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SUNFLOWER BIOMASS DISTRIBUTION AND SEED YIELD IN SALINE SOIL OF MEXICO HIGHLANDS

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SUMMARY

Soil salinity is a worldwide problem. The aim of this study was to evaluate biomass production and partition in the organs of sunflower under a gradient of salinity in the soil. The Victoria sunflower was sown on 15 June 2007 at a density of 100,000 plants ha^{-1} in Montecillo Mex. (19° N, 48° W and 2,400 m). The area has an arid climate (less dry), an annual rainfall of 558.5 mm, and an average temperature of 14.6°C. Based on soil analysis, three areas were used as the treatments, each having 4 replicates. These were: high salinity (EC 11 dS m^{-1}, HS), medium salinity (EC 7 dS m^{-1}, MS), and low salinity (EC 5 dS m^{-1}, HS). Crop emergence occurred eight days after sowing (DAS), anthesis (R5) 80 DAS, and physiological maturity (R9) 130 DAS. Dry matter accumulation (%) in plant organs, total biomass, yield and survival all decreased with increasing salinity, whereas DM distribution did not. The highest biomass, yield and survival were found in the LS treatment (1055, 102 g m^{-2}, and 100%), while the lowest values of these parameters were recorded in the area with HS (312, 29 g m^{-2}, and 60%), respectively. The greatest dry matter accumulation was observed in the stem, followed by the receptacle, seeds and leaves. The harvest index and the filled capitulum index were not affected by salinity. In conclusion, biomass accumulation, yield and survival of sunflower decreased with increasing soil salinity. The phenology and biomass distribution in the plant organs were not affected by salinity.

Key words: ***Helianthus annuus* L., phenology, climate elements, dry matter, distribution, harvest index**

INTRODUCTION

Salinity is one of the main factors limiting world crop production (Tanji, 1990). In Mexico, this problem occurs in arid irrigated areas on the coast and in closed basins, as is the case of Lake Texcoco, which covers an area of 26,760 ha (Fernández, 1990). Thus, studies on the knowledge of the physiological variables affected by salinity could provide a guideline for developing strategies that lead to a reduc-

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tion of the damage caused by this factor. Salinity inhibits plant growth due to water deficit, ion toxicity, nutritional imbalance or a combination of these factors (Cramer and Bowman, 1984). The effect manifests itself in the inhibition of leaf expansion and biomass production (Leidi *et al.*, 1991). Argentel *et al.* (2008) suggest that the magnitude of the effect of salinity depends on the phenological stage in which it occurs. In wheat the flowering stage is the most sensitive. Seed number is the yield component most affected by salinity. In contrast, Villa-Castorena *et al.* (2006) report that in pepper (*Capsicum annuum* L.) early growth stages are more sensitive. To increase crop production in saline regions, a number of strategies have been proposed, one of which is the use of salt tolerant species. This has led physiologists to focus their studies on trying to understand the mechanisms that determine the difference between cultivars tolerant and sensitive to this factor (Epstein, 1985). When sunflower (*Helianthus annuus* L.) considered tolerant of salinity (Maas, 1990) was grown in a hydroponic system, the growth and transpiration rate decreased with salinity (Escalante, 1995). Also, Slama and Bouzaidi (1978) have shown that electrical conductivity of 3.7 to 5.1 mmhos cm^{-1} reduces the height of sunflowers but not seed yields. Studies on biomass distribution in plant organs and the yield of sunflower in saline soils are limited, although recent studies have reported a very variable yield possibly due to the mosaic of salt content in soil (Escalante and Rodriguez, 1998). The aim of this study was to determine the effect of soil salinity on sunflower phenology and biomass production, accumulation and distribution in plant organs and seed yield.

MATERIALS AND METHODS

The study was carried out in Montecillo, Mexico (19° N, 48° W, 2,400 m altitude) in an area measuring approximately 1.5 ha. The soil at the site is saline-sodium (Huez *et al.*, 1989) as a mosaic with variable soil characteristics. The climate is BS1 (semiarid, mean annual of rainfall 558.5 mm, and a temperature of 14.6°C). The vegetation is mainly halophytic salt grass (*Distichlis spicata* L.) and "romerito" (*Suaeda nigra* L.) (Gutierrez and Ortiz, 1999). Some areas have been improved for agriculture through washes and manure applications among other things. Rainfed agriculture and irrigation on a smaller scale are used to grow maize, alone or in association with beans and squash. The yields are low, but the advantage is getting a crop in infertile soil (Fernandez, 1990). Victoria sunflower was sown on 15 June 2007 at a density of 100,000 plants ha^{-1} with 100–100–0 NPK. Based on soil analysis (six samples taken from each replicate before planting at 30 cm depth), three areas measuring 100 m^2 each were selected. The areas had the following characteristics:

a) low salinity (pH 7.3, EC 5 dS m^{-1}, Na^+ exchangeable 1.6 cmol kg^{-1}),
b) medium salinity (pH 7.8, EC 7 dS m^{-1}, Na^+ interchangeable 3.0 cmol kg^{-1}) and
c) high salinity (pH 8, EC 11 dS m^{-1}, Na^+ interchangeable 9.5 cmol kg^{-1}).

Hereafter, the areas will be referred to as LS, MS and HS, respectively. Each area was subdivided into 4 plots (replicates) of 25 m^2 each. A section of each plot, 4 m^2 in size, was used to record the phenology of the crop (Schneiter and Miller, 1981). The plants were harvested to evaluate: survival rate (%) (number of emerged plants/population density × 100), yield (dry seed weight, g m^{-2}), total biomass (dry weight, g m^{-2}), DM accumulation (g m^{-2}) and distribution (%) in plant organs, and the filled capitulum index (FCI, (seed DM/receptacle DM)×100). Analysis of variance by SAS was applied to these variables. Monthly mean maximum temperature (T max), monthly mean minimum temperature (T min), photosynthetic active radiation (PAR, monthly mean), monthly amount of rainfall (PP), and monthly amount of evaporation (Evap) were also recorded.

RESULTS AND DISCUSSION

Phenology and climate elements

At all salinity levels, sunflower phenological stages happened at a similar time. From the elements of climate presented in Table 1, we can see that the highest T max value (30°C) was recorded during crop emergence (VE, 8 days after planting, DAP) along with a T min value of 9.2°C, an RFA mean of 8.8 MJ m^{-2} day^{-1}, and 102 mm and 131 mm of PP and Evap, respectively.

Table 1: Monthly mean maximum and minimum temperatures (°C), photosynthetic active radiation (PAR), and monthly rainfall (PP, mm) and evaporation (Evap, mm) during development of sunflower (*Helianthus annuus* L.). Montecillo, Mex. 2007

Month	T max (°C)	T min (°C)	PAR	PP (mm)	Evap (mm)
			MJ $m^{-2}day^{-1}$		
June	30.0	9.2	8.8	102	131
July	28.0	9.2	8.5	125	104
August	28.0	8.9	8.6	78	131
September	26.0	9.7	7.3	141	102
October	28.2	5.4	8.7	25	121
Mean	28.5	8.1	8.5	Σ 482	Σ 768

At the beginning of anthesis (R5, 80 DAP) these values were lower (28°C T max, T min 8.9°C, RFA 8.6 MJ m^{-2} day^{-1}, PP 78 mm), while evaporation was similar (131 mm). From R5 to R9, or physiological maturity (reproductive stage of 50 days duration), and especially at the final stage of seed filling, there was a decrease in T min to 5.4°C, with PP at 25 mm and Evap at 121 mm. This temperature can be considered within the appropriate range for sunflower development (Vranceanu, 1977; Macchia *et al.*, 1985). The PAR values were close to those reported by Rawson *et al.* (1984) with 9.5 MJ m^{-2} day^{-1} for the start of the reproductive stage (R1, Schneiter and Miller, 1981), which in this case was 32 DAS. Moreover, during most of the period of growth, the sunflowers were under severe water stress, since evaporation exceeded rainfall (Table 1), thus limiting the production of biomass and yield (Table 2).

Biomass, yield and survival

Biomass, yield and survival of sunflower decreased in relation to salinity. The highest biomass production, yield and survival were obtained in the LS treatment (5 dS m^{-1}) with 1055 g m^{-2}, 102 g m^{-2} and 100%, followed by MS (7 dS m^{-1}) with 750 g m^{-2}, 63 g m^{-2} and 90% and HS (11 dS m^{-1}) with 311 g m^{-2}, 29 g m^{-2} and 62% (Table 2). The biomass production and yield variability was related to changes in population density and survival generated by soil salinity. This suggests that besides of low population density, the effect of "mitigating" or reduction of damage by salinity that it happens in dense populations is lowest (Francois, 1982). Finally, given the highest yield (1055 g m^{-2}) and the amount of available rainfall (482 mm) for crop growth, the obtained yield is located in the category "favorable" for production in no saline soils (Ortegon *et al.*, 1993).

Table 2: Biomass (g m^{-2}) and its distribution in the organs of sunflower (*Helianthus annuus* L.) as a function of salinity. Montecillo, Mex. Summer 2007

Salinity	Stem (g m^{-2})	Leaves (g m^{-2})	Receptacle (g m^{-2})	Seed (g m^{-2})	Total (g m^{-2})
Low	594 a	99 a	260 a	102 a	1055 a
Medium	440 ab	78 b	170 b	63 b	750 ab
High	164 c	39 c	80 c	29 c	311 c
Mean	399	72	170	65	705
Prob.F	*	*	**	**	**
Tukey 5%	332	20	85	31	464

*,** P>0.01, 0.05, respectively

Table 3: Survival (SOB, %), harvest index (%) and filled capitulum index (FCI,%) of sunflower (*Helianthus annuus* L.) as a function of salinity. Montecillo, Mex. Summer 2007

Salinity	SOB (%)	Harvest index (%)	FCI (%)
Low	100 a	10	41
Medium	92 a	10	39
High	60 a	10	38
Mean	84	10	39
Prob.F	*	NS	NS
Tukey 5%	18	---	---

*,** P>0.01, 0.05, respectively; NS - no significant differences (P>0.05)

Biomass accumulation and distribution in the organs of sunflower

In Table 2, which presents DM accumulation in sunflower organs, it can be observed that this parameter decreased with increasing salinity. This accumulation was greater in the stem, followed by receptacle, leaves, and seeds (yield). In contrast, in the case of DM distribution (%), no significant changes were observed. Mean distribution was 56%, 25%, 10% and 9% for stem, receptacle, leaves and seeds (yield), respectively, with the last figure representing the harvest index. A similar trend was observed for the filling capitulum index (Table 3). These trends are similar to those generated by other kinds of stress such as nitrogen deficiency or high intraspecific competition caused by dense populations (Vega *et al.*, 2001), suggesting that DM accumulation in plant organs is mainly determined by changes in the environment and that DM distribution is determined by the genotype and, to a smaller degree, by changes in the environment. Moreover, harvest index values observed under salinity are lower than those reported under other stress conditions such as the ones mentioned above.

CONCLUSIONS

Biomass accumulation in the organs, yield and survival of sunflower decreased with increasing salinity. The phenology and biomass distribution in sunflower plant organs are not affected by salinity.

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DISTRIBUCION DE BIOMASA Y RENDIMIENTO DE GIRASOL EN SUELOS SALINOS DEL ALTIPLANO DE MEXICO

RESUMEN

La salinidad del suelo es un problema mundial. El objetivo de este estudio fue evaluar la producción de biomasa y la partición en los órganos de girasol en un gradiente de salinidad. El girasol cultivar Victoria se sembró el 15 de junio de 2007, a la densidad de 100 mil plantas ha^{-1} en Montecillo Méx. (19° N, 48° W y 2.400 m), de clima árido (el menos seco), con precipitación anual de 558,5 mm y temperatura media de 14,6°C. Los tratamientos de salinidad fueron: alta (CE 11 dS m^{-1}, HS), media (CE 7 dS m^{-1}, MS) y baja (CE 5 dS m^{-1},LS) con 4 repeticiones. La emergencia del cultivo ocurrió a los 8 días de la siembra (DAS), la antesis (R5) a 80 DAS y la madurez fisiológica (R9) a 130 DAS. En los órganos de la planta, la acumulación de materia seca (AMS), pero no la distribución (%), la biomasa total, el rendimiento y la supervivencia disminuyeron con la salinidad. La mayor biomasa, rendimiento y sobrevivencia fue de 1.055 y 102 g m^{-2} y 100% en LS, y el más bajo de 312 y 29 g m^{-2} y 60% en HS, respectivamente. La mayor AMS se observó en tallo, seguido del receptáculo, semillas y hojas. El índice de cosecha y el índice de capítulo no mostraron cambios. En conclusión, la acumulación de biomasa, rendimiento y sobrevivencia de girasol son afectados por la salinidad. La fenología y distribución de biomasa en los órganos de girasol no son afectados.

DISTRIBUTION BIOMASSE ET RENDEMENT DE TOURNESOL DANS DES SOLS SALINS DU PLATEAU DU MEXIQUE

RÉSUMÉ

La salinité des sols est un problème mondial. L'objectif de cette étude était d'évaluer la production de biomasse et la partition dans les organes de tournesol dans un gradient de salinité. Le cultivar de tournesol a été semé Victoria le 15 Juin 2007, la densité de plantes 100 mille ha-^{1} dans Montecillo, Mex. (19° N, 48° W et 2400 m), du climat aride (moins sèche), avec une pluviométrie annuelle de 558,5 mm et la température moyenne de 14,6°C. Salinité traitements étaient les suivants: élevé (CE 11 dS m^{-1}, SH), moyen (CE 7 dS m^{-1}, MS) et faible (CE 5 dS m^{-1}, LS) avec 4 répétitions. La levée se produit à 8 jours après le semis (DAS), l'anthèse (R5) à 80 DAS et la maturité physiologique (R9) à 130 DAS. Dans les organes de la plante accumulation de matière sèche (AMS), mais pas la distribution (%), la biomasse totale, le rendement et la diminution de la survie avec la salinité. Le plus grand rendement de la biomasse et de la survie a été de 1055 et 102 g m^{-2} et 100% en LS, et le plus bas de 312 et 29 g m^{-2} et 60% en SH, respectivement. La plupart des AMS a été observée dans les cellules souches, suivi par le récipient, les graines et les feuilles. L'indice de récolte et de l'indice chapitre a montré aucun changement. En conclusion, l'accumulation de la biomasse, le rendement du tournesol et la survie sont affectés par la salinité. La phénologie et la distribution de la biomasse dans les organes de tournesol ne sont pas affectés.