Revista Ceres, 51(294):201-213,2004

BORDER EFFECT DUE TO PLANTS REMOVAL FROM MAIZE PLOTS[1]

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ABSTRACT

Maize is frequently evaluated based on its green ear yield and grain yield in plots with two usable rows. One row is utilized for green ear yield assessment and the other for grain yield assessment. A few plants producing green ears sometimes should be removed in order to assess forage yield. This removal could cause a border effect on the plants in the other row. The objectives of this work were to evaluate green ear yield and grain yield in three cultivars and determine whether the above mentioned border effect exists and exerts an influence on the experimental precision. A sprinkler-irrigated randomized complete-block experiment with four replications was used. Four proportions of plant removal (0%, 33%, 66% or 100%) were combined in a factorial scheme with three cultivars. The best cultivars with regard to the total number of green ears/ha, weight of marketable unhusked ears and number of marketable husked ears were AG 405, AG 1051 and Curingão, respectively. Cultivars AG 1051 and Curingão had a superior performance relative to the other cultivar with regard to weight of marketable husked ears. In terms of grain yield, cultivar AG 1051 was the most productive, followed by cultivars Curingão and AG 405. A border effect was found for the 100-grain weight and grain yield, but it has no effect on the experimental precision.

Key words: *Zea mays*, field plot technique, green corn, grain yield, experimental error.

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[1] Aceppted for publication on July 10, 2003.
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RESUMO

EFEITO DE BORDADURA DEVIDO À REMOÇÃO DE PLANTAS DA PARCELA DO MILHO

Freqüentemente o milho é avaliado quanto aos rendimentos de espigas verdes e de grãos em parcelas com duas fileiras úteis. Uma fileira é usada para avaliação do rendimento de espigas verdes e a outra, do rendimento de grãos. Existe interesse na remoção de algumas plantas que produziram espigas verdes, para avaliação do rendimento de forragem. Essa remoção poderia causar efeito de bordadura sobre as plantas da outra fileira. Os objetivos deste trabalho foram avaliar os rendimentos de espigas verdes e de grãos de três cultivares e verificar se o referido efeito de bordadura existe e influencia a precisão experimental. O experimento foi realizado em blocos ao acaso com quatro repetições, com irrigação por aspersão. Quatro proporções de plantas removidas (0%, 33%, 66% ou 100%) foram combinadas em esquema fatorial com três cultivares. Os cultivares AG 405, AG 1051 e Curingão foram os melhores quanto ao número total de espigas, peso de espigas empalhadas comercializáveis e número de espigas despalhadas comercializáveis, respectivamente. Os cultivares AG 1051 e Curingão foram superiores ao outro cultivar quanto ao peso de espigas despalhadas comercializáveis. Em termos de rendimento de grãos, o cultivar AG 1051 foi o mais produtivo, seguido pelos cultivares Curingão e AG 405. O efeito de bordadura ocorreu no peso de 100 grãos e no rendimento de grãos, mas não influenciou a precisão experimental.

Palavras-chave: *Zea mays*, técnica de parcela de campo, milho verde, rendimento de grãos, erro experimental.

INTRODUCTION

The difference in behavior between plants that are external and plants that are internal relative to the experimental plot is called border effect. This effect could be due to different treatments in neighboring plots or to areas without plants surrounding the plots. Two types of border effects on the plot are usually considered: side-border effect and end-border effect. The border effect in maize depends on the experiment (*7*, *11*), evaluated cultivars (*3*) and evaluated trait (*14*), among other factors.

One type of border effect that might occur, but apparently has not been adequately studied, is caused by partial plant removal from the plot. Plant removal might occur naturally, due to pest attack (*11*), or intentionally, when studies of various aspects of the crops must be carried out. For example, plant removal might be necessary for growth analyses, forage yield evaluation, studies on poor stands or missing plants (*9*). On the other hand, some plants should be maintained in the plot in order to assess yield or other traits at maturation. In this case, the spaces left by the removed plants could cause a border effect on the remaining plants.

Maize is frequently evaluated simultaneously with respect to green ear yield and grain yield in plots containing two usable rows (*12*, *13*, *15*). One of the rows is utilized for green ear yield assessment and the other for grain yield assessment. Since growers are interested in the husks, after the green ears are harvested, to be fed to the herds, researchers are interested in removing a few plants that produced those ears for forage yield assessment. Such removal could cause a border effect on the plants in the next usable row which was left for grain yield assessment.

Several important aspects are associated with this internal border effect. The treatments could respond differently to it and, in this case, an increase in experimental error would be produced. The internal border effect might be present without increasing the experimental error, thus contributing to overestimate yield for plants that remain in the plot. Its presence might suggest that larger plots should be utilized. Crop growth stage might also have an influence. Plants removed at the early stages probably have greater influence on the border effect than plants removed at the final growth stages. When few plants are removed, the border effect is probably different than when many plants are removed. In other words, the sample size of the removed plants can also influence the border effect.

The objectives of this work were: a) to evaluate green ear yield, grain yield and other traits in three cultivars; b) to verify the existence of border effects in one of two usable rows (in plots with four rows) when maize plants in the next usable row are removed after the green ears are harvested; c) to verify whether the border effect influences the experimental precision.

MATERIAL AND METHOD

The experiment was carried out at Fazenda Experimental "Rafael Fernandes", of Escola Superior de Agricultura de Mossoró (ESAM), located 20 km away from the municipal district seat of Mossoró, RN, Brazil, in the first semester of 2002, with sprinkler irrigation. Carmo Filho e Oliveira (*1*), based on data obtained from a weather station located in Mossoró,RN (latitude 5°11' S, longitude 37°20' W and altitude 18 m), stated that the maximum temperature in the region is between 32.1 and 34.5°C and the minimum temperature is between 21.3 and 23.7°C, with June and July as the coolest months. The mean annual precipitation is 825 mm, with March and April as the rainiest months and September, October and November as the driest. The mean annual evapotranspiration in the region is around 2,000 mm and the mean insolation is 236 h/month, with the driest months also being the months with the least insolation. The relative humidity is between 61 and 79% and the mean monthly wind speed is between 2.6 and 5.6 m/s. According to W. Köppen's classification, the climate in the region is a BSwh type, i.e., very dry, with the summer rainy season delayed toward the fall, and insufficient for the normal development of crops throughout the year. According to W. C. Thorntwaite's classification, the climate in the region is a DdAa type, i.e., semi-arid and mega thermic.

The experimental soil, a Red-Yellow Alfisol (RYP) was tilled by means of two harrowings and received, as sowing fertilization, 30 kg N (ammonium sulfate), 60 kg P_2O_5 (single superphosphate) and 30 kg K_2O (potassium chloride) per hectare. The fertilizers were applied in furrows made alongside and below the sowing furrows. Planting was performed on 8 August 2,000, with four seeds/pit, at a row spacing of 1.0 m x 0.4 m. A replanting operation was made five days after planting, to eliminate the few occurrences of planting faults. Thinning was carried out 27 days after sowing, with two plants left per pit (population of 50 thousand plants/ha). Pest control, especially against *Spodoptera frugiperda* Smith, was performed with deltamethrin sprays, at seven and 14 days after sowing. Weeds were controlled by hoeing, 26 and 42 days after planting. After each weeding operation, the experiment was fertilized with 30 kg N/ha (ammonium sulfate).

A randomized complete-block design with four replications was used. Four sampling sizes (0, 33, 66 and 100% of plants removed) were combined in a factorial scheme with three cultivars (AG-405, AG-1051 and Curingão). The two first cultivars were obtained from Sementes Agroceres (Agroceres Seeds). The other cultivar was obtained from Sementes Santa Helena. Each plot consisted of four 5.6 m long rows, i.e., rows with 14 pits. The usable area was considered as the space occupied by the two central rows, with the elimination of one pit at each end. Therefore, the plants of 0, 4, 8 and 12 pits were removed from one of the rows, and the other usable row was left intact to reveal the effects of treatments.

The following traits were evaluated: green ear yield, fresh and dry matter yield in the aerial part, in the row where plants were removed; and plant height and ear insertion height, grain yield and its components, in the plants of the usable row utilized to test the effects of treatments. The green ear yield was measured by the total number and weight of unhusked, and both marketable unhusked and husked ears. Marketable unhusked ears were considered as those with a suitable appearance for commercialization (without blemishes or evident markings of attack by diseases or pests) and with a length equal to or above 22 cm. Marketable husked ears were considered those displaying health and grain set suitable for commercialization, and with a length equal to or above 17 cm. Fresh matter yield in the aerial part of the plant was estimated based on six plants cut even with the ground after the last green corn harvest. The plants were ground in a forage grinder and a 500 g homogenized sample of the ground material was placed in a forced air circulation oven, adjusted to a temperature of 70° C, until constant weight. The weight of the dry sample made it possible to obtain an estimation of the dry matter weight in the aerial part. Plant height and ear insertion height were evaluated in 20 plants selected at random. The distance from ground level to the insertion point of the highest foliar blade was considered as plant height. The distance from ground level to the insertion point of the highest ear was considered as ear insertion height. Grain yield was estimated based on the ears harvested in the entire row (allowing to estimate the number of ears/ha) and was corrected to a moisture content of 15.5 % (wet basis). A 10-ear sample was utilized to evaluate the number of grains/ear. The 100-grain weight was estimated based on five samples of 100 grains.

Soil tillage was performed with a tractor; spraying was performed with a back-pack sprayer; weeding with a hoe and the other experiment operations by hand.

The statistical analyses were performed according to recommendations by Gomes (*5*) and StatSoft (*18*).

RESULTS AND DISCUSSION

Cultivars AG 405, AG 1051 and Curingão were the best with regard to the total number of green ears/ha, weight of marketable unhusked ears and number of marketable husked ears, respectively (Table 1). Cultivars AG 1051 and Curingão did not differ between themselves and were superior relative to the other cultivar with regard to the weight of marketable husked ears. There were no significant differences between cultivars with regard to total weight of ears, number of marketable unhusked ears, and fresh and dry matter yield in the aerial part of the plant, after harvesting the green ears. The fact that cultivars showed significant differences with regard to the total number of green ears, but not with respect to the number of marketable unhusked ears, indicates that the most productive cultivars with regard to the first trait showed greater rates of unhusked ears not suitable for the market. In cultivars AG 405, AG 1051 and Curingão these rates were 14%, 8% and 12 %, respectively. By a similar rationale, it can be calculated that the unhusked ears that became unsuitable for the market, when husked, were, for the same cultivars, 21%, 11% and 10%, respectively. Therefore, cultivar AG 405, despite having yielded the greatest total number of ears, produced the least marketable ears, unhusked or husked. The opposite occurred with the other two cultivars. This emphasizes the importance of yield assessment for marketable ears. Differences between cultivars with regard to green ear yield were also observed by Silva e Silva (*15*), Silva et al.(*12*) and Silva et al. (*13*). Similarly to what was observed in the present work, these authors verified that a cultivar superior with respect to a given attribute utilized to assess green corn yield is not necessarily superior with regard to another attribute used to assess the same trait.

No significant effect was observed for the interaction removal x cultivar with respect to plant height and ear insertion height, number of mature ears, number of grains/ear, 100-grain weight and grain yield (Table 2). Therefore, the border effect does not influence the experimental precision, since cultivars showed the same behavior under the plant removal treatment. The absence of significant effects of the interaction cultivar x non-planted space were also found for rice (*2*), sorghum (*6*), maize (*13*, *17*), and cucumber (*20*). Other papers show that this interaction was significant for soybean (*10*) and rice (*19*).

Even though it may depend on the cultivars being evaluated (*10*, *19*), the border effect also depends on the environment conditions present in the study, as observed in rice (*7*, *11*).

There was no effect of cultivars and proportions for plant height as well (Table 2). The mean height of the evaluated cultivars was about 187 cm (Table 3). The analysis of variance indicated only an effect of cultivars for ear insertion height (Table 2). The regression analysis performed for the two traits did not show effects for proportions either. Cultivar Curingão showed the smallest ear insertion height (Table 3). According to Malavolta and Dantas (*8*), even though maize growth may vary depending on several factors, it generally stops around 74 days after planting. In the present work, the green ears were harvested during a period ranging from 73 to 80 days after planting. Thus, it would be unlikely that plant removal after harvesting green ears would influence plant growth in the neighboring row.

The analyses of variance and regression did not reveal cultivar and plant removal effects in the number of mature ears/ha as well (Table 2). The mean number of ears produced was 49,560 ears/ha (Table 3). These data corroborate the data in Table 1, where cultivars did not differ significantly between themselves with regard to the total number of green ears.

In addition, no effects of proportions of removed plants were observed on the number of grains/ear, both in the analysis of variance (Table 2), and in the regression analysis; however, cultivars AG 1051 and Curingão did not differ significantly between themselves and surpassed cultivar AG 405 concerning this trait (Table 3).

TABLE 1 - Green ear yield and fresh and dry matter yield in the aerial part of plants, after harvesting the green ears, in maize cultivars[1]

Cultivars	Total number of ears/ha	Total ear weight (kg/ha)	Number of marketable unhusked (ears/ha)	Weight of marketable unhusked ears (kg/ha)	Number of marketable husked ears (kg/ha)	Weight of marketable husked ears (kg/ha)	Fresh matter (kg/ha)	Dry matter (kg/ha)
AG 405	51,944a	14,985	44,870	13,449ab	35,382b	6,604b	33,479	8,768
AG 1051	48,173b	15,398	44,548	15,118a	39,686ab	8,532a	30,347	7,557
Curingão	51,116ab	14,415	45,200	12,925b	40,904a	8,630a	30,819	8,363
Means	-	14,933	44,872	-	-	-	31,549	8,229
C.V. (%)	7	11	11	16	13	14	21	20

[1]Means followed by a common letter are not significantly different among themselves at 5% probability by the Tukey test.

Effects of cultivars and proportions of removed plants were observed for the 100-grain weight, as indicated by the regression analysis (Figure 1). Cultivars AG 1051 and Curingão did not differ between themselves and were superior relative to the other cultivar. As the proportions of removed plants increased, grain weight also increased.

For grain yield, the analysis of variance indicated effects of cultivars and proportions (Table 1). Cultivar AG 1051 was the most productive, followed by cultivars Curingão and AG 405. The regression analysis showed that grain yield increased linearly with the increase in the proportion of removed plants (Figure 2). The fact that plant removal did not influence the number of ears/ha and the number of grains/ear demonstrates that the increases in grain yield obviously depended on increases in grain weight.

After the green ears were harvested, the number of ears/plant and the number of grains/ear had already been established, but grain filling is in progress and plants in the row next to the row where plants were removed should benefit from a less intensive competition.

After the green ear harvesting, the maize root system should be completely formed. On the other hand, according to Malavolta and Dantas (*8*), the absorption of N, K, Ca and S by the maize plant increases, until a peak is reached 80 days after planting. The absorption of P remains more or less constant after this period and the absorption of magnesium continues to increase until maturation. Competition between plants for water probably did not occur, since the experiment was irrigated. It seems, therefore, likely that plants competed especially for light. Plants in rows adjacent to the rows where plants were removed received more light and had a greater yield.

Despite the fact that the border effect observed in the present work (Figures 1 and 2) did not influence the experimental precision (Table 2), the higher yield (Figure 2) in rows surrounding the row where plants were removed could cause an overestimation of varietal yields.

This aspect of yield overestimation has been emphasized in papers dealing with maize (*17*), rice (19) and cucumber (*20*), among other crops. In order to eliminate this internal border effect that arises when plants are removed from a plot, it is advisable to plant additional rows that would function as an internal border. This recommendation is important especially when plant removal occurs in the early stages of the crop, because, as shown, the reduction in competition during a period of only 20 days (from green ear harvest to mature ear harvest) was sufficient to determine the occurrence of the effect.

TABLE 2 - Analysis of variance of data on plant height and ear insertion height, number of ears/ha, number of grains/ear, 100-grain weight and grain yield of one out of two usable rows in plots of three maize cultivars, where different proportions of plants were removed from the neighboring usable row, after green ears were harvested[(1)]

Sources of variation	Degrees of freedom	Mean square					
		Plant height	Ear height	Number of ears/ha	Number of grains/ear	100-grain weight	Grain yield
Blocks	3	1,064.4	185.5	9,970,913.7	920.4	22.6	5,042,847.5
Treatments	11	86.2^{ns}	119.9*	14,891,974.6^{ns}	3,348.8*	7.5^{ns}	3,270,251.5*
Removals (R)	3	33.3^{ns}	15.2^{ns}	7,391,981.7^{ns}	303.3^{ns}	6.1^{ns}	3,413,389.6*
Cultivars (C)	2	16.9^{ns}	509.6*	34,980,706.5^{ns}	17,334.0*	15.6*	83,198,831.8*
R x C	6	135.8^{ns}	42.4^{ns}	11,945,727.0^{ns}	209.9^{ns}	5.5^{ns}	1,515,489.0^{ns}
Residue	33	77.5	56.4	20,297,333.9	1,518.6	5.1	1,049,835.8
C.V. (%)		5	5	9	9	7	14

(1) ^{ns}Not significant. *Significant at 5% probability by the F test.

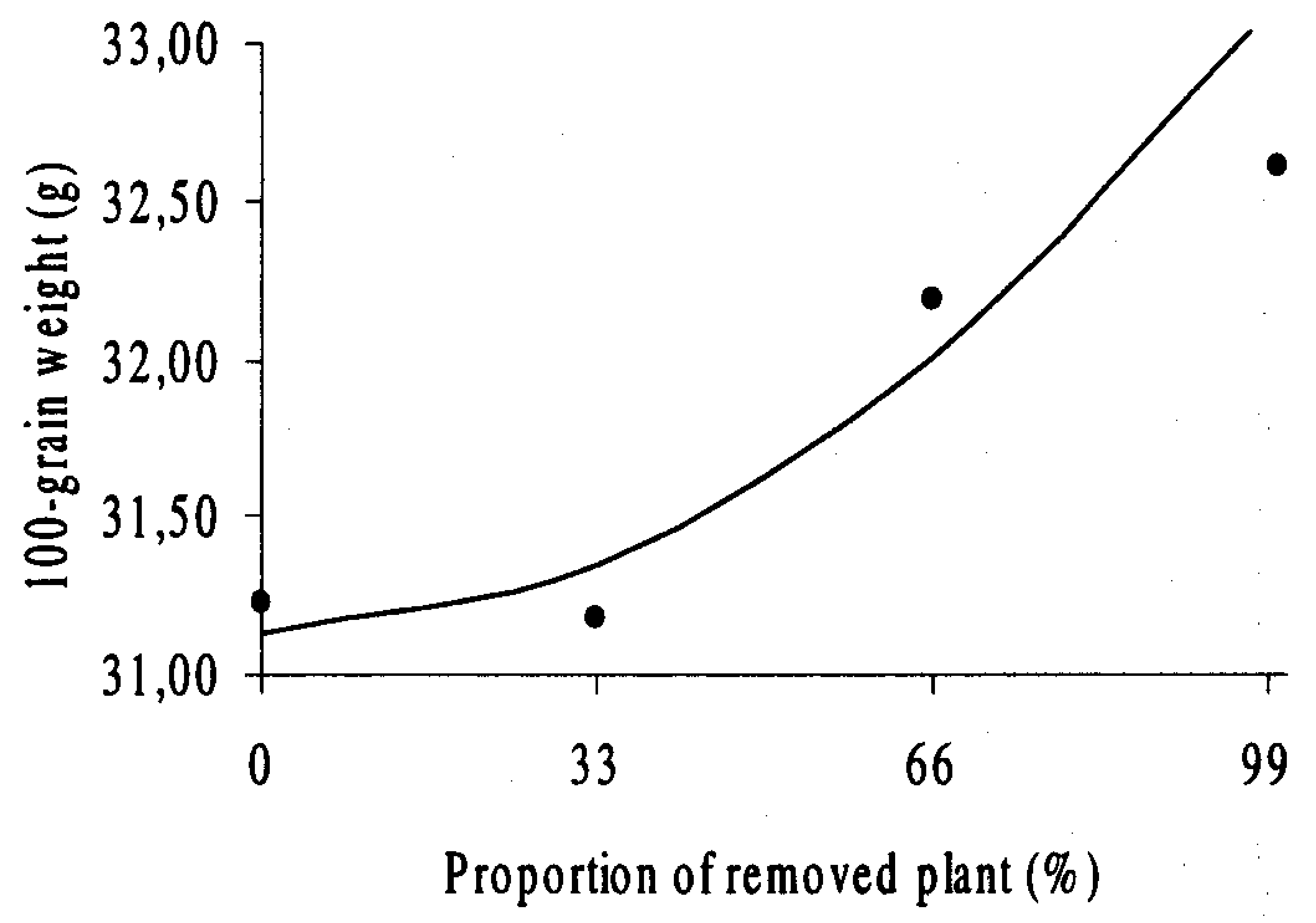

FIGURE 1 - Means of 100-grain weight (gw) of three maize cultivars evaluated in ears from a row relative to the removal of proportions (p) of plants in the neighboring usable row, after green ears were harvested. gw = 31.13 + 0.0002 p^2, $R^2 = 99\%$, The coefficients were significant at 1% probability by the t test.

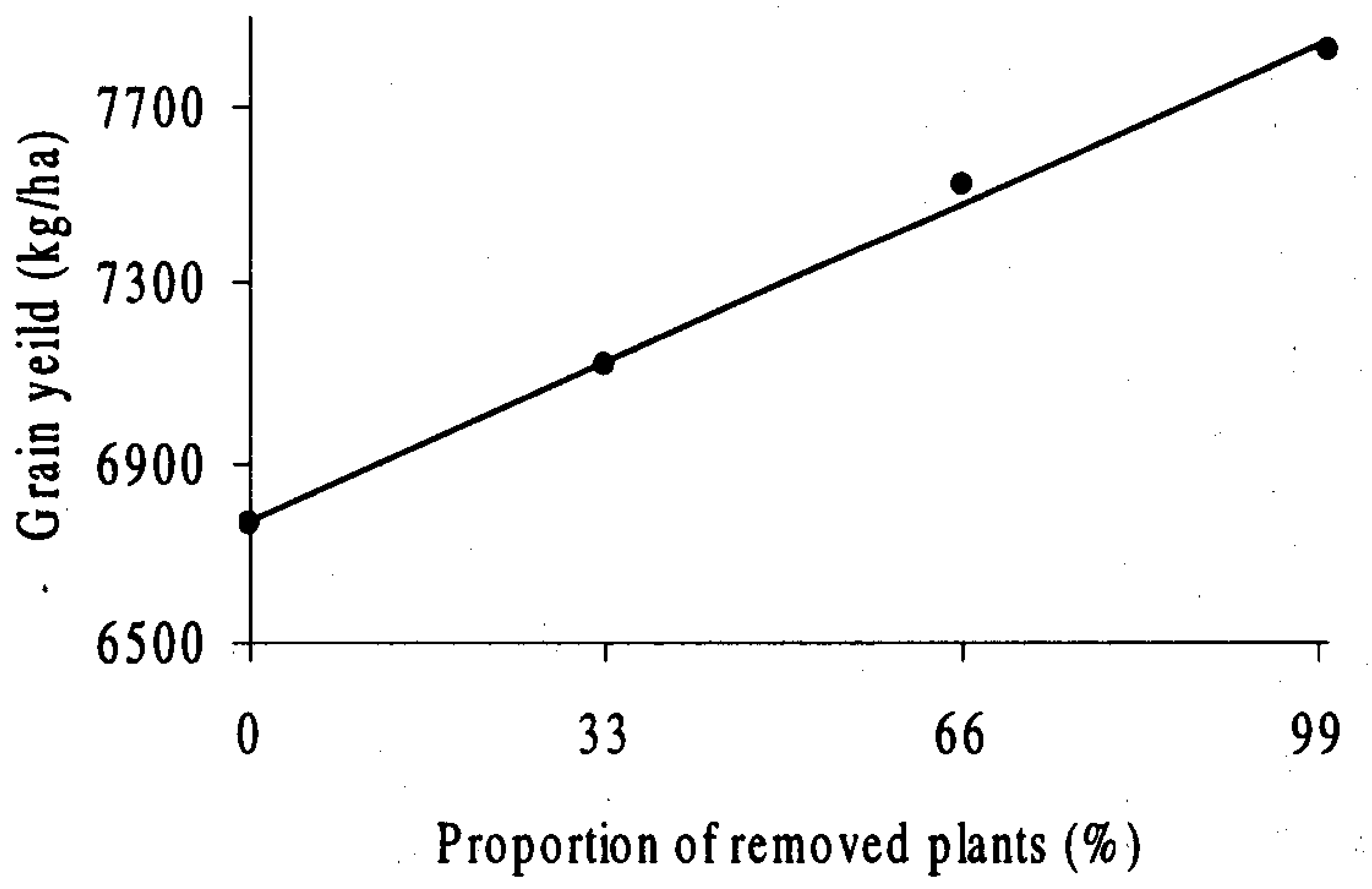

FIGURE 2 - Means of grain yield (gy) in three maize cultivars, evaluated in one row relative to the removal of proportions (p) of plants in the neighboring usable row, after green ears were harvested. gy = 6767.78 + 10.82 p, $R^2 = 99\%$. The coefficients were significant at 1% probability by the t test.

TABLE 3 - Plant height, ear insertion height, number of ears, number of grains, 100 grain weight and grain yield, evaluated in one of two usable rows, at maize maturation, relative to the removal of proportions for plants in the neighboring usable row, after green ears were harvested from three cultivars[1]

Cultivars	Proportion of removed plants				Means
	0	33	66	100	
	Plant height (cm)				
AG 405	190	189	179	189	187
AG 1051	184	185	195	183	187
Curingão	194	183	190	187	189
Means	189	186	188	186	187
	Ear insertion height means (cm)				
AG 405	102	102	94	100	99ab
AG 1051	104	101	109	101	104a
Curingão	95	92	91	93	92b
Means	100	98	98	98	99
	Means of number of ears/ha				
AG 405	52,363	50,481	51,481	50,747	51,268
AG 1051	48,667	49,081	50,021	47,057	48,706
Curingão	45,979	47,493	50,525	50,833	48,707
Means	49,003	49,018	50,676	4,9546	49,560
	Means of number of grains/ear				
AG 405	412	437	424	414	422b
AG 1051	488	487	478	483	483a
Curingão	474	468	467	472	472a
Means	458	464	456	457	459
	Means of 100 grain weight (g)				
AG 405	32.8	30.8	32.0	32.4	32.0a
AG 1051	30.8	32.5	34.4	32.9	32.7a
Curingão	30.1	30.2	30.2	32.5	30.7b
Means	31.2	31.2	32.2	32.6	-
	Means of grain yield (kg/ha)				
AG 405	6,596	5,838	5,735	6,797	6,241c
AG 1051	6,907	8,332	9,535	8,721	8,374a
Curingão	6,776	7,184	7,292	7,961	7,303b
Means	6,760	7,118	7,521	7,826	-

[1]Means followed by a common letter are not significantly different at 5% probability by the Tukey test.

CONCLUSIONS

1) Cultivars AG 405, AG 1051 and Curingão are the best with regard to the total number of green ears/ha, weight of marketable unhusked ears and number of marketable husked ears, respectively.

2) Cultivars AG 1051 and Curingão are superior relative to the other cultivar with regard to the weight of marketable husked ears.

3) There are no differences between cultivars with regard to the total weight of ears and the number of marketable unhusked ears.

4) In terms of grain yield, cultivar AG 1051 is the most productive, followed by cultivars Curingão and AG 405.

5) There are border effects for the 100-grain weight and for grain yield, but they do not influence the experimental precision.

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