is extremely important and helps verify the potential financial return, thereby determining which option offers greater profitability (Johann, Silva, Uribe-Opazo, & Dalposso, 2010).

Conclusion

The cultivars Fundacep Horizonte, Marfim, and Fundacep Campo Real have more stable grain productivities; therefore, it is not necessary to reseed them because the costs of reseeding do not compensate for the increased grain productivity obtained. The grain yields of Mirante and Quartzo cultivars are dependent on the initial number of plants. Reseeding Mirante is necessary when the reduction in the number of plants is 50% and the wheat price is over US$ 13.49 bsh^{-1}. For Quartzo, reseeding should take place when the plant reduction is 25% and the wheat price is US$ 12.59 bsh^{-1}.

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