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Effects of Salinity on Germination Behaviour of Two Paddy Landraces Grown in Chakrata, Dehradun, Uttarakhand, India

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Abstract : Germination ability of seeds varies significantly amongst different varieties of same crop when exposed to the stress. Paddy (*Oryza sativa* L.) is known to be highly sensitive to salinity during germination and young seedling stages. Present study was aimed to observe the effects of six salinity concentrations (0%, 0.1%, 0.5%, 1%, 1.5% and 2%) on the germination behaviour of two paddy landraces (Chenaphool and Gyasu), frequently grown in Chakrata area of district Dehradun, Uttarakhand. Salinity (>0.1%) was inversely related to final germination percentage, germination energy, plumule dry weight, plumule length, radical dry weight, radical length and speed of germination. Chenaphool landrace showed higher germination and growth (plumule and radical) at 0% salinity (control), while Gyasu landrace at 0.1% salinity level.Dry weight percentage reduction increased with increasing salinity level, while negative correlation was observed between salinity and salt tolerance index and seed vigour index for both the varieties. The study concluded that the long grained, irrigated landrace Chenaphool was more sensitive to salinity in comparison to short grained, non-irrigated landrace Gyassu. Lower salinity conditions have no adverse effects on the germination behaviour of Gyasu landrace.

Keywords : Germination behaviour, landraces, paddy, salinity , seed

Introduction

India is the largest paddy (*Oryza sativa* L.) growing country. Approximately 44.6 million ha paddy is grown annually under 4 major agro-ecosystems: irrigated (21 million ha), rainfed lowland (14 million ha), rainfed upland (6 million ha) and flood-prone (3 million ha) which contribute 67.3%, 22.9%, 6.6% and 3.3% in total rice production respectively (Sati 2005). Paddy is grown up to 2300 m a msl in hills of northern India but there is a wide gap between the productivity of hills and plains, low temperature being main constraint at higher altitude. Paddy apart from being a source of food is intimately related to religious, cultural and social functions of the life of hill peoples. It also provides feed for cattle, thereby, reducing pressure on grazing land and forests. Thus, paddy helps to balance the delicate ecosystem of Himalayas, where fodder scarcity is more acute (Siddiq *et al*. 2009). In hill regions, farmers prefer to grow the paddy landraces adapted to rainfed terraced lands.

Uttarakhand, one of the Himalayan states of India is well known for its rich natural resources. It comprises of two distinct physiographic regions *viz*. hills (86.07%) and plain (13.93%). Larger part is characterized by a difficult terrain, undulating topography, remote and inaccessible villages, sparse population, tiny land holdings, agriculture-based economy and weak infrastructure (Negi *et al*. 2009). Agriculture based activities are the main source of livelihood for the major population (Javed and Khan, 1995; Kumar *et al*., 2010). About 75–90% population of the state is engaged either in the main occupation of agriculture or its allied practices, dominated by traditional subsistence cereal farming (Maikhuri *et al*., 2011; Nasim *et al*., 2008).

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Fragmented and small land holdings, sloping lands and rainfall-dependent farming aggravated by migratory grazing lead to very poor yields.

Cultivated crops are exposed to various environmental stresses such as salt, drought and freezing. Salinity is the second most widespread soil problem in rice growing countries after drought (Bliss *et al* 1986) and is considered as a serious constraint in increasing rice production worldwide (Lutts, 1996). In Asia alone, 21.5 million ha of land area is thought to be salt-affected. India has 8.6 million ha of such area which constitutes a major part of soil problem throughout the country (Chandra *et al* 2008). Most of the rice varieties are extremely sensitive to salinity during germination and young seedling stages (Prisco and Vieira 1976; Michael *et al* 2004). Low concentrations of salt suppress plant growth while higher concentration can cause death (Hakim *et al* 2010). Under saline conditions, germination ability of seed varies from one crop to another, even significant variation was observed amongst different varieties of the same crop (Ruan *et al* 2002; Sahi 2006). It is necessary to identify the sensitivity and tolerance level of a variety at early seedling stages for successful crop production in a saline environment. Some studies are available on this aspect from India (Khan *et al* 1997) however virtually no attempts have been made on indigenous landraces of Uttarakhand. The present study was aimed to assess seed germination and subsequent seedling growth *vis-à-vis* salinity tolerance of two rice landraces from Uttarakhand hills.

Materials and Methods

The study evaluated two paddy landraces (locally identified) *viz*. Chenaphool (China-4) and Gyasu, commonly grown in the Chakrata area of Dehradun district in Uttarakhand. The voucher specimens of Chenaphool (GUH 20984) and Gyasu (GUH 20985) have been submitted in the Herbarium of Garhwal University (GUH). Chenaphool is cultivated under irrigated conditions and has relatively higher yield potential than Gyasu grown under non-irrigated conditions. The comparative morphological features of the seeds of these two landraces are presented in Table 1. A major part of the cultivated land in Chakrata region is unirrigated. However, the land along the streams and rivers sites receive irrigation water from a well-established network of canals and thus these are considered as irrigated lands. Seeds of each landrace were collected directly from farmers (n=10) and composite samples were prepared by mixing seeds of respective landraces.

Table 1. Seed morphology of Chenaphool and Gyassuice variety

Parameters	Rice variety	
	Chenaphool	**Gyassu**
Density ($gmml^{-1}$)	0.033±0.004	0.034±0.002
Length (mm)	8.66±1.24	6.71±1.14
Moisture content (%)	9.92±1.84	9.7±1.62
Physical purity (%)	99.79±0.64	99.76±0.56
Weight (g)	24.82±1.62	30.55±2.32
Width (mm)	3.01±0.15	3.36±0.12

The physical purity, seed moisture content, germination test, seed weight, density, length and width of seeds were analyzed (Anonymous 2008). Prior to the experiments, all the glassware were sterilized by autoclaving while seeds were surface sterilized by 1% sodium hypochlorite (NaOCl). Seed germination bioassay was used to test the effect of salinity. The soil solutions *i.e.* 0.1%, 0.5%, 1%, 1.5% and 2% along with a control (0% NaCl) were prepared. Four replicates per treatment each containing 25 seeds were kept for germination. The petri dishes were placed in seed germinator at 25±1°C temperature, 62±1% relative humidity and 12 hour photoperiod for 14 days. The seeds were kept moist regularly either by applying distilled water (control) or with respective NaCl solution.

The number of seeds germinated was counted daily up to 14 days under each treatment to record germination percentage. Final germination percentage (FGP), germination energy (GE) and speed of germination (SG) were calculated as per Ellis and Robert (1981) and Ruan *et al*. (2002). Plumule length (PL) and radical length (RL) was measured by selecting 5 seedlings from each treatment randomly at the time of final count. Plumule dry weight (PDW) and radical dry weight (RDW) was recorded immediately after oven drying at 80°C for 24 hours. Dry weight percentage reduction (DWPR), salt tolerance index (STI) and seed vigour index(SVI) were calculated with the following formula:

$$DWPR\ (\%) = 100 \times [1 - (Dry\ weight_{salt\ stress} / Dry\ weight_{control})] \quad (1)$$

$$STI\ (\%) = 100 \times (Total\ dry\ weight_{salt\ stress} / Total\ dry\ weight_{control}) \quad (2)$$

$$SVI\ (\%) = Germination\ percentage \times Means\ of\ seedling\ length\ (root + shoot) / 100 \quad (3)$$

Results and Discussion

In Uttarakhand, the farmers in the focal area traditionally use landraces of paddy having ability to withstand climatic exigencies, possessing many vital qualities such as pest resistance, drought-resistance, high protein content, flavour, *etc*. (Bisht *et al* 2007). The seeds of the studied landraces, Chenaphool (irrigated) and Gyasu (non-irrigated), were found to be almost similar with respect to density, moisture content and physical purity (Table 1). Land races were significantly distinct from each other in respect of seed length, seed width and seed weight. Seeds of Chenaphool (8.66±1.24 mm) were longer than Gyasu (6.71±1.14 mm), while seed weight of Gyasu was more (30.55±2.32 g) in comparison to Chenaphool (24.82±1.62 g).

Effects of Salinity on Germination

Germination initiated on the fourth day after sowing and differences were noticed under different saline stress conditions from 5th day onwards. FGP, GE and SG were higher under controll conditions for Chenaphool landrace (Table 2). Gyasu landrace showed highest FGP, GE and SG at 0.1% salinity stress (Table 3). In Chenaphool, FGP, GE and SG gradually decreased with increasing salinity from 0.1%–0.5%, and an abrupt fall at (1%–2%). Detrimental effects of higher salinity levels occur because of osmotic stress (Bliss *et al*. 1986;Almansouri *et al* 2001) and specific ion toxicity (Hampsonand Simpson, 1990). Salinity showed significant negative correlation with FGP, GE and SG in both the landraces (Table 4 and 5). Negative effects of salinity on FGP, GE (Mondal *et al* 1988) and SG in paddy were also reported by some earlier workers (Khan *et al*. 1997, , Hakim *et al*. 2010, Vibhuti *et al*., 2015).

Table 2. Effects of salinity on different physiological attributes of Chenaphool rice variety

Parameter*	**Salinity level**(%)					
	0	**0.1**	**0.5**	**1.0**	**1.5**	**2.0**
FGP (%)	98.75±0.48	97.5±0.71	97.5±1.81	88.75±2.19	82.5±0.96	21.25±1.38
GE (%)	98.75±0.64	97.5±0.81	97.5±0.74	62.5±0.54	7.5±0.48	Nil
PDW (g)	5.6±0.71	4.8±0.72	3.7±0.24	1.5±0.10	0.6±0.13	Nil
PL (cm)	9.49±0.91	6.16±0.78	6.12±0.42	2.1±0.26	0.74±0.21	0.1±0.01
RDW (g)	4.8±0.82	3.4±0.45	2.8±o.26	0.3±0.12	0.2±0.1	Nil
RL (cm)	7.47±0.68	5.14±0.30	4.57±0.54	1.62±0.35	0.54±0.30	0.1±0.20
SG (%)	9.87±0.85	9.75±0.77	8.77±0.62	4.5±0.65	2.5±0.67	0.65±0.21

*FGP=final germination percentage, GE=germination energy, PDW=plumule dry weight, PL= plumule length, RDW=radical dry weight, RL= radical length and SG=speed of germination.

Table 3. Effects of salinity on different physiological attributes of Gyassu rice variety

Parameters	Salinity level (%)					
	0	0.1	0.5	1.0	1.5	2.0
FGP (%)	45±0.82	47.5±0.76	27.5±1.26	21±1.30	17.5±1.14	12.5±1.56
GE (%)	35±0.71	45±0.66	25±0.55	20±0.63	10±0.48	Nil
PDW (g)	6.3±0.68	8.4±0.62	4.4±0.42	3.4±0.24	1.1±0.13	Nil
PL (cm)	9.61±0.58	10±0.60	5.22±0.34	3.53±0.28	1.13±0.15	0.26±0.02
RDW (g)	6.5±0.56	5.5±0.54	4±0.35	1.5±0.43	0.4±0.13	Nil
RL (cm)	9.17±0.74	8.39±56	5.58±0.51	2.54±0.41	0.81±0.36	0.13±0.12
SG (%)	3.5±0.51	3.5±0.77	1.91±0.48	1.56±0.42	0.7±0.29	0.41±0.17

Table 4. Correlation between different physiological attributes of Chenaphool rice

	Salinity	FGP	GE	PDW	PL	RDW	RL
FGP	-0.836*	1.00					
GE	-0.961**	0.787	1.00				
PDW	-0.977**	0.723	0.928**	1.00			
PL	-0.943**	0.687	0.903*	0.982**	1.00		
RDW	-0.921**	0.625	0.858*	0.981**	0.987**	1.00	
RL	-0.949**	0.681	0.902*	0.989**	0.998**	0.991**	1.00
SG	-0.988**	0.80	0.970**	0.980**	0.950**	0.935**	0.953**

*. Correlation is significant at the 0.05 level (2-tailed), **. Correlation is significant at the 0.01 level (2-tailed).

Table 5 Correlation between different physiological attributes of Gyasu rice

	Salinity	FGP	GE	PDW	PL	RDW	RL
FGP	-0.938**	1.00					
GE	-0.963**	0.960**	1.00				
PDW	-0.954**	0.963**	0.996**	1.00			
PL	-0.965**	0.992**	0.972**	0.977**	1.00		
RDW	-0.968**	0.960**	0.921**	0.925**	0.975**	1.00	
RL	-0.973**	0.975**	0.943**	0.947**	0.988**	0.998**	1.00
SG	-0.961**	0.989**	0.967**	0.971**	0.998**	0.970**	0.983**

*. Correlation is significant at the 0.05 level (2-tailed), **. Correlation is significant at the 0.01 level (2-tailed).

Table 6. Dry weight percentage reduction (DWPR), Salt tolerance index (STI) and Seed vigor index (SVI) for two traditional varieties rice (Chenaphool and Gyasu)

Salinity level (%)	Chenaphool			Gyassu		
	DWPR (%)	STI (%)	SVI (%)	DWPR (%)	STI (%)	SVI (%)
0	-	-	16.75	-	-	8.45
0.	21.15	78.84	11.99	-8.5	108.59	8.73
0.5	37.5	62.5	11.39	34.37	65.62	2.97
1.0	82.69	17.30	3.30	61.72	38.28	1.27
1.5	92.30	7.69	1.056	88.28	11.71	0.34
2.0	100	Nil	0.042	100	Nil	0.048

Effect of Salinity on Plumule Growth

Plumule dry weight (PDW) and plumule length (PL) were maximum under the control conditions for Chenaphool, which gradually decreased with increasing salinity. In Gyasu, highest PDW and PL were recorded in 0.1% salinity. Salinity (above 0.1% to 2%) correlated negatively with the PDW and PL. Reduction in seedling height is common phenomenon of many crop plants grown under saline conditions (Javed and Khan, 1995). Higher concentration of salts reduces the water potential in the medium which hinders water absorption by germinating seeds and thus inhibit or delay seeds germination and seedling establishment (Hakim *et al*. 2009).

Effects of Salinity on Radical Growth

Radical dry weight (RDW) was 4.8±0.82 g and 6.5±0.56 g for the Chenaphool and Gyasu landrace respectively under controlled conditions. Also, maximum radical length (RL) was observed under control conditions in both the landraces. RDW and RL showed significant negative correlation with salinity. The PL and RL showed decreasing trend with increasing salinity, indicating that the salt stress not only affected germination but also the growth of seedlings, and in turn dry matter production of the seedlings (Vibhuti *et al*. 2015). Lower salinity stress reduces radical growth at earlier seedling stage by slowing down the water uptake (Kazemi and Eskandari, 2011), while higher salinity completely inhibits growth.

Dry Weight Percentage Reduction

Maximum dry weight percentage reduction (DWRP) was recorded at 1.5% salinity for both the landraces, while no germination was observed at 2% salinity. Lowest DWPR was observed at 0.1% salt solution in Chenaphool landrace while at 0.5% in Gyasu. DWPR (%) showed positive relation with salinity for both Chenaphool (r = 0.912) and Gyasu (r = 0.958). Reduction in the fresh and dry weight percentage reduction in the shoots than in the roots, as a result of salt stress has also been reported by Achakzai *et al*. (2010) and Akram *et al*. (2010).

Salt Tolerance Index (STI)

Salt tolerance index (STI) decreased with increasing salinity level from 0.1%–2% in both the landraces. In Chenaphool, STI varied between 7.69 (at 1.5% salinity) and 78.84 (at 0.1% salinity), and 11.71(1.5%) to 108.59 (0.1%) in Gyasu (Table 4). Gyasu landrace showed better STI in comparison to Chenaphool. STI in both landraces showed negative correlation with salinity (Fig. 1 & 2). Inverse relation of STI with salinity level in the present study is in agreement with Vibhuti *et al*. (2015).

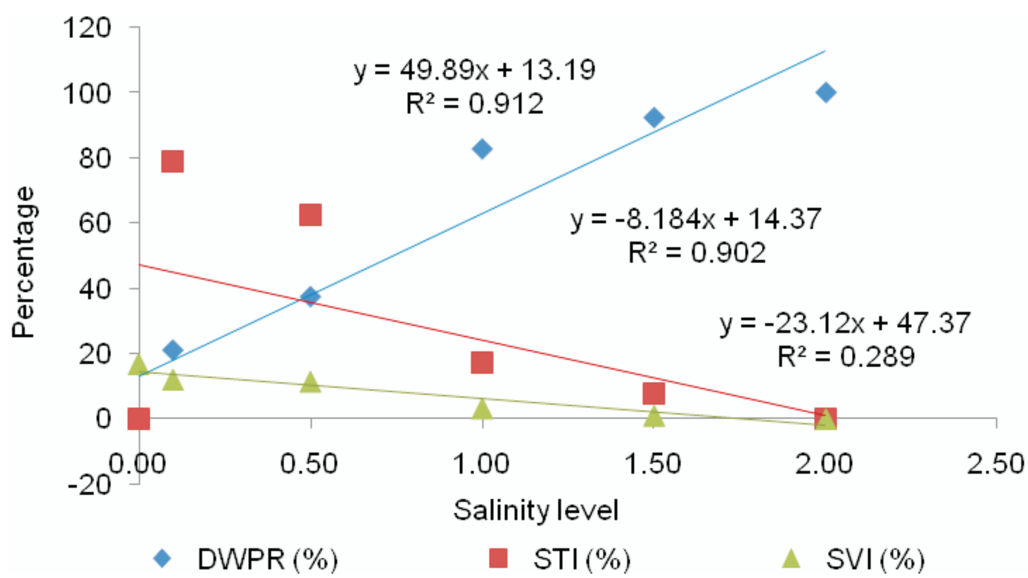

Fig. 1 Effects of salinity on DWPR, STI and SVI of Chenaphool rice

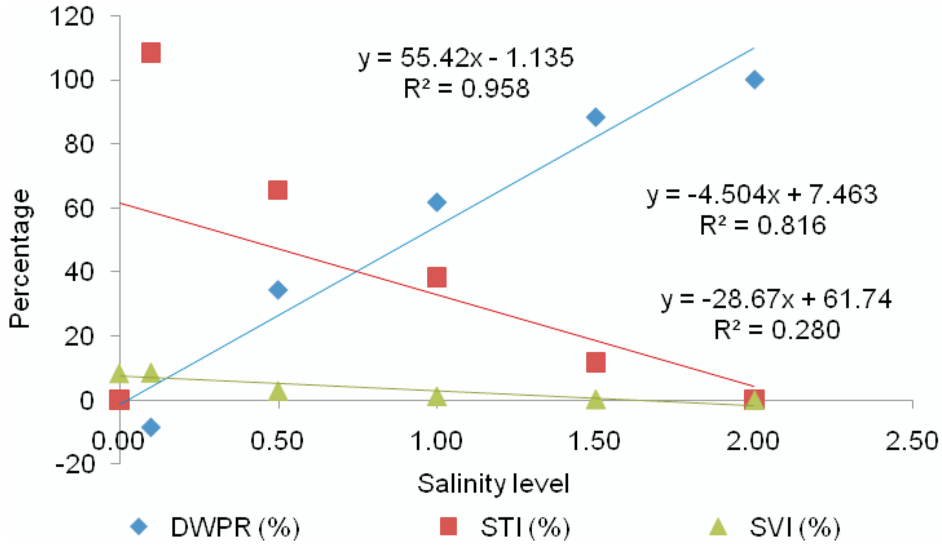

Fig. 2 Effects of salinity on DWPR, STI and SVI of Gyassu rice

Seed Vigor Index (SVI)

Seed vigor index (SVI) was recorded highest (16.75%) in control for Chenaphool, while in 0.1% salinity level for Gyasu (8.73%). Lowest SVI was 0.042 and 0.048 for Chenaphool and Gyasu respectively, owing to 2% salinity level. Salt stress conditions decrease water uptake during imbibitions and seedling establishment, which can then be followed by uptake of ions (Prisco and Vieira, 1976). Salinity suppresses the uptake of essential nutrients like P and K (Nasim *et al*., 2008), which could adversely affect seedlings growth and vigor.

Conclusions

The salinity (>0.1%) has inverse effects on the final germination percentage, germination energy, plumule dry weight, plumule length, radical dry weight, radical length and speed of germination for two paddy landraces (Chenaphool and Gyasu). The long grained, irrigated landrace Chenaphool showed higher dry weight percentage reduction, seed vigor index but lower salt tolerance index and is more sensitive to salinity in comparison to short grained, non-irrigated landrace Gyasu. Gyasu showed very low germination than Chenaphool in general, but was more tolerant to salinity with low dry weight percentage reduction and higher salt tolerance index.

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