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USE OF COMPOST BEDDED PACK BARN IN MAIZE FERTILIZATION FOR SILAGE

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ABSTRACT: This article aims to study the effect of different time intervals for bed maturation in compost sheds for dairy cattle, such as organic manure in maize crop for silage. The experimental design was a randomized block in split-plot with five treatments, six collection times, and five replicates. The data were submitted to variance analysis and compared by Scott-Knott. Sigmoid functions of logistic growth were adjusted to the data. The treatments with addition of fresh and mature compost with nitrogen cover showed higher hoot dry matter production when compared to treatments without compost. For maize plant height, stalk diameter and number of leaves, it was observed that from 35 days after plant germination, these variables were considered superior for the treatments that received bedding. The sigmoid function was proper to represent the plant growth to the silage point. It is concluded that the use of bedding from compost sheds as an organic manure is recommended as a sustainable alternative in the reuse of waste from milk production.

KEY WORDS: Housing systems; Organic manure; Statistic al analysis; Sustainable technology.

USO DE CAMA DE CONFINAMENTO *COMPOST BARN* NA ADUBAÇÃO DA CULTURA DO MILHO PARA SILAGEM

RESUMO: Este artigo tem como objetivo estudar o efeito de diferentes intervalos de tempo para maturação da cama em galpões de composto para bovinos leiteiros, e seu efeito como adubação orgânica no cultivo de milho para silagem. O delineamento experimental utilizado foi em blocos casualizados em parcelas subdivididas

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no tempo com cinco tratamentos, seis tempos de coletas e cinco repetições. Os dados foram submetidos à Análise de Variância e comparados pelo teste Scott-Knott. Funções sigmóides de crescimento logístico foram ajustadas aos dados. Os tratamentos com adição de composto fresco e composto curtido com cobertura nitrogenada apresentaram maior produção de matéria seca quando comparados com os tratamentos sem uso de composto. Para a altura da planta do milho, diâmetro do colmo e número de folhas, estudados ao longo do tempo, foi observado que a partir dos 35 dias após a germinação das plantas, essas variáveis foram consideradas superiores para os tratamentos que receberam a cama. A função sigmoidal se mostrou adequada para representar o crescimento da planta do milho até o ponto de silagem. Conclui-se que o aproveitamento da cama de galpões de compostagem, como adubo orgânico, é recomendável como uma alternativa sustentável no reuso e tratamento de dejetos da produção leiteira.

PALAVRAS-CHAVE: Adubação orgânica; Análise estatística; Sistema de confinamento; Tecnologia sustentável.

INTRODUCTION

One of the determining factors on the production costs in rural properties is related to the crop fertilization. The substitution of mineral fertilizers by organic manures may bean alternative to reduce these costs (BULEGON et al., 2012). The development and integration of sustainable agriculture is the basis for subsidizing a short-term managerial decision and measuring the sustainability of a long-term rural enterprise (MOTA, 2018).

The use and utilization organic waste in agriculture can contribute significantly to productivity, cost/benefit ratio and agricultural quality. There are a variety of organic wastes that can be used in agriculture, e.g., cow dung (CASTOLDI et al., 2011), chicken manure (HANISCH; FONSECA; VOGT, 2012), pig manure (MORAES et al., 2014), green manures (ANGELETTI et al., 2016), among others. Several studies have shown the positive and gradual effect of using and utilizing cow dung. This has been used for cultivation of several crops, such as sweet potato (*Ipomoea batatas*) (LEONARDO et al., 2014), cackrey (*Cucumis anguria)* (OLIVEIRA et al., 2014), common bean (*Phaseolus vulgaris* L.) (MARTINS et al., 2015), and maize (*Zea mays* L) (GUARESCHI et al.,2013; MOTA et al., 2019).

Toward a higher production with lower costs, the option for organic wastes occasionally available in agricultural soil sis economically, socially and environmentally recommendable (ABREU JÚNIOR et al., 2005). Reina et al. (2010) recommend the use of cow dung as organic soil manure as long as it is available and there is labor for the application of waste in the agricultural area.

Brazil is characterized predominantly by small holdings, where producers have their activities based on milk production. Dairy cattle have been usually reared in housing systems, such as the compost bedded pack barns (CBP) (FERREIRA, 2016; PILATTI; VIEIRA, 2017; MOTA et al., 2018). That system has been preferred by producers.

In the CBP housing system, the main differential is in the animals resting bed. The bed contains nitrogen derived from the urine and the waste from housed cows. Additionally, the bed contains carbon sources from sawdust, woodchips, chopped corn stover, among others (GALAMA et al., 2015).

Since the CBP is properly managed, there is the occurrence of mixing of animal waste and urine in bedding material. With the increase of bed temperature and the reduction of moisture, the composting process promotes an active microbial activity, forming a matured compost that can be used as organic fertilizer (MOTA, TAVARES; LEITE, 2019; MOTA et al., 2019). This can be an alternative for reducing production costs (MOTA et al., 2019).

The use and utilization of these organic wastes represent a balanced way to provide nutrition al and mineral properties to plants. These properties could be applied in the planting of maize for silage. Maize is commonly used in the dairy herd ration (NASCIMENTO et al., 2008).

Thus, with the increasing concern with the environment al impacts generated by organic wastes derived from cattle housing, the composting process and the recycling of the se wastes have been stimulated (COTTA et al., 2015). Much of the manure from the bed of dairy cattle from CBP housing systems could supply a large demand for fertilizers. Moreover, with the continued growth of these wastes in small rural properties, their use in a ration al and sustainable way diminishes their polluting potential and becomes economically feasible. In light of the foregoing, this article aims to evaluate the maturation time of the CBP bed and its effect as organic fertilizer in the maize crop for silage.

2 MATERIAL AND METHODS

The present study was performed in a greenhouse at the Federal University of Lavras (UFLA), Southern region of the state of Minas Gerais, Brazil, 21º 14' S latitude and 45º 00' W longitude, with approximately 918 m altitude. The regional climate is Cwa, with two defined seasons: dry, with lower temperatures from April to September, and rainy, with higher temperatures from October to March, total average annual rainfall of 1530 mm and annual average temperature of 19.4°C (DANTAS et al., 2007).

The experiment was conducted between November 2016 and February 2017. The climatic data external to the greenhouse for the experiment period were obtained from the main weather station of Lavras located on the campus of UFLA, belonging to the network for surface meteorological observations of the National Meteorological Institute (INMET). The average, minimum and maximum temperature on the underlying period were 23.0°C, 18.4°C and air relative humidity was 72.8%.

Data on temperature and relative humidity in to the greenhouse (internal values) were obtained through the portable model weather station No. TTWH - 1080 of brand Instrutemp with appropriate sensors to collect and store these data. A summary of the collected data is as follows: average temperature of 25.3°C and relative humidity of 68.7%.

The experimental design was a randomized complete block design in split-plot with five treatments, six collection times, and five replicates, totaling 150 observations for each variable. The experimental plot consisted of two pots, being left one plant in each pot (the average of two plants was used), and five replicates were used, totaling 25 experimental plots. The plots were represented by pots with a capacity of 15 dm^3, filled with a mixture of soil and washed sand at 3:1 ratio, respectively. The pots were irrigated daily until reach the field capacity, and kept in a non-heated greenhouse (GUARESCHI et al., 2013).

In the main plot, five treatments were evaluated (Table 1). The sub-plot was constituted of thee valuation seasons. The first collection occurred seven days after plant emergence (DAE), the remaining collections occurred at 22, 35, 49, 63, and 77 DAE.

Table 1. Descriptions of the treatments

Treatments (Treat.)	Descriptions
Treat.1-TM	Fresh compost added to the pot 15 days before planting, with nitrogen coverage.
Treat.2 -TC	Mature compost for 30 days and added to the pot on the sowing day, with nitrogen coverage.
Treat.3 -TF	Fresh compost added to the pot on the sowing day, with nitrogen coverage.
Treat.4 -TL	No compost, only with nitrogen coverage - conventional.
Treat.5 -T (Control)	Soil corrected without nitrogen coverage.

The mathematical model for the design with treatments arranged in a split-plot (Banzatto and Kronka, 2015) is:

$$y_{ijk} = \mu + \alpha_i + b_j + \epsilon_{ij} + c_k + \xi_{jk} + ab_{ik} + e_{ijk} \qquad (1)$$

where: treatments; , blocks; times.

is the value observed in the plot corresponding to -th time in -th treatment, and in the-th block;

is a constant inherent to all observations, usually defined by the overall average;

is the effect of -th treatment;

is the effect of -th block;

is the effect of interaction treatment (considered as waste (a));

is the effect of -th time;

is the effect of time interaction (considered as waste (b));

is the effect of interaction between the -th treatment and the -th time;

is the random error assigned to observation .

The soil used for planting was classified as type 3 soil – clayey texture, with Clay 70, Silt 4 and Sand 26 (dag kg^{-1}) in the depths between 0 and 0.2 m, located on the campus of the Federal University of Lavras, in a ravine area, whose chemical characteristics were determined through sampling. The soil chemical analysis used in the experiment revealed the following composition: pH - 6.0; K (Potassium) - 6.08 mg dm^{-3}; P (Phosphorus) - 1.63 mg dm^{-3}; Ca (Calcium) - 1.0 cmol dm^{-3}; Mg (Magnesium) - 0.48 cmol dm^{-3}; Al (Aluminum) - 0.10 cmol dm^{-3}; H+Al (Extractor: SMP) - 2.96 cmol dm^{-3}; CTC (T) (cation exchange capacity at pH 7.0) - 4.51 cmolc dm^{-3}; SB (exchangeable bases) - 1.55 cmolc dm^{-3}; V (Base Saturation Index) - 34.27%; m (Aluminum Saturation Index) - 6.06%; O.M. (Organic Matter) - 1.09 dag kg^{-1}; P-Rem (Remaining Phosphorus) - 4.86 mgL^{-1}; Cu (Copper) - 1.05 mg dm^{-3}; Zn (Zinc) - 0.46 mg dm^{-3}; Mn (Manganese) - 3.81 mg dm^{-3}; Fe (Iron) - 20.28 mg dm^{-3}; and S (Sulfur) - 104.65 mg dm^{-3}.

The organic manure used in the experiment was obtained in a CBP housing for dairy cattle in a rural property in the municipality of Três Corações, in the state of Minas Gerais, Brazil. The physical and chemical characteristics of the organic material, in this case called bed material used in the housing, are presented in Table 1. For determination of N-Total, the Kjeldahl method (HOEHNE et al., 2016) was used; and the O.M. determination was based on the method proposed by Carmo and Silva (2012).

A 24.87ton ha^{-1}dose of CBP was applied manually 15 days before sowing of maize crop (Treat. 1-TM), while the other 24.87ton ha^{-1} doses of the compost (Treat. 2 -TC and Treat. 3 -TF) were applied due to sowing of maize crop together with the chemical fertilization. Soil chemical correction was performed from the base saturation, and 0.0015 $m^3$of dolomitic limestone per pot was applied. The fertilization at the sowing time in each NPK pot was: 0.00075 kg ammonium sulfate in the composition of 20% N; 0.0045 kg Super Simple in composition of 20% Phosphorus (P); and 0.00225 kg potassium chloride (KCL) in the composition of 60% Potassium (K).

The guide lines of the fifth approach of Minas Gerais (ALVES et al., 1999) were considered to perform correction and nitrogen fertilization by mulch, with recommendations of 180 t ha^{-1} N divided in to three plots, calculated for each pot. Nitrogen sulfate with 20% N was used as the nitrogen source for mulch application. At 15 DAE, the first nitrogen fertilization with a concentration of 0.000482 kg per pot was carried out. The second and third nitrogen fertilization occurred at 30 and 45 DAE.

The hybrid maize (*Zea mays* L.) cultivar (Roundup Ready® - NK 603) was sown on November 18, 2016, with three seeds per pot at a depth of 5 cm. The emergence of plants occurred on November 23, 2016. The thinning occurred at seven DAE, leaving one plant per pot.

The shoot dry mass (SDM) was evaluated at the time of silage point of maize (February 14, 2017). The plants were cut close to the ground, weighed and placed in plastic bags. They were identified and transferred to a greenhouse eat 65°C, until obtaining a constant mass. The variables plant height (PH), stem diameter (SD) and number of leaves (NL) were evaluated over time in randomized blocks with split-plot in time.

Initially, the basic principles of analysis of variance were verified. The Shapiro-Wilk test was applied to verify the data normality; the Hartley's test to test the variance homogeneity, and the Residual analysis to examine the data independence (BANZATTO; KRONKA, 2015). For the counting variable, the square root transformation was applied. The data were submitted to analysis of variance and the averages were compared by the Scott-Knott test. It was considered a 5% probability for all the mentioned tests. Subsequently, sigmoid functions of logistic growth were adjusted to the data (FLORENTINO; BISCARO; PASSOS, 2010). The model performance was calculated according to the root-mean-square error (RMSE) (LEITE et al.,2019; SOARES et al, 2017). The analyses were performed in the R software (R CORE TEAM, 2018), SISVAR (FERREIRA, 2014) and STATISTICA version 5.0 (STATSOFT, 2004).

3 **RESULTS AND DISCUSSION**

According to the Shapiro-Wilk test for the analyzed variables, the residues follow a normal distribution. When applied the Hartley's test, a homogeneity of variances was found and residual analysis showed that the residues are well dispersed around zero, without a defined pattern. It was found that the errors are independent. Thus, the basic assumptions of the analysis of variance were tested for all variables.

It was verified that the different forms of maturation and application of the bedding material produced in the housing system in-containing CBP model show different effects on hybrid maize crop (Roundup Ready® - NK 603). There is significant difference by the *F* test at 5% significance level among the different treatments. This justifies the importance of organic manure or mineral fertilization in maize crop.

The dose of organic material derived from the bed of housing system for dairy cattle in the CBP model provided higher shoot dry matter (SDM) to the NK 603 hybrid cultivar when compared to the treatments without compost. The SDM values for TC, TF and TM treatments are, respectively, 0.426 kg, 0.422 kg and 0.394 kg; for TL treatments, the SDM is 0.164 kg; and for T, the SDM value is 0.192 kg. Thus, there is a greater availability of silage material and feed for dairy cows for treatments that received organic manure. The Scott-Knott test at 5% probability level showed that the TC, TF and TM treatments were not different with one another, but were superior to the TL and T treatments.

According to the initial analysis performed with the bedding material (Table 2), it is within the recommended standards for organic manure (ABREU JÚNIOR et al., 2005). Cow dung mixed with CBP bed (which is rich in nutrients and available at low cost to dairy farmers) can be used when removed from the housing shed. The CBP bed needs a regular addition of material (sawdust, shavings wood, among others) to prevent excessive wet in the top layer. These materials added in bed are rich in carbon, which mixed with urine and cow dung (nitrogen-rich materials) balance the nitrogen carbon ratio of the compost. Table 2 shows the C/N values of the organic material used in the experiment for the TC (8:1), TM (14:1) and TF (22:1) treatments. These are within the values recommended by Silva et al. (2013).

The reference values are a consumption of 8.4 tons of woodchip sand/ or sawdust per cow per year, and 12 tons of compost per cow per year. However, these numbers can vary widely among farms (GALAMA et al., 2015). With this huge availability of mature bedding material, it can be reused by farmers both in organic manure of their agricultural crops and in resale to other properties.

Table 2. Physical and chemical characteristics of the organic compost (bed) from the feed system of dairy cattle in the CBP model used in the experiment

Characterization of the organic compost (bed)			
	Treat. 1 -TC	Treat. 2-TM	Treat. 3 -TF
T. S.	46.22	49.32	53.73
pH in H_2O	9.43	9.05	9.11
Characterization of the organic compost (bed)			
F. M. R.	18.49	28.98	15.69
O. M. (%)	46.31	43.64	71.79
T. N.	3.50	1.80	1.90
A. N.	1.90	1.40	1.00
C	26.86	25.31	41.64
C/N ratio	8:1	14:1	22:1

Notes: T. S. (Total solids -%); O. M. (Organic matter -%); F. M. R. (Fixed mineral residue - Ashes -%); T. N. (Total Nitrogen -%); A. N. (Ammoniacal nitrogen -%), C (Carbon -%). Result on wet basis.

For the analysis of variance considering the variables plant height (PH), stalk diameter (SD) and number of leaves (NL) in split-plot in time, it was verified that there is a significant effect for the treatments, collection days after emergence (time), and in relation to the treatment/time interaction. For blocks, the effect was not significant, indicating that there is no need to use randomized block sin this experiment.

In this experiment, three coefficients of variation (CV) could be observed for each variable, PH, SD and NL, in relation to the treatments, collection days after emergency, and in relation to the interaction. Generally, the experiment showed good accuracy. A low percentage variation in relation to the average, as considered in the CV scale in Andrade and Ogliari (2013), can be noticed.

Thus, the interaction was arranged considering the time within each treatment level and treatment within each time interval. The result analysis was significant for the different treatments, initially applying the average test to analyze each collection day (Table 3) and later, as the data are quantitative, using growth curves that were approximated using logistic sigmoid models (Table 4).

Table 3. Average comparison of treatment level sat each time, and average comparisons of time at each treatment level, for plant height (PH), stalk diameter (SD), number of leaves (NL)

Plant height (m)					
Days	T	TL	CT	TM	CT
7	10.06 a A	10.35 a A	10.16 a A	10.99 a A	10.35 a A
22	22.43 a B	20.68 a A	27.61 a B	26.32 a B	25.61 a B
35	63.64 a C	55.52 a B	110.03 b C	102.99 b C	106.66 b C
49	109.40 a D	98.50 a C	190.90 b D	183.50 b D	197.70 b D
63	147.60 a E	145.70 a D	213.50 b E	213.10 b E	214.00 b E
77	171.00 a F	172.60 a E	227.80 b E	221.40 b E	224.80 b E
Stalk diameter (mm)					
Days	T	TL	CT	TM	CT
7	2.90 a A	3.25 a A	3.23 a A	3.52 a A	3.29 a A
22	7.36 a B	6.06 a B	8.39 a B	8.65 a B	8.03 a B
35	12.49 a C	11.20 a C	17.91 b C	15.67 b C	15.02 b C
49	14.81 a D	15.24 a D	20.95 b D	21.15 b D	18.61 b D
63	16.16 a D	16.40 a D	22.08 b D	22.53 b D	19.66 b D
77	16.66 a D	17.31 a D	22.81 b D	23.04 b D	20.82 b D
Number of leaves					
Days	T	TL	CT	TM	CT
7	1.41a A	1.45 a A	1.48 a A	1.55 a A	1.48 a A
22	2.38a B	2.32 a B	2.48 a B	2.44 a B	2.47 a B
35	2.89 a C	3.13 a C	3.45 b C	3.40 b C	3.44 b C
49	2.90 a D	3.16 b C	3.46 c C	3.42 c C	3.45 c C
63	3.26 a E	3.37 a D	3.53 b D	3.51 b D	3.53 b D
77	3.37 a F	3.40 a D	3.56 b D	3.57 b D	3.60 b D

a,b,... – at each time, average treatment levels followed by the same lower case letter in the row do not differ (Scott-Knott 5%).

A,B, ... – at each treatment level, average times followed by the same capital letter in the column do not differ (Scott-Knott 5%).

When analyzing the time unfolding within each treatment level, there was a significant effect. This result was already expected for plant growth. However, when studying the level effect of each treatment within each time, the results provided practical and significant information regarding the study of maize development until the silage point.

It can be observed by the Scott-Knott test at 5% probability level that, for seven and 22 days after germination, the variables PH, SD and NL did not show significant differences (Table 4).

Table 4. Summary of the adjusted parameters for the sigmoid logistic function considering the variables PH, SD and NL

Maize plant height (m)					
Treatments\Coefficients	a	b	c	R^2	RMSE
T	1.811791	33.89154	0.080641	99.819%	0.002877
TL	370988.0	1371980	0.024721	92.492%	0.164127
CT	2.241629	109.9601	0.132029	99.791%	0.009665
TM	2.212843	104.4766	0.127791	99.863%	0.013124
CT	2.223594	186.2041	0.147274	99.816%	0.023698
Stalk diameter (mm)					
Treatments\Coefficients	a	B	c	R^2	RMSE
T	16.63480	9.222630	0.092341	99.838%	0.001986
TL	17.68495	9.803638	0.080325	99.498%	0.084816
CT	22.60977	19.13175	0.117073	99.339%	0.174482
TM	23.44765	12.54340	0.092883	99.847%	0.081465
CT	20.66192	11.73555	0.095661	99.689%	0.052216
Number of leaves					
Treatments\Coefficients	a	B	c	R^2	RMSE
T	12.66897	18.64767	0.139946	98.178%	0.1441941
TL	11.38385	10.39327	0.107366	98.226%	0.0221475
CT	12.80006	18.33184	0.136568	98.265%	0.1404688
TM	12.59341	14.15924	0.126101	97.634%	0.1142932
CT	12.80006	18.33184	0.136568	98.265%	0.1404688

A change in plant behavior can be observed at 35 DAE onwards. For PH and SD, it was observed by the Scott-Knott test that at the 35, 49, 63, and 77 DAE, the TC, TM and TF treatments were superior than the TL and T treatments. The averages of these three treatments were considered similar for all days of data acquisition (specifically for 35, 49, 63 and 77 DAE).

It is possible to observe that, from the first application of nitrogen fertilization by mulch at 22 DAE, the treatments TC, TM and TF, i.e., the treatments that received the bedding dose of the composting shed showed a higher growth than that showed by treatments TL and T. The TL treatment showed plant growth very similar to the control T treatment. This is explained because the mulch fertilization was not effective. It is observed that the CBP bedding material allows the production of an effective fertilizer for the soil.

These results corroborate with those found by Leonardo et al. (2014), which verified a significant effect of nitrogen doses on the presence and absence of cow dung in the production of sweet potato. The authors noticed the superiority between the combination of cow dung and nitrogen, which demonstrate the possibility of establishing a more viable alternative fertilizer for sweet potato crop, especially for those places where manure is available at low cost.

Table 4 shows the coefficients of logistic sigmoid models adjusted for PH, SD and NL. There is a high positive correlation among data as a function of time, with R values ranging from 0.96 to 0.99. For the R^2 of the maize plant height (PH), values above 99% for the treatments T, TC, TM and TF are noticed. Only the TL treatment showed an R^2 of 92.49%, see Figure1.

It can be verified for the five treatments that 99% of variations occurred in the SD are explained by the time variation. On the other hand, the NL showed values of R^2 above 98% for treatments T, TL, TC and TF. A lower value of R^2 is noticed for the TM treatment; however, a high adjustment value, 97.634%, was also achieved.

The adjusted logistic models showed satisfactory performance, for which the lowest values of RMSE were found. Thus, the sigmoid logistic function was appropriate to represent the maize plant growth up to the silage point.

Base don't he above, there is a need for technologies that make possible to increase crop yield, seeking an ecologically sustainable and low-cost farming system. Therefore, the use of wastes from cattle housing systems in the CBP model adds value to the produce rand to the product, besides providing farming-lives tock integration. It is a natural resource available in milk producing properties.

Finally, besides increasing soil fertility, this type of organic manure pollutes less the agricultural environment.

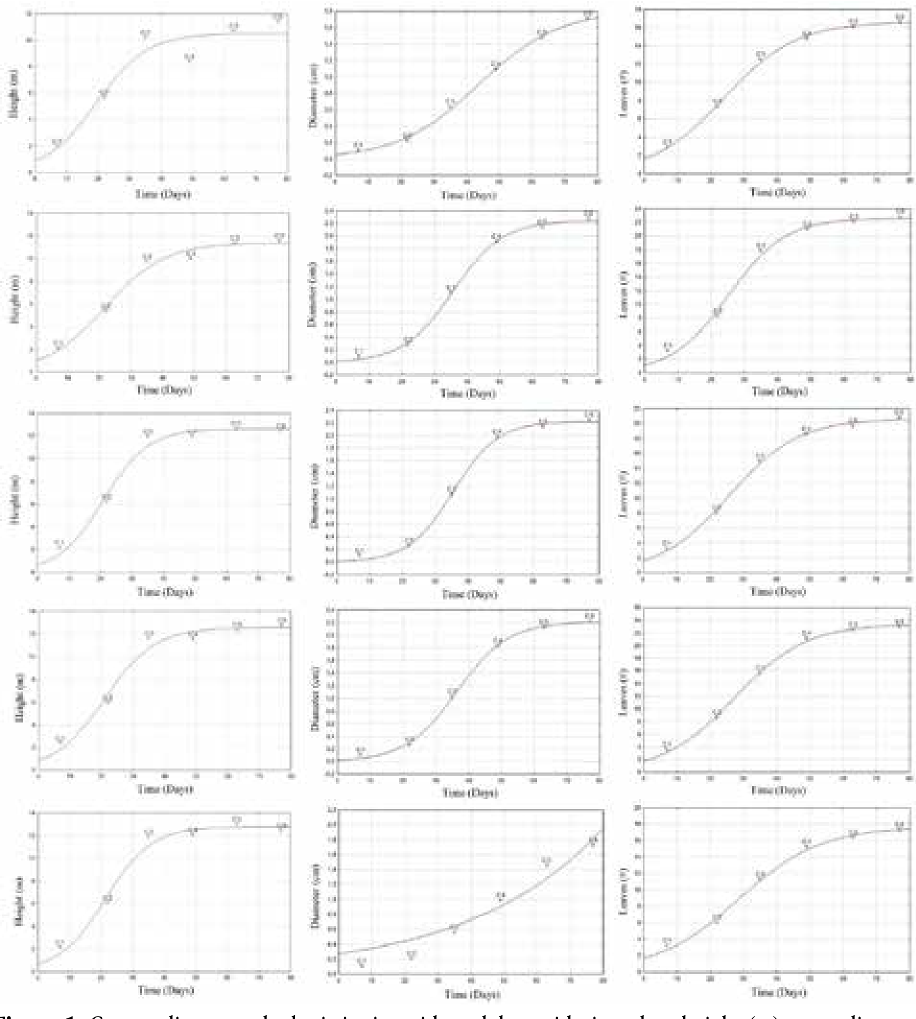

Figure 1. Curve adjustment by logistic sigmoid model considering plant height (m), stem diameter (mm) and number of leaves. The rows are data related to treatments T, TL, TC, TM, and TF, respectively.

4 FINAL CONSIDERATIONS

The treatments TC, TF and TM have shown higher shoot dry matter production when compared to treatments that do not use compost. The sigmoid logistic function was proper to represent the maize plant growth, up to the silage point. The bedding material of the CBP barn can be applied directly to the soil, being suitable in maize planting for silage. There is no need for compost maturation. The utilization of bedding material as organic manure is recommended as a sustainable alternative in the reuse and treatment of waste from milk production.

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