Role of Phosphorus (^{32}P) in Inducing Salt Tolerance in Sunflower

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1 Introduction

Salinisation of land is progressively increasing throughout the world (K o z l o w s k i, 1997). Excessive salt concentrations can transform fertile and productive lands to barren and often leads to habitat and reduction of bio-diversity (G h a s s e m i et al. 1995). It is estimated that about one third of the world's irrigated land and half of the lands in semi arid and coastal regions are affected by salinisation and about 10 million hectares of irrigated lands are abandoned annually because of excessive salinity (A b r o l et al. 1988 and R h o d e s and L o v e d a y, 1990).

One of the major approaches to control salinity has been to leach soluble salts from the soil profile by irrigation with high quality water. But this practice is no longer acceptable because of increased salt content in water bodies due to irrigation returns, rising water tables and limited water resources. One of the cost-effective strategies to cope with salinity involves the cropping of plants which have the inherent ability to tolerate a saline environment. But due to excessive spatial and temporal variations in the salt concentration, this attempt is relatively unsuccessful (H o l m, 1983). During the last years the possibility to mitigate salinity hazard by nutritional factors has been studied. Phosphorus nutrition has been implicated in modifying the effect of salinity upon growth of glycophytes (F e i g i n, 1985). Phosphorus/salinity interactions have been reported from an induced enhancement (A w a d et al., 1990 and M o r and M a n c h a n d a, 1992) to create antagonism (C e r d a et al., 1977 and C e r d a and B i n g h a m, 1978) while other studies report no interaction between phosphorus and salinity (T e r m a a t and M u n n s, 1986).

Much of the research quantifying the salt tolerance of plant species has been based on the experiments in which NaCl is the predominant salt. There has been comparatively little research examining plant responses to situations where sulphates of other salts including Ca and Mg dominate. In the few studies where plant responses to both Cl and SO_4-dominated salinity have been examined and compared, it has been found that degree of growth suppression differs according to which salt dominates and the species that is being studied (K h a n et al., 1995, and M a n c h a n d a et al., 1982). The objective of the present study was to evaluate phosphorus and salinity interaction in order to enhance salt tolerance of sunflower crop employing radio-tracer techniques.

2 Materials and methods

To achieve the desired objectives, a green house experiment was conducted on sandy soil. The bulk soil sample was air dried, passed through the 2 mm sieve and mixed thoroughly. The physico-chemical properties of the experimental soil were determined employing standard procedures (A n o n, 1968, and J a c k s o n, 1967) and are listed in **table 1**.

2.1 Preparation of saline soils

In order to achieve desired levels (SL: 4, 8 and 12 dSm^{-1}) and types (ST: $Cl:SO_4$ = 70:30 and 30:70) of salinity, calculated amounts (on equivalent basis) of Cl and SO_4 salts were added to the soil in Ca, Mg and Na form. At equilibrium the saturated extract was analysed for its salt content by measuring the electrical conductivity - EC_e (A n o n, 1968) and osmotic potential. The total amounts of the salts added and exact values of EC_e and osmotic potential obtained are presented in **table 2**.

2.2 Layout

Polyethylene lined plastic pots were filled with 10 kg soil. Phosphorus as $NH_4H_2PO_4$ was applied @ 0, 30, 60 and 90 mg P kg^{-1} soil. Before its application it was tagged with carrier free ^{32}P (@ 0.30 mci g^{-1} P. Other nutrients such as

Table 1: Important physico-chemical properties of the soil used for the experiment

01	Soil texture			
	a) Sand	(%)	:	90.80
	b) Silt	(%)	:	8.20
	c) Clay	(%)	:	1.00
02	Soil type		:	Sand
03	Taxonomic class		:	Typic Torripsament
04	Saturation capacity	(%)	:	30.00
05	pH (1:2)		:	7.77
06	$EC_e(dSm^{-1})$		:	1.66
07	$CaCO_3$	(%)	:	Traces
08	Organic carbon	(%)	:	0.05
09	Available N	(mg kg^{-1})	:	70.00
10	Available P	(mg kg^{-1})	:	3.52
11	Water soluble K	(mg kg^{-1})	:	6.20
12	Morghan's S	(mg kg^{-1})	:	12.81

Table 2: Amount and proportion of different ions added to the soil to attain desired EC_e levels

Desired EC_e level (dSm^{-1})	Total salt added ($meq\ L^{-1}$)	Na^+ ($meq\ L^{-1}$)	Ca^{2+} ($meq\ L^{-1}$)	Mg^{2+} ($meq\ L^{-1}$)	Cl^- ($meq\ L^{-1}$)	SO_4^{2-} ($meq\ L^{-1}$)	Obtained EC_e levels (dSm^{-1})	Osmotic potential (bars)
Cl-dominated ($Cl:SO_4$ = 70:30)								
Non-saline	0	00.00	00.00	00.00	00.00	00.00	1.66	-0.50
4	50	25.00	6.25	18.75	35.00	15.00	4.14	-1.23
8	105	52.50	13.13	39.37	73.50	31.50	8.10	-3.97
12	152	76.00	19.00	57.00	106.40	45.60	11.79	-6.52
SO_4-dominated ($Cl:SO_4$ = 30:70)								
Non-saline	0	00.00	00.00	00.00	00.00	00.00	1.66	-0.50
4	60	30.00	7.50	22.50	18.00	42.00	3.96	-1.09
8	125	62.00	15.63	46.87	37.00	87.50	7.80	-3.89
12	185	92.50	23.12	69.37	55.50	129.50	11.22	-5.79

N, K, Cu, Mn, Zn and Fe were applied @ 40.6, 25.0, 2.5, 2.5, 5.0, 5.0 and 10.0 mg kg^{-1} soil, respectively as basal dose. In order to make the system homogeneous, these contents were thoroughly mixed. At a moisture content of field capacity, 5 seeds of sunflower (cv. EC-68415 C) were sown at uniform depth (2 cm) and after establishment, in total 2 plants were retained. A hollow plastic feeder tube (1.5 cm diameter) was embedded in the centre of the pot to a depth of 15 cm. The plants were irrigated with deionised water alternatively at surface and subsurface (through tube) when required. This irrigation strategy ensures free movement of the salts in the system and prevents an accumulation at the bottom. All necessary agronomic practices were followed during the course of experiment. The crop was harvested at

Table 3: Effect of P application on yield (g pot^{-1}) of different plant parts of sunflower at various levels and types of salinity

Added P (mg kg^{-1})	EC_e (dSm^{-1}) Cl-dominated 1.66	4	8	12	Mean	SO_4-dominated 4	8	12	Mean
Leaf									
0	1.29	0.61	0.66	-	0.85	1.90	0.72	-	1.30
30	4.62	1.72	1.09	-	2.47	4.31	1.58	-	3.50
60	5.67	2.97	1.64	-	3.43	4.64	1.70	-	4.00
90	6.92	3.66	1.63	-	4.07	5.61	2.61	-	5.05
Mean	4.62	2.24	1.25	-	2.70	4.11	1.65	-	3.46
Stalk									
0	0.79	0.64	0.53	-	0.65	1.22	0.53	-	0.85
30	2.50	0.97	0.60	-	1.36	2.50	0.86	-	1.95
60	2.87	1.20	0.69	-	1.59	2.44	0.80	-	2.04
90	3.49	1.82	0.74	-	2.02	2.59	1.07	-	2.38
Mean	2.41	1.16	0.64	-	1.40	2.19	0.81	-	1.80

LSD (<0.05)

		Leaf	Stalk
P level	=	0.27	0.17
Salinity type	=	0.19	0.12
Salinity level x Salinity type	=	0.33	0.21
Salinity type x P level	=	NS	NS
Salinity level x Salinity type x P level	=	NS	NS

Table 4: Effect of P application on yield (g pot^{-1}) of different plant parts of sunflower at various levels of salinity

Added P (mg kg^{-1})	EC_e (dSm^{-1}) 1.66	4	8	12	Mean
		Leaf			
0	1.29	1.25	0.69	-	1.07
30	4.62	3.01	1.33	-	2.98
60	5.67	3.80	1.67	-	3.71
90	6.92	4.63	2.12	-	4.56
Mean	4.62	3.17	1.45	-	
		Stalk			
0	0.79	0.93	0.53	-	0.75
30	2.50	1.73	0.73	-	1.65
60	2.87	1.82	0.75	-	1.82
90	3.49	2.20	0.90	-	2.20
Mean	2.41	1.67	0.73	-	

LSD (<0.05)		Leaf	Stalk
P level	=	0.27	0.17
Salinity level	=	0.23	0.15
Salinity level x P level	=	0.47	0.29

pre-flowering stage. The plants were washed sequentially with diluted HCl, tap water and finally with distilled water. After soaking the extra water, the samples were separated into different parts i. e. leaf and stalk. After oven drying, the samples were weighed and ground in mill to a particle size of <2 µm. The samples were analysed for P (John, 1970), S (Chesnin and Yein, 1950), Cl (Chhabra, 1976), Ca and Mg (versenate titration using EBT as indicator) and Na and K (flame emission spectrophotometer). Radio-assay was carried out using a liquid scintillation counter (LS-1000 C Beckman, USA) with POP and POPOP as scintillators. The efficiency of added P was calculated according to the method of Mackenzie and Dean (1948). The experiment was carried out in a completely randomised block design with three replicates and the data were analysed calculating the least significant differences (LSD).

3 Results and discussion

3.1 Biomass/yield

The curse of the salinity is revealed by the fact that only one month after germination, all plants died at the highest salinity level independent on the salinity type (12 dSm^{-1}), so that, these pots were excluded from further analysis (**table 3**). Increasing salinity stress was accompanied by a significant reduction in yields of both plant parts under both salinity regimes. It is also evident that Cl-stress is more deleterious than that of SO_4 as there has been a 42 percent decrease in yield of leaf as well as of stalk due to Cl-stress in comparison with non-saline soil, whereas, the corresponding reduction under SO_4-stress was only 25 percent. Furthermore, yields of both plant parts were significantly higher under SO_4-salinity than Cl-dominance at all the salinity levels. It may also be inferred from the data that compared to the non saline soil, about 48 and 27 percent in Cl-dominated and 90 and 35 percent of crop potential in SO_4-dominated could be exploited at 4 and 8 dSm^{-1} EC_e levels, respectively. These results indicate that under conditions of moderate salinity (4 dSm^{-1}), SO_4 could enhance crop growth. The P supply had a significant effect on biomass production of both leaf and stalk while interaction with salinity type and levels were not significant (**table 4**). However, the response decreased with increase in salinity levels irrespective of type in the non-saline soil, the biomass production increased by 242, 310 and 400 percent with the application of 30, 60 and 90 mg P kg^{-1} soil, respectively, in comparison with control. The corresponding figures for 4 dSm^{-1} are 117, 157 and 213 and those for 8 dSm^{-1} are 69, 98 and 147 percent. It could be further concluded that about 96 per cent of the yield (total biomass) obtained with the application of 30 mg P kg^{-1} soil of non-saline soil could be obtained by increasing P application to 90 mg P kg^{-1} in the soil having an EC_e of 4 dSm^{-1}. The positive effect of P can be attributed to the fact that P has been recognised to enhance root growth (Tisdale et al., 1993) and it was found that the plant root growth under drought condition can be stimulated by localising the P fertiliser in the root zone (Mohammed, 1993). This effect on root growth may enhance the performance of the crop grown under saline conditions. The results of the study are in agreement with those of Soliman et al. (1981, who observed a reduction in the yield of sunflower due to salinity. Soliman et al. (1981) and Dravid and Goswami (1988) also suggested that salt tolerance of sunflower could be maintained at higher P treatment.

Table 5: Effect of P application on P content (%) of sunflower leaf at various levels of salinity

Added P (mg kg^{-1})	EC_e (dSm^{-1}) 1.66	4	8	12	Mean
0	0.18	0.22	0.22	-	0.20
30	0.31	0.32	0.36	-	0.32
60	0.38	0.41	0.45	-	0.42
90	0.43	0.50	0.57	-	0.50
Mean	0.32	0.36	0.40	-	

LSD (<0.05)		
P level	=	0.03
Salinity level	=	0.02
Salinity level x P level	=	0.04

Table 6: Effect of P application on P content (%) of sunflower stalk at various levels and types of salinity

Added P (mg kg^{-1})	EC_e (dSm^{-1})	Cl-dominated				SO$_4$-dominated			
	1.66	4	8	12	Mean	4	8	12	Mean
0	0.15	0.20	0.22	-	0.19	0.22	0.24	-	0.20
30	0.31	0.24	0.27	-	0.27	0.29	0.36	-	0.32
60	0.40	0.28	0.38	-	0.35	0.33	0.50	-	0.41
90	0.49	0.43	0.34	-	0.42	0.47	0.56	-	0.51
Mean	0.34	0.29	0.30	-	0.31	0.33	0.41	-	0.36

LSD (<0.05)

Salinity type	=	0.01
Salinity level x Salinity type	=	0.02
Salinity type x P level	=	0.02
Salinity level x Salinity type x P level	=	0.04

3.2 Ionic concentration and distribution

3.2.1 P concentration

It is apparent from the data that the P content of leaf, irrespective of type of salinity and salinity levels increased significantly with increasing P levels (**table 5**). There was a linear increase of the P content with increasing P supply whereby the P uptake was enhanced with increasing levels of salinity and thus increased biomass production. Phosphorus concentration of sunflower stalk increased significantly with increasing P levels at all levels and type of salinity (**table 6**). It is also clear from the data that the P concentration of the stalk increased by 226 percent with the application of 90 mg P kg^{-1} soil as compared to control in non-saline soil. The corresponding increase is 115 and 54 per cent at 4 and 8 dSm^{-1} Cl-dominated salinity and 114 and 113 per cent at SO_4-dominated salinity, respectively. These results indicate that dominance of Cl depressed the uptake of P by sunflower stalk highly, particularly at higher levels (8 dSm^{-1}) as compared to SO_4 saline soil. The dominance of SO_4^{2-} also reduced the P absorption by sunflower as compared to non-saline soil; however, it increased with increasing content of SO_4^{2-} in growth medium. In the absence of P application, increasing salinity increased the P content of sunflower stalk in both types of salinity that may be due to reduction in dry matter yield. But with the application of P, the P content of stalk was higher in non-saline soil as compared to both the levels of Cl-dominated and 4 dSm^{-1} of SO_4-dominated salinity. However, the P concentration of stalk at 8 dSm^{-1} SO_4 salinity was statistically at par with non-saline soil.

The leaf accumulated higher concentrations of P as compared to stalk. These results are in agreement with those of Heikal et al. (1980a and 1980b) who at low and mode-

Table 7: Effect of P application on total P utilisation (%) by sunflower at various levels and type of salinity

Added P (mg kg^{-1})	EC_e (dSm^{-1})	Cl-dominated				SO$_4$-dominated			
	1.66	4	8	12	Mean	4	8	12	Mean
0	-	-	-	-	-	-	-	-	-
30	5.1	2.9	2.0	-	3.3	6.4	2.7	-	4.7
60	6.5	3.6	2.3	-	4.2	6.2	2.7	-	5.1
90	6.1	4.1	1.7	-	4.0	5.9	3.0	-	5.0
Mean	5.9	3.5	2.0	-	3.8	6.1	2.8	-	5.0

LSD (<0.05)

Salinity type	=	0.47
Salinity level	=	0.57
P level	=	NS
Salinity level x Salinity type	=	0.81
Salinity type x P level	=	NS
Salinity level x P level	=	NS
Salinity level x Salinity type x P level	=	NS

rate levels of salinity (20 and 40 meq L^{-1}) observed an increase in P content of sunflower, however, at higher level of salinity (60 and 100 meq L^{-1}), the P content was found to decrease and Sánchez-Raya (1997) reported an increase in P content of sunflower as an interactive effect of P and salinity.

3.2.2 P utilisation

Levels and types of salinity and their interaction (**table 7**) influenced the total P utilisation by sunflower significantly while the P supply yielded no significant effect. In Cl-dominated salinity, the total P utilisation of sunflower was decreased significantly with increasing levels of salinity. In SO_4-dominated salinity, a significant reduction was observed only at 8 dSm^{-1} level compared to the non-saline soil. Dravid and Goswami (1988) observed a reduction in utilisation of added P by sunflower at a salinity level of 10.6 dSm^{-1} compared to the non-saline soil. The crop utilised significantly higher amounts of added P under SO_4 stress than Cl stress at all salinity levels. This may explain the higher crop yield under SO_4 dominated as compared to Cl-dominated salinity. The P utilisation in non-saline soil and 4 dSm^{-1} SO_4 salinity was statistically at par. The results further support that Cl^- in growth medium controls the uptake of added P by the sunflower crop. A tendency (non-significant) towards the increase in P utilisation with increased application rates over lower rate seems to occur which is quite contradictory to findings of Reddy et al. (1997) who observed decrease in P utilisation with increase in added P rates. Bahl and Toor (1999) reported that percentage of P derived by sunflower from freshly applied P decreased significantly with increasing P levels.

3.2.3 S and Cl concentrations

It is apparent from the data (**table 8**) that the S concentration of leaf increased significantly with increasing salinity levels of both types whereas in case of stalk such increase was observed only up to 4 dSm^{-1} level in both types of salinity. The S content of both leaf and stalk was significantly higher under SO_4-dominated compared with Cl-dominated salinity at both levels. This is due to higher SO_4 content of growth medium. A synergistic interaction between S and P was also being observed as S concentration of both plant parts increased significantly with application of P in comparison with the control at both kinds of salinity. On an average, the application of P induced a 36 and 49 percent increase in S content of leaf and stalk, respectively, in comparison to control, under the influence of SO_4-dominance compared to 25 and 46 percent in case of Cl-dominance.

Like the S content, the Cl content of both plant parts also increased significantly with increasing levels of salinity independent of the salinity type. The Cl content was significantly higher at all salinity levels in the Cl dominant treatment due to higher Cl content of growth medium. A non-significant increase in the Cl content of both plant parts was observed with the application of P in both plant parts and plant accumulated higher concentrations of Cl in leaf than stalk.

Table 8: Sulphur and Cl-content (%) of sunflower as affected by various levels of salinity and P in Cl and SO_4-dominated salinities

Treatments	EC_e type							
	Cl	SO_4	Cl	SO_4	Cl	SO_4	Cl	SO_4
	Leaf		Stalk		Leaf		Stalk	
	S				Cl			
EC_e levels (dSm^{-1})								
1.66	0.53	0.53	0.30	0.30	1.41	1.41	1.06	1.06
4	0.68	0.91	0.59	0.72	2.65	2.29	1.85	1.47
8	0.90	1.05	0.52	0.71	3.20	2.97	2.52	2.30
12	-	-	-	-	-	-	-	-
Mean	0.70	0.83	0.47	0.58	2.42	2.22	1.81	1.61
P levels (mg kg^{-1})								
0	0.56	0.61	0.32	0.39	2.17	1.99	1.59	1.35
30	0.67	0.73	0.44	0.51	2.35	2.17	1.72	1.56
60	0.81	0.99	0.51	0.66	2.51	2.29	1.89	1.70
90	0.77	0.99	0.62	0.78	2.65	2.44	2.04	1.84
Mean	0.70	0.83	0.47	0.58	2.42	2.22	1.81	1.61

LSD (<0.05)		S		Cl	
		Leaf	Stalk	Leaf	Stalk
P levels		0.04	0.04	0.05	0.06
Salinity type	=	0.03	0.03	0.04	0.04
Salinity type x P level	=	0.06	0.06	NS	NS
Salinity level x Salinity type	=	0.05	0.05	0.06	0.08

Table 9: Elemental composition (%) of sunflower as affected by various levels of salinity and P in Cl and SO_4-dominated salinities

Treatments	EC_e type							
	Cl	SO_4	Cl	SO_4	Cl	SO4	Cl	SO_4
	Leaf		Stalk		Leaf		Stalk	
EC_e levels (dSm^{-1})	Ca				Mg			
1.66	1.48	1.48	1.12	1.12	0.42	0.42	0.23	0.23
4	1.91	1.81	1.39	1.24	0.43	0.43	0.33	0.38
8	2.68	2.38	1.85	1.54	0.67	0.85	0.50	0.65
12	-	-	-	-	-	-	-	-
Mean	2.02	1.89	1.46	1.30	0.51	0.57	0.35	0.42
P levels (mg kg^{-1})								
0	2.27	2.12	1.66	1.51	0.40	0.44	0.29	0.35
30	2.12	1.98	1.52	1.38	0.45	0.51	0.34	0.38
60	1.90	1.81	1.40	1.25	0.63	0.68	0.39	0.44
90	1.81	1.64	1.26	1.07	0.56	0.64	0.40	0.51
Mean	2.02	1.89	1.46	1.30	0.51	0.57	0.35	0.42
EC_e levels (dSm^{-1})	Na				K			
1.66	0.10	0.10	0.09	0.09	1.32	1.32	1.07	1.07
4	0.52	0.67	0.43	0.50	1.09	1.14	0.80	0.79
8	0.78	0.96	0.46	0.88	1.04	1.08	0.48	0.70
12	-	-	-	-	-	-	-	-
Mean	0.47	0.58	0.33	0.49	1.15	1.18	0.78	0.85
P levels (mg kg^{-1})								
0	0.36	0.47	0.28	0.41	1.04	1.05	0.66	0.68
30	0.46	0.53	0.31	0.44	1.14	1.19	0.73	0.80
60	0.51	0.62	0.34	0.53	1.15	1.21	0.82	0.92
90	0.56	0.70	0.38	0.58	1.28	1.28	0.92	1.02
Mean	0.47	0.58	0.33	0.49	1.15	1.18	0.78	0.85

LSD (<0.05)		Ca		Mg		Na		K	
		Leaf	Stalk	Leaf	Stalk	Leaf	Stalk	Leaf	Stalk
P level		0.06	0.04	0.04	0.03	0.04	0.02	0.04	0.04
Salinity type	=	0.04	0.03	0.02	0.02	0.02	0.02	0.03	0.03
Salinity type x P level	=	NS	NS	NS	NS	NS	0.03	NS	NS
Salinity level x Salinity type	=	0.07	0.05	0.04	0.03	0.04	0.03	NS	0.05

3.2.4 Ca, Mg, Na and K concentrations

The perusal of data in **table 9** indicates that tissue concentration of Ca, Mg and Na of both plant parts increased significantly with increase in salinity levels over non-saline soil in both type of salinity (except leaf Mg content which is statistically equal to non-saline soil). This increase in elemental concentration is caused by the salts added in order to obtain different levels of the salinity. At each salinity level significantly higher concentration of Ca in both leaf and stalk were observed under Cl-salinity than SO_4-salinity. This effect can be attributed to formation of sparingly soluble $CaSO_4{\cdot}2H_2O$ which limits the Ca supply. In case of Mg and Na this behaviour has been reverse to that of Ca since significantly higher concentrations of these ions have been observed under SO_4-dominated than Cl-dominated salinity at both levels (except at 4 dSm^{-1} in case of leaf Mg). Application of P did not bring any significant change in Ca and Mg content of sunflower plant parts. However, a considerable reduction in Ca content of both parts was observed under both types of salinity. The reason may be assigned to precipitation of P and Ca as of $Ca_3(PO_4)_2$. In case of Na in stalks, it increased significantly with increasing P levels under both types of salinity. So far as K concentration is concerned, the interactive effect of type and level of salinity did not yield any significant change in K concentration of leaf but that of stalk decreased significantly with increasing salinity levels. This decrease in the K concentration under saline conditions has been previously described and explained in terms of competitive uptake between Na and K (Marschner et al., 1981, Savvas and Lenz, 1996 and Botiá et al. 1998). Furthermore, the K content of both parts was significantly higher under SO_4-salinity than Cl-salinity. Application of P brought a non-significant improvement in the K status of both plant parts. Heikal et al. (1980a, 1980b) observed that at low and moderate salinity levels (20 and 40 meq L^{-1}), the Mg and K concentration of sunflower was found to increase whereas at higher levels (60 and 100 meq L^{-1}) concentration of these elements decreased but that of Na increased. Sánchez-Raya and Delgado (1996) observed a reduction in the Ca and Mg concentration in sunflower shoots and Delgado and Sánchez-Raya (1997) reported about an increase in the Na and K content of sunflower with increasing both, salinity and P levels.

4 Summary and conclusion

Salinity mainly occurs in arid and semi-arid conditions where the precipitation is not enough to leach the excess soluble salts from the root zone. Salinity problem also occurs in irrigated agriculture, particularly where poor quality water is used for irrigation. The conventional method of controlling salinity by flushing the salts from root zone is no more viable in the regions where fresh water is a scarce commodity and drainage facilities are not adequate. Exploitation of favourable ionic interaction has been found one of the cheapest approach to cope up with salinity problem. It is in this context, a greenhouse experiment was conducted with different types (dominated by Cl and SO_4 ions) of salinity (EC_e 1.66, 4, 8 and 12 dSm^{-1}). Tagged P (^{32}P) @ 0, 30,60 and 90 mg P kg^{-1} soil was used as substrate to mitigate salinity effect.

The overall conclusion of the study is that sunflower can be termed as moderately tolerant to salinity as yield remains unaffected up to 4 dSm^{-1} EC_e level; beyond that salinity had an adverse effect on performance of sunflower and at highest EC_e level of 12 dSm^{-1}, crop did not survive under either type. It was also found that crop has greater sensitivity to Cl-salinity than SO_4-salinity. Although the application of the P has helped the crop to an extent to cope up with salinity stress, yet the real mechanism behind this remains unanswered. In this study the fact that there is no inverse relationship between P and two deleterious elements Na and Cl, indicates that there is no exclusion mechanism for salt tolerance of this crop. However, the synergistic relationship between P and other beneficial elements like Ca, Mg and K might have mitigated the osmotic effect and thus can be held responsible for salt tolerance to some degree.

Einfluß von Phosphor (^{32}P) auf die Salztoleranz der Sonnenblume

In einem Gewächshausversuch zu Sonnenblumen (*Helianthus annuus* L.) wurde deren Salzempfindlichkeit auf verschiedenen Böden (Ec_e 1.66, 4, 8 und 12 dSm^{-1}) und in Abhängigkeit verschiedener Anionenverhältnisse ($Cl:SO_4$ = 70:30 und $Cl:SO_4$ = 30:70) getestet. Darüber hinaus wurden 0, 30, 60 und 90 mg P kg^{-1} Boden in Form von radioaktiv markiertem Phosphat zugeführt.

Sonnenblumen (*Helianthus annuus* L.) können als mäßig salztolerant eingestuft werden, da auch bei Leitfähigkeitsmeßwerten von bis zu 4 dSm^{-1} EC_e kein Ertragsrückgang feststellbar war. Bei höheren Werten kam es hingegen zu einem kontinuierlichen Ertragsabfall und bei 12 dSm^{-1} EC_e schließlich zu einem Absterben der Pflanzen. Die Pflanzen zeigten eine höhere Empfindlichkeit gegenüber Cl im Vergleich zu Sulfat. Obwohl die P-Zufuhr zu einem höheren Ertrag führte, lassen die Ergebnisse keinen Rückschluß auf die Wirkungsmechanismen zu. Allerdings weisen die Ergebnisse darauf hin, daß anscheinend weder für Na, noch für Cl Ausschluß-Mechanismen existieren, da keine negative Beziehung zwischen diesen Elementen und dem P-Gehalt in verschiedenen Pflanzenteilen gefunden wurde. Die positive Beziehung zwischen dem P-Gehalt und dem Gehalt an Ca, Mg und K dürfte einen positiven osmotischen Effekt gehabt und somit zur Salztoleranz der Pflanzen beigetragen haben.

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