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# Agronomic characteristics of corn hybrids for silage production in the State of Mato Grosso, Brazil

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**ABSTRACT.** The experiment was conducted at the Experimental Farm of the Federal University of Mato Grosso in the municipality of Santo Antônio do Leverger, State of Mato Grosso, Brazil to evaluate the agronomic characteristics of corn hybrids in the cultivation of second crop for silage production. The experimental design was carried out with randomized blocks with 23 treatments (hybrids) and three replications. Corn hybrids from different seed companies and recommended for the midwestern region of Brazil, were used. The agronomic traits were: stem diameter (cm), plant height and ear insertion (m); yield of green matter (ton. $ha^{-1}$), percentage of spike, stem and leaves in green mass; ear productivity (ton. $ha^{-1}$), dry matter content of stem + leaf and whole plant. Hybrids BF 9304, DKB 370, 177 DKB, BF 9534, BF 9417, AG 5020, BE 9701, P 3021 and P 30F98 had the highest production of green matter, plant height and spike insertion. The hybrid BF 9304 was also prominent for spike percentage (50.55%).

**Keywords:** green mass, plant height, silage production, spike yield, *Zea mays.*

## Características agronômicas de híbridos de milho para produção de silagem no Estado do Mato Grosso, Brasil

**RESUMO.** O experimento foi conduzido na Fazenda Experimental da UFMT em Santo Antônio de Leverger, Estado do Mato Grosso, com o objetivo de avaliar as características agronômicas de híbridos de milho em cultivo de segunda safra para a produção de silagem. O delineamento experimental utilizado foi em blocos casualizados com 23 tratamentos (híbridos) e três repetições. As características agronômicas avaliadas foram diâmetro do colmo (cm); altura de plantas e da inserção de espiga (m); produtividade de matéria verde (t $ha^{-1}$); porcentagens de espiga, colmo e folhas na massa verde; produtividade de espigas (t $ha^{-1}$); teores de matéria seca do colmo + folha e da planta inteira. Os híbridos que apresentaram maiores valores para produção de matéria verde, altura de plantas e da inserção de espiga foram BF 9304, DKB 370, DKB 177, BF 9534, BF 9417, AG 5020, BE 9701, P 3021 e P 30F98. O híbrido BF 9304 também se destacou quanto à porcentagem de espiga (50,55%).

**Palavra-chave:** massa verde, altura de plantas, ensilagem, espiga, *Zea mays.*

## Introduction

Climate seasonality is a regional phenomenon in the Brazilian savannah where rainfall is concentrated between October and March, with the three-month period December-February characterized by the highest rainfall rate. Extremely relevant are the occurrences of short summer-like periods, characterized by frequent periods of droughts, high temperatures and high evaporation rates which condition forage production yield and, consequently, animal production. According to Cabral et al. (2002), the two distinct seasons, the dry and rainy seasons, determine scarcity in the production of dry matter in a period and its abundance in another. Animal performance is thus limited due to low supply of feed during the dry period.

Tropical grasses have low forage availability during the dry period and supplements to herds are required. In Central Brazil, 75 to 85% of the production of total annual dry matter is produced between October and March, whereas 15 to 25% is produced between April and September (SOUZA et al., 2005). Forage production and stocking during the summer are required so that animal production would remain constant throughout the year. The production of corn silage is one of the most important alternatives for the provision of quality feed to animals during the dry period.

According to Mittelmann et al. (2005), silage quality is also related to agronomic characteristics of forage plants and thus shows the importance of studies on plant components prior to cultivation. The production of corn silage is extensively used in Brazil due to its high productivity and nutrition values (ZEOULA et al., 2003). Productivity is a criterion that should be evaluated in the choice of corn cultivars for silage production since this quality is inversely related to the costs. In fact, highest corn productivity yields the lowest costs per ton of silage produced.

Spike percentage is another highly important agronomic characteristic. Paziani et al. (2009) reported on the importance of determining the plant's spike percentage since grain quantity is a great help to evaluate forage digestibility and silage. This is due to progress in the animals' genetic improvements and to intensification in cattle breeding.

The agronomic characteristics of corn hybrids in second crop cultures for the production of silage in the State of Mato Grosso, Brazil, are evaluated.

## Material and methods

Experiment was carried out on the Experimental Farm of the Federal University of Mato Grosso in Santo Antônio do Leverger, Mato Grosso State, Brazil, at 15°47'5"S and 56°04'W; mean altitude 140 m above sea level; meso-region Centre-South of Mato Grosso; micro-region of the state capital Cuiabá, Mato Grosso, Brazil.

According to Koppen's classification, climate is Aw, with tropical mega-thermal climate, characterized by two well-defined dry (May to September) and rainy (October to April) seasons. Mean annual rainfall is 1.500 mm, with maximum intensity during December, January and February. Mean rainfall and evaporation during the experimental period (March to June 2009) were respectively 479 and 533 mm (Figure 1).

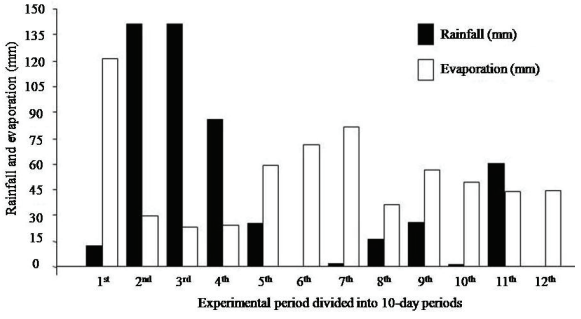


**Figure 1.** Rainfall and evaporation per 10-day periods (March to June 2009) in the Experimental Farm of UFMT, Santo Antônio de Leverger, Mato Grosso State, Brazil.

The predominant soil on the farm consists of plinthosol (moderate halic plinthisol Tb, medium texture, with a plateau landscape), with a texture easily infiltrated by water, with soil aeration, penetration of roots and development of the radicular system. Soil analysis of the experimental area (0 - 20 cm) provided the following characteristics: pH of water = 6.8; P = 9.6 mg $dm^{-3}$; $K^+$ = 54 mg $dm^{-3}$; $Ca^{2+}$ = 2.8 $cmol_c$ $dm^{-3}$; $Mg^{2+}$ = 1.5 $cmol_c$ $dm^{-3}$; $Al^{3+}$ = 0.0 $cmol_c$ $dm^{-3}$; $H^+ + Al^{3+}$ = 1.7 $cmol_c$ $dm^{-3}$; SB = 4.5 $cmol_c$ $dm^{-3}$; T = 6.2 $cmol_c$ $dm^{-3}$; V = 72.7%; MO = 14.0 g $dm^{-3}$; sand = 672 g $kg^{-1}$; silt = 120 g $kg^{-1}$; clay = 208 g $kg^{-1}$.

Corn hybrids evaluated were AG 5020, AG 6040, AG 8088, AG 9010, DKB 177, DKB 330, DKB 370, DKB 390, DAS 2B587, DAS 2B688, DAS 2B710, DAS 2C520, P 30F98, P 30F80, P 3021, P 3021, BE 8307, BE 9701, BF 9534, BF 9417, BF 9304, BF 9304 and AGN 30A06. The experiment, with randomized blocks consisting of 23 treatments (hybrids) and three repetitions, was carried out in March 2009.

Lots consisted of four 5 m-long rows with 0.90 m space between them. The border had two external rows and 0.50 m at the extremities of the two central rows.

Fertilizing was conducted according to soil analysis results, with 17.5 kg $ha^{-1}$ of N; 105 kg $ha^{-1}$ of $P_2O_5$; 52.5 kg $ha^{-1}$ of $K_2O$ at seeding; 80 kg $ha^{-1}$ of N and 80 kg $ha^{-1}$ of $K_2O$ at top-dressing, divided into two applications. Seeding was undertaken manually and population was maintained after the harvest of 55,000 plants $ha^{-1}$.

The phenological development of five plants in each central row of the parcel, with ten plants per parcel, was carried out after the emergence of seedlings. Control of invasive plants was done with herbicides alachlor (300 g $L^{-1}$) and atrazine (180 g $L^{-1}$) in the pre-emergence period. Insecticide Lannate was applied twice to control the fall armyworm (*Spodoptera frugiperda*).

Corn plants for silaging were cut and sliced after 100 days of seedling emergence when the grains were in the flour stage. The following agronomic characteristics, stem diameter (cm); height of plant and ear insertion (m); productivity of green matter (ton. $ha^{-1}$); spike percentage, stem and leaves in green mass; productivity of spikes (ton. $ha^{-1}$); rates of stem dry matter + leaves and of entire plant were evaluated. Stem diameter was calculated by pachymeter from 10 cm above soil level. Plant height was determined by measuring the plants as from the soil surface to the insertion of the completely expanded last leaf; and from the spike insertion up to the insertion of the highest spike.

Ten plants were evaluated from the two central rows of the area of each parcel. The productivity of green matter was determined by the harvest of all plants in the used area of each parcel, at a height of 10 cm from the soil surface, weighted in a precision scale, and the weight transformed into tons of green matter per hectare.

Part of the original sliced material was sampled during silaging; it was then placed in paper bags, weighed and dried in a forced air buffer at 60-65°C for 72 hours. The pre-dried samples were weighed and ground at 1-mm size and then kept in polyethylene containers for the analysis of their DM rates (SILVA; QUEIROZ, 2002). Data were submitted to variance analysis and to Scott-Knott mean cluster grouping at 5% probability, with software SAEG.

## Results and discussion

Differences ($p < 0.05$) among hybrids were assessed with regard to productivity of green matter (PGM), ranging between 16.40 and 29.62 ton. $ha^{-1}$. Hybrids with high PGM were DKB 370, DKB 390, DKB 177, BF 9534, BF 9417, BF 9304, AG 5020, SOMMA, BE 9701, P 3021 and P 30F98 (Table 1).

Above results were higher than those reported by Oliveira et al. (2011), who evaluated corn hybrids in dystroferric red latisol in the state of Paraná, Brazil, and obtained mean PGM of 15 ton. $ha^{-1}$. On the other hand, results by Rosa et al. (2004), who evaluated three corn hybrids in the state of Rio Grande do Sul, Brazil, in podzolic red-yellow soil, and Santos et al. (2010), who evaluated six corn varieties in the Brazilian semi-arid region, reported even higher productivity, with rates between 29.85 and 38.14 ton. $ha^{-1}$ and between 28.40 and 40.00 ton. $ha^{-1}$, respectively.

Productivity of green matter is one of the first parameters evaluated when information on a determined cultivar is required. Hybrids evaluated in current research showed low viability for silage production. This was perhaps due to the fact that PGM is affected by soil characteristics (plinthisol) and by climatic conditions during growth with mean rainfall and evaporation rates, 479 and 533 mm, respectively, and a water deficit of 54 mm (Figure 1). PGM had a positive co-relation ($p < 0.05$) with regard to plant height (HP), height of spike insertion (HSI) and stem diameter at 10 cm (SD); it was however negative with regard to spike percentage (SPER) (Table 2). The highest hybrid plants were prone to be more productive besides having highest HSI and SD rates to the detriment of SPER. In fact, these characteristics will influence the quality of the future silage.

Differences ($p < 0.05$) were reported among hybrids in the case of SPER (Table 1), with special reference to DAS 2C520, DAS 2B710, DAS 2B587, BF 9304, AG 9010, AG 8088, AGN 30A06, AGN 31A31 and P 30F80, varying between 45.89 and 53.16% of spike.

**Table 1.** Agronomic characteristics in corn hybrids for silage production in the State of Mato Grosso, Brazil.

| Hybrid | PGM | SPER | SP | DMSL | DMP | PERS | PERL | HP | HSI | SD |
|---|---|---|---|---|---|---|---|---|---|---|
| | (ton. $ha^{-1}$) | (%) | (ton. $ha^{-1}$) | (%) | (%) | (%) | (%) | (m) | (m) | (cm) |
| DKB 370 | 25.24 a | 42.21 b | 7.67 a | 34.27 a | 35.19 b | 31.58 a | 26.21 a | 2.31 a | 1.13 a | 1.86 a |
| DKB 390 | 23.94 a | 44.56 b | 7.83 a | 37.39 a | 37.73 b | 32.35 a | 23.09 a | 2.05 b | 1.10 a | 1.47 b |
| DKB 177 | 26.18 a | 43.13 b | 8.09 a | 35.28 a | 39.11 b | 33.79 a | 23.08 a | 2.28 a | 1.21 a | 2.07 a |
| DKB 330 | 16.40 b | 43.62 b | 5.17 a | 34.10 a | 36.71 b | 35.27 a | 21.11 a | 1.84 b | 0.93 b | 2.06 a |
| DAS 2C520 | 19.12 b | 49.44 a | 6.97 a | 36.71 a | 42.00 a | 28.21 a | 22.35 a | 2.10 b | 0.91 b | 1.50 b |
| DAS 2B688 | 18.80 b | 44.56 b | 6.00 a | 36.92 a | 43.01 a | 32.35 a | 23.09 a | 2.08 b | 0.97 b | 1.87 a |
| DAS 2B710 | 19.73 b | 46.94 a | 6.69 a | 35.84 a | 41.74 a | 28.80 a | 24.26 a | 1.90 b | 0.90 b | 1.50 b |
| DAS 2B587 | 18.59 b | 53.16 a | 7.06 a | 36.85 a | 44.70 a | 26.92 a | 19.92 a | 1.92 b | 0.97 b | 1.92 a |
| BF 9534 | 25.76 a | 41.23 b | 7.65 a | 34.07 a | 36.42 b | 31.46 a | 27.31 a | 2.19 a | 1.08 a | 2.01 a |
| BF 9417 | 25.67 a | 42.53 b | 7.92 a | 34.24 a | 37.73 b | 29.28 a | 28.19 a | 2.22 a | 1.19 a | 1.80 a |
| BF 9304 | 23.63 a | 50.55 a | 8.62 a | 36.95 a | 41.27 a | 28.23 a | 21.22 a | 2.22 a | 1.13 a | 1.69 b |
| AG 9010 | 20.84 b | 45.89 a | 9.63 a | 38.06 a | 45.18 a | 35.33 a | 18.78 a | 1.88 b | 0.86 b | 1.58 b |
| AG 8088 | 21.28 b | 52.65 a | 8.06 a | 39.14 a | 44.46 a | 26.05 a | 21.30 a | 2.00 b | 0.88 b | 1.67 b |
| AG 5020 | 29.62 a | 40.54 b | 8.63 a | 35.69 a | 41.48 a | 33.61 a | 25.85 a | 2.34 a | 1.61 a | 2.13 a |
| AG 6040 | 20.15 b | 36.66 b | 5.34 a | 38.58 a | 38.53 b | 41.87 a | 21.47 a | 1.79 b | 0.94 b | 1.36 b |
| SOMMA | 22.74 a | 42.45 b | 6.98 a | 34.63 a | 39.54 b | 33.46 a | 24.09 a | 1.99 b | 1.08 a | 1.52 b |
| BE 8307 | 20.55 b | 41.51 b | 6.18 a | 37.36 a | 37.78 b | 39.84 a | 18.65 a | 1.99 b | 1.02 b | 1.65 b |
| BE 9701 | 24.48 a | 35.92 b | 6.29 a | 35.96 a | 38.69 b | 33.60 a | 30.48 a | 2.37 a | 1.26 a | 2.12 a |
| AGN 30A06 | 19.78 b | 48.64 a | 7.13 a | 37.64 a | 40.09 b | 27.49 a | 23.87 a | 2.01 b | 1.07 a | 1.37 b |
| AGN 31A31 | 18.93 b | 47.10 a | 6.45 a | 34.56 a | 35.84 b | 29.48 a | 23.42 a | 2.07 b | 1.09 a | 1.60 b |
| P 3021 | 25.49 a | 38.07 b | 7.12 a | 37.41 a | 37.35 b | 39.32 a | 22.61 a | 2.17 a | 1.18 a | 1.81 a |
| P 30F80 | 22.36 b | 46.26 a | 7.44 a | 34.73 a | 35.24 b | 28.99 a | 24.75 a | 2.05 b | 1.56 a | 2.18 a |
| P 30F98 | 27.32 a | 40.41 b | 8.06 a | 34.18 a | 37.11 b | 42.50 a | 17.09 a | 2.49 a | 1.31 a | 2.04 a |
| Mean | 22.46 | 44.26 | 7.26 | 36.11 | 39.43 | 32.6 | 23.14 | 2.1 | 1.1 | 1.77 |
| CV[1] (%) | 16.47 | 12.59 | 24.23 | 8.65 | 8.28 | 18.7 | 15.02 | 5.85 | 9.25 | 12.85 |

[1]Coefficient of variation (%). Means followed by different letters in the vertical column statistically differ among themselves by Scott-Knott's test ($p < 0.05$). PGM = Productivity of green matter; SPER = spike percentage in total green mass; SP = spike productivity; DMSL = stem+leaves dry matter rate; DMP = plant dry matter rate; PERS = percentage of stem in total green mass; PERL percentage of leaves in total green mass; HP = height of plant; HSI = height of spike insertion; SD = stem diameter.

**Table 2.** Coefficient of Pearson's co-relation (r) among the agronomical characteristics of corn hybrid forage for the production of silage in Mato Grosso State, Brazil.

| Characteristics | r | Characteristics | r |
|---|---|---|---|
| PGM x SPER | -0.48** | SPER x HSI | -0.36* |
| PGM x HP | 0.80** | HSI x PERL | 0.37* |
| PGM x HSI | 0.71** | HSI x HP | 0.66** |
| PGM x SD | 0.44* | HSI x SD | 0.63** |
| SPER x PERS | -0.77** | HP x SD | 0.56** |

**; *: Significant at 1 and 5% probability by test t, respectively.

Results were lower than those given by Paziani et al. (2009), who using the data bank of the Program of Evaluation of Maize Cultivars for Silaging during the harvests between 1998/1999 and 2004/2005 on four sites in the State of São Paulo, Brazil, obtained mean 55.8% of spikes. When Beleze et al. (2003b) evaluated five corn hybrids in the State of Paraná, Brazil, they obtained a spike variation between 63.62 and 70.25%. Jaremtchuk et al. (2005) evaluated 20 corn hybrids for silaging in the state of Paraná, Brazil, and obtained lower rates for SPER, ranging between 32.4 and 42.4%. Low spike percentage in this experiment is due to water restrictions which, according to Rosa et al. (2004), may impair the spike's development.

There was no significant difference in the productivity of spike (SP) among hybrids (Table 1) since variations occurred between 5.17 and 9.63 ton. $ha^{-1}$. Oliveira et al. (2010), evaluated four forages in the state of Bahia, Brazil, and had similar results, with mean 9.70 ton. $ha^{-1}$ for SP.

According to Cabral et al. (2002), a high proportion of spikes in silage material is highly desirable since a high proportion of grains contributes towards a better quality of forage and thus for future silage. However, a high proportion of hay and corn cobs may decrease the positive effect of SPER in silage quality. According to Table 2, SPER had a negative co-relationship ($p < 0.05$) with PERS and HSI.

There were no significant differences among hybrids (Table 1) with regard to percentage of DM of stem + leaf (DMSL) even with a variation between 34.04 and 39.14%. Nascimento et al. (2008) evaluated corn and sorghum hybrid silages and obtained a low DM percentage for corn hybrid Cocagne (21.4%) in Lusigan, France.

Dry matter percentage of the entire plant (DMP) was higher than that of DMSL, with an increase mainly from SPER. Beleze et al. (2003a), evaluating five corn hybrids in Castro PR Brazil, in red-yellow latisol, reported positive co-relationships between DMP and SPER ($r = 0.78$) (Table 2).

Differences ($p < 0.05$) were reported among hybrids with regard to DMP (Table 1) which varied between 35.19 and 45.18%. Hybrids with lower DMP were DKB 370, DKB 390, DKB 177, DKB 330, BF 9534, BF 9417, AG 6040, SOMMA, BE 8307, BE 9701, AGN 30A06, AGN 31A31, P 3021, P 30F80 and P 30F98.

Lupatini et al. (2004) obtained a variation between 28.47 and 38.51% and reported that MSPLI was the most important factor in the final quality of silaged material. According to these authors, due to the oxygen present, compaction is difficult for silages produced from forages with high MSPLI (over 40%) and with low quality silage. On the other hand, Jaremtchuk et al. (2005) evaluated 20 corn hybrids for silaging in the state of Paraná, Brazil, and obtained DMP rates between 26.56 and 31.70%. According to McDonald et al. (1991), ideal rate of dry matter should be between 30 and 35% and lower rates produce undesirable fermentation due to the development of bacteria of the genus *Clostridium*. High rates in current experiment were probably due to water deficiency that may have decreased the plant's humidity rate.

There was no significant difference among hybrids (Table 1) with regard to percentage for stem (PERS) and leaf (PERL) in total green mass, in spite of the occurrence of great variations in PERS (between 26.05 and 42.50%) and PERL (between 17.09 and 30.48%). Santos et al. (2010) evaluated six corn varieties in the Brazilian semi-arid region and obtained similar results for PERS (between 22.6 and 33.9%) and PERL (between 12.5 and 29.9%). Rosa et al. (2004) obtained percentages between 19.0 and 24.6% for PERL, and lower ones, between 22.7 and 28.5%, for PERS. High stem proportion was probably due to lack of rainfall regularity in the region since seeding occurred in the second crop (end of March) which may have delayed development from the vegetal to the reproduction stage, with an increase in PERS and a consequent decrease in spike percentage (SPER), negatively co-related ($p < 0.05$) with PERS (Table 2). Paziani et al. (2009) also reported a negative co-relationship between PERS and SPER.

There were differences ($p < 0.05$) in plant height (HP), ranging between 1.84 and 2.49 m, among the hybrids evaluated (Table 1), with special reference to DKB 370, DKB 177, BF 9534, BF 9417, BF 9304, AG 5020, BE 9701, P 3021 and P 30F80.

Villela et al. (2003) evaluated nine corn cultivars in the State of Minas Gerais, Brazil, in deep red latisol (1999/2000 harvest) and verified a similar HP, with variations between 1.94 and 2.49 m. Whereas Alvarez et al. (2006) evaluated three hybrids and two

plants in the State of Minas Gerais, Brazil, in deep red latisol, and obtained HP between 2.20 and 2.30 m, Santos et al. (2010) assessed six corn varieties in the Brazilian semi-arid region and obtained similar HP rates, with mean 2.2 m.

Differences ($p < 0.05$) existed in the height of spike insertion, between 0.86 and 1.61 m, among the hybrids evaluated (Table 1), with special reference to DKB 370, DKB 390, DKB 177, BF 9534, BF 9417, BF 9304, AG 5020, SOMMA, BE 9701, AGN 30A06, AGN 31A31, P 3021, P 30F80 and P 30F98.

Alvarez et al. (2006) and Beleze et al. (2003a) obtained similar rates for HSI with variations between 1.18 and 1.46 m and between 1.06 and 1.34 m, respectively. In Uberlândia, Minas Gerais State, Brazil, Santos et al. (2002) obtained lower rates, with mean 0.98 m, probably due to differences in edaphoclimatic conditions between the regions under analysis.

According to Keplin (1996), the best bands for plant height and for spike insertion height in corn for silage are respectively between 2.20 and 2.50 m and between 0.90 and 1.20 m. Rates in current experiment were close to the parameters obtained by the above-mentioned author. HSI had a positive co-relationship ($p < 0.05$) with PERL, HP and stem diameter (SD) (Table 2).

There were significant differences ($p < 0.05$) with regard to SD, between 1.36 and 1.69 cm, among the evaluated hybrids (Table 1) with special reference to DKB 390, DAS 2C520, DAS 2B710, BF 9304, AG 9010, AG 8088, AG 6040, SOMMA, BE 8307, AGN 30A06 and AGN 31A31.

Beleze et al (2003a) obtained higher SD rates, ranging between 2.12 and 2.33 cm, which were probably due to differences in the soil's chemical and physical characteristics. SD had a positive co-relationship ($p < 0.05$) with HP and HSI (Table 2). Rates of neutral detergent fiber (NDF) and acid detergent fiber (ADF) of forage and silage increased in proportion to SD increase, which caused a reduction in silage intake.

Hybrid BF 9304 had the best agronomic characteristics among the evaluated hybrids, with special reference to PGM, SPER, HP, HSI and SD. However, the nutritional value of the hybrid's silage produced should be evaluated so that it may be recommended for silage production in the State of Mato Grosso, Brazil.

## Conclusion

Hybrids BF 9304, DKB 370, DKB 177, BF 9534, BF 9417, AG 5020, BE 9701, P 3021 and P 30F98 had the highest production in green matter, plant height and spike insertion height.

Hybrid BF 9304 also stood out with regard to spike percentage (50.55%).

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