



## Evaluation of open-pollinated corn varieties for silage production under organic cultivation

[ Avaliação de variedades de milho de polinização aberta para produção de silagem em cultivo orgânico ]

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**Abstract:** Open-pollinated corn varieties (OPVs) are generally associated with lower field productivity but can be useful in scenarios with low input investments (e.g., fertilization) and challenging weather conditions. Research on these OPVs for silage production in southern Brazil is limited. Thus, this study evaluated the agronomic performance and chemical composition of seventeen OPVs for silage production in an organic system. The dry matter (DM) yield ranged from 10.6 to 17.9 t/ha, but there was no difference between OPVs ( $P > 0.05$ ). The SINT PF 7031 had the highest grain proportion in the ensiled mass (40.6 %;  $P < 0.001$ ), which resulted in lower ( $P < 0.001$ ) neutral detergent fiber content (59.6 % DM). After the silos were opened, the silage from BRS 3042 had 6.41 % of DM loss, which did not differ ( $P > 0.05$ ) from the lowest DM loss observed (3.70 % for SINT PF 7031). During the aerobic exposure period, the CMST 029 FA showed the highest aerobic stability (213 h;  $P < 0.001$ ). Based on field production, chemical composition, and silage loss and stability, the recommended varieties for organic cultivation in southern Rio Grande do Sul are BRS 3042, CMST 029 FA, and SINT PF 7031.

**Keywords:** agronomic performance; corn silage; open cross genotype; organic fertilization.

**Resumo:** Variedades de milho de polinização aberta (VPAs) geralmente apresentam menor produtividade de campo, mas podem ser úteis em cenários onde há pouco investimento em insumos (e.g., fertilização) e sob condições climáticas desafiadoras. Pesquisas sobre essas VPAs para produção de silagem no sul do Brasil são limitadas. Este estudo avaliou o desempenho agrônomo e a composição química de dezessete VPAs para produção de silagem em sistema orgânico. A produção de matéria seca (MS) variou de 10,6 a 17,9 t/ha, mas não houve diferença ( $P > 0,05$ ) entre as VPAs. A variedade SINT PF 7031 apresentou a maior proporção de grãos na massa ensilada (40,6 %;  $P < 0,001$ ), o que resultou em menor ( $P < 0,001$ ) teor de fibra em detergente neutro (59,6 % MS). Após abertura dos silos, a silagem proveniente da variedade BRS 3042 apresentou perdas de MS de 6.41 %, não diferindo ( $P > 0,05$ ) do menor valor observado para a variedade SINT PF 7031 (3,70 %). Durante o período de estabilidade aeróbia, a variedade CMST 029 FA apresentou a maior estabilidade (213 horas;  $P < 0.001$ ). Com base na produção, composição química e estabilidade da silagem, as variedades recomendadas para cultivo orgânico no sul do Rio Grande do Sul são BRS 3042, CMST 029 FA e SINT PF 7031.

**Palavras-chave:** desempenho agrônomo; silagem de milho; genótipo de polinização aberta; fertilização orgânica.



## 1. Introduction

In Rio Grande do Sul (RS), there are many small farms where family agriculture predominates (80.5 %) <sup>(1)</sup>. These small farms are mainly dedicated to food production, with milk production standing out as a key activity. In this context, organic milk production can help improve the value of farmers' products, as it meets one of society's current demands (i.e., growing concern about environmental issues). Organic milk production is carried out with a focus on animal welfare and the producer's commitment to avoiding environmental harm <sup>(2)</sup>.

Due to the climatic seasonality of RS, which leads to periods of forage shortage (mainly during autumn and early winter) and reduced milk production, some supplementation is needed to maintain animal productivity. Studies evaluating the main sources of roughage offered to animals on dairy farms have shown that milk production in Brazil is largely based on the use of corn silage <sup>(3, 4)</sup>. Corn silage is preferentially used because its chemical composition meets the requirements for producing high-quality silage and because of its high yield potential (15–25 t dry matter (DM)/ha; <sup>(5, 6)</sup>).

For corn production to be considered organic, the use of transgenic seeds is prohibited (the use of non-transgenic hybrids is allowed); however, open-pollinated varieties (OPVs) are preferred in this system. It is also recommended that the seeds originate from organic production systems. Organic production is based on the conservation of natural resources and the exclusion of highly soluble fertilizers and chemical products <sup>(7)</sup>. However, little attention has been given to the production of organic corn silage in Brazil to meet the growing demand for organic milk yield. Therefore, research evaluating corn genotypes for this purpose is highly valuable. In this context, the production of OPVs allows seeds to be produced on the farm or acquired at a lower cost by the farmer <sup>(8)</sup>. The use of OPVs silages for animal feeding also represents an alternative during feed shortage periods in organic dairy production systems, considering that transgenic seeds are prohibited in this system <sup>(7, 8)</sup>.

The corn hybrids available on the market have undergone breeding programs aimed at increasing grain yield and tolerance to biotic stresses. Such research and investments have made seeds a relatively expensive input, which often fails to express their full potential due to soil conditions and the limited use of input by farmers. However, the low level of technological adoption among many producers prevents them from achieving the maximum potential that hybrid and transgenic cultivars can offer, thus requiring the use of more resistant varieties <sup>(8)</sup>.

Describing the materials available to farmers is essential for obtaining high-quality silage; therefore, the objective of this study was to evaluate the agronomic performance and chemical composition of OPVs intended for silage production under an organic production system.

## 2. Material and methods

### 2.1 Location and corn genotypes used

The experiment was conducted from October 2020 to February 2021 at the Brazilian Agricultural Research Corporation (Embrapa), Cascata Experimental Station (EEC), located in Pelotas, RS, Brazil (31°37'S, 52°31'W; average altitude of 170 m). The soil in the experimental area is classified as a Dystrophic Red Argisol <sup>(9)</sup>. The regional climate is classified as Cfa (humid subtropical) according to the Köppen system. Climatic data for the entire crop development period are shown in Figure 1.

At sowing, organic fertilization was manually applied along the planting rows using granulated poultry manure. A second manual application was performed along the rows at the V2–V3 vegetative stages. Fertilizer application was split to prevent seed damage. The total fertilizer amount, including both sowing and topdressing, was  $4.2 \text{ t} \cdot \text{ha}^{-1}$ .

Seventeen corn varieties were tested (BR 5202 Pampa, BRS 4019TL, BRS 4022SE, BRS 015FB, CMST 029 FA, BRS Caimbé, BRS 4103, BRS 4105, BRS 4107, BRS 3042, BRS Planalto, SINT PF 7021, SINT PF 7031, Pixurum 07, Pixurum 05, Dente de Ouro, and Brasino), arranged in three blocks (replications; this design was assumed due to the steep slope of the ground) in the field. Each block consisted of 17 plots with five 5-meter-long rows, spaced 0.8 meters between rows and 0.25 meters between plants. Sowing was performed manually using eight seeds per linear meter.

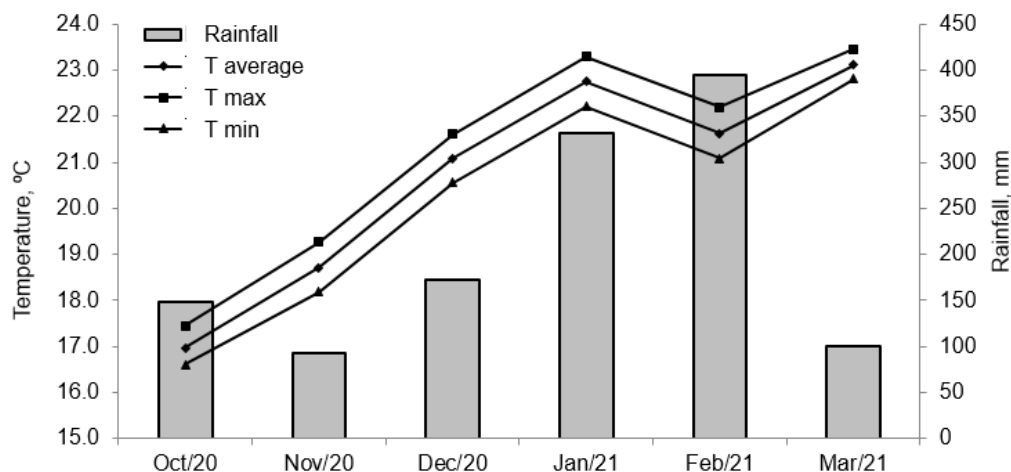


**Figure 1.** Average, maximum, and minimum temperature and rainfall during the development period of open-pollinated corn varieties.

## 2.2 Agronomic evaluations and silage production

Ten plants per replicate were used for field evaluations, and the following characteristics were assessed: plant height (m; from ground level to the base of the tassel), ear height (m; from ground level to the node where the first ear is inserted), stem diameter (mm; measured at the second internode above ground level), and plant and ear weight. The plant fresh matter (FM) yield was calculated using the plant weight multiplied by the number of plants per hectare. After the ears were weighed, the grains were removed manually by threshing and weighed to determine the grain yield. Both plant and grain DM yield were calculated after the DM content was determined. The grain DM yield was adjusted to the overall mean DM content (51.5 %) observed in the grains, using the following equation: corrected grain DM yield = grain fresh yield  $\times 0.515$ . The grain proportion in the ensiled mass was calculated using the grain weight divided by the total plant weight  $\times 100$ . Harvesting was carried out 133 days after planting, and it occurred separately for each replicate, when the kernel milk line was between one-third and two-thirds<sup>(10)</sup>. The corn was manually cut at a height of 10 cm using a machete designed for this purpose. Subsequently, the plants were transported to a barn, where the ensiling process was performed.

The plants were chopped using a stationary forage chopper adjusted to a theoretical particle size of 30 mm and then mixed thoroughly for better homogenization. A portion of forage ( $1.31 \pm 0.08 \text{ kg}$ ) was manually compacted using a wooden rod, achieving a bulk density of  $523 \pm 31.8 \text{ kg fresh matter/m}^3$ . The experimental silos were made of PVC, each with an average capacity of 2.5 L. At the bottom of each silo, 0.35 kg of sand was placed to collect the effluent produced.

The sand was separated from the forage by a fine mesh screen to prevent silage contamination. Forage samples were collected during the filling of each silo for chemical composition analysis (samples were dried in a forced-air oven at 55°C). The silos were sealed, weighed, and stored at room temperature for 120 days.

### 2.3 Evaluation of fermentative losses and aerobic stability

After silo opening, the silos were weighed again to determine DM losses, which were partitioned into gas and effluent losses <sup>(11)</sup>. Two samples were collected from each silo: one for determining the silage chemical composition and another stored at -20°C for pH measurement.

A portion of silage ( $0.71 \pm 0.11$  kg) was placed in plastic buckets to evaluate the aerobic stability. The buckets were kept in a closed room at ambient temperature for 10 days. Temperature was recorded every half hour by using data loggers (Escort Intelligent MINI; Escort Console, Buchanan, VA, USA) inserted in the center of the silage mass in each bucket, while ambient temperature was recorded by data loggers placed around the buckets. The aerobic stability was defined as the time required for the silage temperature to exceed the ambient temperature by 3°C <sup>(12)</sup>. At the end of the exposure period, the buckets were weighed to determine DM losses under aerobic conditions. For this purpose, samples from each replicate were collected to determine DM content.

### 2.4 Chemical analysis

The samples intended for chemical composition analysis were dried in a forced-air oven at 55°C for 72 hours. After drying, they were ground using a Wiley-type knife mill equipped with 1-mm sieves and stored in plastic containers for subsequent chemical analyses. The samples were then dried in an oven at 105°C for 12 hours to determine DM content <sup>(13)</sup> (method no. 930.15), and ash content was determined after combustion in a muffle furnace at 500°C for 5 hours <sup>(13)</sup> (method no. 923.03). Neutral detergent fiber (NDF) was determined using an autoclave and polyethylene filter bags designed for this purpose <sup>(14)</sup>.

Samples preserved at -20°C were used to prepare aqueous extracts by blending 25 g of each forage or silage sample with 225 mL of distilled water. The mixture was homogenized in a blender at the highest speed for 1 minute and filtered through two layers of cotton cloth. The pH of the filtrate was measured immediately using a pH meter (model MA522, Marconi Laboratory Equipment, Piracicaba, SP, Brazil).

### 2.5 Statistical analysis

The variables were subjected to analysis of variance (ANOVA), with verification of data normality and removal of outliers ( $\pm 3$ ). Means were compared using Tukey's test at a 5 % probability level in SAS software. All variables were analyzed using the MIXED procedure in SAS (v. 9.4; SAS Institute Inc., Cary, NC, USA).

## 3. Results

### 3.1 Agronomic performance and chemical composition of corn genotypes

The genotype Pixurum 07 had higher plant height ( $P < 0.001$ ) compared with the other genotypes; however, it did not differ significantly from BRS 4019TL and Brasino (Table 1). Similarly, Pixurum 07 exhibited the highest ear insertion height ( $P < 0.001$ ), which was statistically similar to BRS 4019TL. All genotypes presented similar values for the number and weight of ears per plant, as well as for stem diameter ( $P > 0.05$ ).

**Table 1.** Agronomic performance of open-pollinated corn varieties for silage production under organic cultivation.

| Genotype      | PH, m    | EH, m   | NE    | EW, kg | SD, cm | Stand     | FMY, t/ha | DMY, t/ha | GYf, t/ha | DMg (%)  | GYdm, t/ha | GYc, t/ha | GP, %    |
|---------------|----------|---------|-------|--------|--------|-----------|-----------|-----------|-----------|----------|------------|-----------|----------|
| BR 5202 Pampa | 1.81 DE  | 0.98 CD | 1.33  | 0.325  | 26.7   | 42620 CD  | 39.5 D    | 11.7      | 5.07 CDE  | 56.1 AB  | 2.80 CDE   | 2.61 CDE  | 22.1 CD  |
| BRS 015 FB    | 1.74 E   | 0.87 D  | 1.13  | 0.266  | 25.3   | 52500 BCD | 40.9 D    | 12.6      | 8.70 B    | 60.8 A   | 5.29 B     | 4.48 B    | 31.5 B   |
| BRS 4019TL    | 2.28 ABC | 1.22 AB | 1.20  | 0.358  | 25.7   | 48333 BCD | 51.4 BCD  | 15.2      | 8.48 BC   | 51.7 BC  | 4.36 BC    | 4.36 BC   | 24.3 B   |
| BRS 4022SE    | 1.71 E   | 0.82 D  | 1.33  | 0.263  | 24.6   | 43333 CD  | 42.3 D    | 12.6      | 6.18 BCD  | 57.4 AB  | 3.54 BCD   | 3.18 BCD  | 22.2 BC  |
| BRS 3042      | 1.85 DE  | 0.89 D  | 1.40  | 0.317  | 23.2   | 50462 BCD | 54.9 ABC  | 14.1      | 8.58 B    | 44.6 CD  | 3.86 BC    | 4.41 B    | 22.9 B   |
| BRS 4103      | 2.05 BCD | 0.86 D  | 1.53  | 0.310  | 23.9   | 50833 BCD | 45.4 CD   | 12.3      | 9.11 B    | 51.7 BC  | 4.74 BC    | 4.69 B    | 26.2 B   |
| BRS 4105      | 1.85 DE  | 0.88 D  | 1.53  | 0.235  | 22.0   | 57500 AB  | 48.7 BCD  | 12.9      | 6.71 BCD  | 53.6 ABC | 3.64 BCD   | 3.45 BCD  | 20.1 BC  |
| BRS 4107      | 2.03 CD  | 0.94 D  | 1.47  | 0.314  | 25.6   | 41667 D   | 43.3 CD   | 10.6      | 7.48 BC   | 50.4 BCD | 3.82 BC    | 3.85 BC   | 25.8 B   |
| BRS Caimbé    | 1.84 DE  | 0.87 D  | -     | 0.306  | 26.3   | 42440 CD  | 48.9 BCD  | 14.7      | 6.72 BCD  | 41.3 D   | 2.82 CDE   | 3.45 BCD  | 22.1 BC  |
| BRS PLANALTO  | 1.86 DE  | 0.95 D  | 1.00  | 0.332  | 23.8   | 45833B CD | 48.1 CD   | 13.9      | 8.16 BC   | 61.9 A   | 5.08 B     | 4.20 BC   | 24.5 B   |
| Brasino       | 2.32 AB  | 1.17 BC | 1.53  | 0.257  | 25.0   | 40120 D   | 40.1 D    | 11.0      | 3.40 DE   | 45.7 CD  | 1.53 DE    | 1.75 D    | 18.2 CD  |
| CMST 029 FA   | 1.87 DE  | 0.90 D  | 1.33  | 0.283  | 21.8   | 50833 BCD | 45.4 CD   | 12.3      | 8.43 BC   | 53.2 ABC | 4.49 BC    | 4.34 BC   | 27.2 B   |
| Dente de Ouro | 1.93 DE  | 0.90 D  | 1.73  | 0.292  | 25.1   | 43333 CD  | 39.8 D    | 10.6      | 6.29 BCDE | 55.5 AB  | 3.30 BCD   | 3.24 BCDE | 26.2 BCD |
| Pixurum 05    | 1.95 DE  | 0.94 D  | 1.13  | 0.339  | 23.8   | 54167 ABC | 61.7 AB   | 17.9      | 8.07 BC   | 56.4 AB  | 4.58 BC    | 4.15 BC   | 21.5 B   |
| Pixurum 07    | 2.41 A   | 1.40 A  | 1.13  | 0.226  | 20.9   | 65000 A   | 64.5 A    | 15.6      | 2.92 E    | 21.9 E   | 0.681 E    | 1.50 E    | 6.57 D   |
| SINT PF 7021  | 1.75 E   | 0.79 D  | 1.33  | 0.241  | 25.3   | 50833 BCD | 39.9 D    | 12.5      | 7.63 BC   | 50.7 BCD | 3.89 BC    | 3.93 BC   | 28.1 B   |
| SINT PF 7031  | 1.40 F   | 0.56 E  | 1.27  | 0.308  | 24.4   | 67440 A   | 45.8 CD   | 13.8      | 12.5 A    | 58.5 AB  | 7.33 A     | 6.44 A    | 40.6 A   |
| SEM           | 0.091    | 0.076   | 0.211 | 0.032  | 1.370  | 4935      | 5.300     | 2.150     | 1.240     | 3.160    | 0.757      | 0.636     | 2.670    |
| P-value       | <0.001   | <0.001  | 0.64  | 0.08   | 0.12   | 0.014     | 0.009     | 0.07      | <0.001    | <0.001   | <0.001     | <0.001    | <0.001   |

<sup>a-f</sup>Means followed by different letters within a column differ significantly according to Tukey's test at 5% probability. \*PH = plant height; EH = ear insertion height; NE = average number of ears per plant; EW = average ear weight; DC = stem diameter; Stand = number of plants per hectare; FMY = fresh matter yield; DMY = dry matter yield; GYf = grain yield based on fresh matter; DMg = grain dry matter (55°C); GYdm = grain yield based on DM; GYc = grain yield based on DM corrected to the average DM content observed in the grains (51.5%); GP = grain proportion in the ensiled mass.

The highest plant stand was observed for SINT PF 7031, which did not differ statistically ( $P > 0.05$ ) from Pixurum 07, BRS 4105, and Pixurum 05 (Table 1). Regarding FM yield per hectare, the genotype with the highest production ( $P = 0.009$ ) was Pixurum 07 (64.5 t/ha). However, when DM content was analyzed, no significant differences were found among genotypes ( $P > 0.05$ ).

Regarding grain yield based on FM, the genotype SINT PF 7031 differed from the others ( $P < 0.001$ ), reaching 12.5 t/ha, while genotypes such as Pixurum 07, Brasino, BRS 5202 Pampa, and Dente de Ouro produced lower grain amounts (Table 1). The grain DM content varied ( $P < 0.001$ ) from 61.9 % (BRS Planalto) to 21.9 % (Pixurum 07). When grain yield was evaluated on a DM basis, SINT PF 7031 again presented the highest yield ( $P < 0.001$ ), while Pixurum 07 showed the lowest. These results were consistent even after adjusting grain DM to 51.5 %, the overall mean DM content across all genotypes. The proportion of grains in the ensiled mass was higher ( $P < 0.001$ ) in SINT PF 7031, whereas Pixurum 07 had the lowest grain proportion (Table 1).

All genotypes showed similar forage DM contents ( $P > 0.05$ ; Table 2). Ash content varied ( $P < 0.001$ ) from 6.40 % DM (BRS 4103) to 4.16 % (SINT PF 7021). The genotype Pixurum 07 exhibited the highest forage NDF content ( $P = 0.026$ ), differing significantly from the other genotypes.

### 3.2 Fermentative losses, chemical composition and aerobic stability of silages

The silage of BRS 4107 showed the highest effluent loss ( $P < 0.001$ ; Table 3). Regarding gas and DM losses, BRS Caimbé exhibited the highest values ( $P < 0.001$ ). There was no effect on pH ( $P > 0.05$ ), as all genotypes showed similar values.

Concerning the silage chemical composition (Table 4), the DM content was different among genotypes ( $P < 0.001$ ), varying from 31.6 % (SINT PF 7031) to 23.7 % (Pixurum 07). The BRS 4107 had the highest ash content (7.98 % DM;  $P = 0.0203$ ), not differing statistically from BRS Caimbé (7.71 % DM), Pixurum 07 (7.04 % DM), and BRS 4105 (6.49 % DM). The NDF of silages was different ( $P < 0.001$ ) among genotypes, ranging from 74.2 % DM (Pixurum 07) to 51.1 % DM (SINT PF 7031).

**Table 2.** Chemical composition of open-pollinated corn varieties before ensiling under organic cultivation (values are expressed in % DM).

| Genotype        | DM (%) | Ash (%)   | NDF (%)   |
|-----------------|--------|-----------|-----------|
| BR 5202 Pampa   | 29.57  | 4.85 DEF  | 65.12 BCD |
| BRS 015FB       | 30.75  | 4.76 DEF  | 62.03 BCD |
| BRS 4019TL      | 29.64  | 4.74 EF   | 62.99 BCD |
| BRS 4022SE      | 29.79  | 4.73 EF   | 66.38 BC  |
| BRS 3042        | 25.67  | 5.62 BC   | 65.99 BCD |
| BRS 4103        | 27.12  | 6.40 A    | 67.87 B   |
| BRS 4105        | 26.43  | 5.88 AB   | 66.89 BC  |
| BRS 4107        | 24.55  | 5.94 AB   | 64.05 BCD |
| BRS Caimbé      | 29.98  | 5.49 BCDE | 67.09 BC  |
| BRS Planalto    | 28.83  | 5.33 BCDE | 66.83 BC  |
| Brasino         | 27.45  | 5.15 BCDE | 64.49 BCD |
| CMST 029 FA     | 27.19  | 4.68 EF   | 63.43 BCD |
| Dente de Ouro   | 26.53  | 5.52 BCD  | 65.94 BCD |
| Pixurum 05      | 28.98  | 4.97 CDE  | 62.51 BCD |
| Pixurum 07      | 24.16  | 5.25 BCDE | 77.36 A   |
| SINT PF 7021    | 31.24  | 4.16 F    | 60.69 CD  |
| SINT PF 7031    | 30.05  | 4.68 EF   | 59.60 D   |
| SEM             | 1.776  | 0.290     | 2.490     |
| <i>P</i> -value | 0.0586 | 0.0002    | 0.0261    |

<sup>a-f</sup>Means followed by different letters within a column differ significantly according to Tukey's test at 5 % probability. \*DM = dry matter; NDF = neutral detergent fiber.

**Table 3.** Fermentative losses and pH of open-pollinated corn silages under organic cultivation (values are expressed in % DM, unless otherwise indicated).

| Genotype        | Effluent, kg/t FM | Gas      | DML       | pH     |
|-----------------|-------------------|----------|-----------|--------|
| BR 5202 Pampa   | 6.03 C            | 7.07 D   | 7.41 CDE  | 3.62   |
| BRS 015FB       | 5.46 C            | 13.9 B   | 14.4 B    | 3.59   |
| BRS 4019TL      | 9.43 BC           | 13.2 BC  | 14.0 BC   | 3.62   |
| BRS 4022SE      | 6.27 BC           | 8.42 CD  | 9.00 BCDE | 3.62   |
| BRS 3042        | 6.20 BC           | 5.75 D   | 6.41 DE   | 3.60   |
| BRS 4103        | 12.6 B            | 4.72 D   | 5.82 DE   | 3.58   |
| BRS 4105        | 9.02 BC           | 4.84 D   | 5.72 DE   | 3.58   |
| BRS 4107        | 32.1 A            | 7.37 CD  | 11.7 BCD  | 3.62   |
| BRS Caimbé      | 5.55 C            | 22.3 A   | 22.8 A    | 3.63   |
| BRS Planalto    | 4.73 C            | 4.60 D   | 5.08 DE   | 3.61   |
| Brasino         | 6.49 BC           | 8.21 CD  | 9.41 BCDE | 3.60   |
| CMST 029 FA     | 5.02 C            | 5.82 D   | 6.29 DE   | 3.68   |
| Dente de Ouro   | 7.52 BC           | 5.84 D   | 4.38 E    | 3.58   |
| Pixurum 05      | 9.65 BC           | 5.58 D   | 7.14 DE   | 3.64   |
| Pixurum 07      | 6.51 BC           | 6.19 D   | 6.81 DE   | 3.58   |
| SINT PF 7021    | 4.91 C            | 9.27 BCD | 9.73 BCDE | 3.55   |
| SINT PF 7031    | 6.10 C            | 6.21 D   | 3.70 E    | 3.62   |
| EPM             | 2.450             | 2.020    | 2.300     | 0.024  |
| <i>P</i> -valor | <0.001            | <0.001   | 0.001     | 0.1346 |

<sup>a-e</sup>Means followed by different letters within a column differ significantly according to Tukey's test at 5 % probability. \*FM = fresh matter; DML = dry matter loss.

**Table 4.** Chemical composition of open-pollinated corn silages under organic cultivation (values are expressed in % DM).

| Genotype        | DM (%)      | Ash (%)   | NDF (%)    |
|-----------------|-------------|-----------|------------|
| BR 5202 Pampa   | 27.57 BCDEF | 5.41 CDE  | 59.55 CDE  |
| BRS 015FB       | 27.58 BCDEF | 5.72 CDE  | 64.54 BCD  |
| BRS 4019TL      | 26.96 CDEFG | 6.16 BCDE | 61.61 BCDE |
| BRS 4022SE      | 28.24 BCD   | 5.82 CDE  | 57.47 DEF  |
| BRS 3042        | 25.80 DEFGH | 5.65 CDE  | 61.23 BCDE |
| BRS 4103        | 24.61 FGH   | 5.60 CDE  | 65.89 BCD  |
| BRS 4105        | 26.58 DEFG  | 6.49 ABCD | 60.58 BCDE |
| BRS 4107        | 24.05 GH    | 7.98 A    | 67.54 B    |
| BRS Caimbé      | 24.57 FGH   | 7.71 AB   | 61.96 BCDE |
| BRS Planalto    | 30.29 AB    | 5.58 CDE  | 58.13 DEF  |
| Brasino         | 25.91 DEFGH | 6.17 BCDE | 67.10 BC   |
| CMST 029 FA     | 26.20 DEFGH | 5.21 D    | 59.91 BCDE |
| Dente de Ouro   | 25.35 EFGH  | 6.32 BCDE | 64.80 BCD  |
| Pixurum 05      | 27.98 BCDE  | 5.73 CDE  | 59.27 CDE  |
| Pixurum 07      | 23.69 H     | 7.04 ABC  | 74.20 A    |
| SINT PF 7021    | 29.46 ABC   | 5.11 DE   | 53.85 EF   |
| SINT PF 7031    | 31.61 A     | 4.88 E    | 51.08 F    |
| SEM             | 1.549       | 0.592     | 2.820      |
| <i>P</i> -value | <0.001      | 0.0203    | <0.001     |

<sup>a-h</sup>Means followed by different letters within a column differ significantly according to Tukey's test at 5 % probability. \*DM = dry matter; NDF = neutral detergent fiber.

Aerobic stability and temperature characteristics during the aerobic exposure period showed considerable differences among genotypes (Table 5). The CMST 029 FA exhibited the highest stability after silo opening (213 h;  $P < 0.001$ ), whereas BRS Caimbé (38 h) was less stable, but not differing from the other 12 genotypes. No significant differences were observed for aerobic deterioration ( $P > 0.05$ ), nor for initial temperature, maximum temperature, or heating rate.

During the aerobic stability trial, silage DM content was also evaluated. After 10 days of aerobic exposure, the DM content of silages was different ( $P = 0.006$ ), ranging from 38.9 % (SINT PF 7031) to 27.9 % (BRS 4107). DM losses during aerobic exposure were also affected by genotypes ( $P = 0.008$ ) and varied from 13.5 % (Dente de Ouro) to 2.24 % (BRS 4019TL).

#### 4. Discussion

One of the first parameters to consider when selecting a genotype for cultivation is FM yield, which is important for reducing costs, determining the silo capacity, and projecting the amount of feed available for animal consumption throughout the year <sup>(15)</sup>. In this study, Pixurum 07, Pixurum 05, and BRS 3042 showed the highest FM yields ( $> 54$  t/ha), exceeding the 50.5 and 42.5 t/ha reported by other authors <sup>(6, 16)</sup>. Although FM yield is an important factor in genotype selection, it is directly influenced by other traits such as plant stand, stem diameter, and plant height <sup>(15)</sup>. Genotypes with greater height, except for Pixurum 07, did not achieve the highest yields due to lower plant stands. In turn, despite the absence of measurements, plant stands likely varied due to differences in seed vigor and germination, the occurrence of diseases, and the presence of lodged plants.

Although genotype DM content at ensiling did not differ significantly at the 5 % level, it is important to note that ensiling material with less than 30 % DM is not recommended under practical conditions <sup>(5, 17)</sup>. One reason for this recommendation is the high DM loss through effluent production, as observed by BRS 4107, which had 24.5 % DM at harvest. In the present study, DM yields ranged from 10.6 t/ha to 17.9 t/ha, with most values falling within the 12.7–21.7 t/ha range reported by Ferrari Júnior et al. <sup>(15)</sup>. Lower DM productivity may be associated with harvesting corn at earlier developmental stages <sup>(5, 15, 16)</sup>.

When evaluating three OPVs in the state of Santa Catarina, Patzlaff et al. <sup>(18)</sup> reported DM yields between 14.3 and 16.4 t DM/ha, values like those observed in the present study (10.6–17.9 t DM/ha). Compared with commercial hybrid yields, OPVs show relatively comparable productivity. This is evident when comparing with Scalli et al. <sup>(19)</sup>, who evaluated one single-cross and one triple-cross hybrid, obtaining 17.6 and 12.3 t DM/ha, respectively. In another study, Mittelman et al. <sup>(20)</sup> evaluated several hybrids across different regions of southern Brazil and reported DM yields ranging from 8.69 to 19.2 t/ha, values close to those found in the present work.

The genotype SINT PF 7031 showed the highest grain proportion in the ensiled mass and the highest grain yield on both a DM basis and a DM-corrected basis. A high proportion of grains in the silage mass improves digestibility and is directly related to the number of ears per plant <sup>(6)</sup>.

**Table 5.** Aerobic stability of open-pollinated corn silages under organic cultivation.

| Genotype      | Stability, h | AD, °C | Ti, °C | Tmax, °C | TmaxT, h | HR, °C/h  | DM, %     | DML, %   |
|---------------|--------------|--------|--------|----------|----------|-----------|-----------|----------|
| BR 5202 Pampa | 71.8 BCDE    | 6.43   | 16.9   | 25.3     | 93.6     | 0.099 BCD | 31.3 BCDE | 5.72 BCD |
| BRS 015FB     | 41.8 E       | 0.730  | 17.4   | 21.5     | 59.9     | 0.108 BC  | 36.5 AB   | 9.52 AB  |
| BRS 4019TL    | 55.3 CDE     | 8.84   | 17.3   | 24.6     | 74.9     | 0.098 BCD | 36.5 AB   | 2.24 D   |
| BRS 4022SE    | 50.0 DE      | 2.48   | 16.9   | 22.4     | 62.1     | 0.101 BCD | 36.1 ABC  | 3.14 D   |
| BRS 3042      | 74.7 BCDE    | 6.18   | 16.9   | 24.5     | 88.0     | 0.086 BCD | 31.5 BCDE | 4.35 CD  |
| BRS 4103      | 43.3 E       | 10.5   | 16.7   | 28.8     | 65.1     | 0.200 A   | 29.4 DE   | 4.73 CD  |
| BRS 4105      | 89.3 BCD     | 2.39   | 17.2   | 21.7     | 106      | 0.043 CD  | 32.1 BCDE | 3.79 D   |
| BRS 4107      | 98.3 B       | 1.79   | 17.1   | 21.6     | 105      | 0.038 D   | 27.9 E    | 9.53 AB  |
| BRS Caimbé    | 38.0 E       | 4.78   | 16.9   | 26.3     | 57.1     | 0.185 AB  | 31.3 BCDE | 2.75 D   |
| BRS PLANALTO  | 65.2 BCDE    | 6.48   | 17.0   | 23.0     | 75.0     | 0.081 BCD | 36.0 ABC  | 5.86 BCD |
| Brasino       | 48.0 E       | 3.89   | 16.9   | 23.5     | 68.6     | 0.127 B   | 31.3 CDE  | 8.62 ABC |
| CMST 029 FA   | 213 A        | -0.623 | 16.9   | 20.7     | 63.1     | 0.056 BCD | 33.1 BCD  | 3.89 CD  |
| Dente de Ouro | 91.5 BC      | 3.11   | 17.8   | 21.1     | 135      | 0.041 CD  | 31.1 CDE  | 13.5 A   |
| Pixurum 05    | 53.8 DE      | 5.28   | 17.4   | 23.1     | 63.0     | 0.089 BCD | 35.5 ABC  | 6.99 BCD |
| Pixurum 07    | 54.5 CDE     | 7.77   | 17.2   | 22.3     | 58.0     | 0.043 CD  | 30.0 DE   | 9.79 AB  |
| SINT PF 7021  | 53.8 CDE     | 5.27   | 16.6   | 21.1     | 76.5     | 0.065 BCD | 35.8 ABC  | 7.57 BCD |
| SINT PF 7031  | 59.2 CDE     | 6.89   | 16.9   | 25.8     | 73.7     | 0.122 B   | 38.9 A    | 5.48 BCD |
| SEM           | 13.380       | 2.260  | 0.273  | 1.690    | 16.630   | 0.025     | 2.020     | 1.730    |
| P-value       | <0.001       | 0.051  | 0.305  | 0.097    | 0.052    | 0.006     | 0.006     | 0.008    |

<sup>a-e</sup>Means followed by different letters within a column differ significantly according to Tukey's test at 5% probability. \*AD = aerobic deterioration; Ti = initial silage temperature; Tmax = maximum temperature; TmaxT = time required to reach maximum temperature; HR = heating rate; DM = dry matter; DML = dry matter losses.

Analysis of these data highlights the importance of evaluating multiple factors when selecting a genotype for cultivation. Pixurum 07 showed the best results for FM yield and plant height. In contrast, it exhibited the lowest results for grain yield on both FM and DM bases, DM-corrected grain yield, grain proportion in the ensiled mass, and the highest NDF content. The NDF is inversely correlated with both feed intake and digestibility when consumed by ruminants <sup>(21)</sup>. As noted by ASSIS et al.<sup>(16)</sup>, in cases where DM yield and plant lodging are not compromised, genotypes with lower fiber contents should be preferred for silage production. In the present study, SINT PF 7031 showed the lowest NDF content in both forage and silage. Although Pixurum 07 had high productive performance, it exhibited elevated NDF levels in both forage and ensiled material. This outcome is a consequence of the higher grain proportion in the ensiled mass of SINT PF 7031 and the lower grain proportion in Pixurum 07<sup>(22)</sup>.

Supporting the findings of Rabelo et al.<sup>(22)</sup>, most genotypes showed lower NDF contents after ensiling. However, this does not necessarily indicate improved nutritive value. According to McDonald et al.<sup>(17)</sup>, although silage may have lower NDF content than forage due to hemicellulose hydrolysis, its fiber quality is poorer due to higher participation of lignin and lower levels of potentially digestible components.

Overall, the NDF contents observed in this study (51.1–74.2 %) were broader than those reported by Patzlaff et al.<sup>(18)</sup> (55.3–56.5 %). This wider variation in NDF is likely associated with the larger number of varieties evaluated, intrinsic characteristics of the genotypes, plant development cycle, edaphoclimatic conditions, and management practices at the time of ensiling. Regardless, the broad range of NDF observed in this study provides producers with greater flexibility in selecting varieties.

The genotype BRS Caimbé showed higher DM losses during ensiling, even though the plant DM content at harvest was near the ideal level. Consequently, effluent losses were minimal, but gas losses were high, resulting in the greatest overall DM loss. Despite limited data on microbial populations and end-fermentation products in our study, increased DM losses during fermentation are associated with undesirable growth of yeasts and clostridia <sup>(17)</sup>. Since the DM content of corn forage from BRS Caimbé was near the ideal, the clostridia population was likely suppressed. Thus, the high DM loss reported in this treatment may be associated with increased yeast population growth, which is recognized to degrade WSC and produce ethanol during fermentation, causing 49 % DM loss through this metabolic pathway <sup>(17)</sup>.

All evaluated genotypes had pH values below 3.8, which is below the ideal range (3.8–4.2) for proper fermentation in corn silage <sup>(23)</sup>. However, pH values below 3.8 do not represent a problem, as they indicate that the silages were adequately fermented. This also suggests effective suppression of clostridia, bacilli, and enterobacteria during fermentation, which competes with lactic acid bacteria (LAB) for substrate and can increase silage pH through the production of compounds with lower pKa, such as volatile fatty acids <sup>(17, 24)</sup>.

During the aerobic exposure period, an increase in silage temperature is expected due to nutrient consumption by opportunistic and undesirable microorganisms, such as yeasts and filamentous fungi, resulting in aerobic deterioration of the silage <sup>(25)</sup>. According to Borreani et al.<sup>(26)</sup>, silages with stability below 72 hours are considered to have low aerobic stability. In the present study, only five genotypes (CMST 029 FA, BRS 4107, Dente de Ouro, BRS 4105, BRS 3042) exhibited stability greater than 72 hours. Borreani et al.<sup>(24, 26)</sup> reported that yeast counts above 100,000 colony-forming units (CFU)/g of forage resulted in low silage stability. Increased yeast

populations during aerobic exposure can impair animal performance due to rapid silage spoilage, particularly in silages rich in nutrients and lactic acid. This reduced performance is often linked to decreased silage intake caused by elevated yeast counts <sup>(5, 24, 25)</sup>.

The higher stability observed in some genotypes may be associated with the acetic acid content produced during fermentation. Increased acetic acid concentrations are associated with suppression of yeast growth during fermentation and after silo opening, acting as an inhibitor of aerobic deterioration <sup>(24, 25, 27)</sup>. Danner et al.<sup>(28)</sup> reported a strong correlation (near 1.0) between acetic acid concentration and aerobic stability. However, in the present study, organic acids were not measured, so this explanation remains speculative.

Observing the results for the genotypes BRS 4107 and BRS Caimbé, there appears to be a relationship between DM losses during fermentation and aerobic stability. The BRS 4107 showed the highest effluent losses and achieved the second-highest stability (98.3 h), suggesting a fermentation pathway more directed toward acetic acid production, likely due to the activity of enterobacteria associated with the low DM content at ensiling <sup>(17)</sup>. In contrast, BRS Caimbé exhibited the highest gas losses and lowest stability, indicating that its low stability was probably linked to the production of heterofermentative compounds other than acetic and propionic acids (which also have antifungal effects).

## 5. Conclusion

The current study confirmed that OPVs can be an alternative for farmers who use lower levels of technological resources, aiming to produce silage for organic systems. Based on field production, chemical composition, and silage loss and stability, the recommended varieties for organic cultivation are BRS 3042, CMST 029 FA, and SINT PF 7031.

### Conflict of interest statement

The authors declare no competing interests.

### Data availability statement

The data will be provided upon request.

### Author contributions

Conceptualization: Rediss, W. B., Eicholz, E. D., Rabelo, C. H. S.; Data curation: Rediss, W. B.; Formal analysis: Rediss, W. B.; Investigation: Rediss, W. B.; Funding acquisition: Eicholz, E. D., Schaffhäuser Junior, J., Rabelo, C. H. S.; Methodology: Eicholz, E. D., Schaffhäuser Junior, J., Rabelo, C. H. S.; Resources: Eicholz, E. D., Schaffhäuser Junior, J.; Project administration: Rabelo, C. H. S.; Supervision: Rabelo, C. H. S.; Visualization: Eicholz, E. D., Rabelo, C. H. S.; Software: Rabelo, C. H. S.; Writing – original draft: Rediss, W. B., Eicholz, E. D., Rabelo, C. H. S.

### Generative AI use statement

The authors did not use generative Artificial Intelligence tools or technologies in the creation or editing of any part of this manuscript.

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