Short communication

Determination of flooding time of corn (*Zea mays* L.) cultivated in Ferrallitic Red soil

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ABSTRACT

Knowing flooding time of crops reveals the time that the plant can withstand waterlogging without suffering any effect on its yield. The work was developed in the "Pulido" Scientific and Technical Base Unit, located in Alquízar municipality, Artemisa province, with the aim of determining the time of flooding in the corn crop. Tuzón variety was used and flooding processes were carried out during the flowering stage of the crop. Planting was carried out in pots, with a Ferrallitic Red soil. The experimental design applied was a randomized block design, the treatments consisted of flooding the pots for 24, 48, 96 and 144 hours with a control without flooding. The results revealed that, from the flooding beginning, there was a reduction in relative grain yield of 0.31 % for each hour of flooding and a loss of approximately 50 % was reached with 70 hours of excess humidity. Plants showed losses in cob weight, kernel weight and a decrease in cob length when subjected to flooding from 24 hours to 144 hours. The maize crop showed a minimum threshold (0.0), so the reduction in yield and its components was recorded immediately at the onset of flooding.

Key words: yield, flowering, soil moisture, grains

INTRODUCTION

Climate changes and extreme natural events in recent times are jeopardizing the sustainable development of agriculture in the world. There are factors that are the main cause of excess moisture in soils (1): high precipitation in the soil; that is, the water that enters the crop fields naturally; inadequate irrigation management, since the water applied is often not what the crop fields need; unfavorable topography, such as undulating or flat terrain; and, finally, poor surface and internal drainage.

Water stress due to flooding is a limiting factor in the production of some crops such as corn (*Zea mays* L.) (2), which is one of the most relevant cereals from the social, economic and nutritional point of view worldwide. In Cuba, about 42 % of the agricultural area is affected by poor drainage problems (3), which, combined with heavy rains, leads to flooding of crops.

Problems occur when flooding suffocates crops, as air is replaced by water in the soil pores. This prevents any possibility of oxygen supply, which affects both biological activity and soil structure. In addition, internally it reduces the volume of soil available to roots, affecting aeration and root development, thus reducing the water and nutrient absorption capacity of most plants (4).

If the plant apex is above the water surface, plants can survive a flood that lasts from a few days to several weeks; however, yield reductions occur due to direct and indirect effects (5). Direct effects include root cell death and root decomposition; indirect effects include pathogen infections, nitrogen losses and plant sensitivity to excess moisture stress (5).

Knowing the flooding time of different crops is an important factor when designing surface drainage works. This reveals the time that the plant can withstand flooding without suffering any effect on its yield. Hence, the present research was developed with the objective of determining the time of flooding in the corn crop.

MATERIALS AND METHODS

The work was carried out at the "Pulido" Experimental Station of the Institute of Agricultural Engineering, located in Alquízar municipality, Artemisa province, at 22º45'N and 82º27'W at 6 m a.s.l. Twenty brass containers were used (considered as pots), with a diameter of 500 mm, height 750 mm and volume of 0.147 m^3 to which a perforation was made with a diameter of 25 mm laterally, located 26 mm from the bottom, through which a perforated PVC tube with holes of 5 mm was introduced, separated at 50 mm (Figure 1).

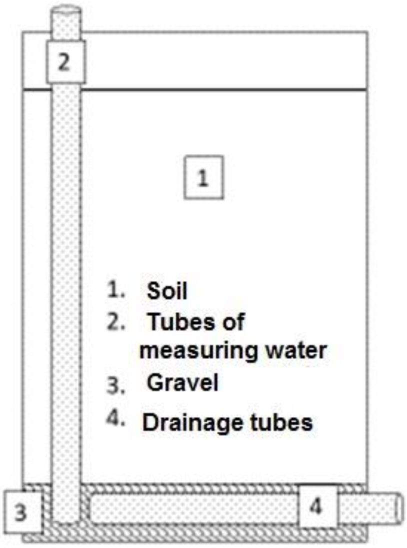


Figure 1. Diagram of pots where experiments were carried out

The tubes were sealed around the contact wall of the pot to avoid water losses. Another slotted tube was placed inside the container perpendicular to the base, with a height of 1128 mm, leaving 10 cm above the soil surface. A layer of gravel 8 cm high was placed as a filter for drainage and the containers were filled with Ferrallitic Red soil from the experimental station. The pots were left 10 cm free, measured from the top edge. The texture and other physical properties of the soil (6) are presented in Table 1.

Table 1. Granulometric analysis and other physical properties of the soil profile Ferrallitic Red

Depth (cm)	Field capacity (cm^3/cm^3)	Apparent density a Field capacity (g/cm^3)	Clay (%)	Silt (%)	Sand (%)	Total porosity (%)
0-20	0.394	1.18	57.4	21.7	20.9	53.7
20-40	0.431	1.28	61.8	20.5	17.7	49.2
40-60	0.397	1.20	62.8	14.3	28.9	51.6
60-80	0.396	1.20	61.4	18.3	20.3	51.6

The crop used was corn, variety Tuzón. Prior to the execution of the experiment, it was determined that the seeds had 91 % germination. Sowing was carried out in January 2019, placing three seeds in two nests separated at 250 mm per pot. A fertilizer dose per pot (complete formula) of 3.75 g N, 225 g P_2O_5 and 2.25 g K_2O was applied, fractionated 66 % at the time of sowing and the remaining 33 % 30 days after germination (7). After germination, only the healthiest plants were left and from the appearance of the second leaf, the treatments were irrigated every two days with a dose of 5.59 L per pot, until reaching the equivalent of 80 % of the field capacity of the natural soil (measured with electromagnetic probe ML3) (8), for a total of 52 irrigations and 290 L per pot. Total rainfall was 199.8 mm during the period of work development (January-April 2019), distributed in 14 events. Harvesting took place in April 2019 (112 days).

Treatments were applied when the plants reached about 80 % of flowering stage, which occurred 60 days after germination, which is a very sensitive stage for the crop (9).

The treatments were as follows:

1. Control (0 flooding).
2. (24 hours flooding, 1 day)
3. (48 hours flooding, 2 days)
4. (96 hours flooding, 4 days)
5. (144 hours flooding, 6 days)

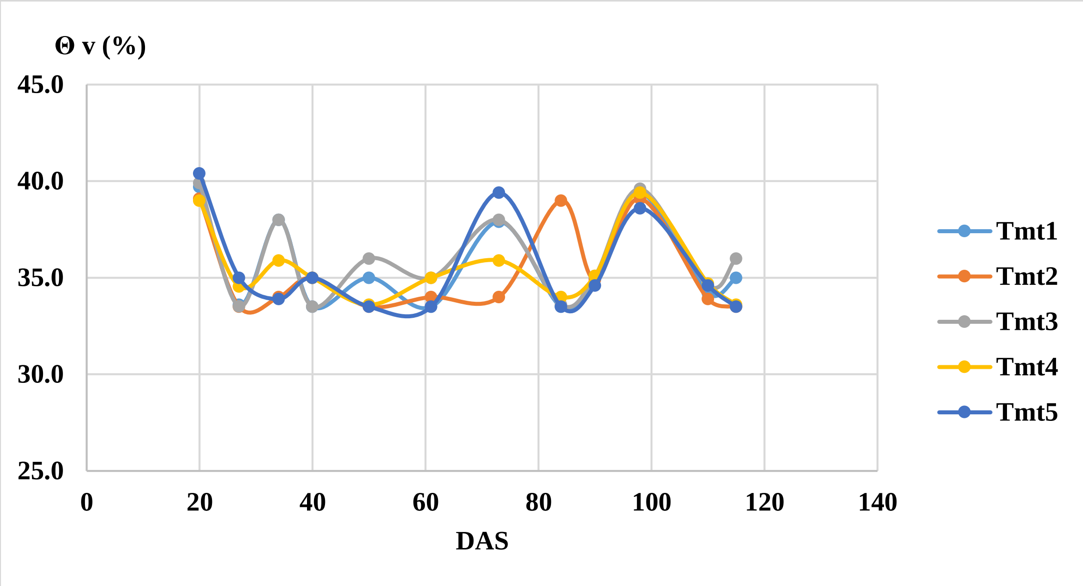
At the flooding time, a plug was placed in the drainage tube, which was removed once the expected flooding time was achieved for each treatment. A randomized block experimental design was used, with four replications.

Yield and its components (weight of ears, weight of 100 grains, weight of all grains), number of ears per plant and quantity of grains per cob, diameter and length of cobs were determined. In addition, the relationship between hours of flooding and relative fresh grain yield was analyzed (3).

Data were processed by double ranked analysis of variance using Statgraphics Plus 5 software. Differences between treatment studied means of they were determined according to the Tukey HSD multiple comparison test with 95 % reliability.

RESULTS AND DISCUSSION

The soil in the pots was always maintained above 80 % of field capacity (Figure 2). The volumetric moisture values varied between 33.49 and 39.4 %, being adequate for this type of soil (6).



DAS: days after sowing, Θ v: humidity

Figure 2. Soil moisture behavior during the crop cycle

Table 2 shows that after flooding stress was applied at the time of evaluation, the highest cob weight was reached in the non-flooded treatment, decreasing with increasing hours of flooding, revealing reductions from 10 % (24 h) to 39 % (144 h). No significant differences were observed among treatments for ear diameter and 100 kernel weight; however, the mean number of kernels per ear and ear length showed significant differences as flooding hours increased. Similar results were obtained in maize and sunflower crops [10-12].

Table 2. Yield components according to hours of flooding (66 DAG)

Treataments	Weight of cobs (g)	Cob diameter (cm)	Cobs per plant	Length of cobs (cm)	Average grains per cob	Weight of 100 grains (g)
6. (0 hours)	195,97 a	4,50	1,75	18,31 a	279,00 a	30,29
7. (24 hours)	176,85 ab	4,35	1,65	17,59 ab	210,00 ab	27,55
8. (48 hours)	130,55 ab	4,28	1,62	15,59 ab	168,60 ab	26,13
9. (96 hours)	123,28 b	4,09	1,37	15,00 ab	123,16 b	26,90
10. (144 hours)	120,24 b	4,00	1,37	14,33 b	116,00 b	24,70
SE	9,96*	0,10 N.S.	0,08 N.S.	0,47*	23,02*	0,68 N.S.
CV (%)	25,82	10,57	25,42	13,17	49,71	9,82

* Means with different letters in the same column differ according to Tukey's test (0.05).

When reviewing the effect of poor drainage on agricultural production in Cuba, it has been pointed out that yield losses in the main agricultural crops of the country, as a result of soil over-wetting, could vary between 30 and 80 %. This occurs because aeration decreases and, therefore, the concentration of oxygen, which can reach up to 2 % [13].

The macro pores, where air normally exists, are occupied by water, causing a direct effect on root respiration and an indirect effect by modifying microbial action [14,15]. In addition, this oxygen deficiency causes the plant to change its metabolism from aerobic respiration to fermentation, as an adaptive mechanism, which significantly affects plant development.

Figure 3 shows a decrease in grain yield, as the hours of flooding increase from 24 h to 144 h in the flowering stage of the crop, revealing a reduction of 0.31 % for each hour of flooding and a loss of approximately 50 % is reached with 70 hours of excess moisture, in this case the crop shows a minimum threshold (tolerance to over-wetting of crops) of 0.0, so the reduction in yield and its components was recorded immediately at the beginning of flooding.

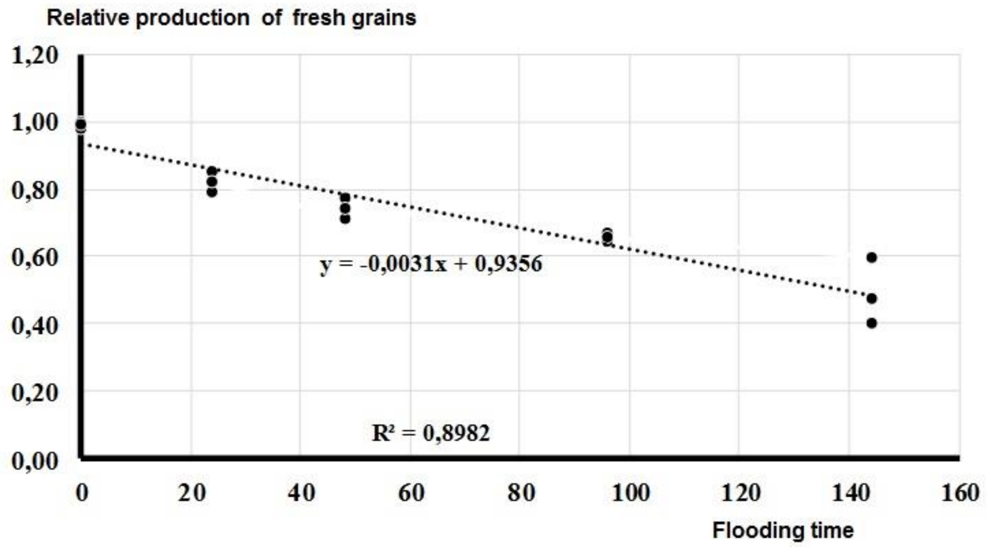


Figura 3. Relationship between hours of flooding and relative grain yield

In reviewing the international literature, the corn crop decreases its yield between 9.2 and 11.3 % for each day of over-wetting and reaches a decrease of 50 % of its potential yield between three to five days of excess soil moisture [3].

CONCLUSIONS

- Plants showed losses in cob weight, ear length and average kernels per ear when subjected to flooding from 24 hours to 144 hours in the flowering phase.
- In the Ferrallitic Red soil, the decrease in corn production is manifested from the first 24 hours of flooding in the flowering phase of the crop, the minimum threshold value obtained (0.0) indicates that the drainage time is 0.0.
- As the flooding time in the soil increases, there is a reduction in corn yield of 0.31 % for each hour and a loss of 50 % is reached, approximately with 70 hours of excess moisture.

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