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Response of five eco-physiological parameters, to the application of potassium in sunflower (Asteraceae), under semi-arid climate

Respuesta de cinco parámetros ecofisiológicos, a la aplicación de potasio en girasol (Asteraceae), bajo clima semiárido

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Abstract

In order to know the effect of three levels of potassium on five eco-physiological parameters in sunflower, open-pollinated achenes Victory cultivar, were sown at a density of 11.08 plants m^{-2} with a fertilization of 100N-50P kg ha^{-1} N=nitrogen, P= phosphorous, K= potassium. Traits evaluated were: agronomic yield, leaf area index, light attenuation coefficient and intercepted radiation. The treatments consisted of three potassium levels: 0, 50 and 100 kg ha^{-1} (K_2O) and four repetitions (3x4) resulting in 12 experimental units, which were evaluated under a randomized complete block design. The results indicate that the application of 50 and 100 kg ha^{-1} of potassium increase the agronomic yield, leaf area index, intercepted radiation as well as the light attenuation coefficient. From this investigation it can be concluded, that potassium is a very important nutrient for sunflower when it is sown in dry climates such as the Tehuacan valley, Puebla.

Key words: *Agronomic yield, light attenuation coefficient, solar radiation.*

Resumen

Con el objetivo de conocer el efecto de tres niveles de potasio, sobre cinco parámetros ecofisiológicos en girasol, aquenios de polinización libre del cultivar Victoria fueron sembrados a una densidad de 11.08 plantas m^{-2}, con una fertilización de 100-50 kg ha^{-1} de NP. Las características a evaluar: fueron rendimiento agronómico, índice de área foliar, coeficiente de atenuación de luz y radiación interceptada. Los tratamientos consistieron de tres niveles de potasio: 0, 50 y 100 kg ha^{-1} (K_2O) y cuatro repeticiones (3x4)=12 unidades experimentales, los cuales fueron evaluados bajo un diseño de bloques completos al azar. Los resultados indican que la aplicación de 50 y 100 kg ha^{-1} de potasio, incrementan el rendimiento agronómico, índice de área foliar, radiación interceptada así como el coeficiente de atenuación de luz. De esta investigación se puede concluir, que el potasio es un nutrimento de suma importancia para el girasol cuando es sembrado en climas secos como del valle de Tehuacán, Puebla.

Palabras clave: *Rendimiento agronómico, coeficiente de atenuación de luz, radiación solar.*

Introduction

Sunflower (*Helianthus annuus* L.), is an oilseed plant that belongs to the Asteraceae family (Redonda & Villaseñor, 2011). For many years it has been subject to the extraction of fatty acids, for human consumption and industrial use, due to the high quality of the oil extracted from its achenes. This cultivation plant is currently used as an ornamental, due to the large range of shades of its flowers linked to the newly created hybrids, although free-pollinated materials can also be exploited as ornamentals (Ávila, 2009). Among other uses, sunflower can be cited as livestock feed, in arid and semi-arid areas of northern Mexico. For instance, it is important to carry out studies of this species in arid and semi-arid areas, such as the Tehuacán Valley, in the state of Puebla, where it can be a viable alternative to obtain foreign

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exchange, and thus, become an option to monoculture corn. In relation to potassium, this together with nitrogen and phosphorus, are considered as indispensable macro-elements in plant nutrition, due to the high amounts that crops require. Thus, under this trend, potassium is involved in physiological processes of great importance in plants, among them we can mention: stomatal opening and closing Mejía et al. (2008), as well as in nautical movements such as thigmotropism, which present some species like *Mimosa pudica* L. (Salisbury & Ross, 1998). Another aspect of great importance in which potassium intervenes, is directly in the cellular water balance, maintaining the turgidity of the protoplasm and, consequently, it has a very important role in the postharvest quality of fruits and flowers, as well as the structural component of the sclerenchematic system, so it avoids stemming in crops such as corn (Maya & Ramírez, 2002). Despite the previous arguments about this nutrient, in Mexico the importance that this element deserves in plant nutrition of extensive crops has not been given. Thus, for the foregoing, the objective of the present investigation was: to evaluate the effect of three potassium levels, on five eco-physiological parameters in sunflower, when it is sown under a semi-arid climate. The hypothesis was: the application of high potassium levels will increase the leaf area index, intercepted radiation, as well as the sunflower's agronomic yield, when it is sown under arid weather conditions.

Materials and methods

The present investigation was carried out in the experimental field of the Universidad Tecnológica de Tehuacan, located at 18° 24´51´´ north latitude, 97° 20´ 00´´ west longitude and 1409 masl. The climate of the region is semi-arid whose family is: Bs_1eg, which corresponds to a semi-arid climate, whose annual average temperature is greater than 18 °C and less than 27 °C. The rainfall regime runs from May to September, with the total rainfall being greater than 400 and less than 600 mm. The temperature oscillation between the warmest month and the coldest month is greater than 7 °C and less than 14 °C, respectively. The warmest month, occurs before the summer solstice (García, 2005). The genetic material consisted of open pollinated sunflower achenes cv. Victory of, which were sown in beds 25 m long, 1.50 m wide and 0.25 m high. The topological arrangement was (0.30 x 0.30), resulting in a population density of 11.08 plants m^{-2}, distributed in three rows. The soil corresponds to an endoleptic lithosol, which is why the planting beds were made. To know the initial soil conditions, a composite sample was taken, the analysis data are presented in table 1.

The above parameters were carried out using the following methodology: pH, in water by the potentiometric method with a soil water ratio (1:2) (w/v); organic matter by the method of Walkley & Walk (2005); saturated bases, by extraction of ammonium acetate and neutral

Table 1. Physical and chemical properties of an endoleptic lithosol soil. Universidad Tecnológica de Tehuacán. Summer of 2017.

Physical properties		Chemical properties	
Apparent density	1.75 g cm^{-3}	Nitrogen	5.3 mg Kg^{-1} Kjeldahl
Texture	Clay-loam	Phosphorus	3.3 mg Kg^{-1} Olsen
colour		pH	7.5
Dry	10 YR 7/4	E. C.	4.5 dS m^{-1}
Damp	10 YR 4/4	Saturated bases cMol(+) kg^{-1}	
		Na^+	0.3
		K^+	0.8
		Ca^{++}	3.7
		Mg^{++}	0.9
		O. M.	1.5 %

E. C.: electric conductivity; O. M.: organic matter.

pH; texture, by means of the Bouyoucos hydrometer using sodium hexametaphosphate as dispersant (Loeza et al., 2016; Secretaría del Medio Ambiente y Recursos Naturales, 2000). The entire experiment was fertilized with 100 kg ha^{-1} of Nitrogen and 50 kg ha^{-1} of phosphorus, whose sources were urea (46% N) and triple calcium superphosphate (46% P_2O_5), applied at the time of planting respectively.

Weed control was carried out manually as they appeared within the crop. In the same way, as a preventive way to attack cutting worms and whiteflies, cypermethrin was applied at 30 days. The treatments consisted of three levels of potassium 0, 50 and 100 kg ha^{-1} whose source was potassium chloride (60% K_2O), applied at the time of planting and four replications (3x4), for a total of 12 experimental units. The treatments were evaluated under a randomized complete block design, using the mathematical model $Y_{ij} = \mu + T_i + \beta_j + \varepsilon_{ij}$ where: Y_{ij}, is the variable response of the i-th level of potassium in the j-th block; μ, is the true general mean; T_i, is the effect of the i-th level of potassium; β_j, is the effect of the j-th block and ε_{ij}, is the experimental error of the i-th level of potassium in the j-th block (Cochran & Cox, 2008). The experimental unit consists of three grooves, within which the central groove served as a useful plot. The response variables were: agronomic performance and total weight of three-chapter achenes with a PCE-LS model analytical balance. The corresponding means for each treatment were calculated. For the leaf area index, destructive sampling was performed at 30, 60, 90 and 120 days after sowing (das), to obtain the values and use the equation LAI = ((LA) (PD)) / 10000 where: LAI, is the leaf area index; LA, leaf area determined by the ratio LA = (L) (W) (0.70), so LA, is the leaf area in centimeters; L and W, are the length and width of the true leaf, respectively (Díaz et al., 2015; Escalante & Kohashi, 1993); is the population density. Radiation intercepted, measured directly from the culture, with the help of an AccuPAR LP-80 model ceptometer (Díaz et al., 2013). Light attenuation coefficient, determined by Beer's law

F = 1-exp (-KLAI), where: F, is the radiation intercepted in percentage; K, is the light attenuation coefficient and LAI, is the leaf area index (Morales et al., 2014; Díaz et al, 2011). Evaporation was calculated with the help of an "A" type tank evaporimeter to express the results in mm. When the response variables are significant, the Tukey multiple comparison test (P≤0.05) was applied, using the SAS Proc glm statistical package (SAS Institute, 2004).

Results and discussion

The agronomic yield presented significant differences, so the treatments where 50 and 100 kg ha^{-1} of potassium were applied, exceeded the control with 41.11 and 46.05 g plant^{-1} respectively. In relation to control, this just presented, 33.12 g plant^{-1}, that is, 19.43% lower yield than the treatment with the application of 50 kg ha^{-1} of potassium and 28.07% less than the application of 100 Kg of potassium (Figure 1). These results differ with those reported by (Maya & Ramírez, 2002), who mention that the application of 0, 120 and 240 kg ha^{-1} of potassium in the crop of corn, had no significant effect on grain yield, when applying, high doses of potassium. This difference might be caused by the different species used in their study compared to our study. In addition, the phenotypic plasticity for the absorption of nutrients such as potassium, due to the large radical system that sunflower presents and its ability to absorb alkali metals such as potassium (Escalante et al., 2017; Díaz et al., 2017) might be causing a different response.

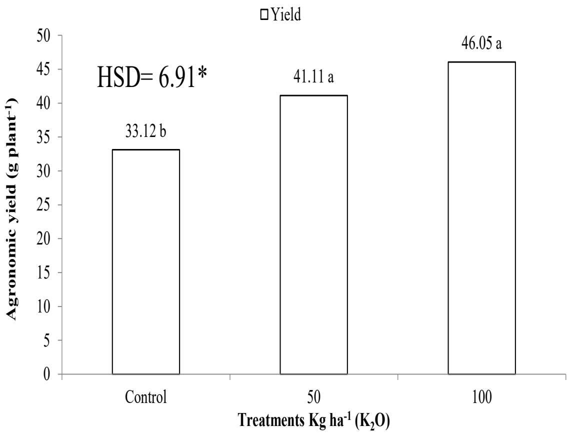

Figure 1. Sunflower agronomic yield (*Helianthus annuus* L.), under three levels of potassium. Universidad Tecnológica de Tehuacán. Summer, 2017. HSD, honest significant difference.

The leaf area index for all treatments, was adjusted to a third-grade model, with a high coefficient of determination 0.99 and highly significant (*P≤0.05*), which indicates that 99 % of the LAI, is a function of the days after planting. The treatments in question indicate an average increases between 30 and 90 days and then decrease due to the senescence of the leaves at 120 days. It is evident that the application of potassium in 50 and 100 kg ha^{-1}, produced a positive effect on the LAI, increasing this ecophysiological index compared to the control (Figure 2). This behavior has been corroborated by Aguilar et al. (2005), Shipley (2002) who report that the LAI in sunflower at 90 das, reaches its maximum expansion, and then decreases, due to the abscission of leaves at a density of 7.5 plants m^{-2}, coinciding with the present investigation under a similar climate.

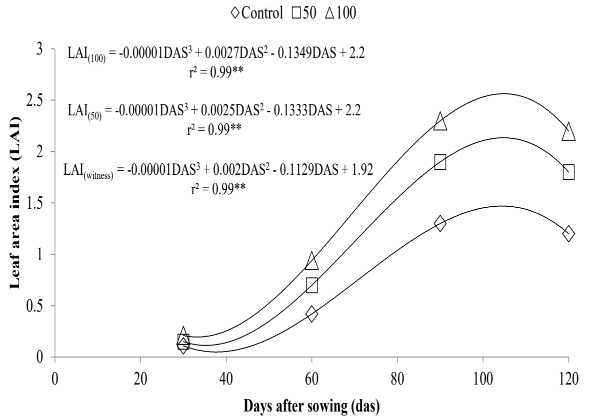

Figure 2. Dynamics of the sunflower leaf area index (*Helianthus annuus* L.) at 30, 60, 90 and 120 das, under three levels of potassium. Universidad Tecnológica de Tehuacán. Summer, 2017.

The radiation intercepted by the culture was adjusted to logarithmic models in all treatments (Figure 3). It can be seen that the coefficient of determination was highly significant for all treatments. Thus, the highest amount of intercepted radiation was for treatments 50 and 100 kg ha^{-1} of potassium, with 80 and 83% of intercepted radiation, while the control only reached 75% of radiation. This greater amount of radiation was reached at 120 das. This response has been corroborated by Díaz et al. (2010), who worked with a combined sunflower-bean agro-ecosystem and mentioned that when the sunflower inflorescence is cut, the system only intercepts 80% of the radiation, thus coinciding with the present study.

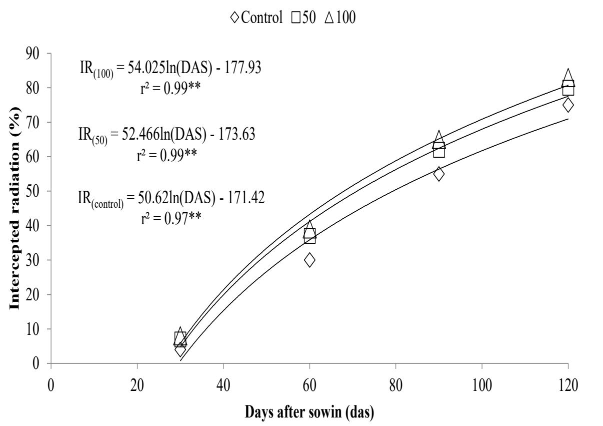

Figure 3. Radiation intercepted by sunflower (*Helianthus annuus* L.), as a function of three levels of potassium 0, 50 and 100 Kg ha^{-1}. Universidad Tecnológica de Tehuacán. Summer, 2017. das, days after sowing.

Regarding the light extinction coefficient, the adjustment models K *vs* time (days), in all cases they were adjusted to quadratic models, with highly significant determination coefficients for 50 and 100 kg ha^{-1} of potassium, while the control it only presented a significant coefficient of determination. Under this tenor, the values of potassium for 50 and 100 kg ha^{-1} of potassium, ranged between 0.47 and 0.70 at the beginning and end of the ontogenic cycle, indicating that only 53% of the intercepted radiation passed to the lower stratum of the canopy, while at the end of the crop cycle, only 30% managed to reach the lower stratum (figure 4). This result might be explained by an increase in the index of foliar area of the crop that produces a greater interception of the light favoring a greater amount of radiation intercepted by the upper canopy and allowing to pass only a small fraction of radiation (Díaz et al., 2010; Rodríguez et al., 2004) .

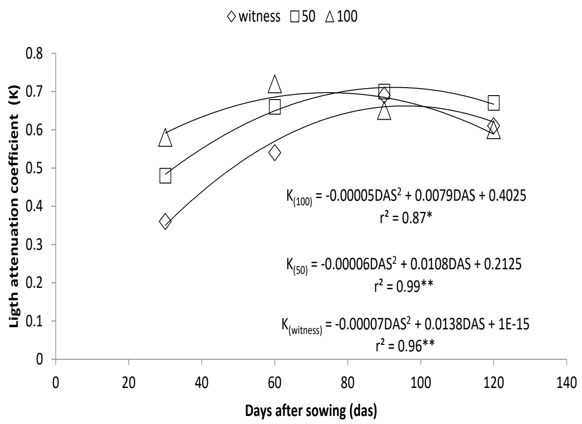

Figure 4. Light attenuation coefficient (K), in sunflower (*Helianthus annuus* L.) under three potassium levels at 30, 60, 90 and 120 days after sowing. Universidad Tecnológica de Tehuacán. Summer, 2017. DAS, days after sowing.

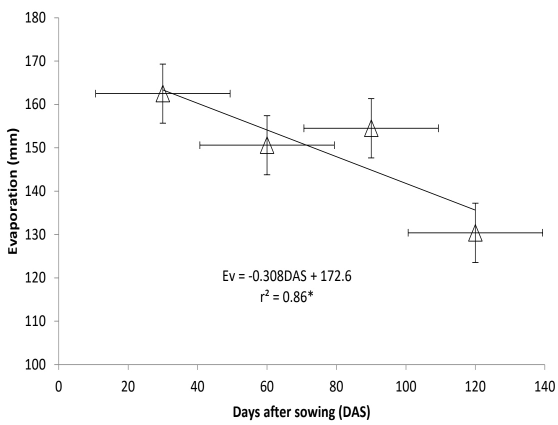

Figure 5. Evaporation of water during the sunflower cultivation cycle (*Helianthus annuus* L.), at 30, 60, 90 and 120 das. Universidad Tecnológica de Tehuacán. Summer, 2017.

The total accumulated evaporation of the culture, during its ontogenic cycle was 598 mm, of which the greatest evaporation occurred at 30 das, with 162.5 mm, to subsequently decrease progressively at 120 das with 130.4 mm. This evaporation behavior is explained by the foliar area index, because when it increases, it intercepts a greater amount of radiation, preventing it from reaching the ground, and per se prevents soil water from evaporating (Figure 5). Thus, the adjustment model for this variable was linear, with a significant coefficient of determination. The negative slope of the model indicates that evaporation decreases by 0.308 mm every day of the crop cycle.

Conclusions

The main conclusions of our study were: i) the highest index of foliar area and intercepted radiation were obtained with the high level of potassium; ii) similarly, the highest agronomic yield was obtained with the application of 100 kg ha^{-1} of potassium; iii) the greatest extinction of light caused by the vegetable canopy was presented with the application of potassium at levels of 50 and 100 kg ha^{-1}; and the ontogenetic development of the crop increased the canopy causing a decrease of the evaporation of the crop as it reached physiological maturity; iv) potassium is an essential nutrient for the growth and yield of sunflower; v) This study shows that fertilization with potassium is necessary for the crop of sunflower, when it is planted in the valley of Tehuacan, Puebla.

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