Phytomass partition of sunflower silage, under boron and calcium fertilization

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Abstract
This work aimed to determine the distribution of sunflower phytomass and the effect/cause relation between the variables analyzed in silage production, under calcium and boron fertilization. The experiment was carried at Federal Technology University of Paraná, *Campus* Dois Vizinhos, PR, Brazil, from September, 2008 to Abril, 2009. The soil is a Nitossolo Vermelho Distroférrico úmbrico by Brazilian classification and Ferralsol by WRB. Treatments were composed of: (i) Witness; (ii) 2000 g of B/ha applied via soil at sowing; (iii) 250 (iv) 500 (v) 750 and (vi) 1000 g of Ca/ha applied in leaves; (vii) 250 (viii) 500 (ix) 750 and (x) 1000 g of B/ha applied in leaves. Leaf application was made by dissolving each treatment and applying in 200 litres (L)/ha solution, with the respective treatments, about two weeks before flowering stage. Plants were harvested to produce silage when grains were with 35% humidity. Boron and calcium fertilization does not change the phytomorphologic variables analyzed in this experiment. Inside the variables, dry phytomass of seeds was the most important in silage production, with a direct correlation with final yield in the field. Indirectly, the variables dry phytomass of stem + achene and green leaves were responsible for increasing silage yield, also.

Key Words
Helianthus annuus L., ensilage, crop production, micronutrients.

Introduction
Sunflower is an oleaginous plant, responsible for producing excellent edible oil. This crop has a great potential to increase the cultivation in Brazilian agricultural areas, especially because is resistant to cool and dry climate conditions, when compared to other crops used for silage in Brazil, like corn and sorghum. Calcium (Ca) and boron (B) are two important nutrients for apical bud and root end development, since are nutrients of low internal plant mobility, being not capable to retranslocate after synthesis in plant compounds. Their main function in higher plants is structural, as component of cell wall and plasma membrane. Without them, shoot and root growth are strongly inhibited. Calcium is normally provided efficiently from soil, especially when the pH is high. However, boron necessity is higher than other species in sunflower, and this crop is not efficient to absorb B from soil, being possible to observe losses of 15 to 40% in grain yield when cultivated in soils with lower levels of B (Souza *et al.* 2004). The possible ways to apply boron on plants are: soil borate fertilization, on the sow crop line or spread before sowing; and leaf application, applied alone or together with crop defensives. It is recommended to apply 1.0 to 2.0 kg of B/ha in soils with deficiency (Castro 2006). Deficiency of B in sunflower promotes growth inhibition and dry mass reduction, reducing, on this way, achene diameter and seed weight, what consequently depletes sugar, oil and starch contents (Bonacin *et al.* 2008). This work aimed to determine the distribution of sunflower phytomass and the effect/cause relation between the variables analyzed in silage production, under calcium and boron fertilization.

Material and methods
The experiment was carried at Federal Technology University of Paraná, *Campus* Dois Vizinhos, PR, Brazil, during the period of September, 2008 to April, 2009. The experimental area is located at latitude 25°44' South, longitude 53°04' West and mean altitude of 520 meters. The climate is classified as mesothermic humid (Cfa) by Koppen (Maak 1968). The soil is a Nitossolo Vermelho Distroférrico úmbrico by Brazilian classification (Bhering *et al.* 2008) and Ferralsol by WRB/FAO (1998). Soil chemical results are presented on Table 1. Soil nutrients availability (P, K, Ca and Mg) are interpreted as high, according to regional recommendations. The genotype used was Agrobel - La Tijereta. Sowing was made at September, 26, 2008, putting three seeds each small line hole, adjusting the population to 50.000 plants/ha by hand after germination. The experimental design was in completely randomized blocks, with three replicates. Plots were composed of six meters long and five seed lines of 0.9 meters spaced, harvesting only the central lines.

Table 1. Results of chemical soil analysis preceding sunflower experiment establishment. UTFPR, Dois Vizinhos, PR, Brazil, 2008.

Depth layer (cm)	pH $CaCl_2$	O.M. (g/dm^3)	P (Mehlich1) (mg/dm^3)	Al^{3+}	H+Al	Ca^{2+}	Mg^{2+}	K^+	V %
				(----------	$cmol_c/dm^3$			-----------)	
0-20	5.00	40.21	12.84	0.00	4.28	4.88	2.67	0.73	65.9

Treatments were composed of: (i) Witness (control); (ii) 2000 g of B/ha applied via soil at sowing; (iii) 250 g of Ca/ha applied in leaves; (iv) 500 g of Ca/ha applied in leaves; (v) 750 g of Ca/ha applied in leaves; (vi) 1000 g of Ca/ha applied in leaves; (vii) 250 g of B/ha applied in leaves; (viii) 500 g of B/ha applied in leaves; (ix) 750 g of B/ha applied in leaves; and (x) 1000 g of B/ha applied in leaves. Leaf application was made by dissolving each treatment and applying in 200 litres (L)/ha solution, with the respective treatments, about two weeks before flowering stage. Soil and leaves treatment with boron were made with Sodium Octaborate (20.5% of total B, and 9% of soluble B), considering the safe soluble concentration for leaf application. Calcium treatments were carried with Calcium Chloride PA.

The harvest to ensilage was made at January, 08, 2009, when sunflower grains were at about 35% of moisture. Just one line of five meters of sunflower plants was used in the ensilage process, cutting the plants at about 30 cm from surface. After, one plant each plot was selected to evaluate the composition fractions, segregating stem + achene, photosynthetic green leaves, dead leaves, and seeds. All fractions were dried at 55 ºC to determine dry mass in each fraction. Other harvested plants were crushed in a mill (3-5 cm pieces), and compacted in PVC pipes of 10 cm of diameter and 50 cm long, simulating conditions of silage preparation in the field (called micro-silo). The pipes were stored in laboratory, and opened at June 19, 2009. By the opening process, a sample was taken, and was dried at 55 ºC. Variables analyzed were: number of plants per hectare, fresh phytomass per plot, dry phytomass of stem + achene, dry phytomass of green leaves, dry phytomass of dead leaves, dry phytomass of seeds, dry phytomass of milled plants, dry phytomass of silage, number of green leaves, number of dead leaves, mass of micro-silo after compaction, and mass of silage after open the micro-silo. All data were submitted to ANOVA, considering the following statistic parameters: minimum, maximum, mean, variation coefficient and LSD% by Tukey (5%), and multicollinearity test by the Genes software (Cruz 1997).

Results and discussion

ANOVA analysis showed that the variables considered were not significant between treatments (Table 2). On the Table 3 are presented the various fractions analyzed in fresh and dried samples of silage, what shows that fresh plant presents about 33.146 kg/ha, being the great part represented by stem + achene (71.12%), the second most important was the phytomass of seeds (13.35%), phytomass of green leaves in third (11.29%) and the last one was the phytomass of died leaves (4.24%). After the samples be dried at 55 ºC, it was possible to observe changes in the proportion of each plant composition. Phytomass of stem + achene represented less than a half of total plant (47.03%) and phytomass of seeds increased significantly (29.29%). Died leaves, once they are almost dried in the field, almost did not lose humidity by 55 ºC, then amplified the amount proportional to total plant in three times, responsible for 12.42%, and green leaves maintained the proportion in plant partition.

Table 2. Variation source (FV), values of minimum, maximum, mean, variation coefficient (CV) and least significant difference (LSD by Tukey, 5%), for the variables: number of plants per hectare (NP); fresh phytomass of total plants (FFTP, kg); dry phytomass of stem + achene (MSHC, %); dry phytomass of green leaves (MSF, %); dry phytomass of dead leaves (MSFS, %); dry phytomass of seeds (MSS, %); dry phytomass after plant mill (pre-ensilage) (MST, %); number of green leaves (NFV); number of dead leaves (NFS); micro-silo mass (PMS, %); silage mass after micro-silo opening (MSAA, %); dry mass of silage (MSSI, %).

FV	NP	FFTP	MSHC	MSF	MSFS	MSS	MST	NFV	NFS	PMS	MSAA	MSSI
Minimum	42222.0	6.50	14.07	20.92	70.67	57.49	18.3	5.0	7.0	3.44	1.94	26.77
Maximum	64444.0	12.80	24.45	45.81	115.41	73.05	33.08	18.0	20.0	4.08	3.24	33.33
Mean	52518.5	9.53	19.45	31.34	84.90	63.13	26.03	12.06	13.23	3.72	2.55	29.46
CV (%)	9.90	16.84	13.05	21.01	9.49	5.95	15.79	26.63	24.80	5.56	9.43	3.86
LSD (5%)	15234.6	4.70	7.43	19.27	23.59	10.99	12.03	9.40	9.60	0.60	0.70	3.33

By the data presented on Table 3, total dry mass on the sunflower plants were responsible for about 28.55% of fresh phytomass of silage. Rezende *et al.* (2002) showed that mean sunflower dry mass is 32.83%. Stem + achene were responsible for 18.88% of dry phytomass, green leaves were responsible for 28.47%, died leaves and seeds presented higher amounts of dry mass, 83.66 and 62.64%, respectively, what was resultant of low humidity by the field harvest. Author results are similar to the present experiment data.

On the Table 4 are presented the direct and indirect effects of dependent variables about main variable (phytomass of silage). It is verified that number of plants per hectare has a direct effect about phytomass of silage, but negative, what means that decreasing the number of plants per hectare will increase plant capacity to incorporate more carbohydrates, and produce more dry mass, because of the stress that is higher between plants when in conditions of higher population density. From all variables considered in the study, the one that presented higher direct effect, and positive, about the phytomass of silage was the dry phytomass of seeds, with correlation value of 0.977. Other variable with direct effect was the dry phytomass after plant mill (0.684). On this way, the maximization of silage dry mass occurs when higher values of seed dry mass are obtained, in expense to other variables.

Table 3. Phytomass of a full plant (PI), phytomass of stem + achene (HC), phytomass of green leaves (FV), phytomass of dead leaves (FS) and phytomass of seeds (SP), percentage of different fractions (%) evaluated in green samples (Green) and dried samples (Dried), and final percentage of dry phytomass (FMS).

	Green %	Green	Dried	Dried	FMS
	%	kg/ha	%	kg/ha	%
PI	100.00	33146.67	100.00	9462.99	28.55
HC	71.12	23574.67	47.03	4450.80	18.88
FV	11.29	3742.47	11.26	1065.49	28.47
FS	4.23	1404.81	12.42	1175.27	83.66
SP	13.34	4423.68	29.28	2771.40	62.64

Table 4. Path analysis of dependent variables number of plants per hectare (NP), fresh phytomass per plot (FMFP, kg), dry phytomass of stem + achene (MSHC, %), dry phytomass of green leaves (MSF, %), dry phytomass of died leaves (MSFS, %), dry phytomass of seeds (FMS, %), dry phytomass after plant mill (MST, %) and dry phytomass of silage (MSS, %).

	NP	FMFP	MSHC	MSF	MSFS	FMS	MST
Direct effect about MSS	-0.617	0.334	-0.343	0.263	0.413	0.977	0.684
Indirect effect via NP	---	-0.163	-0.244	-0.35	-0.034	-0.061	-0.392
Indirect effect via FMFP	0.088	---	0.079	0.009	0.003	-0.126	-0.009
Indirect effect via MSHC	-0.136	-0.081	---	-0.195	-0.058	0.166	0.637
Indirect effect via MSF	0.149	0.007	0.149	---	-0.048	0.119	0.741
Indirect effect via MSFS	0.023	0.004	0.072	-0.076	---	-0.194	0.103
Indirect effect via FMS	0.097	-0.371	0.472	0.443	-0459	---	-0.238
Indirect effect via MST	0.435	-0.188	-0.127	0.192	0.170	-0.167	---
Total	0.041	-0.288	0.056	0.286	-0.13	0.380	0.285
Determination coefficient	0.495						
Variable residual effect	0.71						

Conclusion

According to statistical correlations, boron and calcium fertilization does not change the phytomorphologic variables analyzed in this experiment. Within the variables, dry phytomass of seeds was the most important in silage production, with a direct correlation with final yield in the field. Indirectly, the variables dry phytomass of stem + achene and green leaves were responsible for increasing silage yield, also.

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