

Production and nutritive value of silage corn in different reproductive stages

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Abstract— Corn has been the most used crop for whole plant silage, due to its high potential for dry matter production, high energy and great adaptability to different growing regions. Due to the great importance of the culture for this purpose, the region of the Far West of Santa Catarina, due to the presence of one of the largest dairy basins in Brazil, demands the supply of this food to the animals mainly during the season of forage. Thus, the objective of this work was to evaluate different hybrids and to identify the optimal corn cutting time for silage production that provides a greater economic return to the system. The experimental design used was a randomized complete block design in a 2x4 factorial scheme, allocating different maize hybrids (P30F53 VYHR®; P32R48 VYHR®) to the main plot and the reproductive stages (R2, R3, R4, R5). The experiment had 8 treatments and 3 replicates, totaling 24 experimental units. The studied variables were: dry matter content (DM); crude protein (PB); acid detergent insoluble fiber (FDA); neutral detergent insoluble fiber (NDF); total digestible nutrients (NDT), and CNF-amido, at the reproductive stages. The best economic yield is obtained when the maize crop is ensiled at the reproductive stage R4 and R5. Among the hybrids, the P32R48 VYHR® was the one that obtained better yield, providing greater production of milk by area.

Keywords— qualitative parameters, harvest point, economic income, Zea mays

I. INTRODUCTION

The importance of dairy monoculture in the state of Santa Catarina is indisputable, both as a source of income for rural properties, as for the generations of jobs in the processing industries. Currently, the state is the fourth largest milk producer in the country, with 2.83 billion liters of milk, with emphasis on the western region of Catarinense, which represents 79% of this production (EPAGRI/CEPA, 2018). To maintain this growth, producers constantly seek, forms of supply the nutritional demands of their herds, with quality pastures, supply of concentrated feedingstuffs or preserved foods (silage or hay). In this sense, it gains prominent role, the making of corn silage plant. Due to food shortages during certain periods of the year, when the forage used as the basis for feeding livestock, cannot meet the nutritional demands. Maize has been the most used crop for making plant silage whole due to its high potential for dry matter production and its large adaptability to different cultivation regions (FACTORI et al., 2012). Still, there is

a large number of maize hybrids destined for silage production, from which significant differences with respect to the production of Green forester, production of grains, leaves and stalk directly interfering with the nutritional value of the silage (MORAES et al., 2013). In this sense, the choice of hybrid and reproductive stage of cutting becomes determinant factors for the success of the system, since the hybrid may represent up to 50% of the final yield (FACTORI et al., 2012), and the stage of cutting that the plant is in, is directly related to the available energy of this material, by increasing the participation of grains (MARAFON et al., 2015). In this context, it is important studies, which demonstrate the best strategy for harvesting these hybrids, which provide higher milk production ha⁻¹ and economic income for the rural producer. In this way, the objective of this work was to evaluate different hybrids and identify the ideal moment of cutting of maize for silage production that provides greater economic return to the system.

II. MATERIALS AND METHODS

The experiment was conducted in the agricultural year of 2017/2018, in the municipality of Iraceminha-SC, located in the extreme West region of the state of Santa Catarina (26 ° 48'25.36's and longitude 53 ° 20 ' 4.50 ' ' W). The region's climate according to the system of Köppen classification, is humid subtropical with hot summer (CFA; ALVARES et al., 2014), with an average altitude of 401 m. Maximum and minimum air temperatures (°C) and rainfall (mm) observed during the experiment period are presented in the figure 01.

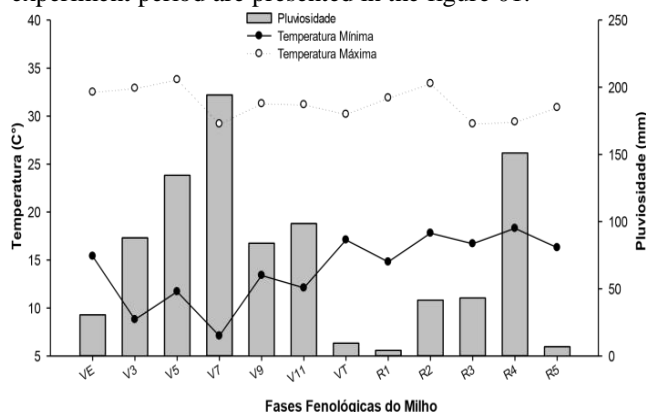


Fig. 1 - meteorological data observed during the experimental period (maize: Stadiums in the region of Iraceminha – SC. Source: INMET, São Miguel do Oeste-Santa Catarina-PR 2018.

The soil of the experimental area is classified as NITOSSOL BRUNO. Dystrophic with clayey texture and smooth wavy relief (EMBRAPA, 2013). According to soil analysis, the soil chemical attributes of the experimental area before the maize crop implantation are presented in table 1.

Table 1 – Chemical characterization of the soil in the depth of 0-20 cm, collected before the sowing of corn hybrids

pH	M	P	K	Ca	Mg	Al ³⁺	H+Al CTC	SB	Ca	Mg ⁻¹	CA	K ⁻¹	Mg	K ⁻¹
0														
H ₂ O	%	mg dm ⁻³				mol _c dm ⁻³		%						
5,8	3,0	9,48	138,1	6,36	2,5	0,0	9,22	13,7	70,33	2,54	18,02	7,09		

*Soil collected in August 2017; Soil Analysis Laboratory Terranálises-Fraiburgo(SC).

The experimental design used was the complete randomized blocks, in factorial scheme 2x4, allocating the hybrids (P30F53 VYHR®; P32R48 VYHR®) in the main plot and in the subplot the stadiums (R2, R3, R4, R5). The experiment had 8 treatments and 3 replications,

totaling 24 experimental units with an area of 17.5 m² (3, 5m wide x 5m in length), with a useful area 7.35 m² (5 lines length of 3m). The total area of the experiment was 420 m². Each subplot consisted of 7 lines of 5 meters, spaced 0.49 m apart.

Corn sowing was performed on 09 September 2017, in a no-tillage system, in succession to black oat (*Avena strigosa*), which was desiccant 30 days before sowing with a herbicide based on Glyphosate (Original Roundup® 2.5 L ha⁻¹). A tractorized sow was used, with a density of 74500 seeds ha⁻¹.

For the fertilization of the crop, the soil analysis was interpreted for an expectation of productivity of 24 tons of MS per hectare, using as basis the Manual of liming and fertilization of the Commission of Soil Chemistry and fertility RS/SC, 2016.

The base fertilization used was 520 kg ha⁻¹ of the fertilizer MAP (11-52-00), the pre-planting fertilization (21 days before sowing) was 800 kg per hectare of potassium chloride 00-00-60, and in the fertilization of coverage were used 320 kg per hectare of the fertilizer nitrogenated urea (45-00-00), at V4 Stage, and 480 kg per hectare of Sulfammo MeTA® (29-00-00), in the V6 stadium.

The hybrids used were the Pioneer brand, P30F53 VYHR® and P32R48 VYHR®, both with Leptra® technology (maize cartridge caterpillar, Spodoptera Frugiperda) and RR (Roundup Ready®), with industrial seed treatment (Dermacor® + Poncho® + Derosal Plus®). Weed control was performed 20 days after sowing of the crop with a herbicide based on Atrazine + Simazine (Primatop® 6, L ha⁻¹).

As soon as the culture reached the stages of R2, R3, R4 and R5, the cuttings of the whole plants were performed in the useful area of each plot and at the cutting height of 25 cm, in order to achieve maximum milk production per hectare, considering beyond the quality of the ensiled mass, also a larger amount of stored dry mass.

The cut in the aforementioned reproductive stages, aim to represent the different harvesting points observed in the region of study, where most farmers, because they are family farmers, depend on the outsourcing of the service of harvest. In this way, some crops occur when maize is in the R2 stage (anticipating the harvest), or in R5, due to the high demand of farmers for this type of service. On the other hand, the producers with better implement structure, which can perform the harvesting when they deem appropriate, perform the cut normally when the plants are in R4.

The samples were packaged in mini PVC silos with 75 mm in diameter and 50 cm in height. After 30 days of

ensilage, the samples were referred to the laboratory of Bromatological analyses for analysis, through which the contents of a) dry matter (MS) were obtained; b) crude protein (PB) (Prates, 2007); c) Acid detergent insoluble fiber (FDA); D) neutral detergent insoluble fiber (NDF); e) Starch (ANFAR, 2009; method n ° 11-NIR), and f) Total digestible nutrients (TDN) calculated through the near infrared spectrophotometer – NIRS.

Using these parameters, milk production per hectare was estimated, considering the need for nutrients for maintenance, locomotion and milk production, according to the methodology proposed by NRC (2001). For this, we considered the nutritional need of 3 cows of 450 kg PV during one year and milk production with 3.5% of fat. Based on the values obtained from total milk production and the average price per liter of milk paid to the producer in the month of October 2018 for the state of Santa Catarina of R \$1.3636 (CEPEA/ESALQ-USP, 2018), one can estimate the economic yields of each hybrid in each Reproductive stage of cutting. The method used does not take into account losses occurring in the process of silage, fermentation and desilage of the roughage.

Data were subjected to analysis of variance by the F test using the statistical software sratgraphics (12.5). When the data did not present interactions among the factors (hybrids and reproductive stages of cutting), were analyzed as simple effects. The averages that showed significance were compared by the Tukey test ($P < 0.05$).

III. RESULTS AND DISCUSSION

The interaction between the factors (hybrids and reproductive stages of cutting) was not significant ($P < 0.05$) in the variables studied, and the isolated effect of each factor was analyzed, as can be seen in table 2 and 3. For the hybrid maize factor, there was no significant effect for the variables MV, MS and PB. However, there was a difference ($P < 0.05$) between the response variables, starch, NDT, NDF and FDA (table 2).

Table 2 – Quantitative and qualitative parameters of silage in relation to the hybrid maize factor (Iraceminha, SC – 2017/2018 crop)

pH	M.O	P	K	Ca	Mg	Al ³⁺	H+Al/CTC	SB	Ca/Mg ⁻¹	Ca/K ⁻¹	Mg/K ⁻¹	
H ₂ O	%	mg dm ⁻³				mol _e dm ⁻³		%				
5,8	3,0	9,48	138,1	6,36	2,5	0,0	9,22	13,1	70,33	2,54	18,02	7,09

Averages followed by the same letter in the column

do not differ from each other ($P < 0.05$) by the Tukey test).

Observing the data presented in table 2, it is noted that the hybrids used in the experiment, because they are of double aptitude (grain and silage), have qualitative and quantitative characteristics within the expected standard for a good quality silage. As shown in Figure 1, one of the factors responsible for this result was the good climatic conditions, recorded during the development of the culture.

The production of 84.51 and 87.70 Mg of MV ha⁻¹ in the hybrids analyzed were much higher, the production above 55 Mg of MV ha⁻¹ considered by Neumann et al., (2015), as characteristic ideas of a good hybrids. This high production per hectare, in addition to allowing greater production of meat or milk per area, still dilutes the production costs.

There was no difference between the crude protein values between the hybrids and neither between the different reproductive stages (table 2 and 4). COSTA et al., (2006) considers that PB contents below 7% could be limiting animal production, because they imply less voluntary consumption, reduction in digestibility and negative nitrogen balance. However, it is observed that the silages produced in this work (table 2 and 4) would satisfactorily meet ($PB \geq 7,81$) to the minimum requirements of ruminants. On the other hand, in the case of milk production, the PB contents would be limiting the productivity, since the NDT values could provide conditions to obtain higher production values.

In the different reproductive stages of cutting, there was a significant statistical difference ($P < 0.05$) for the variables MV, DM, starch, NDT, FDN and FDA, with no difference between treatments only for the variable PB (table 3).

Table 3- Quantitative and qualitative parameters of silage in different reproductive stages of cutting (Iraceminha, SC-2017/2018 crop)

Estádios Reprodutivos	MV	MS		PB	Amido	NDT	FDN
		FDA					
		<i>Mg ha-1 -----g 100 g MS</i>					
		<i>-----</i>					
R2	88,29A	20,07C	7,99A	8,17C	67,34B	47,30A	29,29A
R3	86,26AB	23,17C	8,08A	17,32B	68,76B	45,23B	27,25A
R4	92,26A	27,17B	7,88A	30,14A	71,61A	41,51C	23,18B
R5	77,60B	32,91A	7,81A	32,13A	71,49A	41,66C	23,36B
CV (%)	5,1	5,38	3,59	10,59	1,07	2,09	4,15

Averages followed by the same letter in the column do not differ from each other ($P < 0.05$) by the Tukey test)

Considering the MV variable, it is observed that the R4 stage providing approximately 15 Mg ha⁻¹ of MV to more than the R5 stage. However, the highest DM content (32.9%) Observed at the R5 stage, it provided about 500 kg ha⁻¹ more than DM when compared to R4. This result was expected, since with the advancement of phenological stages, there is an increase in the DM content and a decrease in MV values. Marafon et al., (2015) verified in his work, an increase of 26.70% to 34.78%, in R3 for the R5 stage, respectively.

The DM content has a great influence on the final quality of the ensiled material, and it is indicated levels between 30 and 35% of MS (LAUER, 1996). The ensilage of materials with DM content above 35%, generates difficulty in compaction, increasing the oxygen levels between the forage mass, causing the development of aerobic microorganisms and nutrient losses (OLIVEIRA et al 2014). On the other hand, high moisture content, above 70% are correlated with higher nutrient losses by effluent, lower final dry matter production, bacterial proliferation, which slow down pH (SILVEIRA, 2009).

For the variable starch, it is observed that with the advancement of the reproductive stage the levels increase, with no difference between the stages R4 and the R5, obtaining values of 30.14 and 32.13% respectively. This result is linked to the advancement of the grain formation, which increases the starch content in the silage. This same response behavior is observed for the NDT parameter, that increase with the advances of the reproductive stages. According to Cabral et al., (2012) The higher the proportion of grains in the mass, the higher the values of total digestible nutrients found.

Therefore, besides the total mass production, it should also be considered the quality of the silage, which is influenced by the proportion of the plant components and the advancement of the reproductive stage of the plant. Thus, despite the increase in the fraction in more advanced stages of maturation, the increase in grain participation, provides higher energy levels and the quality of silage in greater proportion, than the losses caused by the fibrous portion (Oliveira, 2010), a situation observed in this work.

The FDN and FDA values (table 3) decrease with the advancement of the reproductive stages, this result is due to the greater participation of grain in silage, consequently higher energy value (starch) and higher nutrient content digestible (NDT). Ensiled crops, before the ideal point, besides presenting lower total mass production, have a higher NDF content due to the occurrence of effluent and the lower share of the grain fraction in the mass (VAN SOEST, 1994; VILELA et al.

2008). Similarly, Marafon et al. (2015), evaluating different maize harvesting stages, observed that maize plants in the R5 stage presented lower FDN and FDA content, when compared to the R3 stage due to the dilution of these fractions, by the transformation of simple sugars into starch in the grain component.

Also, VAN SOEST et al., (1991), points out that good silage must comply with some minimum quality criteria. Thus, values lower than 50% of neutral detergent fiber and 32% of acid detergent fiber (table 4), are important because they have a high correlation with the capacity of daily dry matter consumption and energy density of the resulting silage, respectively (VAN SOEST et al., (1991). For the production estimate (L cow⁻¹ day⁻¹; L ha⁻¹), a significant isolated effect was verified between the hybrids and between the reproductive stages of cutting. Thus, the production estimate was higher for the hybrid P32R48 VYHR®, with values of 15.43 L cow⁻¹ day⁻¹, 16900.4 L ha⁻¹, while the P30F53 VYHR®, obtained an average yield of 14, 47 L Vaca⁻¹ day⁻¹, 15845.7 L ha⁻¹ (table 4).

Table 4 - Milk production estimation per hectare based on qualitative parameters and quantitative silage for different maize hybrids (Iraceminha, SC – 2017/2018 crop).

Híbridos	Produção de Leite	
	----- L vaca ⁻¹ dia ⁻¹ -----	----- L ha ⁻¹ -----
P32R48 VYHR [†]	15,43 A	16900,4 A
P30F53 VYHR [†]	14,47 B	15845,7 B

Averages followed by the same letter in the column do not differ from each other (P < 0.05) by the Tukey test. Standard error of Mean ± (0.299 L cow⁻¹ day⁻¹), and ± (327.69 L ha⁻¹).

The highest production observed in hybrid P32R48 VYHR®, possibly due to the fact that it has a higher MS content, which raises the amount of PB available (table 2), approximately 90 kg of PB more per hectare, even if it does not differ from the other treatment. According to Pereira et al., (2007), the MS and PB contents of the plant are important factors in the ensilage process and in the determination of the nutritional value. This hypothesis may be considered because the protein in this case is the limiting factor of production, therefore greater availability of PB, higher production.

In addition to being highly demanding in energy, lactating animals also present high protein demand that can limit the productive potential of these animals. The protein content in the diet has a positive correlation with the consumption, being this effect partly from the increase in

rumen degradable protein and improvement in food digestibility (CARDOSO et al., 2017). Several studies have shown that the increase in crude protein consumption increases milk yield per animal. As data presented in the NRC (2001), of which milk production increased 0.75 Kg cow-1 day-1 when the PB content in the ration was increased from 15 to 16%, and 0.35 Kg cow-1 day-1 when the PB content was increased from 19% to 20% , being the maximum milk production was observed with contents of 23% PB ration.

The production estimate in relation to the reproductive stages of cutting (table 5) increased as the phenological stages of the plant occurred. Thus, the highest productivity was observed in R5 and R4, with values of 17.58 and 17.44 L Cow-1 day-1 and 19244.5 and 19099.1 L ha-1, respectively, with no difference between them.

The phenological stage interferes directly in the amount of dry matter of the ensiled material, this evaluation is important, since in stage MS are contained all the nutrients, having great effect on the quality of the final material (OLIVEIRA et al., 2014). Thus, the highest productions were verified in the most important reproductive stages advanced, where increments in the parameters occurred; MS, starch and NDT, and decrease in NDF and FDA values.

Table 5 - Estimation of milk production based on qualitative and quantitative parameters of silage in different reproductive stages (Iraceminha, SC-Safra 2017/2018).

Estágio Reprodutivos	Produção de Leite	
	----- L vaca ⁻¹ dia ⁻¹ -----	-----L ha ⁻¹ -----
R2	11,32 C	12385,4 C
R3	13,48 B	14763,2 B
R4	17,44 A	19099,1 A
R5	17,58 A	19244,5 A

(Averages followed by the same letter in the column do not differ from each other (P < 0.05) by the Tukey test. Standard error of Mean (0, 423 L Cow-1 day-1), and ± (463, 42L ha-1)

Table 6 and 7, refers to the estimated economic income achieved in each hybrid and at each reproductive stage, considering the amount paid to the producer by the liter of milk. For the hybrid factor, the highest economic return (R\$ ha-1) is obtained by the hybrid P32R48 VYHR®, being higher in 1438.18 R\$ ha-1, compared to the P30F53 VYHR® (table 7).

Table 6 - Estimate of economic income (R\$ ha-1) for corn hybrids, estimated based on quantitative and qualitative parameters of silage and the price paid per liter of milk (Iraceminha, SC-2017/2018 crop).

Híbridos	Rendimento Econômico
	-----R\$ ha ⁻¹ -----
P32R48 VYHR [†]	23045,4 A
P30F53 VYHR [†]	21607,2 B

Averages followed by the same letter in the column do not differ from each other (P < 0.05) by the Tukey test. Standard error of mean ± (446.833)

In relation to the economic performance of the different reproductive stages, the R5 and R4 are superior to the other treatments, with no difference between the same (Table 7).

Table 7 – Economic Income estimation (R\$ ha-1) for the reproductive stages, estimated based on the quantitative and qualitative parameters of the silage and the price paid per liter of milk (Iraceminha, SC – Harvest 2017/2018).

Estádios Reprodutivos	Rendimento Econômico
	-----R\$ ha ⁻¹ -----
R2	16888,7 C
R3	20131,0 B
R4	26043,6 A
R5	26241,8 A

Averages followed by the same letter in the column do not differ from each other (P < 0.05) by the Tukey test. Standard error of mean ± (631.918).

It can be seen that when the harvest of corn for whole plant silage was performed at the R2 stage, although it provides the producer with the removal of the early crop of the crop and allows to anticipate the sowing of the second crop, the producer fails to win, R\$9353.11 Ha-1 when compared to the cut performed in R5. It is also important to emphasize that the ensilage process can be done between the R4 stages and R5 without significantly compromising the economic performance of the system, since the difference between these two cutting moments (R4 and R5) is only R\$198.285 ha-1.

This result is important as it allows a longer interval of time for the producer to perform the harvesting and ensiling of the material, decreasing the disorder and financial losses to the system.

IV. CONCLUSION

The Hybrid P32R48 VYHR® presented the best economic return to the system, for providing higher milk production per hectare.

The best breeding stages for making silage are the R4 and R5.

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