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EFFECT OF DIESEL ON THE EARLY DEVELOPMENTAL STAGES OF CORN

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Abstract: Pollution from oil spills affects the soil and crops, so this study evaluated the effect of soil contaminated with diesel at different concentrations on the development of Creole corn (*Zea mays*). Creole corn seeds were placed in soil contaminated with diesel at different concentrations: 0%, 0.5%, 1%, 2%, 4% and 8%, each treatment had four replicates, the experimental units were kept under controlled laboratory conditions. Variables such as germination percentage, plant height, leaf area, mortality rate, aerial and root biomass were evaluated at 7, 10, 14, 21 and 28 days after sowing. The results indicate that germination was delayed and a delay in the appearance of the sprout was also observed at higher concentrations. Plant height, root area, biomass, and taproot were affected at higher concentrations ($p < 0.05$). Presence of chlorosis and malformations in the leaves were observed on the ninth day after planting, causing the onset of wilting of the leaves in the 4% and 8% treatments. Exposure to diesel significantly reduces the growth of native corn in its early stages of development.
Keywords: Soil, contamination, *Zea mays*, hydrocarbons.

INTRODUCTION

L Soil contamination by hydrocarbons has had considerable effects on the development of plants, such is the case of germination and vegetative growth of different species, observing a marked delay in the growth of plants in contaminated areas (Okonwu et al., 2010; FiriAppah et al., 2014), an effect has also been observed on plant height, stem density, photosynthetic rate, among other effects on the plant (Vázquez-Luna et al., 2010; Hernández-Valencia et al., 2017). On the other hand, the hydrophobic properties of hydrocarbons and their derivatives reduce the potential of plants to absorb water and minerals (Afzal et al., 2013).

In the corn plant (Zea mays) Marín-Velásquez (2016) observed that the germination percentage decreased when the seeds were exposed to a higher concentration of oil. Cevher-Keskin et al. (2018) observed the reduction in leaf growth and chlorosis as well as delay in cell expansion of corn in the presence of light oil (1, 2.5 and 5%), in addition to the above, the study revealed the inhibition of root growth and shoots that were attributed to drought stress.

The presence of polluting substances, such as petroleum hydrocarbons, have a negative effect on the economic, social (Carvazos-Arroyo et al., 2014), environmental (Yan et al. 2012), and health (Ortíz-Salinas et al., 2012) sectors, 2012) therefore, the presence of hydrocarbons is one of the problems that can affect the harvest in the morphology of the plant and, in turn, reduce its food security, because the toxic levels of the contaminants cause the crops are dangerous for consumption by animals and humans. (Saha et al., 2017; Rodríguez-Eugenio et al., 2019). It is then that it becomes necessary to pay attention to this concept, investigating in more specific ways the effects that oil has on the sowing of corn plants, selecting it for its climatic adaptation and its agricultural importance in oil-producing areas (Quiñones et al. al., 2003). The objective of this work is to evaluate the response of Creole corn in early stages of development in a soil contaminated with diesel.

MATERIALS AND METHODS

SUBSTRATUM

The soil used was of the Andosol type, collected in the city of Xalapa, Veracruz, Mexico.

INDUCED SOIL POLLUTION

Soil contamination was carried out with diesel fuel characterized by being a mixture of paraffinic, olefinic and aromatic hydrocarbons derived from the processing of crude oil used as automotive fuel (PEMEX, 2020). A mixture of 450 g of soil with 50 g of agrolite was made; plus the corresponding diesel to obtain the following concentrations: C0 or control (soil without contamination), C.5 (soil with 0.5% diesel), C1 (soil with 1% diesel), C2 (soil with 2% diesel) C4 (soil with 4% diesel) and C8 (soil with 8% diesel); each with 4 repetitions to obtain 24 experimental units.

CORN SOWING

Once the contamination was over, 3 Zea mayz seeds were planted per experimental unit with a depth of 4 cm (ANDES Association, 2019). The experimental units were controlled under an artificial Climatic Chamber brand ECOSHEL model C1000D, 16/8 light/darkness. At a temperature of 25°C, an ambient humidity of 60% and a soil humidity of 45%. Daily monitoring was carried out and the soil was irrigated with the help of a water spreader. The variables evaluated were: germination percentage, plant height, number of leaves, leaf area, mortality rate, main root length and biomass expressed in wet and dry weight of the aerial and root parts at 0, 7, 10, 14, 21 and 28 days after sowing.

STATISTICAL ANALYSIS

The results were analyzed by one-way ANOVA analysis of variance and as a posteriori test a Tukey test was applied to determine specific differences between treatments, for $p \leq 0.05$. All analyzes were performed with the RStudio program.

RESULTS AND DISCUSSION

GERMINATION

Germination was observed on the fourth day after sowing, with the control or C0 (0%) having the highest percentage with 83.3% of the germinated seeds and treatments C1 and C8 having the lowest germination with 8.33%. On the fifth day of sowing, treatments C0, C.5, C1 and C2 were added, germinating at 100%. Subsequently, C4 reached 100% germination on day 7. With respect to treatment C8, it obtained a germination of 91.6% (11 seeds) on day 8; being its maximum percentage of germinated seeds after 28 days.

Diesel pollution retarded the germination of corn seeds; This result indicates that at higher concentrations of diesel corresponding to 4% and 8% of induced contamination, soil properties can be more affected in such a way that it limits and/or alters seed germination (Ekundayo et al., 2001; Adam and Ducan 2002). The hydrophobic property that diesel presents can explain its inhibitory effect on germination by generating a diesel film around the seeds, becoming a physical barrier that prevents or reduces the entry of water and oxygen into the corn seeds (Adam and Duncan, 2002).

PLANT HEIGHT

The growth of the native maize plants before the different treatments had a similar tendency in its early stage (see Figure 1). After 28 days, C0 ended up being the highest with 53.12±2.2 cm, presenting differences between the treatments with the highest concentration of diesel (C2, C4 and C8). Treatment C8 was shorter, 33.81±1.28 cm, showing significant differences between all other treatments ($F=11.01$, $p<0.01$).

As shown in Figure 1, the height was affected by the higher concentration of diesel. These results coincide with Obgo (2009) and Quiñones et al. (2003) where they concluded that the inhibition of plant growth shows a directly proportional relationship with higher concentrations of hydrocarbons. Likewise, a study carried out by Arias et al., (2017) with

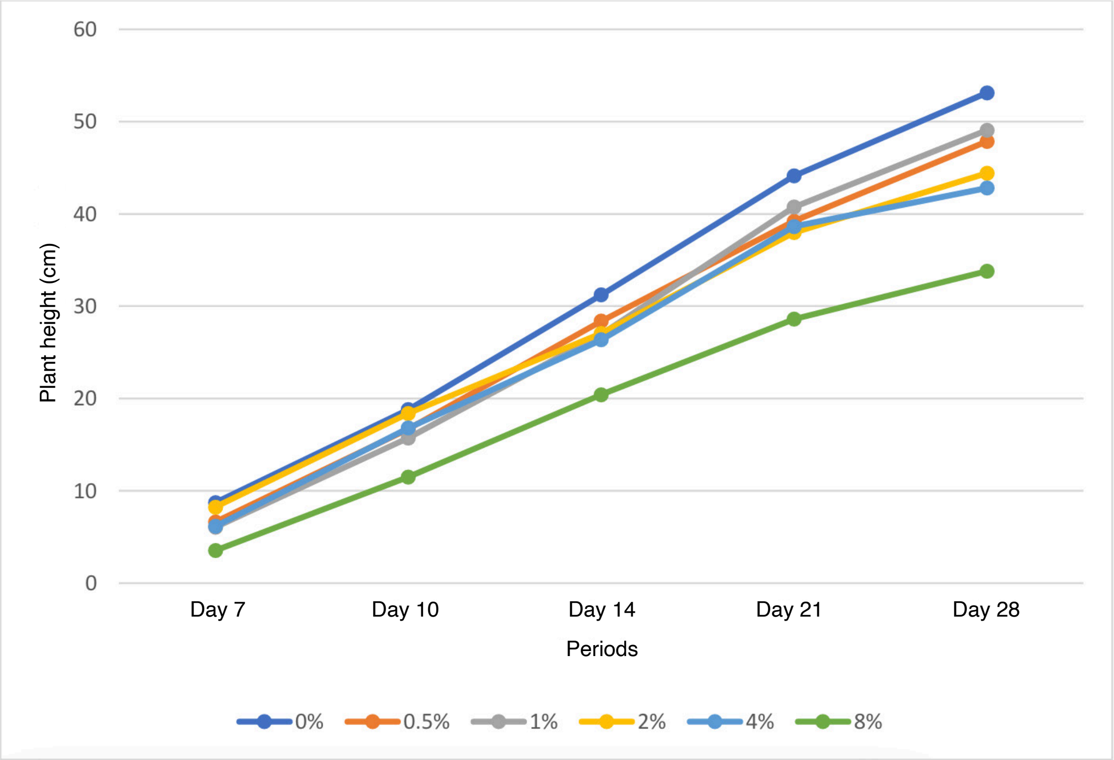

Figure 1. Corn growth of treatments 0%, 0.05%, 1%, 2%, 4% and 8% of induced contamination on days 7, 10, 14, 21 and 28. The highest percentage of contamination (8%) shows differences statistically significant (p<0.01) with all other treatments.

bean plants (*Phaseolus vulgaris*) in the presence of hydrocarbons at different concentrations (0.15%, 0.3%, 0.45%, 0.6%, 0.75% and 0.9%), reported that the longer the exposure time, the greater the damage to the plant in increasing concentrations (0.3% to 0.9%).The negative repercussions on the height of the corn may be due to the fact that the hydrocarbon leachates reduce the metabolism and physiological development of the plants, by inhibiting the physiological maturity of the roots and aerial part (Hernández Rodríguez et al., 2022).

EFFECT OF DIESEL ON LEAVES

Leaf sprouting began on day 7 after sowing in treatments C0 and C2, and from day 9 treatments C4 and C8 showed leaves stuck to each other and curled. By day 10, all treatments presented at least one leaf per germinated seed; showing significant differences between treatments (F=4.284, p=0.00198**) with a maximum number of 3 leaves in treatments C0, C2, C4 and C8, and a minimum of 2 leaves in C.5 and C1. On this same day, leaves with chlorosis were observed in treatments C2, C4 and C8, which were increased and showed greater damage until the final day (day 28). These results agree with those reported by Cevher-Keskin et al. (2018) where they observed that at concentrations of 1%, 2.5% and 5% the leaves presented yellowing due to the presence of hydrocarbons in the soil.

Between days 14 and 21, the increase in the number of leaves was one per plant and the increase in leaves with chlorosis began to become more evident in treatments C.5 and C1. It must be noted that, by day 21, the repercussions on the leaves increased, causing the wilting of smaller leaves in C2, C4 and C8 with a mortality rate of 14.89%, 13.95% and 29.27%, respectively. On day 28, the number of leaves showed significant differences between treatments ($F=10.44$, $p < 0.01$), with treatments C2, C4 and C8 having the lowest average number of leaves and the highest mortality rate with 27.27%, 24% and 38.78. % (Table 1). In this sense, Abha and Swaranjit (2012), point out that, due to the penetration of hydrocarbons at the cellular level, intracellular metabolic changes are induced in the leaves that lead to wilting, a response appreciated in the present study.

	#Leaves	Leaf area (cm^2)	Mortality rate
CO	4±0.21ab	59.03±3.47a	14.29
C.5	4.25±0.22a	42.1±2.78b	5.56
C1	4.08±0.19a	44.52±3b	14.04
C2	3.25±0.13bc	37.2±3.04b	27.78
C4	3.17±0.17c	34.48±2.96bc	24
C8	2.72±0.19c	24.43±1.99c	38.78

Tabla 1. Efectos de diésel en sus diferentes concentraciones sobre el área foliar. Las letras corresponden a las diferencias significativas entre tratamiento. 28 DDS ($p \leq 0.5$)

On day 28, the decrease in leaf size was more evident ($F=15$, $p<0.01$). The decrease in the size of the leaves has been associated with a lower absorption of nutrients and water, coupled with changes in the activity of some metabolites within the plant due to the presence of diesel, generating osmotic and oxidative stress (Oguntimehin et al, 2010). During osmotic stress, the damage begins immediately after the concentration of the contaminant in the rhizosphere increases above the tolerance level of the plant, due to the hydrophobic effect that limits the availability of water for the roots, affecting the development of the aerial system (Adenipekun et al., 2009) thus inhibiting growth, and reducing cell division and elongation, resulting in a decrease in leaf area (Oguntimehin et al., 2010). The oxidative damage caused by the hydrocarbon is manifested by the alteration of fundamental biomolecules (sugars, lipids, proteins, DNA and vitamins) (Foyer and Noctor, 2005) and can cause mutations due to the breakage of the DNA chain when reacting with OH- (Møller *et al.,* 2007).

ROOT

The length of the maize main root was affected by the different concentrations of diesel in the soil, showing significant differences between treatments ($F=18.82$, $p < 0.05$), resulting in a decrease in length with respect to the percentage of germination, having the length largest root at C0 (48.84±3.16 cm) and the smallest at C8 (18.64±2.33 cm).

Petroleum hydrocarbons have negative effects on the root due to the reduction in the availability and absorption of water and nutrients (Hernández-Rodríguez, 2022). In turn, the presence of an organic contaminant results in cell disruption as a direct effect on mitochondrial respiration or indirectly through cell growth and division (Issoufi et al., 2006), significantly altering the rate of cell division in cells. root apices, the size of the meristematic regions and the structure of the root hairs (Bona et al., 2011) further causing the adverse effects of diesel on root length to be reflected. These changes have been recorded in different species grown in contaminated soil, and it is considered that they are part of the adaptations that plants present to be able to develop under these stress conditions (Hernández-Ortega, 2014).

DRY BIOMASS AND WET BIOMASS OF THE ROOT AND AERIAL PART

The humidity biomass of the aerial part ($F=27.1$, $p < 0.01$) and humidity biomass of the root ($F=6.932$, $p < 0.05$) showed

	Aerial			Root		
	Moist biomass (g)	Dry biomass(g)	Humidity (%)	Moist biomass(g)	Dry biomass(g)	Humidity (%)
C0	3.45±.0. 27a	0.29±0.48a	91.7	1.91±0.20a	0.37±0.04a	80.56
C.5	2.16±0.22b	0.18±0.31a	91.57	1.08±0.14b	0.23±0.03a	78.68
C1	1.94±0.13bc	0.17±0.01a	91.3	0.85±0.08b	0.17±0.4a	79.68
C2	1.47±0.13bcd	0.18±0.01a	87.94	1.3±0.14ab	0.4±0.11a	69.23
C4	1.28±0.10bd	0.27±0.14a	78.53	0.9±0.08b	0.21±0.2a	77.12
C8	0.9±0.9d	0.12±0.01a	87.2	1.02±0.19b	0.22±0.3a	78.52

Table 2. Wet and dry biomass, area and root section and percentage of moisture of corn plants at different treatments. Small letters indicate significant differences between treatments ($p \leq 0.5$).

significant differences between the treatments with different concentrations of diesel, this result could be due to the fact that the The presence of hydrocarbons in soils inhibits seed germination and limits growth and therefore the accumulation of plant biomass (Adam and Duncan, 2002; Ogbo, 2009) due to the fact that plants experience a physiological drought caused by the limited absorption of water and impaired gas exchange (Omosun et al., 2009) (Table 2). A decrease in aerial humidity biomass of up to 74% is observed comparing the control treatment against the treatment with the highest concentration (C8). On the other hand, aerial and root dry biomass did not show statistically significant differences between treatments.

CONCLUSIONS

Under controlled conditions in the laboratory, it was observed that the presence of diesel in the soil negatively affects *Zea mayz* in its early stages of development causing a decrease in plant height, leaf area, main root length and biomass.

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