

Corn Production for Silage Subjected to Potassium Fertilization and Water Depths

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Abstract

This study was carried out with the objective of evaluating the effect of water depths and potassium fertilizer levels on corn yield for silage. The experimental design was a randomized block design in a split-plot with six water depths based on crop potential evapotranspiration (ET_{cp}) in levels: 0.25; 0.50; 0.75; 1.00; 1.25 and 1.50 ET_{cp} , and six amounts of potassium, 0, 20, 40, 60, 80 and 100 $kg\cdot ha^{-1}$, in four replicates. The irrigation system was dripped. Before sowing was applied to the soil to nitrogen (N) and phosphate (P) fertilizers, corn was sown ten days after the fertilization using seeds from hybrid AG 1051. Manual harvesting of ears occurred 67 days after sowing. Production variables observed were fresh matter of plant with (FPMwith) and without (FPMwithout) the ears. The fresh matter of plant with and without the ears was influenced significantly by factors analyzed, the 1% level of probability by F test. The water depths in irrigation that maximized the physiological parameters of plants as FPMwith and FPMwithout were, respectively, 690 mm and 766.7 mm. The quantitative potassium to maximize physiological parameters of FPM with ears and FPM without ears was, respectively, 104.75 $kg\ ha^{-1}$ and 52.1 $kg\ ha^{-1}$.

Keywords

Zea mays L., Irrigation, Silage, Plants

1. Introduction

Livestock has constituted one of the main economic activities and plays an important role in the agricultural system of the Brazilian semiarid region. However, a major problem for the success of this activity is the production and quality of forage for the herds, which presents as determinant factors water deficiency in soil, asso-

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ciated to high temperatures and strong evapotranspiration, which reduces the nutritional value of this food [1].

The silage is an important agricultural technique for maintaining and increasing the productivity of herds, especially during the off-season, when there is scarcity of food for ruminants. Among the various forages, annual and/or perennial plants, maize (*Zea mays* L.) is one of the most used in ruminant nutrition by presenting a good yield of green matter, excellent quality fermentation and maintaining nutritional value of silage, low operating cost of production, and is grown in various soil and climatic conditions [2]. Silage corn is capable of providing 50% - 100% more digestible energy per hectare than any forage. According [2] the corn cultivars evaluated conferred higher nutritional value to silage when compared with sorghum cultivars.

Some researchers have shown that the production of high quality silage depends on the physical composition of the anatomical structures of the corn plant must with around 60% - 65% of ears, which determines the share around 45% of grains in the ensiled material. However, other researchers note that the increase in dry matter production without concomitant increased participation spike in total mass can reduce silage quality. However, not always the greatest proportion of grain in the forage gives better quality silage. The quality of grain and green fraction of the plant (stem, leaf, and straw), combined with the percentage of each of these parts in the plant, determines the nutritional value of the silage [3].

In maize crop, water availability, especially in regions where the rainfall distribution is irregular, becomes a decisive factor in the production and yield [4], in the same way that the nutrients, such as potassium, have high mobility between individual cells, tissues and long-distance transport by xylem and phloem. Potassium can increase the production of dry matter and protein content of the plant due to participation in the activation of enzymes, photosynthesis, translocation of assimilates and nitrogen uptake. However, the deficiency of this nutrient reduces the accumulation of carbohydrates. To avoid this deficiency, the management of potassium fertilizer should be correctly minimizing losses and avoiding the depletion of soil K [5]. According to [6], the potassium fertilizer on corn planting increased the production of dry biomass of shoots, but did not influence the productivity.

For adequate silage production in the semiarid region, this paper aimed to evaluate the yield of silage corn of the whole plant, subjected to doses of potassium and different amounts of water through irrigation.

2. Material and Methods

The experiment was carried out in Sumé, Paraíba State, Brazil (36°52'48"W, 07°40'17"S; 532 m asl) during the period, from January to March 2012, in soil classified as Litholic Neosol. The climate of the region is dry characterized by insufficient rainfall (monthly average in January, February and March 2012: 40.4 mm, 85.5 mm and 144.8 mm, respectively; however in this year there was no precipitation event) and high temperatures; the average temperature is around 24°C.

The chemical and physical properties of surface layer (0 - 0.20 m) were determined according to [7] presented the following attributes: pH (H₂O) = 7.63; Ca²⁺ = 10.06 cmol_c·kg⁻¹; Mg²⁺ = 7.56 cmol_c·kg⁻¹; Na = 0.07 cmol_c·kg⁻¹; K⁺ = 0.25 cmol_c·kg⁻¹; organic matter = 13.4 g·kg⁻¹; P = 54 mg·kg⁻¹; 641.5 g·kg⁻¹ clay, 271.0 g·kg⁻¹ silt and 87.5 g·kg⁻¹ sand.

The experimental design was a randomized block design in a split-plot design with six water depths (0.25 ET_{cp}; 0.50 ET_{cp}; 0.75 ET_{cp}; 1.00 ET_{cp}; 1.25 ET_{cp} and 1.50 ET_{cp}) (based on crop potential evapotranspiration) and six amounts of potassium (0; 20; 40; 60; 80 and 100 kg K₂O per hectare) in four replications (based on plant fertilizer recommendation), totaling 144 experimental units arranged in an area of 2086.56 m². Data were analyzed using an analysis of variance split plot design, with treatments assigned. Statistical analysis were done using software [8].

According to the results of the soil chemical properties and fertilization recommendation for irrigated maize, in the foundation were placed 66.67 kg·ha⁻¹ of urea and 105.26 kg·ha⁻¹ of super-simple phosphate and more 133.33 kg·ha⁻¹ of urea of covering. The various doses of potassium followed the criterion of lower (0, 20, kg·ha⁻¹) and higher (60, 80 and 100 kg·ha⁻¹) amounts of fertilizer recommendation (40 kg·ha⁻¹) considering that this recommendation is designed for areas with very different soil and climatic characteristics of the area of this research. The potassium fertilization was carried out in the foundation, where the product was used potassium sulfate.

The irrigation system used was located with drippers. For estimation of local evaporation (EV) used the tank USWB class A, surrounded by exposed soil (circle with radius of 1.0 m from the tank). Based on relative hu-

midity of air, lower than 40%, and the average wind speed, $2.55 \text{ m}\cdot\text{s}^{-1}$, considered moderate, was adopted a coefficient of 0.65 Kt tank which, multiplying with evaporation tank (EV) resulting in potential evapotranspiration value, $\text{mm}\cdot\text{day}^{-1}$ (ET0) [9]. To determine the potential evapotranspiration culture (ETcp), we used a lysimeter percolation of 4.50 m^2 and depth of 1.50 m. Dividing the value of potential evapotranspiration culture (ETcp) by reference potential evapotranspiration value (ET0) obtains the value of the crop coefficient (Kc). This factor is important in the calculation of replacement water slides corresponding to 25%, 50%, 75%, 100%, 125% and 150% of ETcp.

The maize hybrid AG 1051 was mechanically sown on 13/01/2012 by planting in double rows of square arrangement (three double rows in each split plots). In each planting hole were placed 3 seeds and after germination were kept 2 plants per hole to production. The distance between plants was $0.4 \times 0.4 \text{ m}$ and between irrigation lines was 1.4 m with a population of 71,000 plants $\cdot\text{ha}^{-1}$. Manual harvesting of ears in the green stage occurred 67 days after planting.

Fresh matter of plant along with the ears (FMP with ears) and without the ears (FMP without ears) were observed like production variables. Plants of the two outer rows of the subplots were cut close to the ground to give the fresh matter of plants along with the ears. The fresh matter of plants along with the ears was obtained by weighing in kg.

3. Results and Discussion

The fresh matter of plant with corn ears was significantly influenced by factors water depths and potassium fertilization and the interaction between the two factors referred to the 1% level of probability by F test (Table 1).

The general average of fresh matter of plant with ears throughout the experiment, whereas a population of approximately 56,000 plants per hectare was $62.4 \text{ t}\cdot\text{ha}^{-1}$, *i.e.*, greater than the production of $33.564 \text{ t}\cdot\text{ha}^{-1}$ in cultivar AG 5011 found by [10] studied corn silage for cattle feed.

Mean values of the fresh matter of the plant with the ears, depending on water depths and potassium fertilization are shown in Table 2.

The mean of 42.83 and $79.05 \text{ t}\cdot\text{ha}^{-1}$ corresponding to W_1K_0 and W_6K_5 treatments, respectively, in a population of 56,000 plants, obtained average yield from 0.765 to 1.41 kg per plant; these values were similar to those obtained by [11] who obtained individual plant mass was of 0.712 to 0.925 kg.

These combinations of water with potassium are important because potassium, among nutrients, stands out when the agricultural production system passes of extractive intensive to technical agriculture, with the use of irrigation. In the case of maize harvesting to make silage is high extraction and export of nutrients, including

Table 1. Analysis of variance of the fresh matter of plant with and without ears.

Source	Degree of freedom	Mean square	
		With ears	Without ears
Water depths (W)	5	1265.81**	559.32**
Error-W	18	10.61	20.55
Plots	23		
Potassium (K)	5	877.53**	324.24**
Int. W \times K	25	143.38**	133.03**
Error-K	90	4.66	7.44
Total	143		
CV of plots		2.22%	18.39%
CV of subplots		3.46%	15.33%
General mean		$62.4 \text{ t}\cdot\text{ha}^{-1}$	$49.1 \text{ t}\cdot\text{ha}^{-1}$
N° of observation		144	144

*, ** Significant at 5% and 1% probability, respectively.

Table 2. Mean values of fresh matter of plant with and without ears, depending on the water depths and potassium fertilization Water slides ETcp (mm).

	Water slides		Potassium (K), kg·ha ⁻¹						Mean (t·ha ⁻¹)
	ETcp (mm)	m ³ ·ha ⁻¹	K ₀₋₀	K ₁₋₂₀	K ₂₋₄₀	K ₃₋₆₀	K ₄₋₈₀	K ₅₋₁₀₀	
W ₁	132	1320	<u>42.83</u>	45.24	51.13	53.90	56.22	53.51	50.47
W ₂	264	2640	43.93	54.22	59.08	71.18	69.57	52.79	58.46
W ₃	396	3960	44.90	50.25	62.40	76.26	68.50	67.75	61.67
W ₄	528	5280	51.44	72.60	69.64	64.01	69.05	66.26	65.50
W ₅	660	6600	63.11	68.09	69.79	71.67	74.01	75.05	70.29
W ₆	792	7920	63.47	64.43	73.44	62.08	66.67	<u>79.05</u>	68.19
	Mean (t·ha ⁻¹)		51.61	59.14	64.24	66.52	67.34	65.74	
Fresh matter of plant without ears									
W ₁	132	1320	37.85	38.29	41.88	39.24	44.03	42.93	40.70
W ₂	264	2640	36.70	44.65	48.25	58.08	54.26	42.27	47.37
W ₃	396	3960	<u>35.71</u>	39.53	47.46	60.20	52.72	53.89	48.25
W ₄	528	5280	41.07	57.40	54.12	47.59	53.30	53.09	51.09
W ₅	660	6600	49.13	57.09	53.84	52.28	52.81	58.09	53.88
W ₆	792	7920	51.78	52.81	57.38	44.72	47.56	<u>64.00</u>	53.04
	Mean (t·ha ⁻¹)		42.04	48.30	50.49	50.35	50.78	52.38	

potassium, since the grain addition, the vegetative portion is also removed from the ground-depleting if no replenishment of nutrients. According [12] the increment of K doses influenced positively the yield of corn. However, [13] evaluating potassium irrigated maize, not observed increase in productivity, since the farmers are using rates of potassium fertilizers over than necessary in this experimental region. Similarly, [14] and [15] also found no significant effect on potassium on grain corn.

The amount of biomass produced by the plant can be defined by a single physiological relationship based on the amount of radiation intercepted and their conversion efficiency on dry matter [16].

The mean of FMP with ears relative water depths ranged from 50.47 to 70.29 t·ha⁻¹ for 132 and 660 mm of water. Regarding fertilization with potassium FMP with ears averages ranged from 51.61 to 67.34 t·ha⁻¹ in K₀ and K₄ treatments, respectively.

Regression models that predict FMP with ears depending on water depth (W) and fertilization (K) showed good fits to the data analyzed according to the R² values 0.97 to 0.99 of the two equations, respectively (Table 3).

Through analysis of variance was observed that the factors water depths, potassium fertilization and interaction between them, significantly influenced the level of 1%, green plant mass without ears (Table 1).

The production of FMP without ears ranged from 35.71 to 64.00 t·ha⁻¹ (Table 2) where in the overall average in the experiment was 49.1 t·ha⁻¹, *i.e.*, above the production of 44.98 t·ha⁻¹ recorded by [11] whose authors evaluating the productivity of many corn hybrids observed yields 42.31 to 47.93 t·ha⁻¹. Likewise, the mean 42.04 t·ha⁻¹, corresponding to produce FMP without ears with several layers of water without K fertilization was the highest average 22.02 t·ha⁻¹ observed by [17] evaluated when producing the same hybrid this research, *i.e.*, AG 1051, using various water depths. However, [18], evaluating different irrigation systems in planting hybrid corn *Agrocere* 8011Y, met with full irrigation, 91.7 t·ha⁻¹ of green mass.

By unfolding from mean FMP without ears obtained in water depths within the quantitative potassium showed that the increase in water depths up to W₅ increased production of green mass, decreasing from that point, *i.e.*, W₅ to W₆.

Table 3. Regression models with the water depths and potassium fertilization to maximize the fresh matter of plant with and without ears.

Source of variation		Regression models								
Water depths (W)	FMP with ears	=	-0.00005	W ²	+	0.07	W	42.28	with R ² =	0.97
	FMP with ears	=	66.09	t·ha ⁻¹	To	W =	690	mm		
Potassium (K)	FMP with ears	=	-0.002	K ²	+	0.419	K	51.73	with R ² =	0.99
	FMP with ears	=	73.68	t·ha ⁻¹	To	K =	104.75	Kg·ha ⁻¹		
Water depths (W)	FMP without ears	=	-0.00003	W ²	+	0.05	W	35.66	with R ² =	0.96
	FMP without ears	=	53.29	t·ha ⁻¹	To	W =	766.7	mm		
Potassium (K)	FMP without ears	=	-0.002	K ²	+	0.22	K	43.03	with R ² =	0.89
	FMP without ears	=	48.74	t·ha ⁻¹	To	K =	52.1	Kg·ha ⁻¹		

When the amount of potassium was increased, the FMP without ears also increased of 14.9%, 4.5%, 0.85% and 3.15% from K₀ to K₁, K₁ to K₂, K₃ to K₄ and K₄ to K₅, respectively, but with a slight decrease of 0.28% from K₂ to K₃, without a plausible explanation.

The best combination for FMP without ears was W₆K₅ averaging 64 t·ha⁻¹, and the lowest mean was observed in W₃K₀ combination with 35.71 t·ha⁻¹ in a population of 56,000 plants per hectare.

Factors such as mineral nutrition, radiation and water availability, significantly interfere with photosynthetic mechanism which results in the accumulation of organic matter in the plant. Among these factors, the availability of water plays a significant role because, besides providing the entry of CO₂, it promotes cooling the plant, interfering in this way, the rate of photosynthesis and respiration [16].

The equations of regression models that predict FMP without ears depending on the water depths (W) and potassium fertilization (K), with R² of 0.957 and 0.898, respectively, showed optimal adjustments to the data analyzed (Table 3).

4. Conclusions

Based on the results of this research, the water depths in irrigation that maximized the physiological parameters of plants as FMP with ears and FMP without ears were, respectively, 690 mm (66.09 t·ha⁻¹) and 766.7 mm (53.29 t·ha⁻¹).

According to regression equations, the quantitative potassium to maximize physiological parameters of FMP with ears and FMP without ears was, respectively, 104.75 kg·ha⁻¹ (73.68 t·ha⁻¹) and 52.1 kg·ha⁻¹ (48.74 t·ha⁻¹).

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