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INFLUENCE OF DIFFERENT AMBIENT CONCENTRATIONS OF SULPHATE ION ON THE PARTITIONING OF SULPHUR AND GROWTH OF ROOT, STEM AND LEAVES OF SUNFLOWER

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SUMMARY

Sunflower plants (*Helianthus annuus* L. cv. NK-265) were grown hydroponically in half strength Hoagland nutrient solution (pH 5.7) to study the response of plant parts to graded levels of S (0, 10, 20, 30, 40 and 50 $\mu g\ ml^{-1}$) in triplicate. Twelve-day old seedlings were transplanted. The harvests took place on the 29th and 36th day after transplanting. After harvesting, plant parts were separated into leaf, stem and root. Plant parts were dried in an oven at 70±2°C after recording fresh weight. The samples were digested in HNO_3 and $HClO_4$ and S was estimated. The application of 20 μg S ml^{-1} significantly increased the root and shoot length. The relative growth rate (RGR) of plants grown in 20 μg S ml^{-1} was 0.26 mg mg^{-1} day^{-1} as compared with 0.188 mg mg^{-1} day^{-1} in case of the control. Similarly sulphur was much more efficiently used by plants grown in 20 μg S ml^{-1} than in the other treatments. Sulphur uptake in developing leaves (DL), expanded leaves (EL) and old leaves (OL) was curvilinearly correlated with the S applied. Sulphur uptake was increased by 40 and 480%, in DL and EL, respectively, when plants were grown in 20 μg S ml^{-1}. As the S application increased beyond 20 μg ml^{-1}, the uptake declined. Developing, older and expanded leaves responded clearly to the applied S. Roots acted as a supplier from the source to sink, stem responded lesser than leaves. As the metabolic activities are higher in expanded leaves, they showed a clear response.

Key words: Sunflower, sulphur nutrition, plant growth.

INTRODUCTION

The production of edible oil is insufficient to meet the domestic consumption requirements of constantly growing population of the country. The unpredictable and continuous rise in inputs is adding to the capital investment of a farmer who, like ever, as a successful enterpreneur, struggles for a wider ratio of output to input. Therefore, an accurate and judicious use of fertilizers as per plant growth requirement is desired.

Sunflower is an important non-conventional oilseed crop. Its requirement for nutrients at different growth stages are not known under local conditions. Sulphur is an essential plant nutrient which plays an important role in protein synthesis. Its requirement for several crops is as high as that for phosphorus (Dixit and Shukla, 1984; Bapat *et al.*, 1986; Uexkull, 1988). Hence, requirements of sunflower at seed development stage may increase. Sulphur enters through the root system of a plant in the form of SO_4 (Bardsley, 1960). The response of different vegetative parts of sunflower may be differential to various concentrations of this particular ion in the root medium. Its uptake may be active or passive depending upon the prevailing conditions of the root system. Investigations show that sulphur levels increase with age in some plants but decrease in others (Eaton, 1966). A study was conducted to record the response of different vegetative parts of sunflower to various concentrations of SO_4^{2-} in the root medium and the results are presented in this publication.

MATERIALS AND METHODS

Seeds of *Helianthus annuus* L. (NK-265) were germinated in nutrient free quartz sand. Twelve-day old seedlings were transplanted into plastic pots containing 2 litre of half strength Hoagland's nutrient solution adjusted to pH 5.7. After two days the pots received sulphur as ammonium sulphate at the concentrations: 0, 10, 20, 30, 40 and 50 $\mu g\ ml^{-1}$, in triplicate. The temperature was maintained at 30±2°C. Nutrient solutions were changed weekly. The harvests took place on the 29th and 36th day after transplanting. In each harvest, the plants were separated into leaf, stem and roots. After recording their fresh weight they were dried in an oven at 70±2°C. Relative growth rate (RGR) was calculated (Hunt, 1978):

$$\text{RGR (mg mg}^{-1}\text{ day}^{-1}) = \frac{\ln W_2 - \ln W_1}{T_2 - T_1}$$

where W_1 and W_2 were total dry weight of plants at harvest time T_1 and T_2, respectively. Specific absorption rate of S (Is) per unit of root dry weight ($\mu mol\ g^{-1}\ day^{-1}$) was calculated by Hunt (1978):

$$\text{Is} = \frac{S_2 - S_1}{T_2 - T_1} \times \frac{\ln RW_2 - \ln RW_1}{RW_2 - RW_1}$$

where S_1 and S_2 were total S content of plants and RW_1 and RW_2 were root dry weight at harvest time T_1 and T_2. Efficiency of S utilization (g dry matter produced μmol^{-1} S day^{-1}) by sunflower was determined by calculating specific utilization rate (Us) of S according to Hunt (1978):

$$US = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{\ln S_2 - \ln S_1}{S_2 - S_1}$$

where W, S and T were the same as above.

Dried samples were weighed and digested with HNO_3 and $HClO_4$. Sulphur in the digest was estimated according to Verma (1981). The results were statistically analyzed according to Gomez and Gomez (1976).

RESULTS AND DISCUSSION

An increase in length of root and shoot remained a function of time and it was strengthened by the application of S at different concentrations. Comparing control at 20 μg S ml^{-1}, the increase in root and shoot length was 85 and 36%, respectively. The ascending order of S application effect on the root and shoot length was 0<10<50<30<40<20 (Table 1).

Table 1: Effect of different levels of SO_4 on the root and shoot length of sunflower

SO_4 applied (ppm)	H_1	H_2	Total	SO_4 applied (ppm)	H_1	H_2	Total
	Root (cm)				Shoot (cm)		
0	16.0	26.9	42.9	0	30.3	43.3	73.6
10	23.1	35.3	58.4	10	31.4	57.3	88.7
20	27.3	52.2	79.5	20	40.2	60.5	100.7
30	24.1	39.6	63.7	30	35.5	57.8	93.3
40	23.5	40.5	64.0	40	36.4	58.8	95.2
50	23.2	37.5	60.7	50	33.2	57.6	90.8
LSD	7.81	17.67		LSD	3.94	8.05	

Table 2: Effect of different levels of SO_4 on leaf and stem fresh weight of sunflower

SO_4 applied (ppm)	H_1	H_2	Total	SO_4 applied (ppm)	H_1	H_2	Total
	Leaf (mg/plant)				Stem (mg/plant)		
0	2176.3	5257.9	7434.2	0	1745.2	5617.1	7362.3
10	4243.9	18304.7	52548.6	10	3101.0	16907.5	20008.5
20	5701.3	23620.6	51870.5	20	3293.8	19665.9	22959.7
30	4882.1	15847.2	20729.3	30	2949.3	18225.7	21175.0
40	4541.9	20922.1	25464.0	40	2804.5	20504.8	23309.3
50	4511.5	18441.0	22952.5	50	2646.9	18896.4	21543.3
LSD	1698	7679		LSD	2520	8750	

Sulphur application increased the fresh weight of leaves. The fresh weight was 245% higher when plants were supplied with 20 μg S ml^{-1} as compared with the control. Sulphur application also increased the fresh weight of stem. The stem fresh weight was 211% higher when plants were grown in 20 μg S ml^{-1} as compared with the control.

DMY of stem and root also responded to the SO_4 application. In both cases, it was optimum at 20 μg S ml^{-1}. In stem, the ascending order was 0<30<50<40 <10<20 and in root the ascending pattern was 0<50<30< 40<10<20 (Table 3). Relative growth rate (RGR) was calculated by considering total dry weight at harvest T_1 and T_2. The RGR of plants grown in 20 μg S ml^{-1} was highest. It was 0.26 mg mg^{-1} day^{-1} as compared with 0.188 mg mg^{-1} day^{-1} in case of the control (Table 4). The ascending pattern is 0<50<10<30<40<20. Dry matter yield was also increased with the increasing concentrations of SO_4 and it was more prominent in the case of leaf. As compared with the control, it was increased by 134.6% when plants were fed with 20 μg S ml^{-1}. Dry matter yield of root remained the same at all levels of S application (Figure 1).

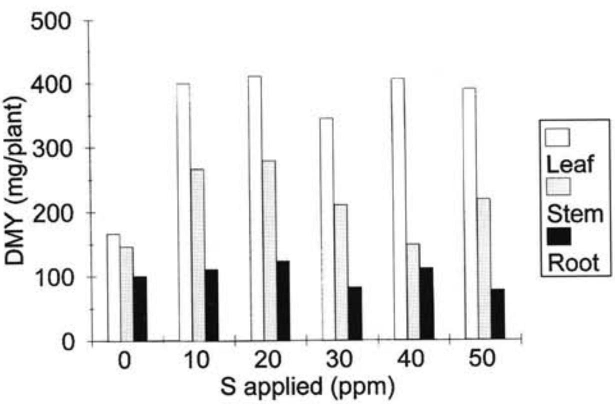

Figure 1. Dry matter yield different plant parts of sunflower supplied with different sulphur concentratios

Leaf growth showed variable response to the S application. The leaves according to the growth stages were classified into old, expanded and developing ones. Leaf growth was selective to the S applied. DMY of old leaves remained constant. Application of S did play a prominent role to increase DMY of the expanded leaves and it was more effective at 20 μg S ml^{-1} (Figure 2). The growth of expanded and developing leaves was in function of time also. In the 4^{th} and 5^{th} week it was increased 5 and 27 times, respectively. Developing leaves increased by 1.5 and 4.3 times in the 4^{th} and 5^{th} week of growth, respectively (Figure 3). In the 5^{th} week of plant growth, the expanded leaves increased 5 times as compared with the 4^{th} week while the growth of developing leaves increased 2.33 times.

Sulphur uptake in developing leaves (DL), expanded leaves (EL) and old leaves (OL) was curvilinearly correlated with the S applied. Up to 10 or 20 μg S ml^{-1} level, its uptake went up. At 20 μg S ml^{-1}, in DL and EL, S uptake was increased by 48 and 329 %, respectively. Its uptake in OL was increased at 20 μg S ml^{-1} applied. Then up till 50 μg S ml^{-1}, the S uptake declined by 22%. At 50 μg S ml^{-1}, in DL, the uptake was decreased by 25%.

Table 3: Effect of different levels of SO_4 on stem and root dry matter yield of sunflower

SO_4 applied (ppm)	H_1	H_2	Total	SO_4 applied (ppm)	H_1	H_2	Total
	Stem (mg/plant)				Root (mg/plant)		
0	110.3	429.0	539.3	0	47.0	225.0	272.0
10	114.7	904.3	1019.0	10	61.8	348.5	410.3
20	135.4	938.6	1074.0	20	77.3	370.0	447.3
30	117.7	628.7	746.4	30	58.4	322.1	380.5
40	106.6	847.7	954.3	40	48.0	341.7	389.7
50	105.0	725.9	830.9	50	46.4	278.5	324.9
LSD	16.8	94.6		LSD	33.78	147	

Table 4: Effect of different concentrations of S on relative growth rate (RGR) of plant, specific absorption rate of S (Is) and specific utilization rate (Us) of S

SO_4 applied (ppm)	RGR (mg mg^{-1} day^{-1})	Is (μg mg^{-1} day^{-1})	Us (μmol g^{-1} day^{-1})
0	0.188	4.03	29.62
10	0.194	6.76	27.27
20	0.26	9.33	20.82
30	0.225	1.71	27.95
40	0.23	1.09	47.11
50	0.19	0.38	67.38

The specific intake rates of S indicate that the maximum intake rate was observed when 20 μg S ml^{-1} were applied (9.33 mg mg^{-1} day^{-1}) and it was 1.31 times higher than the control (Table 3).

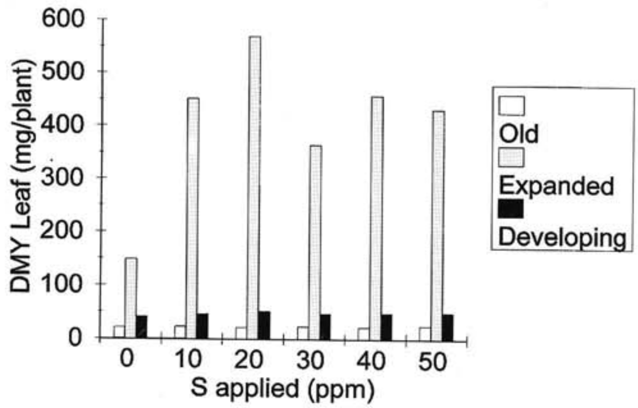

Figure 2. Dry matter yield of older, expanded and developing leaves of sunflower supplied with different sulphur concentrations

The specific intake rate increased up to the application of 20 μg S ml^{-1} and decreased when 30, 40 and 20 μg S ml^{-1} were applied (Table 4). Similarly, specific utilization of S is indicating that S was most efficiently used when plants were fed with 20 μg S ml^{-1} (20.82 μmol g^{-1} day^{-1}) as compared with the plants fed with 50 μg S ml^{-1} (67.38 μmol g^{-1} day^{-1}) (Table 4).

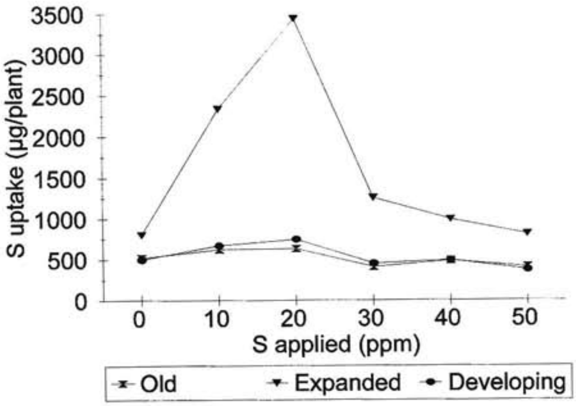

Figure 3. Sulphur uptake by older, expanded and developing laeves

The development of the vegetative parts of sunflower depends on a specific concentration of SO_4 applied. After completing a period when the 'intake' amount of the nutrient is consumed, the uptake process restarts for further differentiation and development. In this study in general, 10 to 20 ppm S were sufficient for maximum growth of leaf at particular growth stage of leaf for a specific concentration of SO_4 applied. This was based on the observation given by Loneragan (1968) that the minimum rate of intake of the nutrient with the maximum growth rate is a crop requirement for a specific crop. The plant parts of sunflower *i.e.* root, shoot and especially the leaf shared a specific response to the range of applied S. The root system showed similar response to the applied range and it acted as a supplier. Stem responded to a lesser extent than the leaf. Various development forms of the leaf were in function of time. As compared with OL and DL, EL required a larger amount of SO_4, but it was decreased with the passage of time and increasing rate of S application. Such observations have also been supported by Subbiah *et al.*, (1970), *i.e.*, a decrease in utilization of S with an increase in the level of applied S. The results show that DMY was increased with the growth time and to a particular range. S applied contributed to DL, OL and EL. A specific concentration of S applied worked at a particular stage of the leaf and its entry may not be based on mass flow.

It can be concluded from RGR, Is and Us that 20 μg S ml^{-1} is the best concentration for the optimum growth of sunflower.

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INFLUENCIA DE DISTINTAS CONDICIONES DE CONCENTRACION DEL IÓN SULFATO EN LA PARTICIÓN DE SULFURO Y CRECIMIENTO ENTRE RAIZ, TALLO Y HOJAS DE GIRASOL

RESUMEN

Plantas de girasol *Helianthus annuus* L. cv. NK-265 fueron cultivadas hidroponicamente en una solución Hoagland (pH 5.7) para estudiar la respuesta de partes de la planta a niveles crecientes de S (0, 10, 20, 30, 40 y 50 $\mu g\ ml^{-1}$) en triplicado. Plántulas con doce días fueron transplantadas. La cosecha se llevó a cabo en el día 29 y 36 despues del transplante. Despues de la cosecha las distintas partes de la planta fueron separadas en hojas, tallos y raices. Las partes fueron secadas en horno a 70.2 °C despues de medir el peso fresco. Las muestras fueron digeridas en HNO_3 y $HClO_4$ y el S fue estimado. La aplicación de 20 µg de S por ml^{-1} incrementó significativamente la longitud de la raiz y del tallo. La tasa de crecimiento relativo (RGR) de las plantas crecidas en 20 µg de S ml^{-1} fué de 0.26 mg mg^{-1} dia^{-1} comparada con 0.188 mg mg^{-1} dia^{-1} en el caso del control. Similarmente el azufre fué mucho mas eficientemente utilizado por plantas crecidas en 20 µg S ml^{-1} en comparación con otros tratamientos. La toma de sulfuro en hojas en desarrollo (DL), hojas expandidas (CL) y hojas viejas (OL) estuvo correlacionada curvilineamente con el azufre aplicado. La toma de azufre fué incrementada por 40 y 480 % respectivamente en DL y CL cuando las plantas fueron crecidas en 20 µg S ml^{-1}. Al incrementar la aplicación de S por encima de 20 µg ml^{-1} la asimilación decreció. Las hojas en desarrollo, viejas y expandidas, respondieron claramonte a la aplicación de S. Las hojas - actuaron como suplidores de la fuente al sumidero, el tallo respondió menos que las hojas. Conforme las actividades metabólicas son mas altas en las hojas expandidas, estas mostraron una clara respuesta.

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INFLUENCE DE DIFFÉRENTES CONCENTRATIONS EN IONS SULFATE SUR LA CROISSANCE ET LA RÉPARTITION DU SOUFRE DANS LES RACINES, LES FEUILLES ET LES TIGES DE TOURNESOL

RÉSUMÉ

Des plantes de tournesol (*Helianthus annuus* L. cv. NK-265) ont été cultivés en culture hydroponique avec une solution nutritive de Hoagland à demi-concentration, (pH 5.7) pour étudier la réponse des diverses fractions de la plante à différents niveaux de S (0, 10, 20, 30, 40 et 50 g ml^{-1}), en trois répétitions. De jeunes plantules âgées de 12 jours ont été repiquées et les récoltes faites le 29 et le 36 jour après le repiquage. Après récolte, les plantes sont fractionnées en feuilles, tiges et racines. Les diverses fractions sont séchées dans une étuve à 70.2°C après mesure du poids frais. Les échantillons sont digérés dans HNO_3 et $HClO_4$ puis S est estimé. L'application de 20 µg de S ml^{-1} augmente significativement la longueur des racines et des pousses feuillées. La croissance relative des plantes (RGR) dans 20 µg de S ml^{-1} était de 0.26 mg mg^{-1} $jour^{-1}$ par rapport à 0.188 mg mg^{-1} $jour^{-1}$ chez le témoin. De même le soufre a été utilisé plus efficacement par les plantes se développant dans 20 µg de S ml^{-1} comparativement aux autres traitements. Le prélèvement du soufre dans les feuilles en développement (DL), les feuilles étalées (EL) et les feuilles plus âgées (OL) était curvilinéairement lié au soufre appliqué. L'assimilation du soufre est augmentée de 40 à 480% respectivement dans DL et EL lorsque les plantes se développent dans 20 µg de S ml^{-1}. Lorsque la dose de soufre est augmentée au delà de 20 µg ml^{-1}, le prélèvement diminue. Les feuilles en cours de développement, plus âgées ou étalées répondent clairement au soufre appliqué. Les racines agissent comme "pourvoyeur" de la source vers le puits, la tige appliqué. Les racines agissent comme "pourvoyeur" de la souce vers le puits, la tige repondant moins que les feuilles. Comme les activités métaboliques sont plus élevées dans les feuilles étalées, elles traduisent une réponse évidente.