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A REVIEW

Spice crops tolerant to salinity and alkalinity

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Abstract : Tolerance and yield of a crop are complex genetic traits, which are difficult to maintain simultaneously since salt stress may occur as a catastrophic agent, be imposed continuously or intermittently or become gradually more severe. Salinity and alkalinity stress have a major impact on spices in the form of their growth, development and yield. Adverse effects of salinity might be due to ion cytotoxicity and osmatic stress, which disrupt homeostasis in water potential and ionic distribution due to disordering in cohesions of membrane lipids and proteins and influence various physiological and biochemical processes. To review the tolerance of spices to salinity and alkalinity, the present paper collates the existing experimental data sets, establishing the salt tolerance limits under saline or alkali environment either in soil root zone or which is created due to the application of saline or alkali irrigation water for crop production. Studies show that the salt affected areas and saline irrigation water can be utilized satisfactorily to raise forest and fruit tree species, forage grasses, conventional and non-conventional crops, oil seed crops, spice crops of high economic value, petro-crops and flower plants.

Key Words : Spice crops, Salinity, Saline soil, Saline water, Varietal tolerance

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INTRODUCTION

The continuous increase in the earth's population requires increasing quantity of water for domestic, industrial and agricultural needs. Presently, about 15 per cent of the India's water resources are consumed in domestic and industrial requirements and share of these two sectors will grow to about 30 per cent by 2050 (Minhas and Samra, 2004). The progressive requirement for more water to irrigate crops for food when water resources are limited has lead to the use of poor quality water in agriculture (Bouwer, 1994 and Ragab, 2005). In many regions of the world, field drainage water is already used successfully for irrigation even when the water is saline (Grattan *et al.*, 1994). Irrigation with saline water has become necessary not only in parts of the world with limited supplies of good quality water but also in areas affected by shallow groundwater where the main purpose is to reduce the depth of the water table. The large scale and indiscriminate use of poor quality water causes secondary salinisation and sodification, which affect the plant growth adversely. The successful use of low quality water requires an integrated management plan based on choice of the most appropriate irrigation system or soil, irrigation water, rainwater, nutrients and crop management (Phogat *et al.*, 2007). The continuous

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use of alkali water without amendments adversely affects physical conditions of the soil, and at the same time, it adversely affects the mineral composition, uptake and yield of crops under most situations.

Plant growth under saline condition is suppressed by osmotic effects, toxic solutes and sodicity (Maas, 1993). Salinity adversely reduces the overall productivity of plants by inducing numerous abnormal morphological, physiological and biochemical changes that cause delayed germination, high seedling mortality, poor crop stand, stunted plant growth and poor yield. Spice production like other crops is also threatened by increasing soil salinity as 40 per cent of the world's land surface is affected by salinity-sodicity related problems. In the world, over 800 million-hectare (mha) land is salt affected (FAO, 2008) either by salinity (397 mha) or the associated condition of sodicity (434 mha). In India, according to a study (CSSRI, 2008), around 6.74 mha land is salt affected, which is further categorized as saline (1.71 mha), alkali (3.78 mha) and coastal saline (1.24 mha) soil.

India is prosperous in spice crops, covering an extensive area with different environmental conditions. Spices form an important part of the treatment in the indigenous medicine systems such as *Ayurveda*, *Unani*, *Siddha*, Traditional Chinese Medicine, Tibetan Medicine, *Julu*, etc. The scarcity of good quality surface as well as groundwater is the main constraint for the success of agriculture in most of arid and semi-arid regions of the country. However, the ground water is either saline or alkali, and almost 60 per cent of it as such is not suitable for irrigation. Concerted efforts have been made by researchers to study the tolerance of spices to salinity and alkalinity but these are not properly documented. Opportunities for raising spice crops on salt affected soil and by using saline water have been discussed in this paper. Spice crops are generally more sensitive to salts than arable, fodder, pulse and oil seed crops. The relative tolerance of different spice crops can easily be seen through the data presented in this paper.

Impact of soil salinity on spice crops:

Excessive soil salinity reduces the productivity of many agricultural crops, including spice crops, which are particularly sensitive throughout the ontogeny of the plant. Plant sensitivity to salt stress is reflected in loss of turgor, growth reduction, wilting, leaf curling and epinasty, leaf abscission, decreased photosynthesis, respiratory changes, loss of cellular integrity, tissue necrosis and potentially death of the plant (Jones, 1986 and Cheeseman, 1988). These adverse effects of salinity might be due to ion cytotoxicity and osmatic stress (Hussain *et al*., 2008), which disrupt homeostasis in water potential and ionic distribution due to disordering in cohesions of membrane lipids and proteins (Rahdari *et al*., 2012) and influence various physiological and biochemical processes. Salinity fluctuates with season, being generally high in the dry season and low during rainy season when fresh water flushing is prevalent. Intra- and inter-generic differences in salt tolerance have been known and extensively reported for arable and field crops. Mangal *et al.* (1989) and Mangal *et al.* (1990a) studied the performance of a number of spice crops (Table 1) at different soil salinity levels (EC_e). The data show that lettuce is more sensitive to salinity as its yield is reduced to 50 per cent at low EC_e of 5 dS/m, whereas, spinach and celery are highly tolerant, as 50 per cent reduction in yield took place at a high EC_e of 10 dS/m (Table 1).

Besides the intra- and inter-generic differences in

Table 1: Reduction in the yield of different spice crops (%) at different soil salinity

Sr. No.	Spice crops	Reduction (%) at a given EC_e (dS/m)			
		0	25	50	100
1.	Celery	2	6	10	16
2.	Hot pepper	1	4	6	11
3.	Fennel	3	6	9	12
4.	Garlic	2	3	7	10
5.	Lettuce	1	3	5	9
6.	Spinach	2	5	10	16
7.	Squash	3	5	6	--
8.	Sweet pepper	2	3	7	10

Source: Mangal (1993)

salt tolerance of crops, the crops also differ in their tolerance to salts from one growth stage to another, while most crops are known to be sensitive to salts at germination and early growth stage but exceptions may occur, and few crops are sensitive to salts at flowering or at phase change stages. In order to assess the crop tolerance of spice crops, several experiments were conducted to evaluate their tolerance at various growth stages (Table 2). It was observed that crops like lettuce, fennel and fenugreek showed less than 50 per cent seed germination even at EC_e 4.0 dS/m. Since a good crop stand is necessary for higher yield, the crop sensitivity at germination or initial growth stage must be kept in view while selecting a crop and to ensure optimum root environment for the selected crop.

Based on these and similar studies, Mangal *et al.* (1990a) classified spice crops into sensitive, semi-tolerant and tolerant category (Table 3). The data on crop tolerance given in the table could be used to assess the crops grown with saline water, considering climate and soil conditions. Spice crops, which are semi-tolerant to tolerant as well as those with low water requirement, should be preferred to cultivate with saline water.

Effect of saline water on spice crops:

Saline water does not affect the crop adversely unless the salts accumulate in soil to an extent that they affect the plant growth. It is well known evident from long-term experiments on saline water use that an interplay of factors like climate, nature and content of soluble salts present in water, soil type, water table conditions, nature of crops grown and the water management practices, govern the salinity dynamics *vis-a-vis* crop performance. Since the salt accumulation in the soil depends on soil texture, being nearly one half that of irrigation water in coarse textured soil (loamy sand and sand) as a thumb rule. It is equal to that of irrigation water in medium textured sandy loam to loam soil and more than two times in fine textured soil (clay and clay loam). Thus, water of as high salt concentration

Table 2: Relative performance (%) of spice crops at different EC_e levels in relation to different growth parameter

Crop (Variety)	Parameter	EC_e (dS/m)				
		2	4	6	8	10
Hot pepper (NP 46-A)[1]	No. of fruits per plant	80	74	55	-	-
	Yield per plant	86	81	61	0	-
Coriander (Narnaul Selection)[2]	Germination	67	38	15	0	0
	Yield	76	39	31	-	-
Fennel (Selection)[2]	Germination	50	40	20	-	16
	Seed yield	76	50	30	20	10
Garlic (HG-6)[3]	Yield per plant	90	85	75	50	-
Kasturi Methi[3]	Seed yield	92	30	0	0	0
Lettuce[4]	Seed yield	81	80	44	35	-
Fenugreek (*Desi*)[5]	Seed yield	66	48	37	0	0
Spinach (S-23)[5]	Seed yield	89	80	68	39	18

Source: [1]Lal *et al.* (1990); [2]Mangal *et al.* (1986); [3]Mangal *et al.* (1988a); [4]Mangal *et al.* (1992) and [5]Mangal *et al.* (1987)

Table 3: Spice crops tolerance to salinity (EC_e dS/m)

Sensitive crops (Upto 4)	Semi-tolerant (4-6)	Tolerant crops (6-8)
Lettuce and fenugreek	Artichoke, sweet pepper and celery	Fennel, spinach, beet root and asparagus

Table 4: Crop and soil interactions using saline water

	Crop tolerance to salinity (dS/m)		
Soil texture	Sensitive (Fenugreek)	Moderately tolerant (Lettuce)	Tolerant (Spinach)
Loamy sand	1.6	4.0	6.0
Loam	1.0	3.0	4.5
Loamy clay	0.8	2.0	3.0
Clay	0.4	1.0	1.6

as an EC of 12 dS/m can be used for growing tolerant and semi-tolerant crops in coarse textured soil, provided that the annual rainfall is not less than 400 mm. However, in fine textured soil, water with EC more than 2 dS/m would often create salinity problem. Shainberg and Shalhevet (1984) also highlighted this interaction (Table 4) as more saline water could be used to grow the same crop on coarse than fine textured soil. At Agra, the significant yield reduction was noticed at EC_{iw} 4, 6 and 8 dS/m in fennel and fenugreek crop (Table 5). However, fenugreek emerges clearly more tolerant than the fennel crop (Anonymous, 2006).

Psyllium (*Isabgol*) is cultivated in arid and semi-arid areas during winter season. Since its spikes at maturity stage have a tendency of shattering the grains, the rains can cause severe damage. Even heavy dew can damage the crop at maturity stage. Therefore, dry weather at maturity stage is absolutely necessary for its cultivation. The *Isabgol* is a quite hardy crop and can be cultivated on varieties of soil but it does grow well on well-drained sandy to sandy-loam soil rich in nutrients. Studies show that it is quite tolerant to salinity and no adverse effect on its yield has been reported even when irrigated with saline water having EC_{iw} upto 8 dS/m (Tomar *et al.*, 2005).

Induction of salt tolerance:

Seed priming (controlled hydration followed by redrying) has been used to hasten and synchronize seedlings emergence, enhance tolerance of seedlings to biotic and abiotic stresses including salinity stress during critical phase of the seedling establishment and consequently can ensure uniform crop stand and yield improvement (Afzal *et al.*, 2009). Studies on the enhancement of salinity tolerance by sowing pre-soaked seeds and seedlings in water, salt solution and/or growth hormones was carried out in different crops or varieties at different growth phases. Roots dipping before transplantation and seed soaking in 250 ppm solution of cycocel and NaCl for 2-8 hours improved the performance of some crops under saline conditions considerably.

Breeding for salt tolerance:

Breeding for salt-tolerant genotypes that can grow more efficiently than the conventional varieties under high salinity stress is a fundamental approach, which is considered economically feasible (Blum, 1988 and Ashraf *et al.*, 2008). Development of a breeding programme for improved salt-tolerant varieties requires efficient screening techniques for the selection and evaluation of specified characters, identification of genetic variability, knowledge of the inheritance of tolerance trait (s) at specific developmental stages, knowledge of biological mechanisms underlying tolerance, reliable direct or indirect selection criteria and designing the most

Table 5: Effect of saline water on yield (q/ha) of fennel and fenugreek

EC_{iw} (dS/m)	Fennel	Fenugreek
BAW	11	21
2	10	21
4	9	20
6	7	20
8	6	18
C.D. (P=0.05)	1	2

Table 6: Tolerance of spice crops to alkalinity

Sensitive crops (ESP <20)	Semi-tolerant crops (ESP 20-40)	Tolerant crops (ESP >40)
Ginger and turmeric	Garlic, hot pepper, coriander, fenugreek and fennel	Spinach and sugar beet

Table 7: Crop varieties tolerant to alkalinity

Crops	Varieties
Fenugreek	Pusa Early Bunching
Spinach	K Hari Chikari
Hot pepper	Pusa Jwala and Chaman
Garlic	Gattar Gola and Hansa

appropriate breeding methodologies or strategies to transfer the tolerance trait (s) into improved genetic backgrounds. Selection and breeding of salt-resistant crop varieties offer tremendous possibilities of utilizing saline water resources for crop production. Attempts to improve the salt tolerance of crops through conventional breeding programs have very restricted success due to limited sources of genes for salinity tolerance and lack of rapid and precise evaluation methods (Flowers, 2004). In addition, tolerance to saline conditions is a developmentally regulated stage-specific phenomenon, and tolerance at one stage of plant development does not always correlate with tolerance at other stages (Foolad, 2004).

In pepper, salt stress significantly decreases germination, shoot and root length, fresh and dry weight including yield. Yildirim and Guvenc (2006) reported that pepper genotypes Demre, Ilica 250, 11-B-14, Bagci Carliston, Mini Aci Sivri, Yalova Carliston and Yaglik 28 can be useful as source of genes to develop pepper cultivars with improved germination under salt stress. Elucidation of salt tolerance mechanism at different growth periods and the introgression of salinity tolerance genes into spice crops would accelerate the development of varieties that are able to withstand high or variable levels of salinity compatible with different production environments.

Effect of alkalinity on spice crops:

Most of the research endeavors, till now, have been aimed at identifying the genotypes and breeding new varieties of crops for normal or saline conditions, limited efforts have been made for alkali environment. Like salinity, there exists a wide genetic variation in crops and their varieties in relation to their tolerance to alkalinity. Crop yield is generally not significantly reduced until the salt concentration in the soil solution and ESP exceed the specific value for each crop. The salt and sodium tolerance of winter crops is generally higher than those grown during the hot season. Therefore, it is suggested that spice crops in low rainfall areas (<400 mm) may be grown during winter season (low ET), keeping the land under arable crop during summer. The efficient strategy should aim at selecting a crop with low water requirement for *Rabi* and a crop that can thrive on rain water for *Kharif*. Compilation of results of various studies reveals that spinach and sugar beet are the most alkalinity tolerant crops, while others are semi-tolerant or sensitive (Table 6). These data sets could be used to identify crops and crop cultivars when alkali water is used to grow spice crops. Garlic crop tested under alkalinity reveals that a reduction of 31 per cent at an ESP of 39.0 me/l as compared to ESP of 11.5 me/l (Anonymous, 2000). Usually, there is a negative correlation between tolerance of varieties and their potential yield. Hence, there are not many varieties, which are tolerant to alkalinity and may produce economic yield, which is major concern for most of the farmers. Some of better performing varieties under alkali conditions to select spice crops have been listed in Table 7.

Conclusion:

This paper reveals that the quantitative salt tolerance data are very limited for spice crops and majority of salt tolerance studies took place under different environmental conditions, measure a variety of growth and yield measurements and sometimes included plant physiological effects of salt stress as well. Spice crops differ in their sensitivity to salinity and water stress. Among spices, fennel, beet leaf, spinach and asparagus are highly salinity tolerant crops. In case of alkalinity, garlic, ash gourd, coriander, fenugreek and fennel are semi-tolerant (ESP 20-40), whereas, spinach and sugar beet are tolerant (ESP > 40) plants. Selection of suitable varieties, cropping systems, irrigation scheduling, and suitable soil and water amendments are the key issues for more profitable use of the salt-affected land and irrigation water. It is well known fact that salt tolerance is a complex trait both genetically and physiologically. Thus, country wide breeding programme on the development of salt tolerant spice crops needs more attention.

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