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Effect of salinity stress on foliar fungal diseases of groundnut

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ABSTRACT: The effect of soil and irrigation water salinity on severity of major foliar fungal diseases of groundnut *viz.,* early leaf spot (*Cercospora arachidicola*), late leaf spot (*Phaeoisariopsis personata*) and rust (*Puccinia arachidis*) was investigated during rainy season of 2003 and 2004 in black clay calcareous soil. The salinity in the experimental plots was developed as a result of saline water irrigation over the years. Four levels of saline irrigation water *viz.,* 0.5 (control), 2.0, 4.0 and 6.0 dS m^{-1} and five cultivars were tested in a split plot design. The results revealed that with increase in salinity stress the severity of major foliar fungal diseases decreased. At higher salinity the crop growth was severely affected and there was no corresponding increase in pod yield of the crop even though the disease was low. Based on the studies it is concluded that although groundnut is a sodium sensitive crop, it can be grown profitably up to a threshold salinity stress of 2.0 dS m^{-1} irrigation water salinity (EC_{iw}) and 2.5 dS m^{-1} soil salinity in black clayey soil as at this salinity the severity of foliar diseases were less and the pod yield was maximum.

Key words: Groundnut, *Arachis hypogaea,* salinity stress, rust, leaf spots

Diseases are the limiting factors for the successful production of groundnut (*Arachis hypogaea* L.) crop. The foliar fungal diseases, early leaf spot (*Cercospora arachidicola* Hori), late leaf spot [*Phaeoisariopsis personata* (Berk. & Curt) V. Arx] and rust (*Puccinia arachidis* Speg.) are the most widespread and destructive. The magnitude of yield losses caused by these diseases is very high ranging from 10 to 70% (Ghewande, 1990). However, the severity of each disease varies between localities and seasons. Gujarat has been the leading state of India in groundnut production. However, in recent years, soil salinization has seriously affected the productivity in over 1.2 million ha land in Gujarat particularly in the coastal areas where the crop is fading out of cultivation.

Groundnut was classified as a sodium sensitive crop by Singh and Abrol (1985). The presence of various salts in soil has been implicated in the suppression or enhancement of plant diseases. The severity of pod rot of groundnut increased with increased potassium (Hallock and Garren, 1968). Shanta (1960) reported that K enhanced *Cercospora* leaf spot of groundnut. Sodium decreased the severity of cotton root rot (*Phymatotrichum omnivorum* Duggar) (Lyda and Kissel, 1974), yellow rust of greenhouse-grown wheat (*Puccinia striiformis* Westend.) (Russell, 1978), and powdery mildew of wheat (*Erysiphe graminis* DC.) (Leusch and Buchenauer, 1989). In contrast, Na-fed plants were more susceptible to *Fusarium* wilt of tomato (*Fusarium oxysporum* f. sp. *lycopersici* (Sacc.) Snyder & Hans.) (Davet *et al*., 1966; Standaert *et al*., 1973). The present work was carried out with the aim of studying the effect of salinity stress on the development of foliar fungal diseases of groundnut.

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MATERIALS AND METHODS

Trial description

Field experiments were conducted in rainy season of 2003 and 2004 at National Research Centre for Groundnut, Research Farm at Junagadh (India) to study the effect of soil and irrigation water salinity on development and severity of foliar diseases. The soil of the experimental plot was shallow (25-50 cm depth), clayey in texture, well drained and calcareous in nature. The salinity in these plots was developed as a result of saline water irrigation to previous crops. The EC_e (electrical conductivity of saturation extract) of 0-45 cm soil depth of the experimental plot were taken after germination and before harvesting. Four levels of electrical conductivity of irrigation water (EC_{iw}) *viz.,* 0.5 (control), 2.0, 4.0, and 6.0 dS m^{-1} using NaCl salt, and five varieties viz., JL-24, ICGS-44, GG-2, Gangapuri and MH-2, former three belonging to Spanish and latter two of Valencia group, were tested in a split plots. A 250 mm polycarbonate sheet was placed at 60 cm soil depth in different channels surrounding the treated plots (5 x 4 m^2). Bunds (30 cm x 30 cm) were raised around each plot to retain maximum rainwater in the plot. The crop was sown in the 3rd week of June and harvested during last week of September. The recommended doses of fertilizer *i.e.* 12.5 kg N and 25 kg P_2O_5 per hectare were applied. Four storage tanks of 1000 litres capacity each were used for different saline water irrigation. The plots were irrigated with saline water in dry spells during the crop growth period. Soil samples were taken from 0-15, 15-30 and 30-45 cm soil depths periodically during the crop growth and bulked. These were analysed for electrical conductivity (EC) and pH. Disease severity in different cultivars and the pod yield were recorded.

Scoring for foliar diseases

The severity of early leaf spot, late leaf spot and rust, arising from natural inoculum sources were recorded after 90 days of sowing and the percent disease severity index (PDI) was calculated on leaf lesions of different groundnut cultivars. For the estimation of disease severity, fifty leaves were collected from each plot in each treatment and the disease was recorded using modified 9-point scale (Subrahmanyam *et al*., 1995) where 1 = 0%, 2 = 1-5%, 3 = 6 -10%, 4 = 11-20%, 5 = 21-30%, 6 = 31-40%, 7 = 41-60%, 8 = 61-80%, 9 = 81 -100% disease severity.

Statistical analysis

The data was analyzed using 2-factor randomized block design. Analysis of variance was carried out to determine least significant differences between treatments and cultivars for percent disease severity and the pod yield. All statistical analyses were conducted using MSTAT software.

RESULTS

Weather conditions, root zone salinity and pH

Weather parameters *viz.,* rainfall, relative humidity (RH) and temperature influence the severity of foliar diseases of groundnut. During the crop growth period the amount of rainfall received in the year 2003 and 2004 were 1274.5 and 970.8 mm, respectively. The total rainfall received was fairly well distributed between July to September during 2003 as compared to 2004. The average temperature and relative humidity ranged from 27-32^{0}C and 43-91%, respectively. During critical phase of crop for disease development, the RH varied between 75 to 90% (Fig. 1). The soil salinity was developed as result of saline water irrigation to previous summer groundnut crop. Saline water irrigation was provided in the dry spell during crop growth. Two irrigation was provided during 2003 while four irrigations were provided during 2004 in the dry spell at an interval of one week. The soil salinity in 0-45 cm root zone at the time of sowing ranged from 1.7 to 5.9 dS m^{-1} during 2003 and 2.7 to 5.1 dS m^{-1} during 2004 (Table 1). The mean soil pH (0-45 cm depth) increased with increase in salinity of the irrigation water. The pH at pod development and towards harvesting differed during both the year. The difference is attributed to amount of rainfall, its distribution and the saline water irrigation provided during the dry spell (Fig. 2).

Early leaf spot

The soil and irrigation water salinity significantly influenced the disease severity of early leaf spots (ELS). It is evident

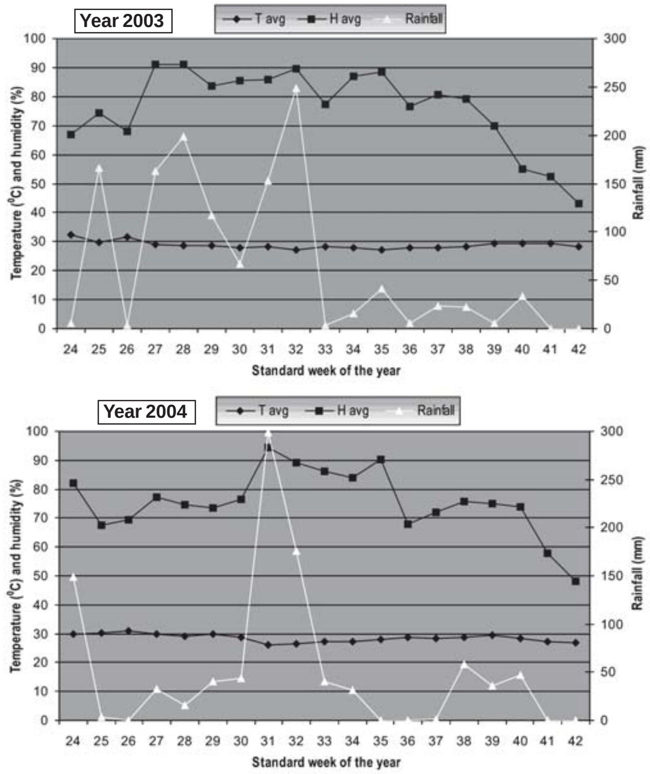

Fig. 1. Weather conditions during rainy season of 2003 and 2004

from the pooled data (Table 2) that as the salinity of irrigation water (EC_{iw}) increased from 0.5 to 6.0 dS m^{-1}, the soil salinity increased from 2.2 to 5.5 dS m^{-1} and there was a corresponding decrease in severity of the disease, the maximum being in the lowest salinity and minimum in the highest salinity level in all the cultivars. Since there was frequent rainfall during the crop growth period the salt was leached down (Fig. 1). However, the addition of saline water during dry spells resulted in build up of soil salinity, which was 1.6 to 2.8 dS m^{-1} just before harvesting. The soil salinity (EC_e) of individual year is given in table 1. The effect of salinity stress on disease severity in the individual years (Fig. 3) showed similar trend i.e. as the salinity increased the disease severity decreased though the maximum and minimum disease varied significantly in both the years. In the year 2003 the disease severity was higher than the year 2004. The least significant difference (LSD) for disease severity of ELS at various level of salinity was 7.61. The LSD for cultivars and the cultivars x salinity were found to be non-significant.

Table 1. Electrical conductivity of soil saturation extract (EC_e) in experimental plots at different water salinity level during 2003 and 2004

Salinity (EC_{iw})	EC_e during 2003 (dS m^{-1})		EC_e during 2004 (dS m^{-1})	
(dS m^{-1})	At sowing	Before harvesting	At sowing	Before harvesting
0.5	1.7	1.2	2.7	2.0
2.0	3.0	2.1	3.5	2.3
4.0	3.6	2.5	4.5	2.6
6.0	5.9	2.8	5.1	2.7

EC_{iw} = Electrical conductivity (salinity) of irrigation water,
EC_e = Electrical conductivity of soil saturation extract

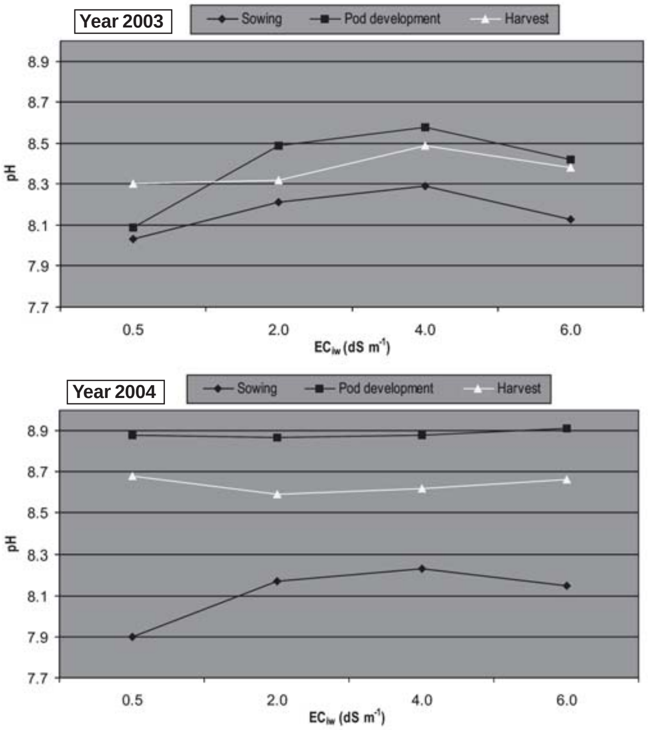

Fig. 2. pH of experimental plot at different stages during 2003 and 2004

Late leaf spot

The severity of late leaf spot was highest (78.4-85.8%) in the control (EC_{iw} 0.5 dS m^{-1}) and the lowest (53.4-58.1%) in the plots that received highest irrigation water salinity (6.0 dS m^{-1}) in all the cultivars of groundnut. Significant reduction in disease severity was observed between different levels of salinity except in the cultivar MH-2 in which the reduction in disease severity was non-significant between EC_{iw} 4.0 and 6.0 dS m^{-1} (Table 2). Disease severity of late leaf spots differed in the year 2003 and 2004 depending on the weather conditions (Fig. 4) especially, rainfall which affected the soil salinity by way of leaching salt from root zone. The resulting salinity stress however showed similar trend on intensity of disease.

Rust

The severity of rust was also decreased with increasing salinity stress but the reduction in disease severity was less as compared to ELS and LLS. In the control (0.5 dS m^{-1}) the rust severity ranged from 85.4 to 89.9%, while at highest salinity (6.0 .5 dS m^{-1}) the rust intensity ranged from 60.7 to 73.3%. Significant reduction in severity of rust was observed with increase in salinity stress except in the cultivar MH-2 between 0.5 to 2.0 dS m^{-1}, and in the cultivar GG-2 between

Table 2. Effect of salinity on severity of major foliar fungal diseases of groundnut during rainy season of 2003 and 2004*

Cultivars	EC_{iw}	EC_e (dS m^{-1})		Percent Disease severity Index			Pod yield(
	(dS m^{-1})	At Sowing	Before Harvesting	Early leaf spot	Late leaf spot	Rust	kg ha^{-1})
JL-24	0.5	2.2	1.6	80.7	78.4	87.0	1582
	2.0	3.3	2.2	72.2	72.2	83.3	1911
	4.0	4.0	2.5	60.5	67.2	75.5	1243
	6.0	5.5	2.8	49.7	56.7	60.7	641
MH-2	0.5	2.2	1.6	80.0	78.4	86.9	1271
	2.0	3.3	2.2	70.4	69.8	84.0	1389
	4.0	4.0	2.5	58.6	60.6	74.9	672
	6.0	5.5	2.8	55.3	57.1	63.1	483
ICGS-44	0.5	2.2	1.6	79.7	81.5	85.4	1691
	2.0	3.3	2.2	65.4	68.1	79.9	1831
	4.0	4.0	2.5	57.4	61.2	75.9	1040
	6.0	5.5	2.8	52.8	53.4	68.9	842
Gangapuri	0.5	2.2	1.6	85.2	79.9	87.0	1497
	2.0	3.3	2.2	69.6	69.1	82.1	1815
	4.0	4.0	2.5	65.1	64.1	74.7	862
	6.0	5.5	2.8	56.7	58.1	67.9	669
GG-2	0.5	2.2	1.6	84.2	85.8	89.9	1467
	2.0	3.3	2.2	75.3	79.6	84.2	1647
	4.0	4.0	2.5	69.8	68.7	83.5	863
	6.0	5.5	2.8	54.7	54.8	73.3	631
LSD (P<0.05)				7.61	5.95	3.10	116

*Average of two years
EC_{iw} = Electrical conductivity (salinity) of irrigation water
EC_e = Electrical conductivity of soil saturation extract
LSD = Least significant difference

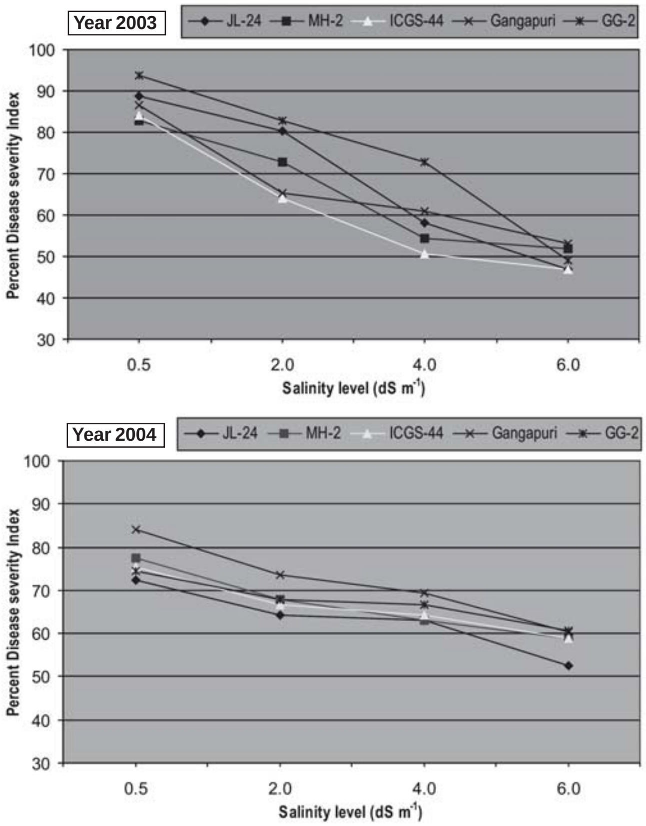

Fig. 3. Effect of salinity stress on early leaf spot during 2003 and 2004

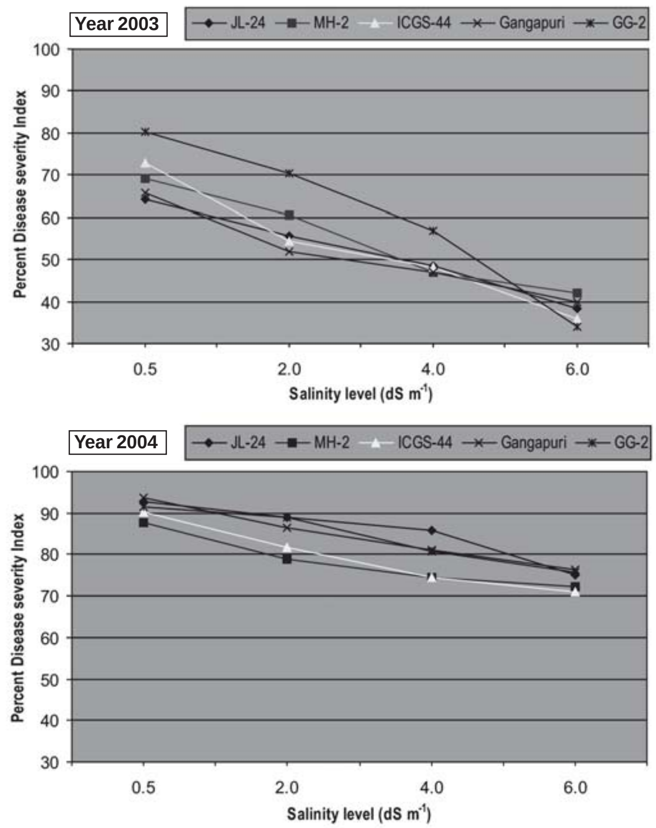

Fig. 4. Effect of salinity stress on late leaf spot during 2003 and 2004

2.0 and 4.0 dS m^{-1} irrigation water salinity. The least reduction in severity was observed in the cultivar GG-2 at all the salinity levels (Table 2). Disease severity of rust differed in the year 2003 and 2004 depending on the weather conditions (Fig. 5) especially, rainfall which affected the soil salinity stress by way of leaching salt from root zone and hence the number of irrigations required during dry spell. The highest disease intensity in control (0.5) during 2003 was 87.65 to 94.69% while in 2004 it was 79.01 to 88.81%. And, the lowest disease severity was in the highest salinity (6.0 dS m^{-1}) were 62.96 to 76.15% during 2003 and 58.4 to 75.31% in different cultivars during 2004. The salinity stress showed similar effect on disease severity in both the years.

Pod yield

Growth of the plants was severely affected at high water salinity as groundnut is a sensitive crop to soil salinity. The pH of the soil in the experimental plot at pod development and before harvest is very important for the crop. The pH at pod development was between 8.09-8.58 and 8.87-8.91, at harvest 8.30-8.49 and 8.59-8.68 during 2003 and 2004, respectively. EC_e of the soil varied from 2.2 to 5.5 and 1.6 to 2.8 at the time of sowing and before harvesting as a result of saline water irrigation. The pod yield at different salinity stress varied significantly (Table 2) and decreased with an increase in EC_{iw} from 2.0 to 6.0 dS m^{-1} over the control (0.5 dS m^{-1}). However the highest yield was realized in the plots receiving saline water of 2.0 dS m^{-1} in all the cultivars. It was noted that the effect of soil and water salinity on pod yield was greater in case of the cultivars MH-2, GG-2 and Gangapuri than in ICGS-44 and JL-24, indicating that the latter genotypes were more resistant to salinity stress.

DISCUSSION

It is evident that as the salinity increased, the severity of major foliar fungal diseases decreased but there was no corresponding increase in pod yield of the crop. This is because groundnut is a sensitive crop to soil salinity. Mensah *et al.* (2006) had reported decrease in seedling emergence, radicle elongation, plant height and dry matter weight with increasing salinity, and that the agronomic characters such as number of leaves/plant and number of branches/plant were significantly reduced with salinities higher than 2.60 mS cm^{-1}. In general, at higher soil and water salinity (*i.e.* EC_{iw} 4.0 dS m^{-1} and EC_e e"2.5 dS m^{-1}) even though the severity of disease was less, the yield was also drastically reduced. Yet, the highest yield (1389 to 1911 kg ha^{-1}) was recorded in 2^{nd} level of soil and water salinity *i.e.* EC_{iw} 2.0 and EC_e 2.2 dS m^{-1}, which is higher than pod yield of control (0.5 dS m^{-1}, 1^{st} level). This was because of the higher disease severity of foliar fungal diseases in the control plots. Severity of the foliar fungal diseases decreased with increasing salinity level in the present study. The possible mechanism for the tolerance to diseases may be that salinity, especially the increase in sodium salts triggers defense mechanism of the plants. Maslenkova *et al.* (1992) reported that salinity stressed barley seedlings showed marked quantitative and qualitative changes in polypeptide profiles as indicated by high jasmonic acid (JA) concentrations. At 100 millimolar NaCl, an eightfold increase in proline content was observed

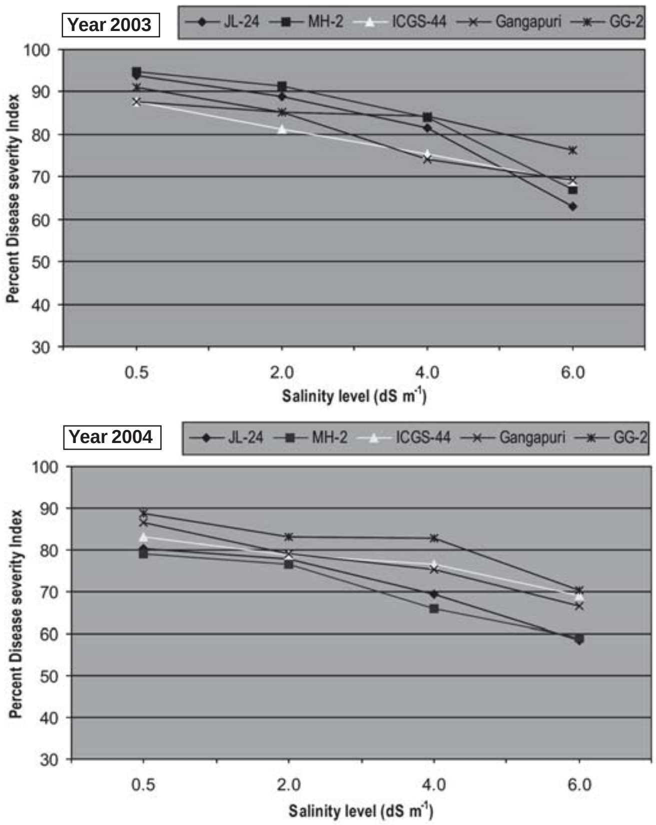

Fig. 5. Effect of salinity stress on rust during 2003 and 2004

while at 250 micromolar JA, the proline content was threefold over the control. Moons *et al.* (1997) found that most JA-responsive proteins accumulated in rice roots when plants were subjected to salt stress. Jasmonic acid is a well-known signal transducer of the defense reactions in plants against pathogens.

The metabolic changes in the host and the pathogen under salinity stress cause repression or stimulation of the activity of hydrolytic enzymes involved in disease development, of which cellulase and polygalacturonase are favoured by acid reactions and galactanase and pectate lyase by alkaline reactions. The reduction in disease severity in the present study may be due to the repression of activity of enzymes like cellulase and polygalacturonase under saline conditions. Ghewande (1973) reported that *in-vitro* production and activity of cellulase enzymes of *Helminthosporium apatternae* was significantly reduced when KCl and NaCl salts were added in the synthetic medium at 0.2%. He also reported that the activity of transeliminase enzyme produced *in-vitro* by *H. apatternae* was completely suppressed by addition of NaCl (0.05 M) in enzyme substrate (pectin and Na-pectate) reaction mixture. El-Abyad *et al*. (1997) reported that the virulence of *Rhizoctonia solani* and *Sclerotium rolfsii* was altered under the impact of salinity stress. Based on the present studies it is concluded that with increase in salinity stress, the severity of major foliar diseases decrease, however, with respect to pod yield only a moderate salinity stress that is the threshold salinity, EC_{iw} 2.0 dS m^{-1} and EC_e d"2.5 dS m^{-1} is advantageous. In the context of black clayey soil of coastal areas affected with salinity, where availability of good quality water for irrigation is a constraint, the groundnut crop can be grown profitably up to this salinity stress harvesting good yield of crop with less disease severity.

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