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pág. 133

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Agronomy and chemical composition of sunflower (*Helianthus annuus* L.) as a forage option in a warm-humid intertropical environment

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ABSTRACT

Objective: To determine the phenology of sunflower and its potential as forage for ruminants in a humid-warm environment.

Design/Methodology/Approach: Six treatments were evaluated during the 2016 dry season, according to the number of cutting days after sowing (DAS): 65 (T1), 72 (T2), 79 (T3), 86 (T4), 93 (T5), and 100 (T6). The SYN3950 HO hybrid was planted in 5×40 m plots with a completely randomized block design and three replications. The following variables were measured: days to reach reproductive stages (Ri), plant height (PH) in cm, stem perimeter (SPM) in cm, flower diameter (FD) in cm, and dry matter production in stem, peduncle, leaf, flower, and total (DM t ha^{-1}), as well as the content of dry matter (DM), crude protein (CP), ash (A), neutral detergent fiber (NDF), and acid detergent fiber (ADF). Analysis of variance were carried out, as well as correlation between variables, mean comparison tests (Tukey, $P<0.05$), and regression between variables and DAS.

Results: There were significant differences ($P<0.05$) between PH, FD, and DM production in stem, peduncle, flower, and total DM (t ha^{-1}), as well as in DM, CP, NDF, and ADF. The highest biomass yields were obtained at 100 DAS (16 t ha^{-1} DM) with 26% DM, 12.7% CP, 21.9% A, 44.2% NDF, and 30.9% ADF. It is concluded that sunflower is an option for feeding ruminants in the study area.

Keywords: Phenology, reproductive stages, humid tropic, nutritional value, forage.

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INTRODUCTION

Livestock production is one of the most important economic activities in the warm-humid intertropical region of Mexico. The main food sources for cattle are pastures (Poaceae) and forages (Rubio *et al.*, 2015); however, pasture and forage production is a seasonal activity (Gray *et al.*, 1987). In areas such as the state of Tabasco, Mexico, the growing seasons are known as lluvias (the rainy season, from June to September), nortes (the windy and rainy season, from October to January), and secas (the dry season, from

February to May) (Ruíz-Álvarez *et al.*, 2012). During the dry season, the production of pastures and forages decreases, as a consequence of the scarcity of water and the high temperatures, resulting in a lower protein and high fiber content, low digestibility, loss of animal body weight, and reduced stocking rate (*i.e.*, animal carrying capacity) (Mello *et al.*, 2006b).

Sunflower (*Helianthus annuus* L.) is an oleaginous crop used as forage, bird feed, ornamental plant, and fuel (Gomes *et al.*, 2017). It adapts to temperate, tropical, and subtropical climates (Debaeke *et al.*, 2021) and it requires little manure or fertilizers (Peniche *et al.*, 2008). It tolerates drought and high temperatures (Granados *et al.*, 2004; Blamey *et al.*, 2009; Sainz-Ramírez *et al.*, 2020). All these characteristics make it an alternative for forage production in the warm-humid region of Mexico. The objective of this study was to determine its phenology, chemical characteristics, and potential for feeding ruminants in a humid-warm intertropical environment.

MATERIALS AND METHODS

The study was conducted at the Colegio de Posgraduados, Campus Tabasco, located at Km. 21 of the Cárdenas-Coatzacoalcos Federal Highway, in Cárdenas, Tabasco, Mexico (18° 00' N and 93° 30' W, 9 m.a.s.l.). The average annual precipitation is 2,163 mm, while the average annual temperature is 25.9 °C (Köppen, modified by García, 1988).

Sowing took place on January 21, 2016, after harrowing and with minimum tillage. One seed per plant was sown every 0.25 m, with 0.80 m between rows. The SYN3950 HO hybrid was rotated with corn, under residual fertilization, and rain fed dependent. The crop was protected with two manual weed controls, two applications of Engeo® at commercial doses (to control Coleoptera, Lepidoptera, and Homoptera), and one application of Priori Xtra® (to control anthracnose).

The variables evaluated in this study covered the reproductive stages based on the Schneiter and Miller (1981) scale, and the following phenological traits: plant height (PH), measured in cm from the ground to the apex; stem perimeter (SPM), measured in cm at the base of the plant; flower diameter (FD), measured in cm; and weight of stem (SW), leaf (LW), peduncle (PW), and flower (FW), measured in g of dry matter.

Likewise, moisture (MC), ash (A), and crude protein (CP) content were measured following the methods established by AOAC (2012). For their part, neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined according to Van Soez *et al.* (1991). Dry matter (DM) was calculated substracting the moisture percentage from 100. The bromatological analyses were conducted in the animal science laboratory of the same institution.

The experimental units were established within three 5×40 m plots, using a randomized complete block design with three replications. The phenological variables were measured in five 2 linear m random sites within each plot. The treatments were assessed on six cutting dates with weekly intervals (65, 72, 79, 86, 93, and 100 DAS). To obtain a helpful biomass sample, four 2 linear m rows were selected from every ten rows of each block. Four representative plants were separated from the material harvested in each block and their stem, petiole, leaf, and flower were measured. The remaining plants were grounded to acquire a sample for the bromatological analysis. The data obtained for each variable was subjected to an analysis of variance, mean comparison test (Tukey, $P<0.05$), regression of variables regarding the DAS, and correlation analysis among variables using the SAS software, version 9.4 (2013).

RESULTS AND DISCUSSION

Significant statistical differences were recorded in all variables, except SPM and A (Table 1).

The R-4, R-5.1, R-5.5, R-6, R-7, and R-8 reproductive stages occurred at 61, 65, 72, 79, 86, 93, and 100 DAS, respectively (Figure 1). They became more evident at the start of R-4 (61 DAS), flowering earlier than the 72 DAS reported by Sainz-Ramírez *et al.* (2020) and after the 50 DAS registered by Gai *et al.* (2020). Complete flower exposure, anthesis, pollination, and grain fill followed a concentric pattern (R-5.1, R-5.5, and R-6, respectively) (Figure 1); meanwhile, R-6 occurred at 79 DAS. The plant began to wither at 93 DAS and its bracts began to show a typical brown color (R-7 and R-7.5), before it finally reached physiological maturity (R-8) at 100 DAS (Schneiter and Miller, 1981).

The highest PH (188.6 cm) was recorded at 100 DAS and it showed no statistical difference with those mean values observed at 86 and 93 DAS, which were 179 and 183.6 cm long, respectively. Therefore, the PH stabilized at 86 DAS (Figure 2a). These values exceed the observations of Martínez *et al.* (2017), who recorded a maximum of 183 cm at 120 DAS (Table 2), and the findings of Escalante-Estrada *et al.* (2008), who reported an average height of 102.3 cm. The highest FD value was reached at 93 DAS (20 cm) (Table 2), a similar result to the one reported by Martínez *et al.* (2017) (19.75 cm, at 120 DAS), and had a significant correlation with SW ($P<0.0001$, $R^2=0.98$) (Table 3).

Table 1. Mean squares and significance level of different variables evaluated in sunflower (Cárdenas, Tabasco, 2016).

Variable	Block	Treatment	Error
PH	5125.2525	32857.0759 ***	591.6228
SPM	29.1495116	37.2716883 NS	17.826693
FD	1.113875	1120.434584***	20.75948
SW	2852.3002	110101.9463***	28751.598
PW	540.40785	12583.63135***	2855.6023
LW	1143.3374	24121.5302**	7359.5645
FW	383.023	312636.793***	12337.441
DM	0.0096167	122.1743967***	0.0534433
CP	3.4482583	39.4346183***	7.1789310
A	26.0101194	50.5004494 NS	53.739872
NDF	18.0739361	86.2141161*	11.7308635
ADF	9.2363194	66.9879778 *	10.6172998

PH: plant height, SPM: stem perimeter, FD: flower diameter, SW: stem weight, PW: peduncle weight, LW: leaf weight, FW: flower weight, DM: dry matter, CP: crude protein, A: ashes, NDF: neutral detergent fiber, ADF: acid detergent fiber, *: $P\leq0.05$, **: $P\leq0.01$, ***: $P\leq0.001$, NS: not significant.

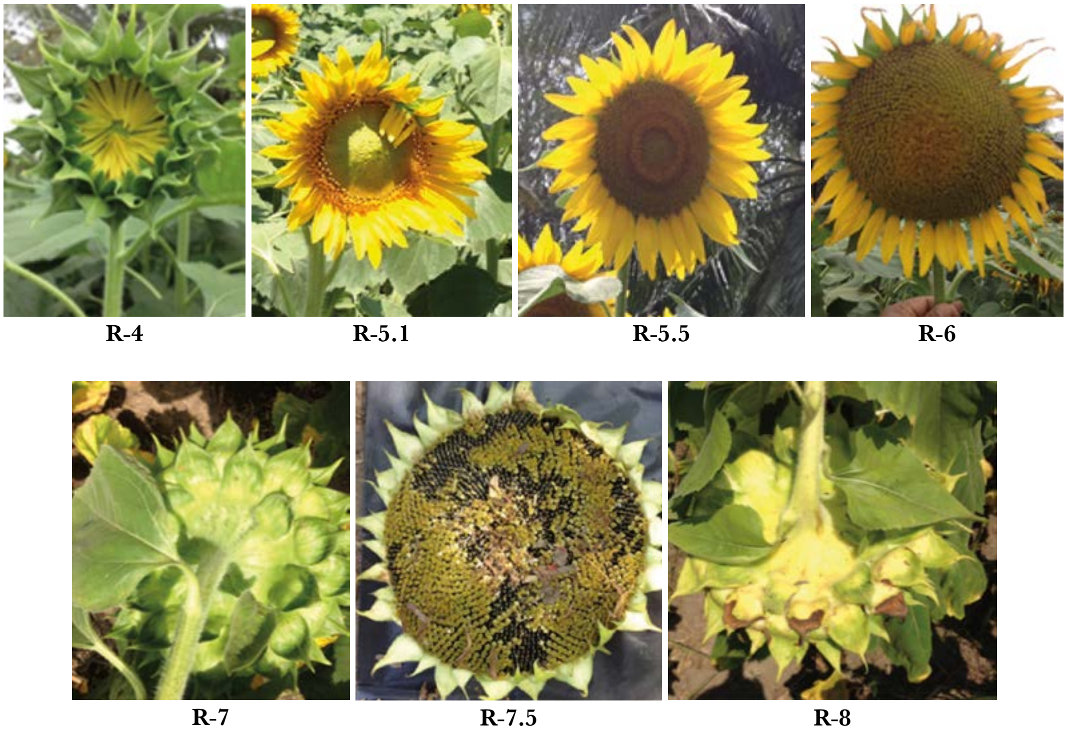

Figure 1. Phenological classification of the different reproductive stages, based on days after sowing (Schneiter and Miller, 1981).

Table 2. Plant height, stem perimeter, and flower diameter of the sunflower on different days after sowing.

Days after sowing	Plant height (cm)	Stem perimeter (cm)	Flower diameter (cm)
65	131.97 c	-	-
72	143.36 c	6.89 a	11.62 c
79	164.02 b	7.25 a	16.54 b
86	179.04 a	7.08 a	17.79 b
93	183.14 a	7.71 a	20.96 a
100	188.62 a	8.55 a	19.90 a
EE	1.13	0.20	0.22

Means with different letters in the same column indicate significant differences (Tukey, $P<0.05$).

Table 3. Pearson correlation coefficients among plant height, stem perimeter, and flower diameter of sunflower.

Variable	Height	Stem perimeter	Flower diameter
Height	1.00000	0.10684	0.14725
Stem perimeter	0.10684	1.00000	0.97549
Flower diameter	0.14725	0.97549	1.00000

Regarding the dry weight (DW) of structures, the highest stem (91 g), leaf (54 g), and flower (163 g) weight were recorded at 100 DAS, with no statistical difference in PW (Table 4). SW and LW showed a quadratic trend (R^2=0.73, R^2=0.84), while FW showed a linear trend (R^2=0.96) (Figure 2d). The highest DS plant and forage weights were recorded at 100 DAS: 323 g and 16.18 t ha^{-1}, respectively (Table 5); these mean values exceed the 11.41 t ha^{-1} recorded by Mello *et al.* (2006a).

The bromatological analyses showed differences ($p<0.05$) in all the variables, except in A (Table 6). The highest DM content (26.0%) was obtained at 100 DAS, while the lowest (7.4%) was recorded at 65 DAS. This structural accumulation of DM had a similar behavior to that observed by Romero *et al.* (2009): the most notable changes were recorded in flowers during the last stages and there were significant differences between samplings within each variable (Table 7). This may be caused by the accumulation of carbohydrates, proteins, and oil as the grain develops (Sainz-Ramírez *et al.*, 2020).

The DM values observed were lower than the 35% recommended for the optimal fermentation of forage (Mello *et al.*, 2006b). However, a low ADF and NDF content favors the digestibility of sunflowers (Table 7), increasing their potential as food for ruminants (Mello *et al.*, 2006b; Romero *et al.*, 2009; Sainz-Ramírez *et al.*, 2020).

Table 4. Dry weight (DW) of the structures of sunflower at different cutting days after sowing (DAS).

Days after sowing	Stem weight	Peduncle weight	Leaf weight	Flower weight
65	46.250 b	10.961 a	22.629 b	6.120 e
72	78.291 ab	13.674 a	32.272 ab	22.133 de
79	83.220 ab	14.373 a	36.984 ab	46.680 cd
86	76.150 ab	13.212 a	35.765 ab	74.120 c
92	82.040 ab	10.112 a	37.916 ab	117.03 b
100	91.595 a	13.797 a	54.490 a	163.878 a
EE±	8.14	13.60	47.44	222.91

Means with different letters in the same column indicate significant differences (Tukey, $P<0.05$).

Table 5. Biomass yield of sunflower per plant and per hectare on a dry basis at different cutting days after sowing.

Days after sowing	Plant weight (g)	Forage yield t ha^{-1}
65	85.96 d	4.298 d
72	146.37 cd	7.318 cd
79	181.26 bcd	9.063 bcd
86	199.24 bc	9.962 bc
93	247.10 ab	12.355 ab
100	323.76 a	16.188 a
EE±	287.31	14.36

Means with different letters in the same column indicate significant differences (Tukey, $P<0.05$).

Table 6. Chemical composition of the whole sunflower plant (%) on different cutting days after sowing.

Days after sowing	Dry matter	Crude protein	Ashes	Neutral detergent fiber	Acid detergent fiber
65	7.4 f	17.5 ab	21.1 a	55.1 a	35.8 ab
72	14.1 e	18.2 a	17.2 a	51.0 a	36.4 ab
79	16.1 d	12.9 bc	17.2 a	50.1 a	41.3 a
86	18.2 c	13.7 abc	20.2 a	50.5 a	37.1 a
93	21.5 b	12.5 c	14.3 a	50.0 ab	37.2 a
100	26.0 a	12.7 bc	21.9 a	44.2 b	30.9 b
EE	0.054	0.54	1.22	0.57	0.54

Means with different letters in the same column indicate significant differences (Tukey, $P<0.05$).

The highest CP content was 18.2% at 72 DAS, while the lowest was recorded at 93 DAS (12.5%). Other studies have also documented this decreasing trend in CP (Mello *et al.*, 2006b; Romero *et al.*, 2009). In this study, CP was negatively correlated with DM (Figure 3a), while its minimum and maximum values were higher than those observed by Peireti and Meineri (2010) and by Pereira *et al.* (2014), who recorded 5.9% at 66 DAS and 6.8% at 101 DAS, respectively.

CP increased from R-4 to R-5, then experienced a linear descent until R-8. Mean CP values exceed those of corn as the main silage source (Guney *et al.*, 2012; Osuna and Martínez, 2017) and favor the integration of sunflowers in the diet of ruminants. The lowest NDF content (44.2%) was observed at 100 DAS, while the highest value (55.1%) was reported at 65 DAS, without statistical difference at 72, 79, and 86 DAS. The lowest ADF content was 30.9% at 100 DAS, while the highest was 41.3% at 79 DAS. The NDF and ADF values were higher than those reported by Pereira *et al.* (2014), who reported means of 43.9, 43.9, 45.7, 44.6, and 45.0% for NDF and 33.8, 33.9, 36.4, 35.5, and 35.5% for ADF, at 66, 73, 80, 87, 94, and 101 DAS, respectively.

Table 7. Percentage of dry matter in sunflower structures at different cutting days after sowing.

Treatment	Stem (%)	Peduncle (%)	Leaf (%)	Flower (%)
65	7.2 f	7 f	8.2 f	7.2 f
72	14.5 e	11.9 e	14.2 e	12.8 e
79	18.6 d	17 c	18.4 d	14.3 d
86	20.2 c	15.3 d	22.6 c	18.5 c
92	21.8 b	18.7 b	27 b	24.9 b
100	21.9 a	20.3 a	29.7 a	30.3 a

Means with different letters in the same column indicate significant differences (Tukey, $P<0.05$).

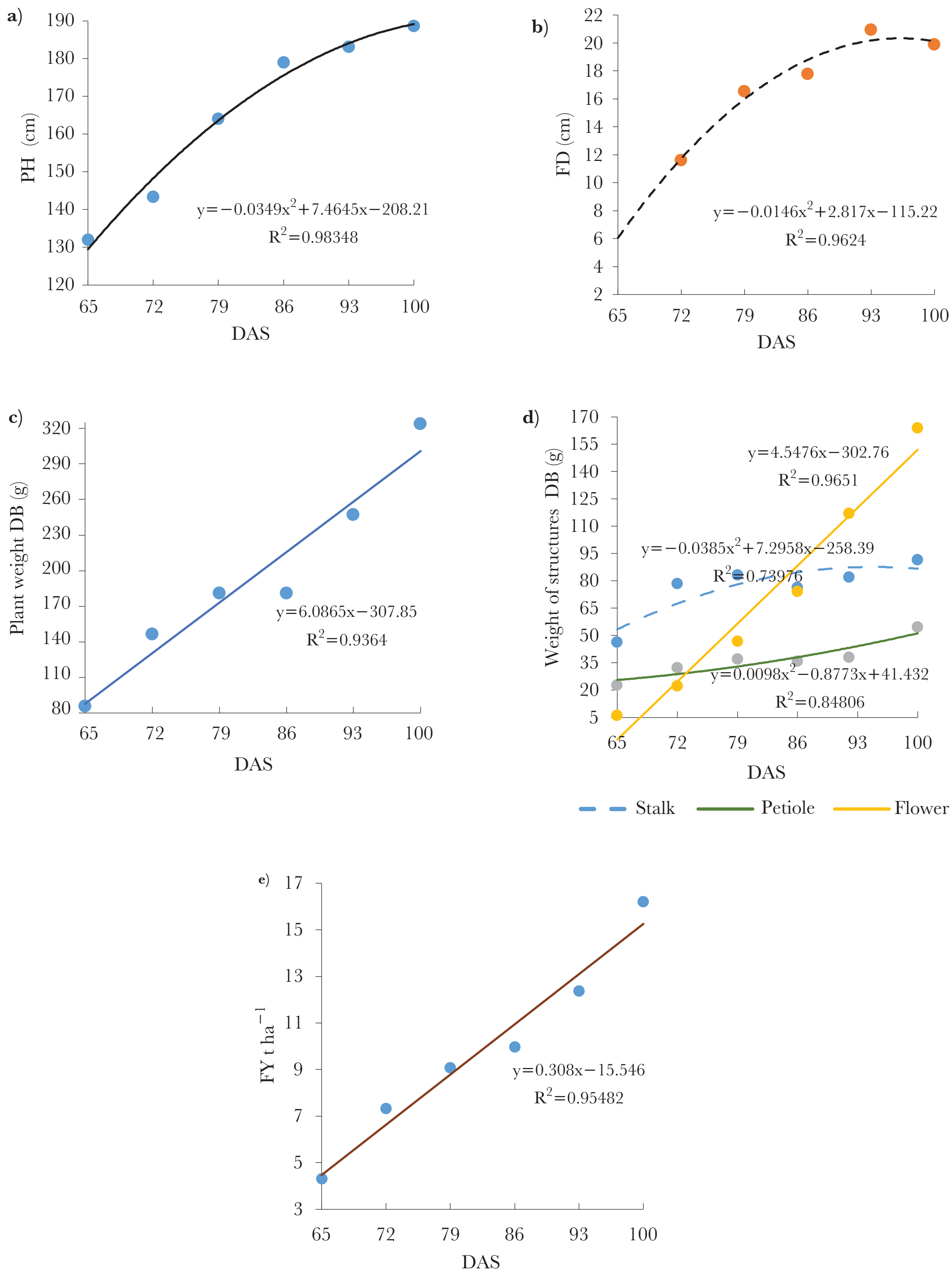

Figure 2. Regression lines on days to cut after sowing (DAS) of: a) Plant height (PH), b) Flower diameter (FD), c) Plant weight (Dried Base, DB), d) Structure weight (Dried Base, DB), and e) Forage yield (FY t ha^{-1}).

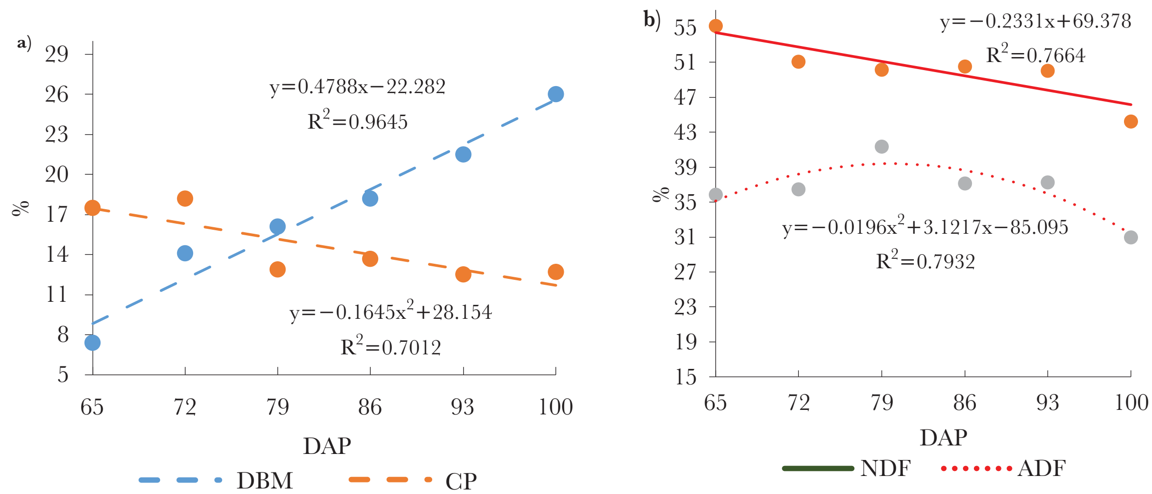

Figure 3. Regression lines of % of Dry Biomass (DBM) and Crude Protein (CP) (a), and Neutral Detergent Fiber (NDF) and Acidic Detergent Fiber (ADF) (b) in sunflower, at different cutting days after planting (DAP).

CONCLUSIONS

Production and nutritional quality of sunflower forage are closely related to cutting dates. The later the date, the higher the DM, although the CP decreases. In terms of forage yield, the best cutting was made at 100 DAS, when the following results, pertaining to the R-6 phase, were obtained: 16.7 t ha1 yield, a nutritional value of 26% DM, 12.7% CP, 21.9% A, 44.2% NDF, and 30.9% ADF. Based on these values, sunflower is a suitable alternative for forage production, destined to ruminant feeding in the warm-humid environment where the study was made.

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