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EFFECTS OF NaCl AND Na_2SO_4 SALINIZATION ON GERMINATION AND EARLY SEEDLING GROWTH OF FIFTEEN GERMPLASMS OF GUAR (*CYAMOPSIS TETRAGONOLOBA* (L.) TAUB.) – *IN VITRO*

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ABSTRACT

Germination of fifteen germplasms of guar (four varieties, BR-2/1, BR-90, BR-99 and BR-2017) and 11 lines (S-5733, S-5742, S-5747, S-5759, S-5761, S-5765, S-5784, S-5785, S-5797, S-5798 and S-5825) has been investigated *in vitro* under NaCl and Na_2SO_4 salinities (0 to 10 bar) corresponding to 0.203 to 22.20 $dS.m^{-1}$ in case of NaCl and 0.203 to 23.0 $dS.m^{-1}$ in case of Na_2SO_4. Final germination percentage (FGP) was of quite high order reaching ≈ 90 % in several germplasms after four days of incubation in 10 bar NaCl except few germplasms in which germination significantly declined. Sequentially descending order of salt tolerance in terms of increasing *per cent* reduction of final germination in 10 bar NaCl and Na_2SO_4 over control was found to be as follows. FGP was generally more affected under Na_2SO_4.

NaCl (Germination reduction in 10 bar over control):

BR-2/1 (-6.67%) = BR-99 (-6.67%) > S-5785 (-11.11%) > BR-90 (-13.33%) > S-5742 (-17.24%) > S-5761 (-19.99%) ≈ S-5733 (-20.0%) > S-5759 (-24.14%) ≈ S-5747 (-24.99%) > S – 5765 (-27.58%) > S-5785 (-33.33%) > S-5797 (-46.67%) ≈ S-5798 (-48.18%) > BR-2017 -51.85%) > S-5784 (-68.97%)

Na_2SO_4 (Germination reduction in 10 bar over control)

S-5825 (-17.24%) > S-5759 (-31.03%) ≈ S-5747 (-32.14%) ≈ S-5785 (-33.33%) = S-5797 (-33.33%) > BR-99 (-40.0%) ≈ BR-2017(-40.74%) > S-5798 (-40.74%) ≈ S-5765 (-41.38%) > BR-90 (-46.67%) > BR-2/1 (-50.0%) > S-5761 (-60.00%) > S-5784 (-62.07%) > S-5733 (-66.67) > S-5742 (-82.76%)

Germination velocity was greatly impeded under both types of salinities. Fifty per cent reduction in GVI on the basis of best fit linear or curvilinear predictive equations associated with in-hand germplasms as follows:

NaCl salinity (50% Reduction in GVI:

S-5784 (6.66 bar) < S-5733 (7.50 bar) < S-5798 (8.55 bar) ≈ S-5742 (8.95 bar) = S-5761 (8.95 bar) < BR-2017 (9.36 bar) < S-5797 (9.92 bar) < S-5765 (10.02 bar) < S-5785 (11.73bar) < S-BR-2/1 (11.83 bar) < S-5759 (12.42 bar) < S-5747 (13.55 bar) < S-5825 (19.56 bar) < BR-90 (20.36 bar) < BR-99 (exhibited promotion by 6.25%).

Na_2SO_4 salinity (50% Reduction in GVI:

S-5733 (5.18 bar) < S-5761 (5.79bar) < BR-2/1 (6.16 bar) ≈ BR-90 (6.27 bar) ≈ S-5742 (6.29 bar) ≈ S-5759 (6.57bar) ≈ BR-99 (6.61bar) ≈ BR-2017 (6.69 bar) < S-5784 (7.34 bar) ≈ S-5797 (7.46 bar) ≈ S-5747 (7.76 bar) < S-5765 (8.74 bar) < S-5825 (9.47 bar) < S-5785 (10.25 bar) < S-5798 (12.49 bar)

Root and shoot length and cummulative seedling weight declined with salinity. Fifty per cent reduction in seedling weight in 10 bar salinities associated with the germplasms as given below:

NaCl salinity (Promotion / Reduction in seedling weight in 10 bar over control:

S-5733 (+163.33%) > S-5785 (+51.16%0 > S-5825 (+ 28.57%) > BR-99 (+21.95%) ≈ S-5742 (+ 21.74%) > BR-2/1 (+14. 38%) > S-5759 (-8.24%) > S-5747 (-9.18%) > S- 5766 (-17.68%) > S-5797 (-18.60%) > BR-90 (-23.08%) > S-5784 (-39.39%) > S-5761 (-57.30%) > BR-2017 (-62.15%) > S-5798 (-70.19%)

Na_2SO_4 salinity (Promotion / reduction in seedling weight on 10 bar over control:

S-5733 (+ 192.22%) > S-5785 (+12.79%) > S-5825 (+6.72%) > BR- 90 (-5.98%) > BR- 2/1 (-7.29%) > S-5765 (-12.71%) > S-5797 (-17.83) > S-5761 (-20.22%) ≈ BR-99 (-21.19%) ≈ S-5742 (-22.46%) > S- 5747 (-30.61%) ≈ S-5759 (-30.77%) > BR-2017 (-49.72%) > S-5784 (-61.04 > S-5798 (-74.04%).

Agglomerative clustering of germplasms at dissimilarity distance of 5% on the basis of FGP, GVI and seedling dry weight in two type of salinities indicated 5, 2 and 8 groups of germplasms in NaCl and 9, 5 and 7 groups in Na_2SO_4, respectively. Obviously the amplitude of behavioural dispersion in Na_2SO_4 salinity was wider than in NaCl. The extracted groups were differentially tolerant to salinity. Since, there was variation in salt tolerance of germplasms on the basis of parameters studied; a composite performance index was designed according to which there were three groups each in NaCl and Na_2SO_4 salinities.

CPI -NaCl salinity:

I. Germplasms with CPI: 70-80 (S-5761, S-5785 and S-5797)
II. Germplasms with CPI: 81-90 (S-5825, BR-2017, BR-90, S-5798, BR- 2/1, and BR-99)
III. Germplasms with CPI: 98-103 (S-5747, S- 5742, S-5784, S- 5759, S-5733 and S-5765) – relatively more tolerant.

CPI - Na_2SO_4 salinity:

I. Germplasms with CPI: 71-79 (S-5785, BR-99, S-5798, S-5797, BR-2017, BR- 2/1). All varietal germplasms except BR-90 entered the composition of this group.
II. Germplasms with CPI: 84-88 (BR-90, S-5825, S-5765, S-5761, S-5784
III. Germplasms with CPI: 95-96 (S-5733, S-5747, S-5742) – obviously, this group was relatively more tolerant.

On the basis of promotion or reduction of CPI in Na_2SO_4 over NaCl following generalizations may be made:

a. Germplasms showing CPI reduction: - 0.82 to -1.95% (BR- 90, S-5742 and S-5747). These germplasms were more or less equally tolerant to NaCl and Na_2SO_4 salinities.
b. Germplasms with CPI reduction: -5.23 to - 6.95% (S-5797, S-5733, S-5785, and BR-2017)
c. Germplasms with CPI reduction: -11.08 to – 15.48% (BR- 2/1, S-5784, S-5759, S- 5798 and S-5765) – more sensitive to Na_2SO_4 than above groups.
d. Germplasms with CPI reduction: -20.99% (BR-99) – most sensitive to Na_2SO_4 amongst the tested germplasms.
e. Germplasms with CPI promotion: + 2.58 to +17.06% (S-5825 and S-5761, respectively) – most tolerant to Na_2SO_4 salinity which was promotory to them over NaCl- particularly S-5761.

The results are discussed in view of the available literature pertaining to guar.

Key Words: Guar (*Cyamopsis tetragonoloba* (L.) Taub., Pakistan's guar germplasms, NaCl and Na_2SO_4 salinity, Germination, Germination velocity, agglomerative cluster analysis, Salinity tolerance

INTRODUCTION

Guar or cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.), is a legume crop, grown for three major purposes primarily as cattle forage, as green manure and raw material for industry (AlShameri *et al*., 2017). It is expected that genus *Cyamopsis* originated from the genus *Indigofera* due to aneupoidy (Senn, 1938). Guar is mainly grown in India (80% of the World production), Pakistan (15%), Sudan and USA (Sharma, 2010). Guar grows best in sandy soil (Raychaudhuri, 1952). It is an excellent soil-binding crop due to potential *Bradyrhizobium* nodulation (ElSheikh and Ibrahim, 1999). Being a valuable crop economically, it has been extensively studied for various biological aspects and its agronomic characteristics (to cite a few: Whistler and Hymowitz, 1979; Omer *et al.,* 1993; Lahiri *et al.,* 1996; Afria *et al.*, 1998; Ashraf *et al.* 2002; Weixin, 2003; Chaudhary *et al.*, 2007 a and b; Morris, 2010; Pathak, 2010; Rao and Shahid, 2011; Rai *et al.*, 2012; Sultan *et al.*, 2012; Singh, 2014; Deepika and Dhingra (2014); Khalid *et al.,* 2017; Muftahizade *et al.,* 2017; Shehata *et al.,* 2017; Amin *et al.,* 2018; AlShameri *et al*., 2017; 2019). Deepak *et al.* (2003) have reported regeneration of guar shoot from cotyledonary nodes. Amin *et al.* (2018) reported that it may grow in Pb-accumulated soil (1000mg/ kg soil). Gresta *et al.* (2018) tested nine guar genotypes (India1, India2, India3, Kinman, Lewis, Metador, monument, etc.) from India, Pakistan, USA and South Africa in Sicily, Italy for germination capability and speed in response to constant temperature (5 to 35 ^{o}C, with 5 ^{o}C increments) and two alternating temperature 15/10 ^{o}C and 20/15 ^{o}C. Optimal temperatures were 30 and 35 ^{o}C but Indian genotype also demonstrated substantial germination percentage (33-43%) at constant temperature as low as 15 ^{o}C. Final germination percentages in all genotypes increased with temperature from 10-35 ^{o}C except Pakistan germplasm which showed decline in germination at higher temperature of 35 ^{o}C. Germination time was generally higher at low temperature. Germination significantly improved when seeds were exposed to 20 ^{o}C for 6h a day. Earlier, in another paper, Sortino and Gresta (2007) evaluated growth and yield of five cultivars in a Mediterranean environment. Singla *et al.* (2016) studied planting time of guar in semi-arid Southern plains of USA and found that delaying planting beyond mid-June is detrimental to guar productivity. Guar may survive in fairly high salinity (Mehta and Desai, 1953; Yadava *et al*., 1974). Many guar genotypes have been tested for salt tolerance in recent years, and some of them have turned out to be indeed salt tolerant. The potential of some guar accessions for saline soils was tested by Teolis *et al.* (2009) by evaluating seed germination of 42 accessions of guar in sodium chloride solution. The seeds were germinated in 200 mM NaCl or double-distilled water (control). There were significant differences in salt tolerance among the accessions tested. Percentages of seeds germinating in the salt solution ranged from 7.7 to 90.3% of the control, with the higher percentages suggesting greater salt tolerance. Twelve of the forty-two accessions were further selected to study the effect of salinity on plant growth. Significant differences were obtained between the accessions for seed yield per pod, but not for seed yield per plant, plant height, branch number, and pod number (percentage of control). The presence of variation in the germplasm suggests some potential for selecting cultivars with increased salt tolerance. Salinity studies should include both germination and plant trials, because germination assays for salt tolerance do not necessarily predict plant growth and yield in saline soils.

Abdou *et al.* (2017) studied the effects of Compost and some bio-stimulants treatments on guar. Khafagy *et al.* (2010) have reported that presoaking of guar seeds in selected phytohormones (ABA or SA) and vitamins (Ascorbic acid and Thiamine) exhibited significant effect on seed germination as well as seedling growth under both normal and NaCl saline conditions compared to control. Generally, phytohormone (Salicylic acid) and plant vitamin (Ascorbic Acid or Thiamine) counteracted the harmful effect of salinity on guar seedling growth. Jat *et al.* (2015) studied two varieties of guar ('Neelam – 51' and 'Naveena') for seed quality enhancement by seed priming. Kumar *et al.* (2017) employed conventional and biotechnological approaches for genetic improvement of cluster bean and Arora and Pahuja (2008) employed chemical and physical mutagens to extend the range of genetic diversity of guar plants but economically important traits were not found in mutants. Ambika and Balakrishnan (2015) investigated the effects of cow urine priming of guar seeds on germination and seedling growth.

Some genotypes of guar from Pakistan were investigated by Rashid *et al.* (2015) using agronomic traits (shoot fresh biomass, shoot dry biomass and plant height) as well as stress tolerance indices of these traits). At adult vegetative growth, genotypes 41671, Khushab White, 5597, 24320, Sillanwali White, 24321, Mardan White, Br-99, Karor White, Hafizabad White, BWP-5611 and Klorkot Black were rated as salt tolerant, while 24323, Khanewal Local 2, Kalorkot White, BWP5589, Chiniot White, 27340, BWP-5599, Bhowana White and BWP-5596 were rated as highly salt sensitive. A significant genotypic variation was found amongst the 31 genotypes tested. They opined that further study is necessitated to elucidate physiological basis of salt tolerance in guar (Rasheed *et al.,* 2015). Alshameri *et al.* (2017) have tested drought and salt tolerance of some guar germplasms and reported that accessions BWP 5595, 24320, Chiniot 1, Chiniot 2, Kaloorkot 2, and BWP 5599 were more drought tolerant than BR-99, BR-90, 027340, 24333, 24332, Khanewal Local 2, and Bhawana 2. Accessions 24320, BWP 5595, Chiniot 1, Chiniot 2, and 22159 were considered to be more salt-tolerant than BWP 5589, 24333, Bhowana 2, 24287, 027340 and BWP 5596. Overall, BWP 5595 and 24320 were found to be drought- and salt-tolerant, respectively, while Khanewal Local 2 and BWP 5589 were drought-sensitive and salt-sensitive, respectively. Thirty six accessions of guar from Pakistan were tested by Ali *et al.* (2015) for enhanced forage production on hot dry lands of Pakistan. Andrade (1985) worked for salt tolerance of three varieties of guar (Kinman, RGC 518 and Santa Cruz. Percent germination of seeds of the cultivars decreased in the media from 5bar to 15 bar. Compared to the control, germination started declining from 5 bar and was minimal around 20-25% in 15 bar medium. Kinman was relatively less affected.

Khan *et al.* (1989) reported that threshold ECiw in case of Lahiya (Punjab) accession of guar with amended Seawater dilution inducing 50% reduction in seed production was $5.76 dS.m^{-1}$. They found that salinity decreased number of pods and seeds per plant. The number of seeds per pod remained unaffected (7- 8 seeds per pod). All cations (Na, K, Ca and Mg) were more allocated to leaf. Abusuwar and Abbaker (2009) *in vitro* investigated forage species including guar for germination in various dilutions of Red Seawater (control = 0.4 $dS.m^{-1}$, and the treatments- 3.095, 5.54, and 16.57 $dS.m^{-1}$ salinity.

Guar is grown with seeds and in this respect germination studies have been undertaken by many workers around the World. To cite a few – Yadava *et al. (*1974), Andrade (1985); Datta and Dayal (1988); Vinisky and Ray (1988); Francois *et al.* (1989); Kumar *et al.* (1988); Miyamoto (1988); Khan *et al.* (1989); Kumar *et al.* (1990); Chunmei *et al.* (2002);Teolis *et al.* (2009); Francois and Kleiman (1990); Khanzada *et al.* (2001); Ashraf *et al.* (2005); Khafagy *et al.* (2010); Rasheed *at al.* (2015); Iqbal (2015); Gul *et al.* (2015); Sambangi and Rani (2016); Alshameri *et al.* (2017); Joshi and Datta (2017); Bina and Bostani (2017); Zheng *et al.*, 2017; Gresta *et al.* (2018); Sudhar *et al.* (2018 a & b); Prakash *et al.* (2019), etc. Guar collection founded in the Institute of Plant Genetic Resources (VIR), Russia, by N.I. Vavilov lists more than 100 accessions. Germination of guar seeds from VIR collection, after 40-year storage at the room temperature, remained high. The research data and the practice of guar growing in Russia testify that the crop could be successfully cultivated in the southern regions of Russia (Dzyubenko *et al.*, 2017).

In present studies, the effects of NaCl and Na_2SO_4 salinities (0 to 10 bar) have been *in vitro* investigated on germination of 15 guar germplasms of Pakistan.

MATERIALS AND METHODS

Freshly collected seeds from the crops of guar, four varieties - BR-2/1, BR-90, BR-99 and BR-2017 and eleven lines including S-5733, S-5742, S-5747, S-5759, S-5761, S-5765, S-5784, S-5785, S-5797, S-5798 and S-5825 were received from Agricultural Research Station, Bahawalpur by the courtesy of Dr. Lal Hussain Akhtar. The biological traits of the guar germplasms employed in this study are presented in Table 1. Germplasms- BR-2/1, BR-90, and BR-99 were released in 1984, 1991 and 2000, respectively whereas var. BR-2017 is recently released. Other germplasms are the accessions collected by the Agricultural Research station and experimented for various agronomic aspects. Germplasms BR-99 and BR-2017 and accessions such as S-5733, S-5747, S-5761, S-5765 and S-5785 are quite high-yielding. All germplasms are cultivated for fodder. S-5733 is an advance line under testing at Agricultural Research Station, Bahawalpur, Pakistan. The seeds were stored at room temperature in dry cabinet not more than 20 days. Longer storage of guar seeds was observed to cause dormancy due to dry hardy seed coat. They are reported to germinate even after 40-year storage (Dzyubenko *et al.*, 2017). Healthier seeds with suitable weights were screened for their salt tolerance (see Khan *et al.*, 2018). The selected seeds were surface sterilized using 1% bleach (NaOCl) and rinsed with sterilized distilled water. Ten seeds of each variety/line were placed on Whatman filter paper in sterilized 9 cm Petri plates. NaCl and Na_2SO_4 solutions were used to investigate the effect of salt stress on guar germination. Ten aqueous concentrations (1 to 10 bar) of NaCl and Na_2SO_4 (Meiri *et al.*, 1971) were prepared in sterilized distilled-deionized water. For the purpose to facilitate comparison, Electrical conductivities of the prepared solutions were measured on EC meter and expressed as ($dS.m^{-1}$) which further ascertained their salinity levels (Fig. 1).

Each Petri plate containing seeds was irrigated with five mL of aqueous solution of NaCl or Na_2SO_4 (1 to 10 bar) and plates were incubated at 28-30 ^oC in a growth chamber to germinate. The optimum temperature for guar germination is reported to 25-30^oC (Zheng *et al.*, 1980). . The sterilized distilled water was used as control for each germplasm. Each treatment had three replicates. Seed germination was recorded every 24 h (AOSA, 1990) until four days. A Seed was considered germinated when its radicle showed at least 2 mm of growth. On 4th day, root length, shoot length and dry weight of healthy seedlings were recorded discarding the seedlings which died (particularly in high concentration of Na_2SO_4). Promotion or reduction was calculated as: treatment - control / control expressed in percent. There are several parameters or indices of germination employed in germination studies (Ranal *et al.*, 2009; Aflaki *et al.*, 2017). It is opined by Al- Mudaris, 1998) that one single parameter is in itself not sufficient to fully describe germination. The 'final germination percentage' is an end phase parameter which only reflects the capacity of a seed lot to reach germination. Since it does not reflect Speed, synchrony or spread of germination - all vital factors from horticultural and agronomic standpoints- it should be accompanied by a measure of germination velocity. In present studies the germination Velocity Index (GVI) was calculated following Woodstock (1976) - GVI = N1/1 + N2/2 + N3/3 + N4 /4……Nn /n, where N1, N2, N3, N4 … Nn are the number of new germinants on a particular day of the test and 1, 2, 3, 4…n are the number of days of observation. GVI is higher if more seeds germinate in lower number of days.

Seed germination involves not only qualitative responses of individual seeds but also population responses which are distributed over time. Standard analysis of variance or regression methods are appropriate when some viable seeds fail to germinate (Scott *et al.*, 1984). Beside variance and regression analyses of the data, varieties /lines were agglomerated in form of a cluster diagram (Ward, 1963) by calculating Euclidean distances on the basis of germination, GVI and seedling dry weight to investigate inter-germplasm similarity of behavior against NaCl and Na_2SO_4 salinities. The technique of cluster analysis has been successfully used by Khalid *et al.* (2017) to delimit clusters on the basis of various agronomic traits amongst 100 accessions of guar from Pakistan into eight clusters of which cluster I (Accessions - 5778, 22267, 22229, 5597, 5588, 5590, 5596, 22228, 5765, 22165, 5789, BR-99, 6036, 6056, 5557, 5752, 5885, 5824, 5823, 5825, 5747, 5601, 5743, 5733 and 21897) and cluster V (6500, 6498, 6499, 6497 and 6496) were considered to be the best performer as regards to grain yield, plant height, number of $pods.plant^{-1}$ and number of $grains.pod^{-1}$ having compact plant type.

Since germination, velocity of germination and the seedling growth varies amongst the species and various cultivars and accessions of a species (Asana and Kale, 1965; Maliwal and Paliwal, 1970), a composite performance index (CPI) was calculated as:

$$CPI = \frac{\text{Final mean germination all over the Treatment Range + Mean velocity of germination all over the Treatment Range + Seedling dry mass at the last day of incubation all over the Treatment Range (0 to 10 bar)}}{3}$$

To compare CPI in two types of salinities, promotion or reduction of CPI in two salinities was calculated as:

$$\text{\% CPI Promotion or Reduction} = \frac{CPI_{Na2SO4} - CPI_{NaCl}}{CPI_{NaCl}} \times 100 \text{ and}$$

$$\text{\% CPI Promotion or Reduction} = \frac{CPI_{NaCl} - CPI_{Na2SO4}}{CPI_{Na2SO4}} \times 100$$

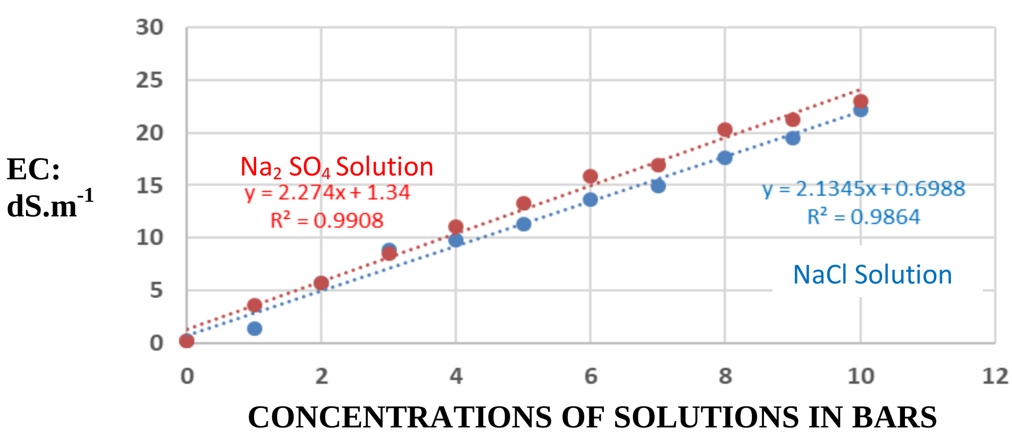


Fig. 1. Relationship of ECs of NaCl and Na_2SO_4 solutions prepared in concentrations expressed in bar following Meiri *et al.* (1971). For ease and convenience bar values were expressed as positive number bearing "bar" as suffix.

RESULTS AND DISCUSSION

Relationship between bar concentrations of NaCl and Na_2SO_4 solutions with their electrical conductivities:

There was statistically highly significant positive correlation between bar and EC units of concentration of NaCl and Na_2SO_4 solutions (Fig. 1). EC values for different bar concentrations of Na_2SO_4 were slightly higher than EC values for NaCl solutions. The EC of NaCl solutions (1 to 10 bar) corresponded to 1.322 -22.20dS.m^{-1}and that of Na_2SO_4 corresponded to 3.58 to 23.0 dS.m^{-1}. Control solutions had EC value equal to 0.203dS.m^{-1}. The equations posted on the curves (Fig.1) may be useful in estimating EC values on the basis of bar concentrations of these salts. It may be mentioned that the osmotic potentials of salt solutions decreases as their concentrations increase. Osmotic potential when represented in bar, they are shown with negative numbers. Higher bar values indicate proportionately lower osmotic potential , with respect to the plant, of a solution i.e., more saline in terms of electrical conductivity of the solutions and consequently lesser and lesser availability of water to seeds, seedlings or plant (see Carrow and Duncan, 2017). Rangaswamy (2010) reported that soil salinity of 25 dS.m^{-1} resulted in an osmotic potential of – 9 bar which greatly reduced plant available water in case of wheat with 89% to 96% of the field capacity unavailable for plant uptake.

Germination

Freshly collected seeds of various guar germplasms exhibited no dormancy in the present experiment. They germinated quite rapidly and synchronously under control conditions. Germination became assynchronized as salinity increased. The final germination percentage (FGP) under NaCl and $N_{a2}SO_4$ salinity is presented in Fig. 2 and 3, respectively. FGP was generally of high order reaching to 90-100% in majority of germplasms after four days of incubation under control as also reported by Thorner (1909) and Ganal Al Awad El-Daw (1998) for guar. Thorner (1909), however, stated that guar seed germination percentage with an initial value of 98% can drop to 2% when submerged in water for 38 days.

FGP of germplasms BR-2017, S-5765 and S-5797 significantly declined under high salinity of NaCl (10 bar) (Fig. 2). There was comparatively larger inhibition of FGP under Na_2SO_4 salinity (Fig. 3). The mean FGP of germplasms under 10 bar concentration and over the entire range of the treatments and control for both salts is presented in Table 2a. FGP of guar germplasms in 10 bar NaCl averaged to 68.88 ± 5.0% which was significantly higher than that (53.78 ± 4.02%) in Na_2SO_4 ($t = 2.24$, $p < 0.05$). Under 10 bar NaCl FGP was higher than the average FGP in 9 germplasms (BR-2/1, BR-90, BR-99, S-5733, S-5742, S-5747, S-5765, S-5759 and S-5825) and was lesser than the average FGP in six germplasms (BR-2017, S-5761, S-5784, S-5797, S-5798 and S-5785). The germination in 10 bar NaCl was maximum in BR-2/1 (93.33± 3.33%) and BR-99 (93.33 ± 3.33%) and minimum in S-5784 (30 ± 15.28%) followed by BR-2017 (43.33 ± 8.82%).

FGP on 4th day in 10 bar Na_2SO_4, was higher than the average FGP in 8 germplasms (BR-99, S-5747, S-5759, S-5761, S-5784, S-5885, S-5797 and S-5825), lower than the average FGP in four germplasms (BR-2/1, S-5633, S-5742 and S-5765) and at par with the average FGP in three germplasms (BR-90, BR-2017 and S-5798).

FGP on the fourth day over the entire range of treatments (0 to 10 bar) was also higher in NaCl (88.52 ± 1.62) than that in Na_2SO_4 (82.21 ± 1.39) ($t = 2.96$, $p < 0.05$). FGP over the entire range of NaCl treatments was the maximum in BR-99 (96.97 ± 1.14%) and the minimum in BR-2017 (75.46 ± 4.88%). In NaCl, nine germplasms had higher FGP than the grand mean and six germplasms had lower FGP than the grand mean. In Na_2SO_4 environment maximum FGP was exhibited by BR-90 (91.82 ± 4.13) and minimum by S-5797 (75.45 ± 4.63). Seven germplasms had FGP higher than the grand mean and eight germplasms had lower FGP than the grand mean.

The adverse effects of salinity on germination are well-known even in drought tolerant species (Khan *et al.*, 1984; Myers and Morgon, 1989; Ismail, 1990; De Villiers *et al.*, 1994; Shaukat and Burhan, 2000). Our results are more or less in agreement with Datta and Dayal (1988) who investigated 25 genotypes of guar (CG-1, HGS-25, HGS-18, CG-4, PLG-174, HFG-314, DSE-IJ, HGS -46, PLG-85, PLG-119, HGS-47, DSE – 16J, HFG-156, PNB, FS-277, HGS-43, HFG-119, Guara, HG-182, HGS-75, HFG-189, Suvidha, HGS-3, HG-17-1 and Hg-258) for salinity tolerance under composite salts (NaCl, $CaCl_2$, $MgCl_2$ and $MgSO_4$ at 30 ± 1 ^oC in Petri dishes irrigated with 10 mL solution of EC: 0, 4, 8,12, or 16dS.m^{-1}. The final germination level didn't vary much with salinity level in their experiment also. Similarly, Zucchini (*Cucurbita pepo* L.) has been reported to germinate more than 90% at 40dS.m^{-1} of NaCl (Bina and Bostani, 2017). Higher salinities differentially reduced germination in all varieties tested of *Vigna unguiculata* (Thiam *et al.* (2013), rice cultivars (Zafar *et al.,* 2015) and maize cultivars (Hassan *et al.,* 2018).

Table 1. Morphological traits of some guar varieties / lines. *

Variety/ Lines	Year of Release	Yield Potential (Kg ha^{-1})	Salient Features
BR-2/1	1984	Grain Yield = 1200 Kg ha^{-1} Fodder Yield = 26 t ha^{-1}	Hairy, Long stature, long duration, branched, grain bold & dark brown, suitable for fodder purpose.
BR-90	1991	Grain Yield = 1400 Kg ha^{-1} Fodder Yield = 28 t ha^{-1}	Hairy, short stature, long duration, profusely branched, golden grain colour, suitable for fodder & grain purpose
BR-99	2000	Grain Yield = 1900 Kg ha^{-1} Fodder Yield = 30 t ha^{-1}	Hairy, Single stemmed, no branching, medium duration, seed colour-grey, tolerant to sucking pests and diseases, suitable for grain, fodder and vegetable purposes.
BR-2017	2017	Grain Yield = 2400 Kg ha^{-1} Fodder Yield = 35 t ha^{-1}	Hairy, erect type, 0-1 branch, higher gum & protein contents, early maturing and short duration variety with heavy fruiting, requires very low inputs, tolerant to sucking pests and diseases, suitable for grain, fodder and vegetable purposes.
S-5274	-		**Approved as BR-2017**
S-5733	Advance line under testing in yield trials	Grain Yield = 1800 Kg ha^{-1} Fodder Yield = 29 t ha^{-1}	Hairy, erect type with 1-3 branches, long duration, tolerant to insect pests & diseases suitable for fodder and seed purposes.
S-5742	-do-	Grain Yield= 1750 Kg ha^{-1} Fodder Yield= 32 t ha^{-1}	Hairy, single stemmed with no branch, early maturing, tolerant to insect pests & diseases, suitable for seed and vegetable purposes.
S-5747	-do-	Grain Yield= 1900 Kg ha^{-1} Fodder Yield= 26 t ha^{-1}	Hairy, erect type with no branch, short duration, tolerant to insect pests & diseases, suitable for seed and vegetable purposes.
S-5759	-do-	Grain Yield= 1700 Kg ha^{-1} Fodder Yield= 27 t ha^{-1}	Hairy, erect type with no branch, short duration, tolerant to insect pests & diseases, suitable for seed and vegetable purposes.
S-5761	-do-	Grain Yield= 1900 Kg ha^{-1} Fodder Yield= 30 t ha^{-1}	Hairy, 0-1 branch, early maturing & short duration, tolerant to insect pests & diseases, suitable for seed, fodder and vegetable purposes.
S-5765	-do-	Grain Yield= 2000 Kg ha^{-1} Fodder Yield= 34 t ha^{-1}	Hairy, no branch, erect type, early maturing & short duration, tolerant to insect pests & diseases, suitable for seed, fodder and vegetable purposes.
S-5784	-do-	Grain Yield= 1800 Kg ha^{-1} Fodder Yield= 24 t ha^{-1}	Hairy, non-branched, early maturing, tolerant to insect pests & diseases, suitable for seed purpose.
S-5785	-do-	Grain Yield = 2200 Kg ha^{-1} Fodder Yield = 22 t ha^{-1}	Hairy, branches 2-4, long duration, tolerant to insect pests & diseases, suitable for seed purpose.
S-5797	-do-	Grain Yield= 1400 Kg ha^{-1} Fodder Yield= 34 t ha^{-1}	Hairy, branches 6-10, long duration, tolerant to insect pests & diseases, suitable for fodder purpose.
S-5798	-do-	Grain Yield = 1300 Kg ha^{-1} Fodder Yield = 33 t ha^{-1}	Hairy, branches 8-10, long duration, tolerant to insect pests & diseases, suitable for fodder purpose.
S-5825	-do-	Grain Yield = 1500 Kg ha^{-1} Fodder Yield = 32 t ha^{-1}	Hairy, branched, long duration, tolerant to insect pests & diseases, suitable for fodder purpose.

*, Courtesy – Regional Agricultural Research Station, Bahawalpur, Pakistan.

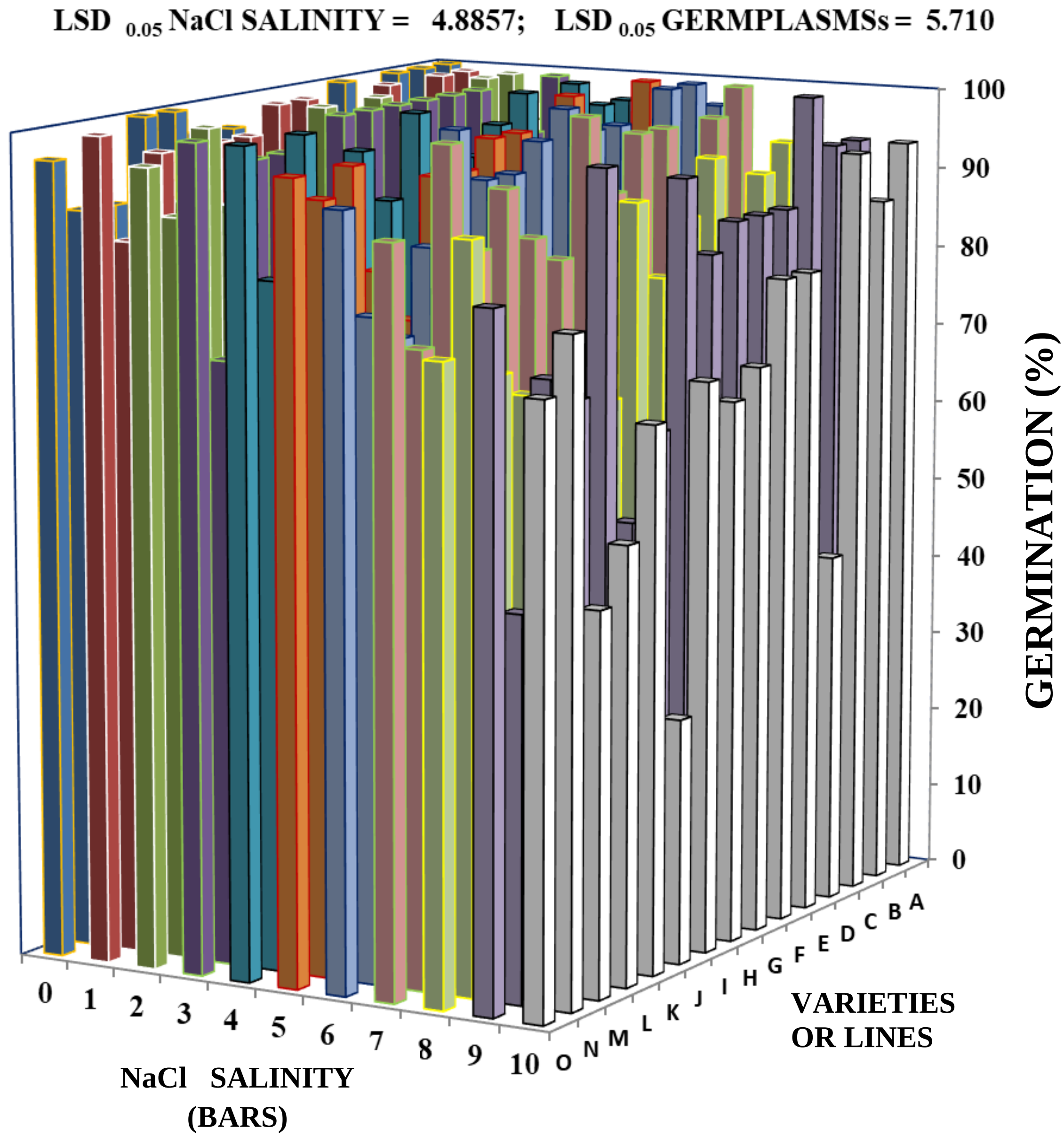


Fig. 2.Per cent final mean germination of Guar varieties / lines under influence of NaCl salinization (0-10 bars). Varieties / Lines: A, BR-2/1, B, BR-90, C, BR-99, D, BR-2017, E, S-5733, F, S-5742, G, S-5747, H, S-5759, I, S-5761, J, S-5765, K, S-5784, L, S-5785, M, S-5797, N, S-5798 and O, S-5825.

The sequential order of FGP of various germplasms in descending order of relative tolerance to NaCl and Na_2SO_4 salinities is given in Table 2b. **Clearly, BR-2/1, BR-99 and BR-90 were highly tolerant to high NaCl salinity** (10 bar) but not to Na_2SO_4. In Na_2SO_4, S-5825 had the highest FGP. Over the entire range of NaCl treatments, BR-99, S-5733, S-5742, BR-2/1, BR-90, S-5747 and S-5761 were comparatively more tolerant. In Na_2SO_4 treatment range, BR-90 and S-5747 exhibited > 90 % germination. The local in-hand germplasm of guar appeared to be more tolerant to NaCl than to Na_2SO_4.

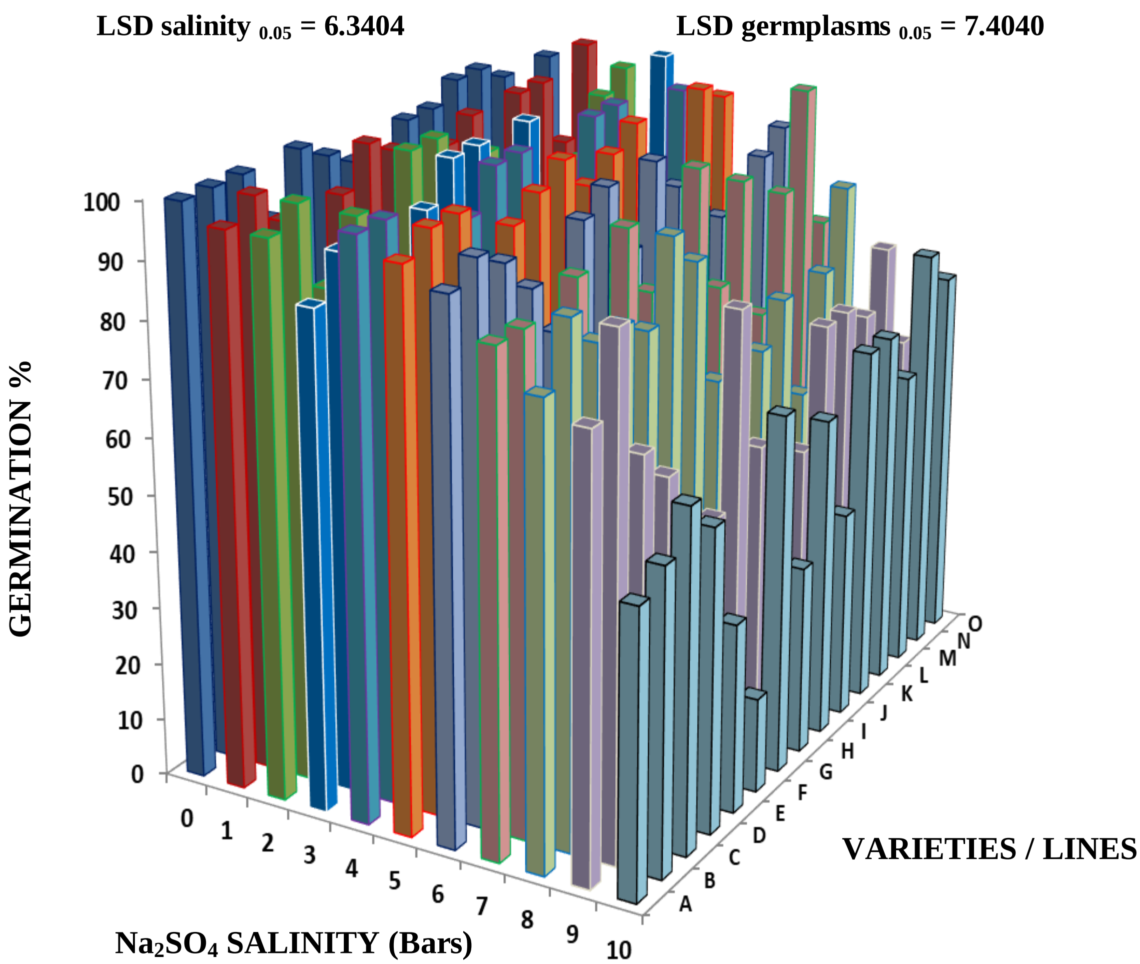


Fig. 3. Per cent final mean germination of Guar varieties / lines under influence of Na_2SO_4 salinization (0-10 bars). Varieties / Lines: A, BR-2/1, B, BR- 90, C, BR- 99, D, BR-2017, E, S-5733, F, S-5742, G, S-5747, H, S-5759, I, S-5761, J, S-5765, K, S-5784, L, S-5785, M, S-5797, N, S-5798 and O, S-5825.

Table 2a. .Mean Final germination (%) of guar cultivars and lines under salinity.

Genotype	Final germination (Day 4) in 10 Bar salinity		Final germination over the treatment range (0 to 10 Bar)	
	NaCl	Na_2SO_4	NaCl	Na_2SO_4
BR-2/1	93.33 ± 3.33	50.00 ± 5.77	92.72 ± 1.671	85.58 ± 4.516
BR-90	86.67 ± 13.33	53.33 ± 24.04	92.27 ± 1.335	91.82 ± 4.129
BR-99	93.33 ± 3.33	60.00 ± 11.55	96.97 ± 1.142	83.34 ± 4.669
Br-2017	43.33 ± 8.82	53.33 ± 6.67	75.46 ± 4.88	80.91 ± 3.973
S-5733	80.00 ± 0.00	33.33 ± 16.67	94.85 ± 2.03	78.18 ± 7.126
S-5742	80.00 ± 10.00	16.67 ± 16.67	93.33 ± 1.85	85.15 ± 8.267
S-5747	70.00 ± 5.77	63.33 ± 21.86	91.21 ± 2.925	90.61 ± 3.591
S-5759	73.33 ± 3.33	66.67 ± 20.28	91.52 ± 2.89	78.18 ± 6.52
S-5761	66.67 ± 12.02	56.67 ± 3.33	91.52 ± 2.96	77.27 ± 5.875
S-5765	70.00 ± 25.17	36.67 ± 13.33	87.88 ± 4.387	84.25 ± 5.845
S-5784	30.00 ± 15.28	63.33 ± 6.67	82.12 ± 6.579	78.48 ± 6.580
S-5785	66.67 ± 3.33	63.33 ± 6.67	88.49 3.633	76.06 ± 4.920
S-5797	53.33 ± 12.02	63.33 ± 3.33	82.43 ± 4.072	75.45 ± 4.633
S-5798	46.67 ± 8.82	53.33 ± 8.82	86.36 ± 5.133	81.21 ± 4.387
S-5825	80.00 ± 10.00	73.33 ± 6.67	80.91 ± 3.92	86.67 ± 2.880
Mean	68.88 ± 5.04	53.78 ± 4.02	88.56 ± 1.62	82.21 ± 1.39

Table 2b. Sequential order of final germination of guar germplasms in 10 bar NaCl and 10 bar Na_2SO_4 and also over the treatment range inclusive control. Germination is shown in parenthesis (see Table 2a).

Final Germination (%) in 10 bar NaCl
BR-2/1 (93.3) = BR-99 (93.3) ≈ BR-90 (86.7) > S-5733 (80.0) = S-5742 (80.0) = S-5825 (80.0) > S-5759 (73.3) > S-5747 (70.0) = S-5765 (70.0) > S-5761 (66.67) = S 5785 (66.67) > S-5797 (53.33) > S-5798 (46.67) > BR-2017 (43.33) > S-5784 (30.0)
Final germination 10 bar Na_2SO_4
S-5825 (73.3) > S-5759 (66.7) > S-5747 (63.3) = S-5784 (63.3) = S-5785 (63.3) = S-5797 (63.3) > BR-99 (60.0) > S-5761 (56.7) > Br-90 (53.3) = BR-2017 (53.3) = S-5798 (53.3) > BR-2/1 (50.0) > S-5765 (36.37) > S-5733 (33.33) > S- 5742 (16.7)
Final Germination over the treatment Range inclusive control (NaCl)
BR-99 (96.7) = S-5733 (94.9) ≈ S-5742 (93.3) ≈ BR-2/1 (92.7) ≈ BR-90 (92.3) ≈ S-5759 (91.5) ≈ S-5747 (91.5) ≈ S-S-5761 (91.5) > S-5785 (88.5) ≈ S-5765 (87.9) ≈ S-5798 (86.4) > S-5797 (82.4) ≈ S-5784 (82.1) = > S-5825 (80.9) > BR-2017 (75.5)
Final Germination over the treatment Range inclusive control (Na_2SO_4)
BR-90 (91.8) ≈ S-5747 (90.06) > S-5825 (86.7) ≈ BR- 2/1 (85.6) ≈ S-5742 (85.2) S-5765 (84.3) ≈ BR-99 (83.3) ≈ S-5798 (81.2) = S-5761 (81.2) ≈ BR-2017 (80.9) > S- 5784 (78.5) ≈ S- 5733 (78.2) = SW-5759 (78.2) > S-5785 (76.1) ≈ S-5797 (75.5)

Table 3. Three way ANOVA of germination data of 15 guar varieties tested against concentrations of NaCl.

Source	SS	df	MS	F	p
NaCl concentrations(bar)	267576.97	10	26757.69	191.68	0.0001 ***
Varieties	1483263.59	14	494421.19	3541.80	0.0001 ***
Days	332884.65	3	23777.47	170.33	0.0001 ***
Bar x varieties	63008.08	140	2100.27	15.045	0.0001 ***
Bar x Days	88494.25	30	632.10	4.528	0.0001 ***
Varieties x Days	227949.29	42	5427.36	38.879	0.0001 ***
Bar x Varieties x Days	135054.04	420	321.55	2.30	0.0001 ***
Error	184266.67	1320	139.596	-	-
Total	2782497.52	1979	-	-	-

NaCl Concentrations LSD $_{0.05}$: 2.4430

Rank	TRT	Mean	n	NSR
1	Control	77.55	180	a
2	1 Bar	76.05	180	ab
3	2 bar	74.28	180	bc
4	3 Bar	72.06	180	c
5	4 Bar	69.33	180	d
6	5 bar	66.22	180	e
7	7 Bar	63.50	180	f
8	6 Bar	63.00	180	f
9	9 Bar	50.72	180	g
10	8 Bar	49.39	180	g
11	10 Bar	40.28	180	h

TRT, Treatments (salt concentrations or varieties; NSR, NS ranges

Varieties or lines, LSD $_{0.05}$: 2.8530

Rank	TRT	Mean	n	NSR
1	BR-90	89.02	132	a
2	BR-99	88.64	132	a
3	BR-2/1	80.23	132	b
4	S-5733	71.14	132	c
5	S-5742	64.47	132	d
6	S-5747	64.09	132	d
7	S-5825	60.61	132	e
8	S-5759	60.08	132	ef
9	S-5797	59.47	132	efg
10	S-5765	59.24	132	efgh
11	BR-2017	57.27	132	fgh
12	S-5798	56.52	132	gh
13	S-5761	56.21	132	h
14	S-5785	50.53	132	i
15	S-5784	40.30	132	j

Days of incubation LSD 0.0-5: 1.4733

Rank	TRT	Mean	n	NSR
1	Day 4	89.64	495	a
2	Day 3	52.51	495	b
3	Day 2	63.96	495	c
4	Day 1	19.31	495	d

Mean germination-based tolerance order (NaCl): N = 132, Range: 89.0 – 40.3% (8 groups) [Br-90 = Br-99] > [BR-2/1] > [S-5733] > [S-5742 = S-5747] >[S-5825 = S-5759 = S-5797 = S-5765 = BR-2017 = S-5798] > [S-5761] > [S-5785] >[S-5784]

Table 4. Three way ANOVA of germination data of 15 guar varieties tested against concentrations of Na_2SO_4.

Source	SS	df	MS	F	p
Na_2SO_4concentrations (bar)	604383.33	10	60438.33	330.30	0.0001 ***
Varieties	145568.69	14	485156.23	2651.42	0.0001 ***
Days	99131.31	3	7080.81	38.70	0.0001 ***
Bar x varieties	127770.20	140	4259.01	23.28	0.0001 ***
Bar x Days	143905.58	30	1027.91	5.62	0.0001 ***
Varieties x Days	59919.19	42	1426.65	7.80	0.0001 ***
Bar x Varieties x Days	181175.25	420	431037	2.36	0.0001 ***
Error	241533.33	1320	182.78	-	-
Total	2913289.89	1979	-	-	-

Na_2SO_4 Concentrations LSD $_{0.05}$: 2.7972				
Rank	TRT	Mean	n	NSR
1	Control	77.78	180	a
2	1 Bar	74.22	180	b
3	2 bar	68.28	180	c
4	3 Bar	65.89	180	c
5	4 Bar	61.11	180	d
6	5 bar	59.17	180	de
7	7 Bar	57.83	180	e
8	6 Bar	46.39	180	f
9	9 Bar	35.61	180	g
10	8 Bar	29.33	180	h
11	10 Bar	23.28	180	i

TRT, Treatments (salt concentrations or varieties; NSR, NS ranges

Varieties or lines, LSD $_{0.05}$: 3.2664				
Rank	TRT	Mean	n	NSR
1	BR-90	69.39	132	a
2	BR-2/1	65.38	132	b
3	S-5825	59.85	132	c
4	S-5798	57.12	132	cd
5	S-5742	56.81	132	cd
6	BR-99	56.06	132	d
7	S-5765	55.98	132	d
8	S-5733	54.92	132	d
9	S-5747	54.02	132	de
10	S-5784	51.29	132	ef
11	S-5785	51.21	132	ef
12	S-5797	50.23	132	f
13	S-5759	48.94	132	fg
14	S-5761	45.68	132	g
15	BR-2017	39.77	132	h

Days of incubation LSD 0.0-5: 1.687				
Rank	TRT	Mean	n	NSR
1	Day 4	81.13	495	a
2	Day3	72.76	495	b
3	Day 2	52.91	495	c
4	Day 1	10.97	495	d

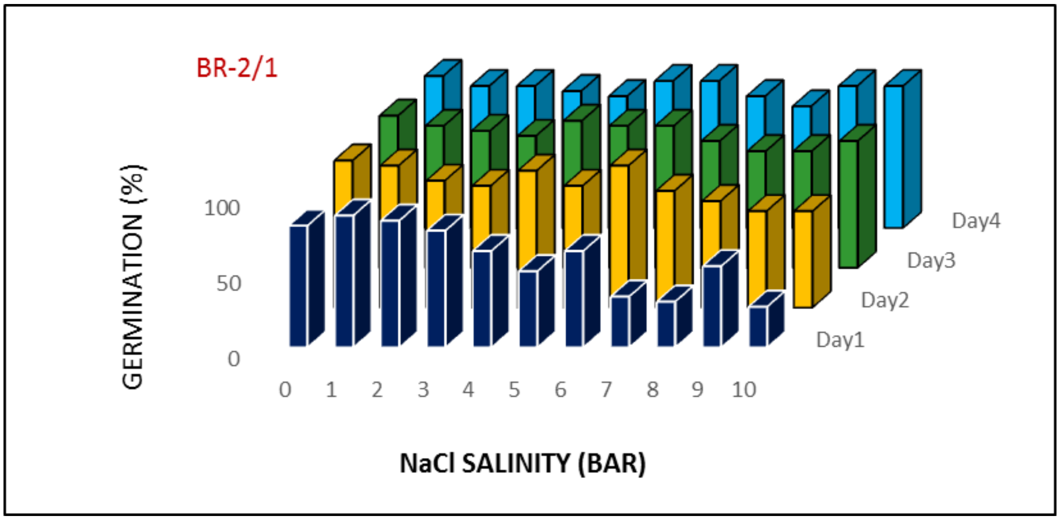
Mean germination-based tolerance order (Na_2SO_4):
N = 132, Range: 69.4 – 39.8% (six groups)

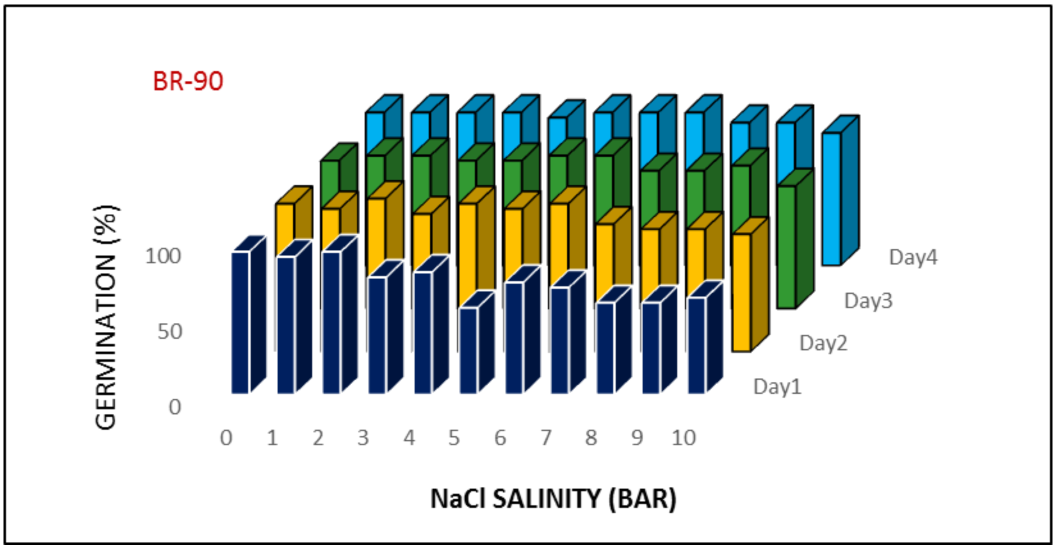
[Br-90] > [BR-2/1] > [S-5825 = S-5742 = BR-99 = S-5765 = S-5733 = S-5747 = S-5798] > [S-5784 = S-5785 = S-5797 = S-5759] > [S-5761] > [BR-2017]

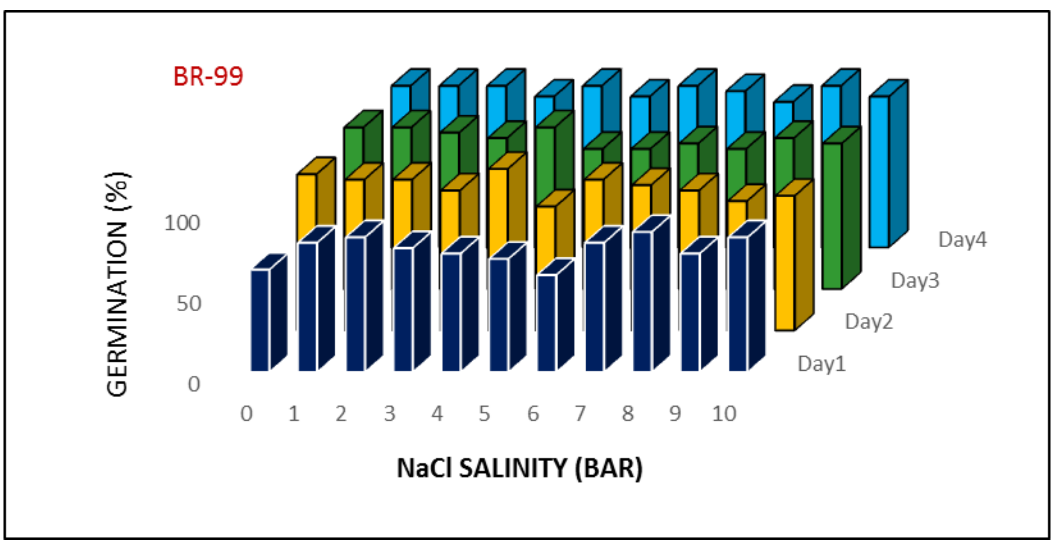
Substantial percentage of germination was observed on first day throughout the NaCl treatment (1 to10 bar) in BR-2/1, BR-90 and BR-99. S-5733 could only germinate up till -7 bar. There was poor germination on first day in BR-2017, S-5742, S-5747, S-5759, S-5761, S-5765, S-5784, S-5785 and S-5798. Germplasms S-5825 and S-5797 could germinate up to 2 and 3 bar, respectively on first day of incubation. In all germplasms, the germination greatly improved with time (Fig. 4).

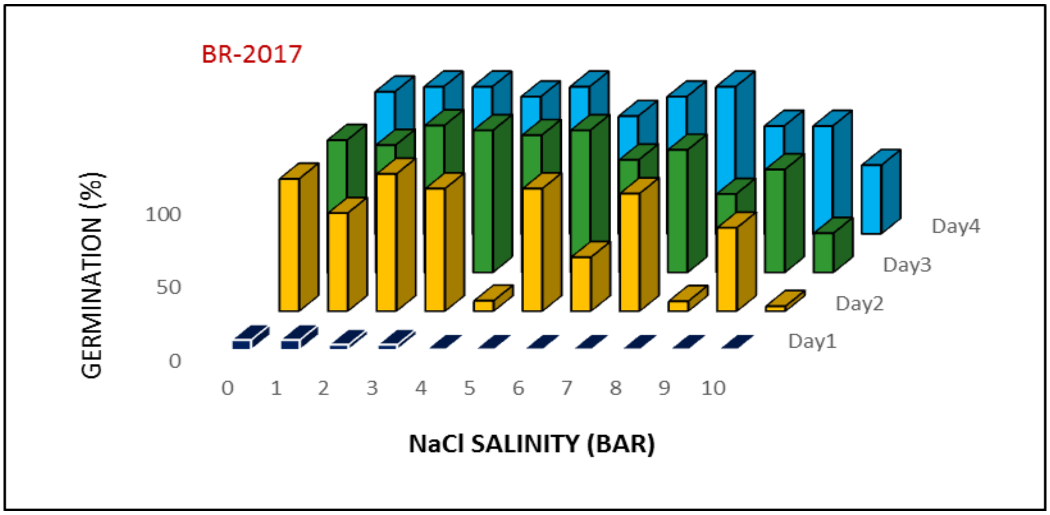
In certain germplasms such as BR- 99, BR- 2017, S-5747, S-5759, S- 5765 and S- 5798, germination on fourth day in 1 bar NaCl solution was somewhat higher than that in control. The promotion of germination (Nasr *et al.*, 2012) and stimulation of seedling growth (Patil and Karadge, 2012) under low NaCl salinity have previously been reported in literature. Slight stimulation of germination was also reported in *Rhynchosia minima* by Shaukat and Burhan (2000) in low NaCl salinity of 1 bar. Mulwani and Pollard (1939) had quite earlier found that small concentrations of NaCl stimulate germination.

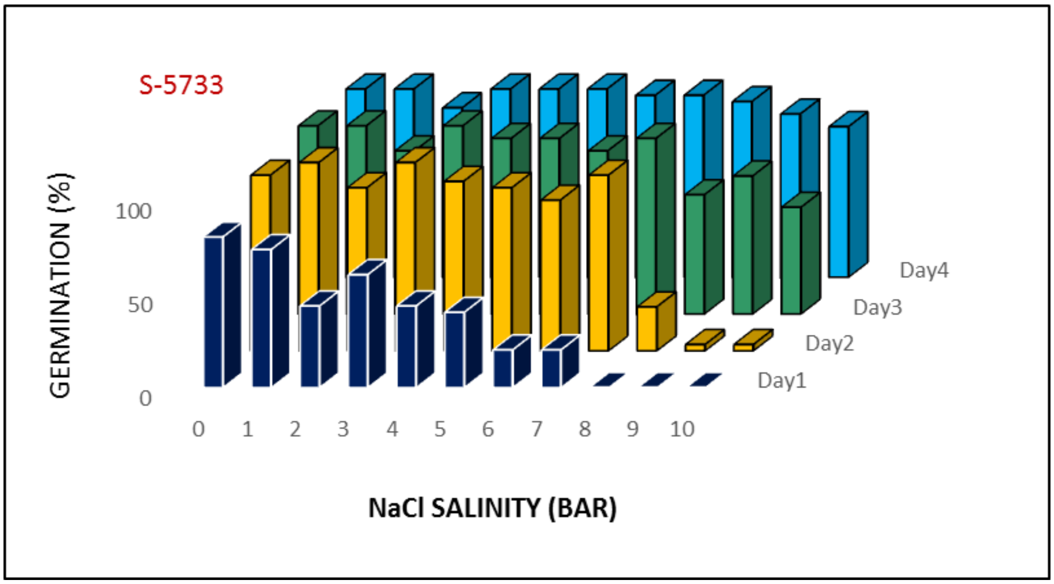
Germplasms, BR-2/1, BR-90, BR-99 and S-5733 showed moderate germination on first day up to 4 bar concentration of Na_2SO_4. In higher concentration, there was meager germination. BR-2017, S-5759, S-5761, S-5765, S-5785 and S-5747 showed no or very little germination on first day except control. On first day of incubation, germplasms S-5825 and S-5797 could germinate up till 2 bar of Na_2SO_4 only. Like, NaCl, in later days of incubation, germination improved differentially in different germplasms. Na_2SO_4, however, appeared to be more deleterious to germination than NaCl (Fig. 5).

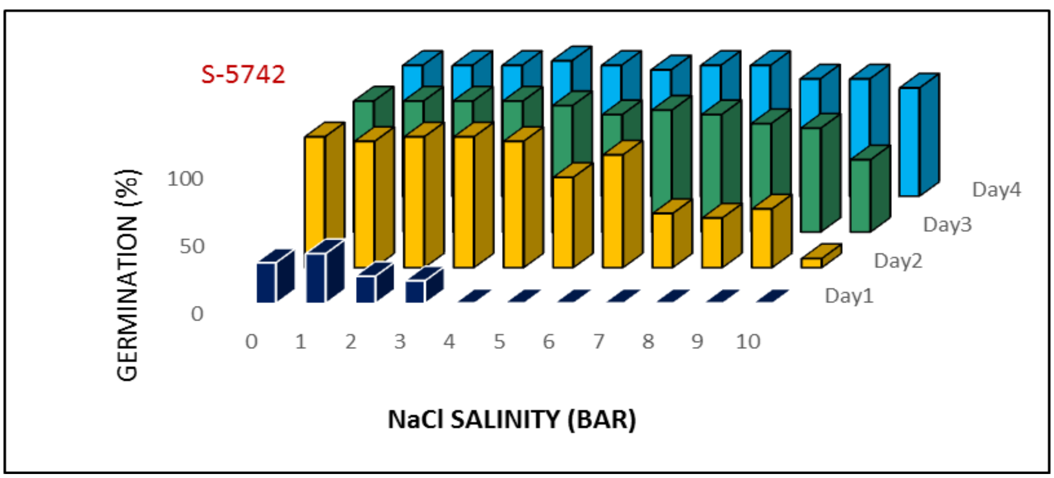

BR-2/1
GERMINATION (%)
0
50
100
0 1 2 3 4 5 6 7 8 9 10
Day1
Day2
Day3
Day4
NaCl SALINITY (BAR)

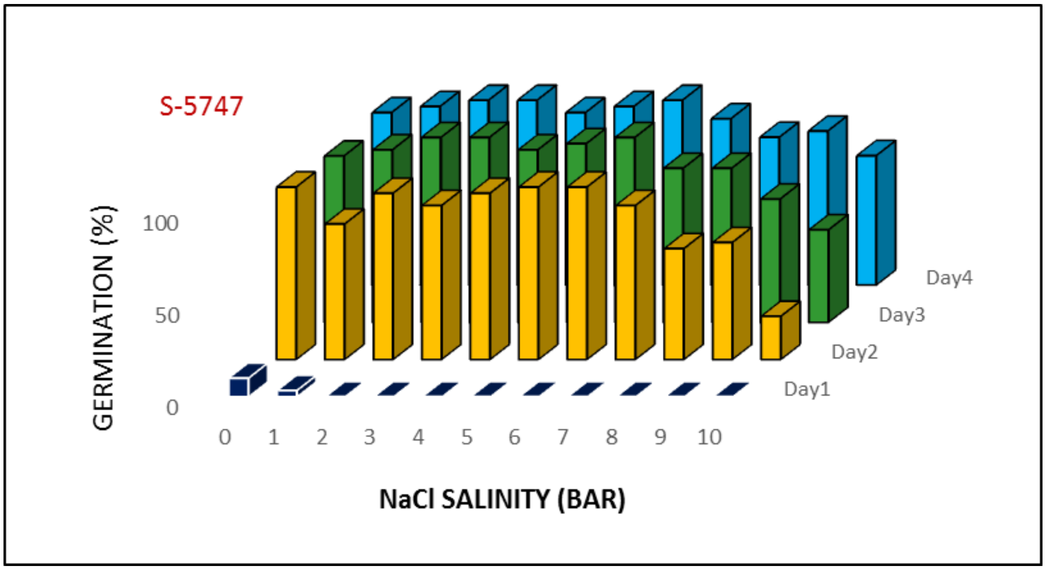

BR-90
GERMINATION (%)
0
50
100
0 1 2 3 4 5 6 7 8 9 10
Day1
Day2
Day3
Day4
NaCl SALINITY (BAR)

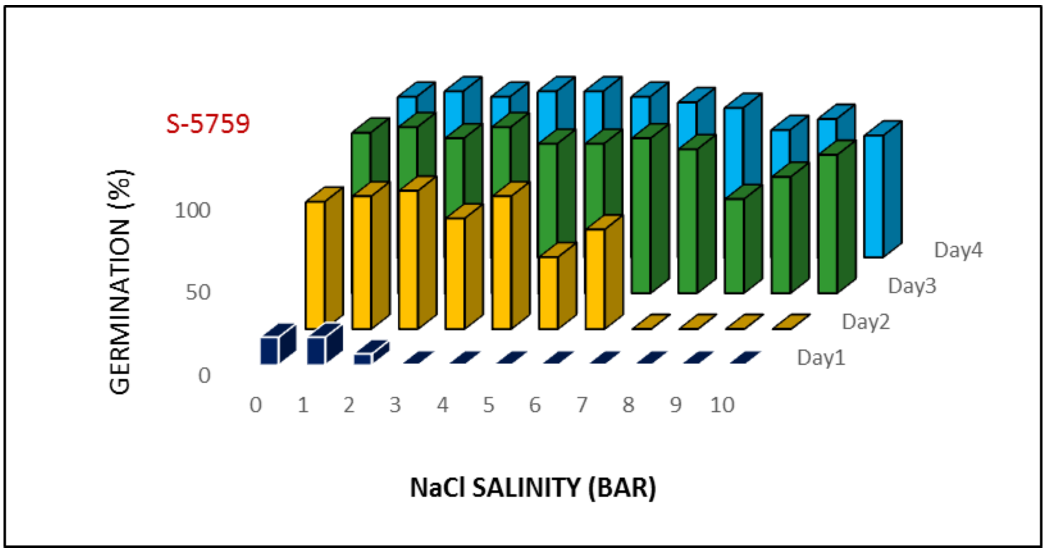

BR-99
GERMINATION (%)
0
50
100
0 1 2 3 4 5 6 7 8 9 10
Day1
Day2
Day3
Day4
NaCl SALINITY (BAR)

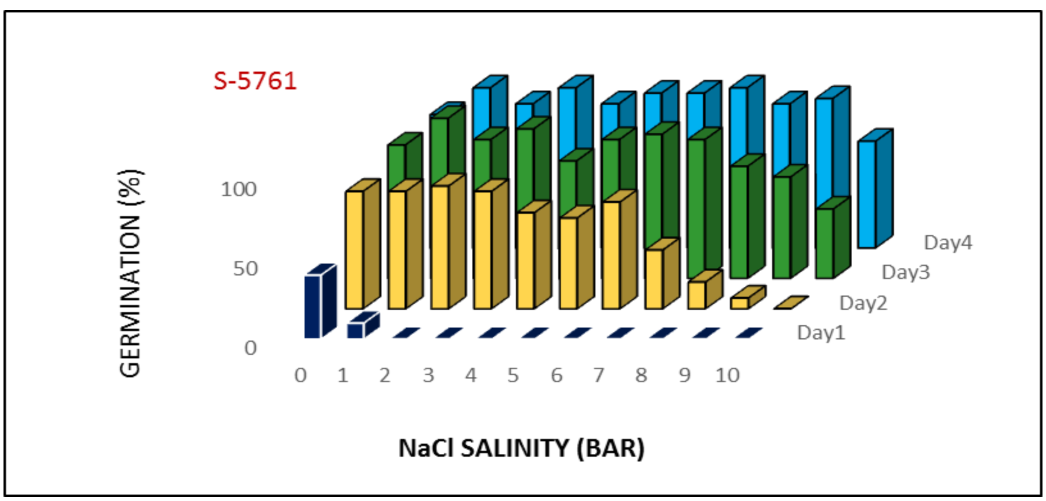

BR-2017
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
NaCl SALINITY (BAR)

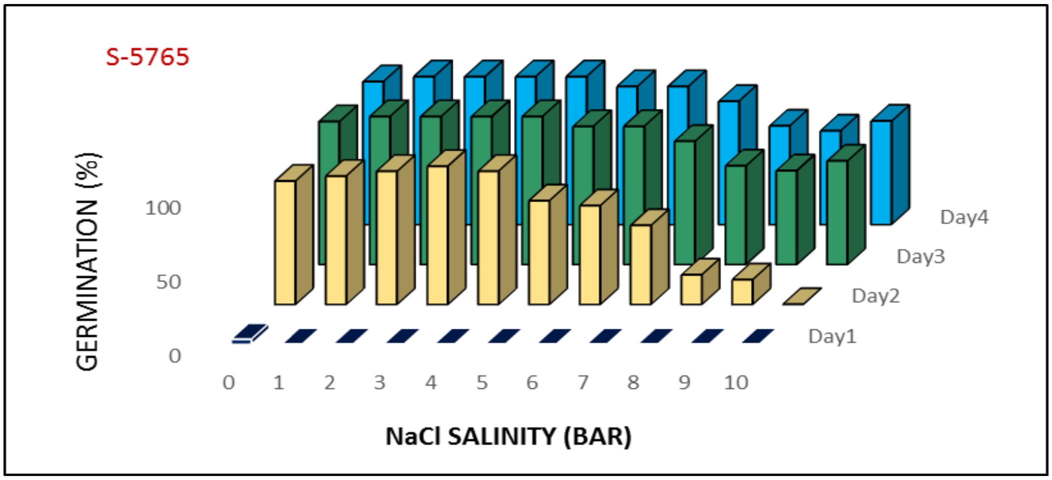

S-5733
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
NaCl SALINITY (BAR)

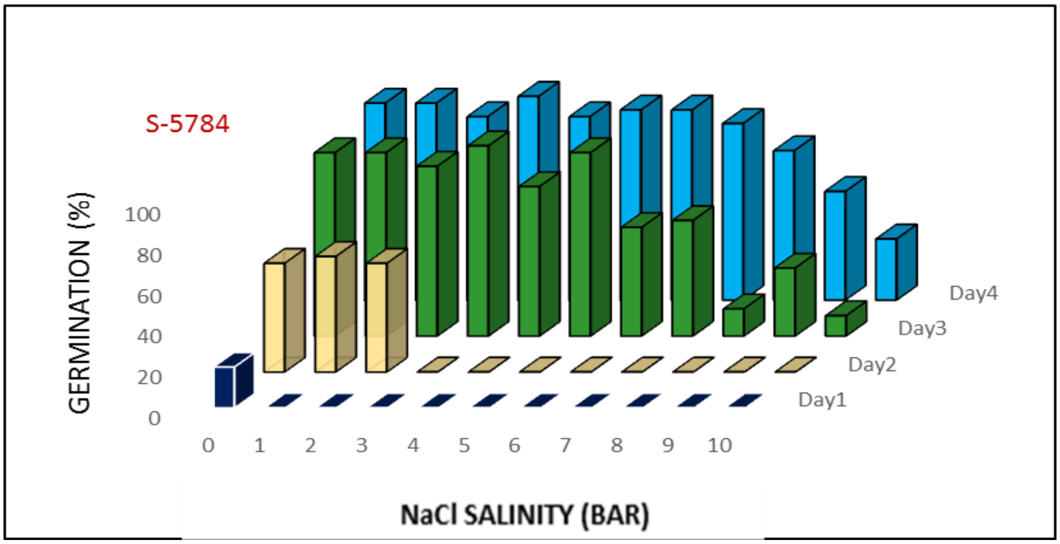

S-5742
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
NaCl SALINITY (BAR)

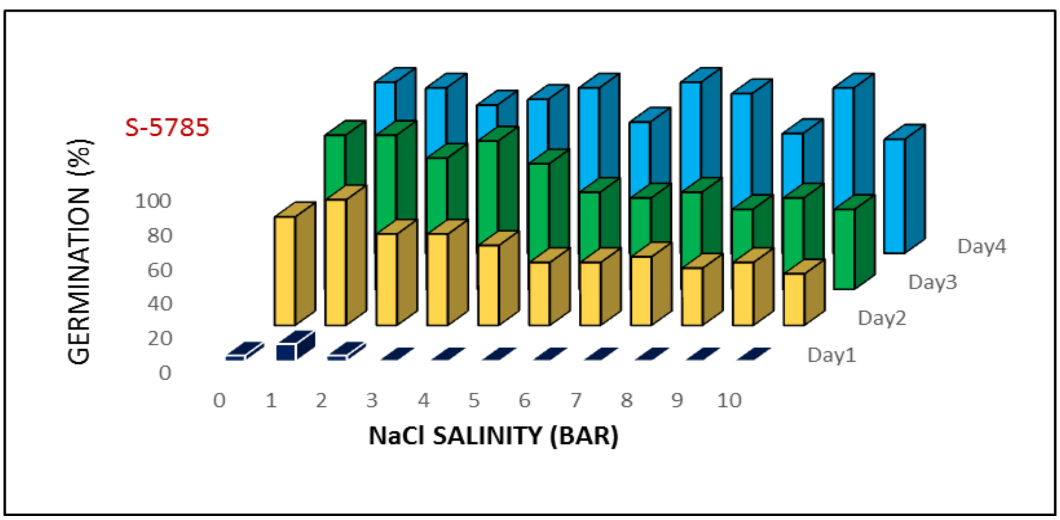

S-5747
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
NaCl SALINITY (BAR)
Day4
Day3
Day2
Day1


S-5759
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
NaCl SALINITY (BAR)
Day4
Day3
Day2
Day1


S-5761
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
NaCl SALINITY (BAR)
Day4
Day3
Day2
Day1


S-5765
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
NaCl SALINITY (BAR)


S-5784
GERMINATION (%)
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
NaCl SALINITY (BAR)


S-5785
GERMINATION (%)
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
NaCl SALINITY (BAR)

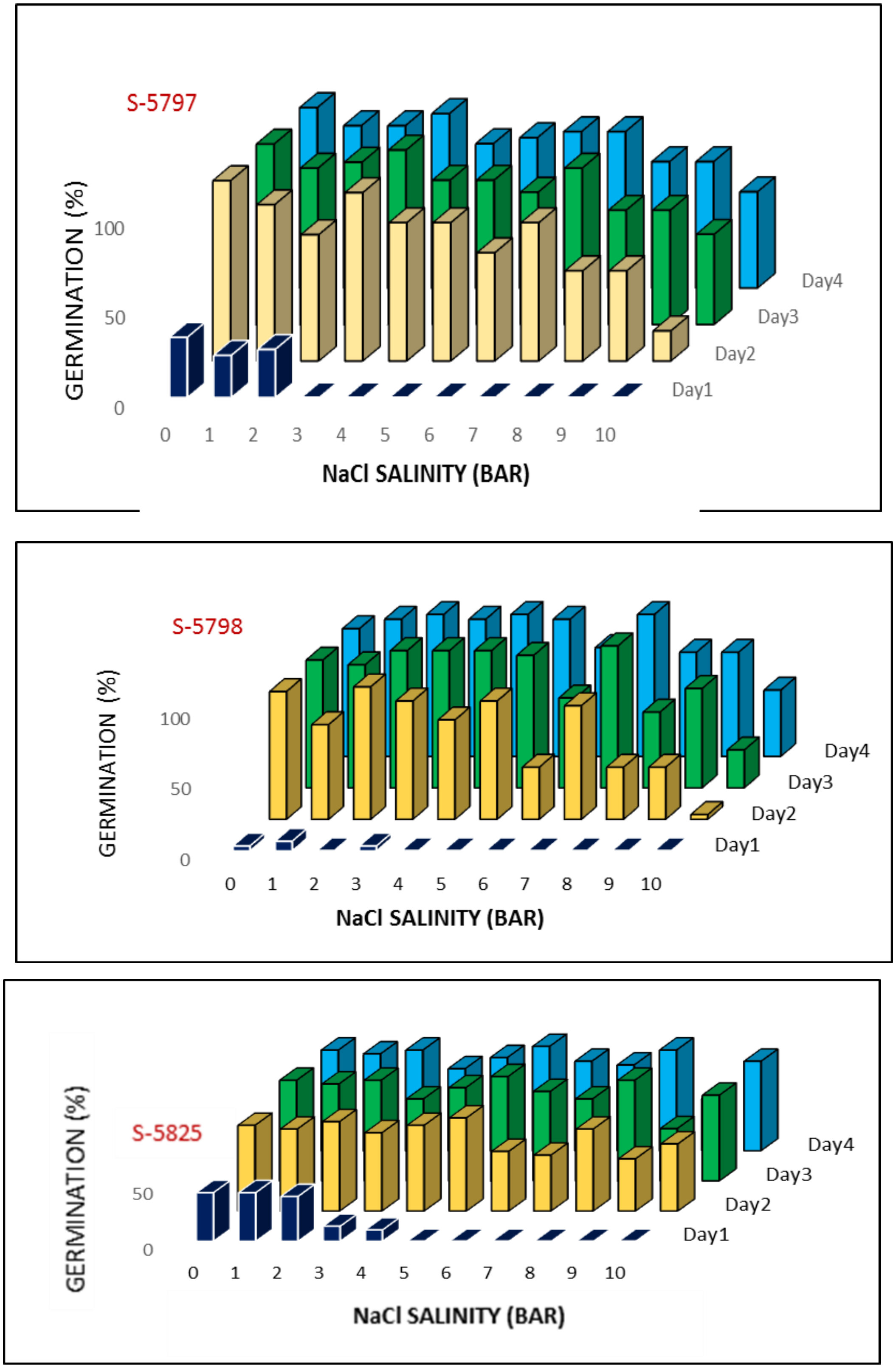
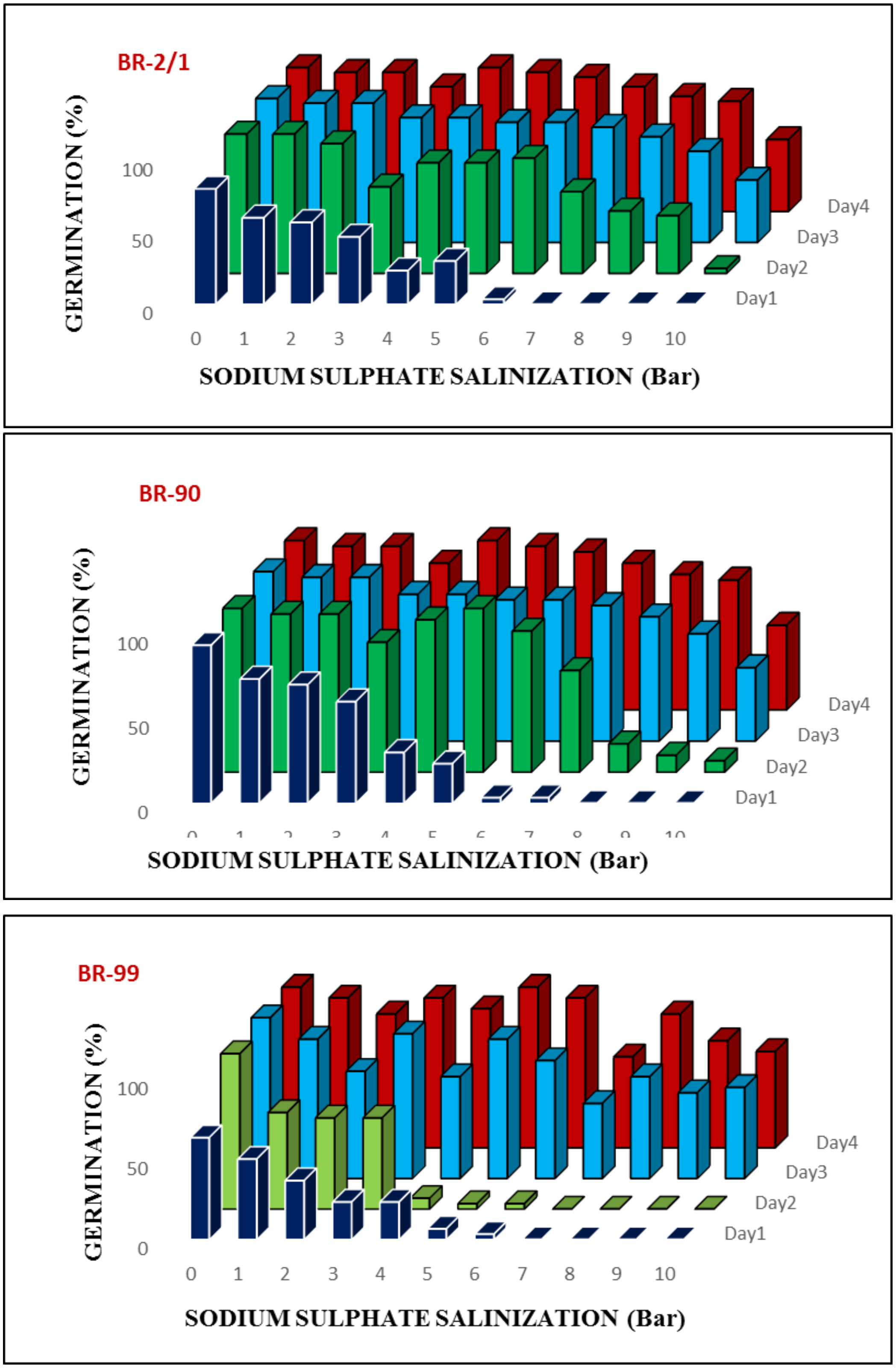
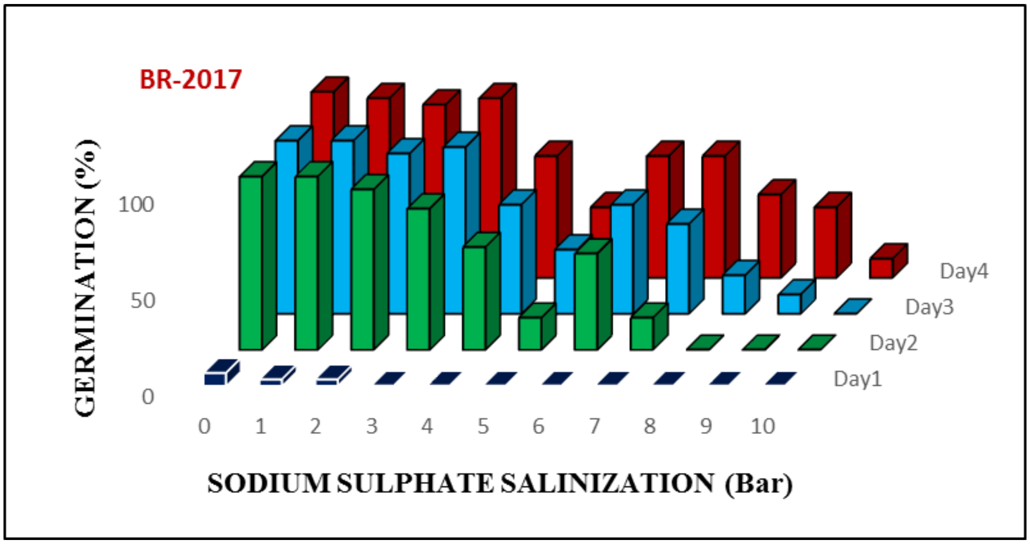
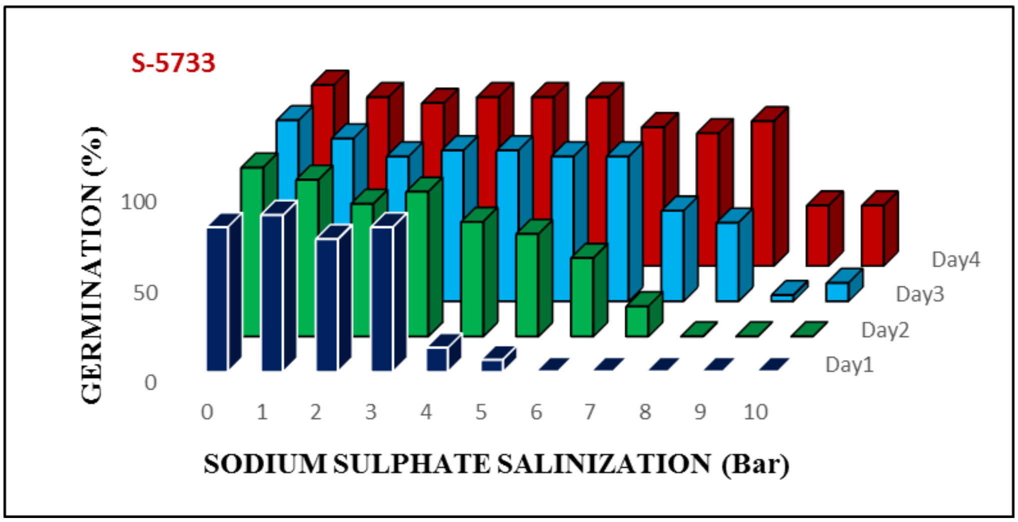
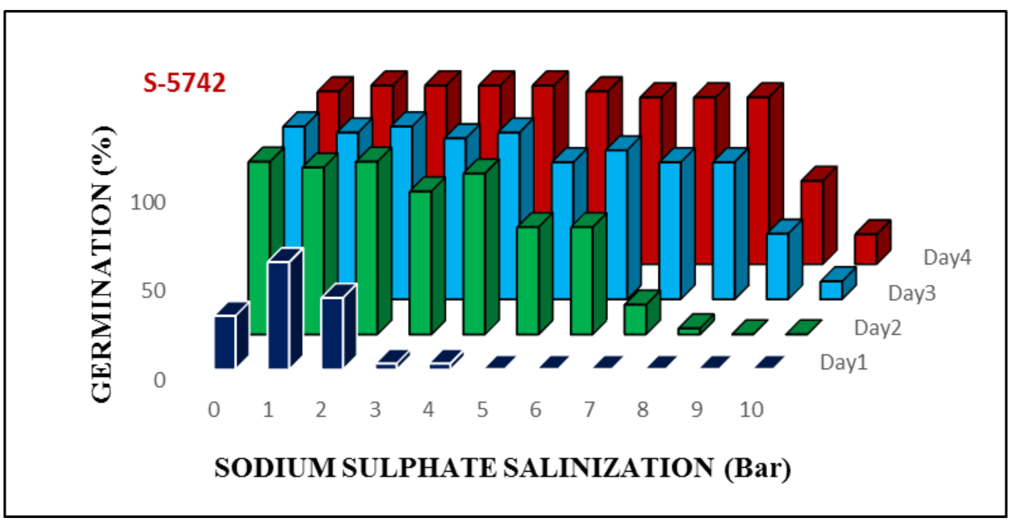


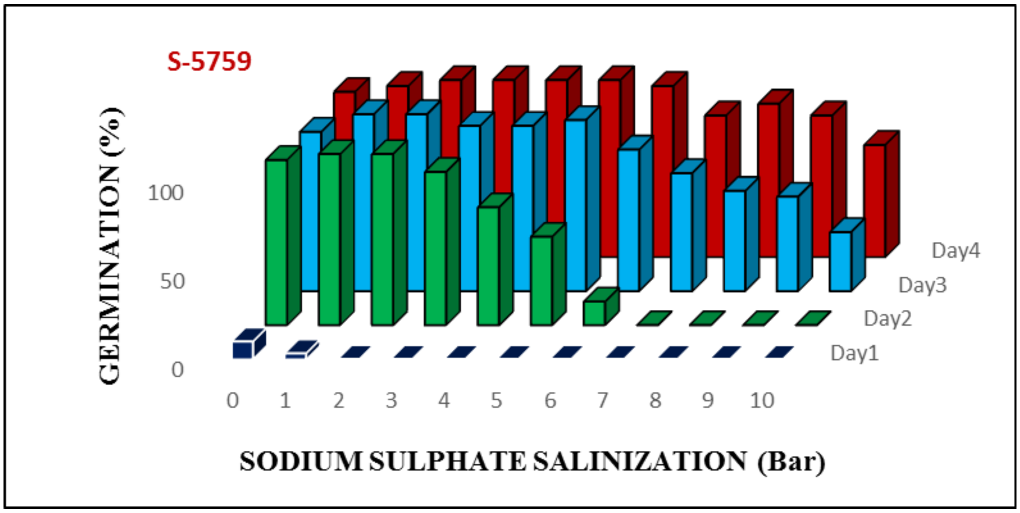
Fig. 4.Germination of 15 guar cultivars / lines under the influence of NaCl salinization and the incubation duration.

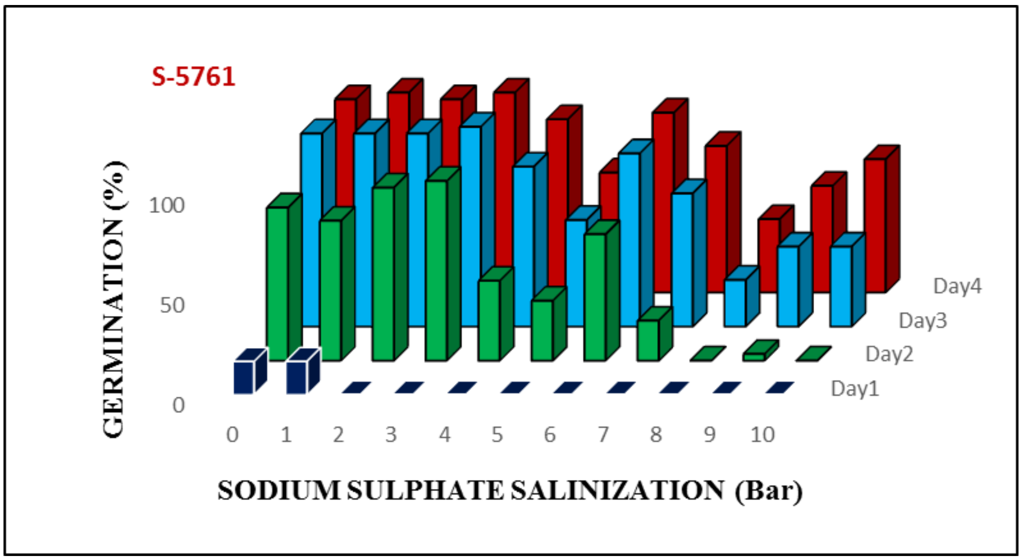

BR-2/1
GERMINATION (%)
0
50
100
Day1
Day2
Day3
Day4
0 1 2 3 4 5 6 7 8 9 10
SODIUM SULPHATE SALINIZATION (Bar)
BR-90
GERMINATION (%)
0
50
100
Day1
Day2
Day3
Day4
SODIUM SULPHATE SALINIZATION (Bar)
BR-99
GERMINATION (%)
0
50
100
Day1
Day2
Day3
Day4
0 1 2 3 4 5 6 7 8 9 10
SODIUM SULPHATE SALINIZATION (Bar)

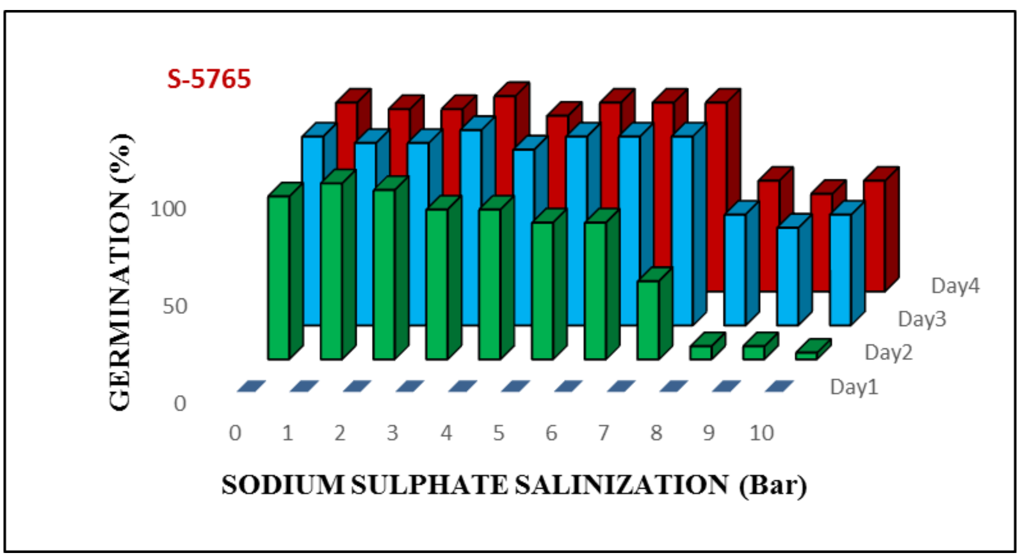

BR-2017
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
SODIUM SULPHATE SALINIZATION (Bar)

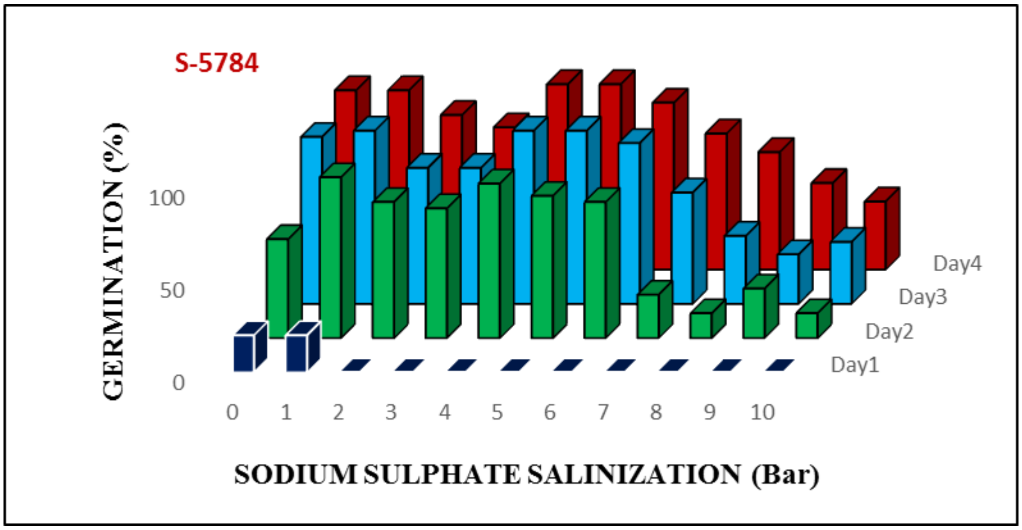

S-5733
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
SODIUM SULPHATE SALINIZATION (Bar)

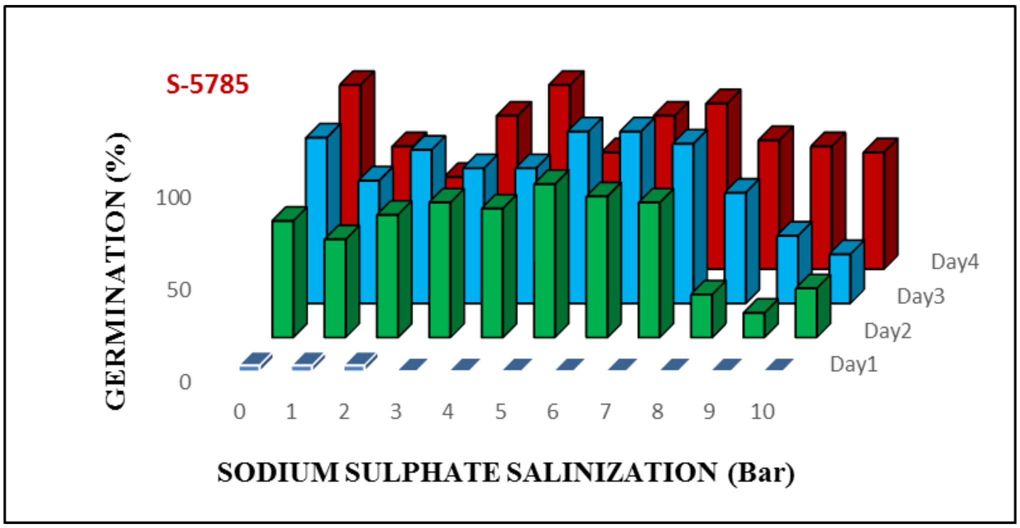

S-5742
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
SODIUM SULPHATE SALINIZATION (Bar)

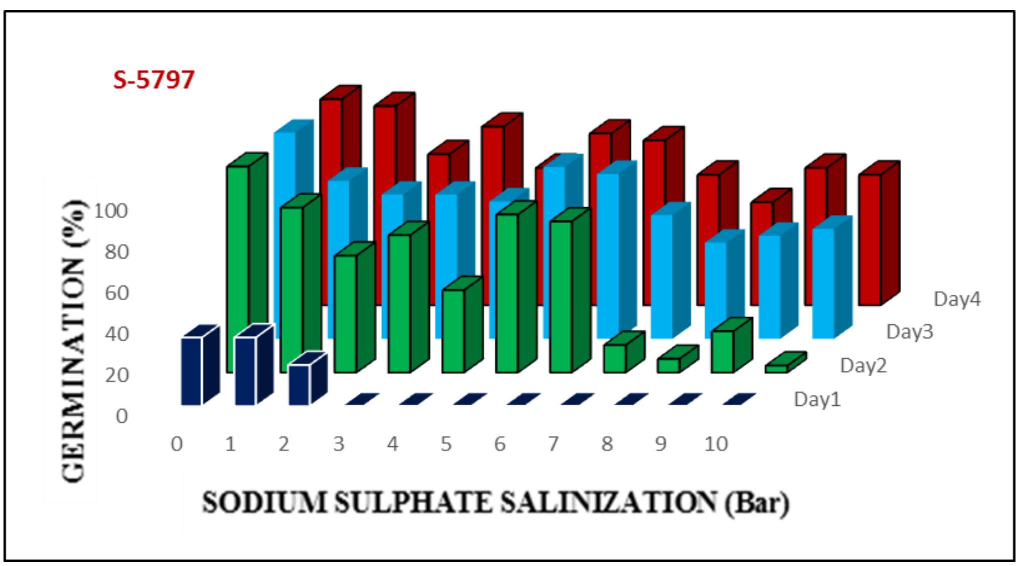

S-5759
GERMINATION (%)
100
50
0
Day4
Day3
Day2
Day1
0 1 2 3 4 5 6 7 8 9 10
SODIUM SULPHATE SALINIZATION (Bar)


S-5761
GERMINATION (%)
100
50
0
Day4
Day3
Day2
Day1
0 1 2 3 4 5 6 7 8 9 10
SODIUM SULPHATE SALINIZATION (Bar)


S-5765
GERMINATION (%)
100
50
0
Day4
Day3
Day2
Day1
0 1 2 3 4 5 6 7 8 9 10
SODIUM SULPHATE SALINIZATION (Bar)


S-5784
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
SODIUM SULPHATE SALINIZATION (Bar)


S-5785
GERMINATION (%)
100
50
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
SODIUM SULPHATE SALINIZATION (Bar)


S-5797
GERMINATION (%)
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10
Day4
Day3
Day2
Day1
SODIUM SULPHATE SALINIZATION (Bar)

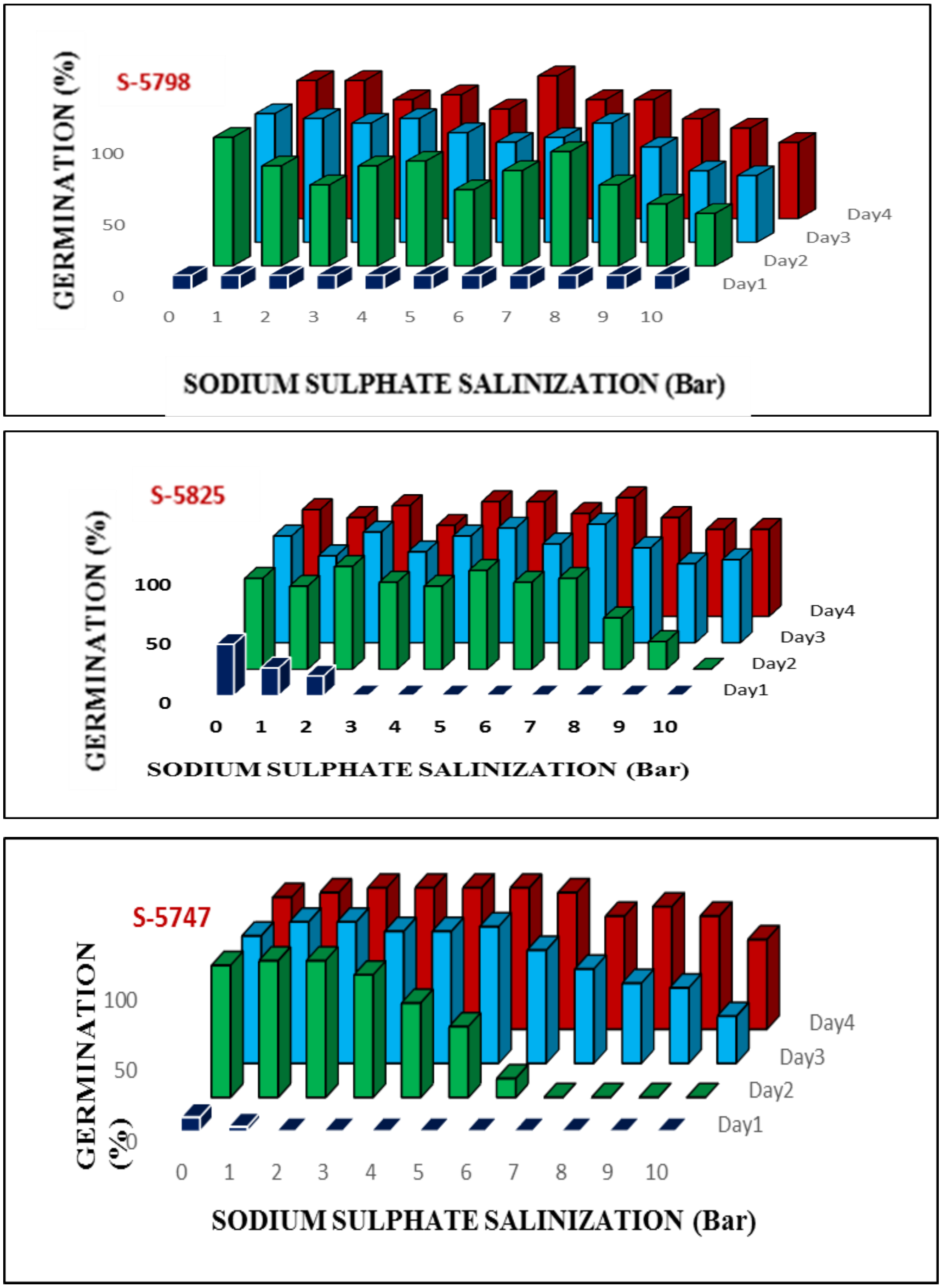


Fig. 5. Germination of 15 guar varieties / lines under sodium sulphate salinization for the given incubation period.

The 3-Way ANOVA of the component sources of variation in germination data is presented in Table 3 and 4. It is clear from the ANOVA that in both salts, the concentration of salts, nature of varieties and the incubation period appeared to influence germination highly significantly and these factors interacted with each other highly significantly. Germination declined in both salts with increasing concentration of the salts but increased with the incubation period. The varietal nature was important and inter-varietal differences of germination were significant. In this interactive system (Table 3) of three factors (germplasms, salt concentration and incubation period), NaCl concentration exhibited detrimental effects on germination more or less regularly. The maximum germination in this system was exhibited in control followed by in 1 and 2 bar. In higher concentration of salts the decline of germination was progressively higher. Amongst the germplasms, the **maximal performance was shown by BR-90 (89.02 %) and BR-99 (88.64%).** Germination was minimal in case of line S-5785 (50.53%). Germination was also direct function of number of days of incubation. Germination was maximum (89.64%) on the fourth day and minimum on the first day of incubation (19.3%).

More or less similar pattern of germination was exhibited under Na_2SO_4 (Table 4). With little irregularity, increase in Na_2SO_4 concentration caused decline in germination. Germination was highest in control (77.78%) followed by that in 2 bar Na_2SO_4 (74.22%). Germination was the lowest in 10 bar Na_2SO_4 (23.28%). The highest germination was exhibited by BR-90 (69.39%) followed by BR-2/1 (65.38%). The lowest germinability was shown by BR-2017 (39.77%). Germination was also the direct function of number of days of incubation. In Na_2SO_4 environment the highest germination was recorded on fourth day of incubation (81.13%) and the lowest at the first day (10.97%). The germination of individual germplasms as function of salinity (NaCl or Na_2SO_4) and number of days of incubation is given in Fig. 4 and Fig.5 showing differential degree of delay of germination in different germplasms. The delay in germination has been reported under salinity by many workers in different species (Fancois *et al.*, 1986; Mondal *et al.*, 1988; Karim *et al.*, 1992; Khan *et al.*, 1984; Khan *et al.*, 1997; Chowdhury *et al.*, 2018). Emergence of guar cultivars Kinman and Esser remained unaffected by salt level up to 8.5 $dS.m^{-1}$ (c. 3 bar), greater levels of salt delayed germination / emergence but didn't significantly reduce the percent emerged (Francois *et al*., 1989). Kumar and Bhardwaj (1981) have, however, reported that germination of mung bean was not affected even up to salinity of 24 $dS.m^{-1}$ (c. 10 bar NaCl). Abusuwar and Abbaker (2009) also reported delay in germination of guar against Seawater dilutions i.e., 31.2% germination on the first day which gradually increased to 76.3% after seven day of incubation. Decline of germination in guar under salinity is also reported by Vinisky and Ray (1988).

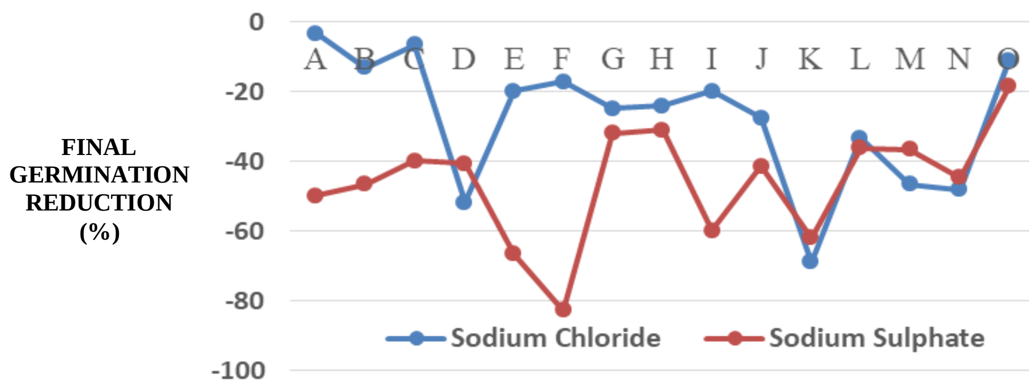


Fig. 6. *Per cent* reduction in Final germination over control under NaCl and Na_2SO_4 salinization. Varieties / Lines: A, BR-2/1, B, BR-90, C, BR-99, D, BR-2017, E, S-5733, F, S-5742, G, S-5747, H, S-5759, I, S-5761, J, S-5765, K, S-5784, L, S-5785, M, S-5797, N, S-5798 and O, S-5825.

The % germination reduction in various germplasms in 10 bar NaCl and Na_2SO_4 solutions over control is presented in Fig. 6. All germplasms exhibited decline in germination. Of course, it varied greatly amongst different germplasms. There was no or little reduction in germination of BR-2/1, BR-90, BR-99 and S-5825 in NaCl treatment and there appeared no significant difference amongst them as well. The germination was quite reduced in BR-2017, S-5797 and S-5798 (c. 50% in each) and in S-5784 (68.97%). Percent reduction in germination generally fluctuated around 20 – 30 % in S-5733, S-5742, S-5747, S-5759 and S-5761. Ramarajan *et al.* (2013) have reported decrease in germination of guar (variety 'Pusa Naubahar') at 150mM NaCl besides some adverse effects on morphological attributes as well. Al-Yemeny and Basahy (1997) reported 44% reduction in germination of guar under NaCl salinity level 16-20 mmhos /cm. Percent germination reduction was comparatively much higher in Na_2SO_4. Maximum reduction of 82.76% was exhibited by S-5742, c. 60 % by S-5761 and 62.07% by S-5784. Even the germplasms such as BR-2/1, BR-90, BR-99 and Br-2017 suffered substantially higher reduction (c. 45 – 50%) under Na_2SO_4 salinity. S-5825 suffered only by c. 20% reduction. The reduction amounted to 66.67% in S-5733. The data indicated that Na_2SO_4 was comparatively inhibitorier to guar germination than NaCl. That is to say that local in-hand germplasms are relatively more tolerant to NaCl at germination stage.

Fig. 7 and 8 presents the results of simple linear correlation and regression of FGP (Y-axis) against NaCl and Na_2SO_4 salinity using replicate data to accommodate all possible variation in germplasms performances. Against NaCl three germplasms, BR-2/1, BR-99 and S-5761 gave non-significant relationship while other related significantly negatively. The germplasms S-5785, S-5784, S-5765, S-5797, S-5798 and S-5825 better related to

NaCl concentration curvilinearly. Against Na_2SO_4, all germplasms showed negative but differentially significant linear correlations but more closely curvilinearly. BR-99 showed significant curvilinear relationship not better than linear one. S-5733, S-5742, S-5761 and S-5765 under Na_2SO_4 showed to follow linear threshold response model of Maas and Hoffman (1977). From these scatter diagrams threshold salinities were approximated and are described later in this paper.

Germination velocity:

It is clear from the data presented above regarding germination of guar germplasms that germination varied considerably along the incubation period, obviously differentially in different germplasms. To quantify velocity of germination in different germplasms over the incubation period under varying salinity caused by NaCl and Na_2SO_4 solutions, Woodstock's (1976) Germination Velocity Index (GVI) was employed. The values of GVI (under NaCl and Na_2SO_4 environments are presented in Table 5a and 5b.

Table 5a. Values of germination velocity index of guar germplasms under NaCl salinity (Bar).

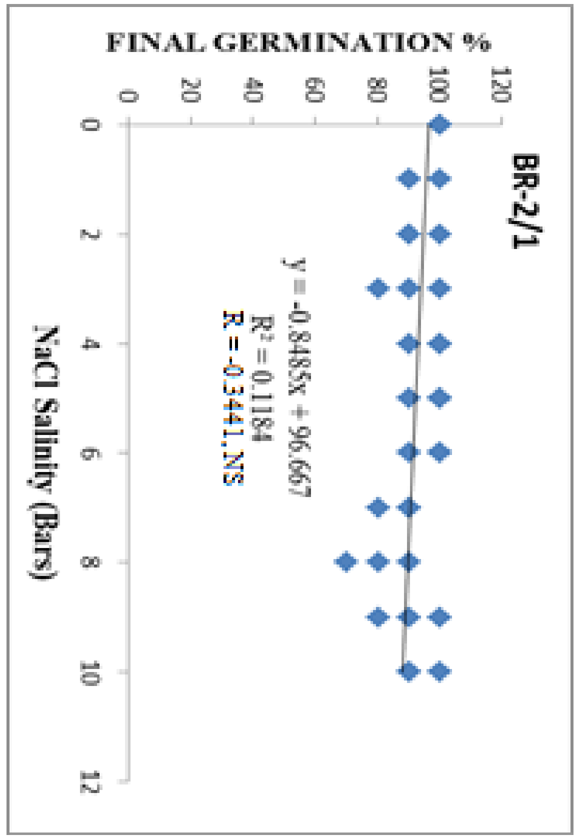
Germplasm	NaCl Salinity (Bar)												
	C	1	2	3	4	5	6	7	8	9	10	Mean*	SE
BR-2/1	26.83	27.83	25.91	24.25	23.67	21.08	23.75	16.75	15.91	20.08	16.08	22.09	1.31
BR-90	28.75	28.10	28.5	23.92	26.5	23.10	25.83	24.17	22.25	22.23	21.83	25.01	0.80
BR-99	24.33	26.6	26.83	25.10	26.0	25.0	23.0	25.5	26.25	24.33	25.85	25.35	0.34
BR-2017	15.0	14.0	15.17	13.5	15.33	13.5	11.0	13.55	8.0	10.08	4.33	12.13	1.05
S-5733	26.67	26.0	19.75	23.5	20.92	20.17	16.42	16.25	9.75	8.50	10.75	18.06	1.91
S-5742	19.0	19.88	17.5	17.25	14.67	12.50	13.66	14.11	10.33	10.58	7.83	14.30	1.16
S-5747	16.0	14.75	14.5	13.87	13.80	14.33	14.67	13.0	11.58	11.25	7.58	13.22	0.70
S-5759	16.0	16.5	14.75	13.3	13.05	11.67	12.33	12.42	8.17	10.92	10.75	12.71	0.73
S-5761	18.0	15.17	12.75	13.5	11.58	12.0	12.5	11.5	9.33	8.92	5.42	11.88	0.99
S-5765	13.83	14.83	14.5	14.66	14.5	13.83	12.67	11.0	8.33	7.13	7.0	12.02	0.94
S-5784	15.17	12.75	11.50	9.83	9.0	9.25	8.33	7.92	5.83	4.83	2.50	8.81	1.09
S-5785	13.5	15.91	11.33	11.58	11.42	9.0	10.67	10.42	8.08	10.17	7.67	10.88	0.71
S-5797	15.0	16.5	16.5	14.58	11.5	12.08	11.33	12.5	9.33	9.08	7.75	12.38	0.90
S-5798	14.5	13.0	14.58	14.67	14.42	13.75	9.17	14.0	7.17	9.08	4.33	11.70	1.09
S-5825	19	18.5	19.0	12.83	13.33	13.50	10.67	10.08	13.16	7.0	10.58	13.42	1.19

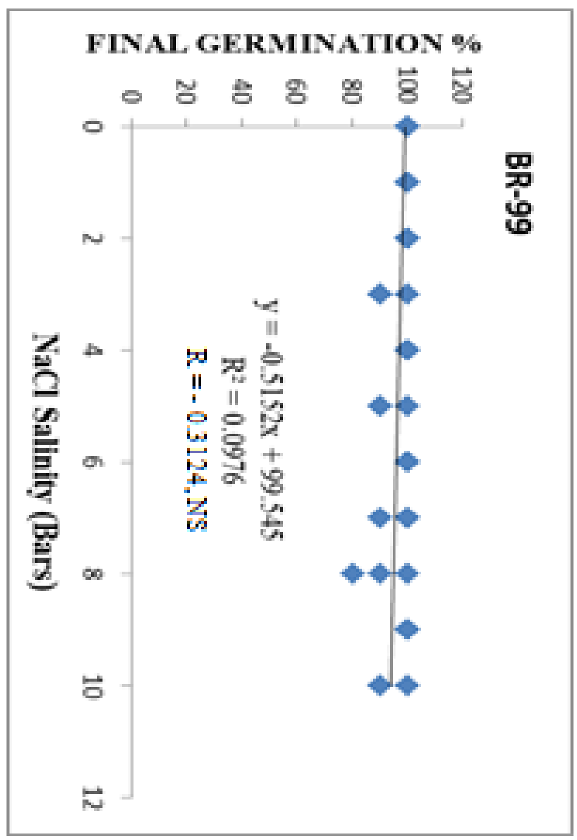
Table 5b. Values of germination velocity index of guar germplasm under Na_2SO_4 salinity (Bar).

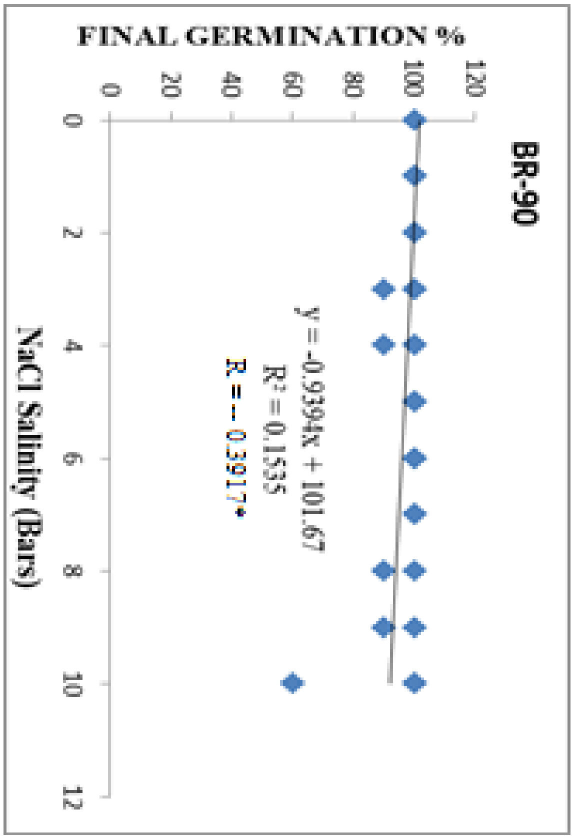
Germplasm	Na_2SO_4 Salinity (Bar)												
	C	1	2	3	4	5	6	7	8	9	10	Mean*	SE
BR-2/1	26.83	23.5	22.66	18.67	16.75	16.92	132.33	11.33	10.0	8.83	5.254	15.83	2.04
BR-90	28.75	25.58	25.08	22.17	18.92	18.25	14.25	12.05	9.75	9.5	5.55	17.26	2.30
BR-99	24.33	19.67	16.25	15.58	13.92	12.67	12.0	7.08	10.17	7.17	6.42	13.21	1.68
BR-2017	15.0	14.25	13.25	13.17	8.88	4.42	8.67	7.16	4.75	3.0	0.75	8.48	1.49
S-5733	26.67	26.58	23.41	25.08	16.16	14.16	11.17	7.92	7.08	2.58	2.75	14.87	2.83
S-5742	19.0	23.50	20.75	14.25	15.25	12.16	11.83	9.75	11.33	7.17	1.50	13.32	1.89
S-5747	16.0	14.8	14.6	14.10	13.17	12.42	10.33	7.67	7.92	7.33	5.58	11.26	1.09
S-5759	16.0	15.92	14.0	14.5	10.5	7.08	12.08	8.17	3.33	4.67	6.0	10.20	1.39
S-5761	18.0	20.5	11.42	12.42	11.25	11.75	9.92	6.83	5.38	4.08	2.50	10.39	1.68
S-5765	13.83	13.83	13.66	13.83	13.5	14.17	14.17	11.67	6.0	5.033	5.83	11.44	1.13
S-5784	15.17	16.92	11.0	12.08	14.0	13.67	12.58	8.17	6.33	5.50	4.25	10.88	1.27
S-5785	13.5	10.0	12.67	12.25	13.0	13.5	13.08	12.55	9.41	6.58	6.75	11.21	0.79
S-5797	15.0	18.25	12.83	11.58	8.67	12.17	11.67	6.92	5.25	7.25	6.25	10.53	1.22
S-5798	14.5	12.92	11.17	13.17	11.0	11.92	11.67	12.3	9.75	8.17	7.0	11.23	0.66
S-5825	19.0	14.67	17.17	11.30	11.20	13.83	11.25	13.83	10.42	8.33	7.25	12.57	1.07

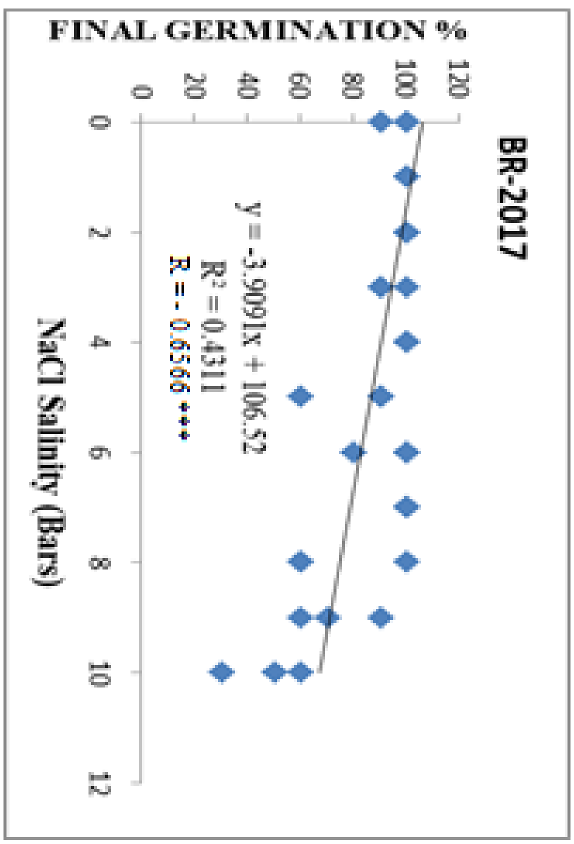
C = control (0 bar); *, Mean over the range of treatments (0 to -10 bar) and the control.

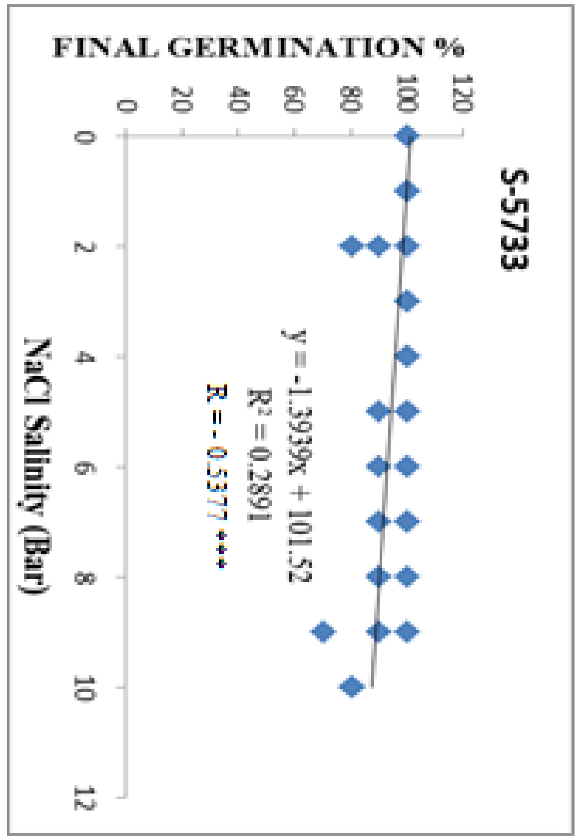
All germplasms exhibited decline in GVI under increasing concentration (1 to 10 bar) of NaCl and Na_2SO_4. In NaCl salinity (Table 5a), germplasms such as BR-90, BR-99 and BR-2/1 had the highest magnitude of mean GVI (25.35, 25.01 and 22.09, respectively) which was followed by S-5733 (18.06). The lowest mean GVI was shown by S-5784 (GVI: 8.81). Other germplasms had mean GVI varying amongst them around 10.88 to 13.22. The magnitude of BR-99 in all NaCl salinity treatments remained at par or above the GVI magnitude in control. This genotype exhibited c. 6.25% promotion of GVI even in 10 bar NaCl treatment. GVI of BR-90 was observed to be higher than that of BR-99 in lower salinities. In higher NaCl salinity BR-99 had little higher GVI resulting in almost equal GVI of the two varieties. BR-90 and BR-99 are the most rapidly germinating varieties amongst the genotypes tested (Table 5a). Under the influence of Na_2SO_4 salinity, magnitude of GVI declined in comparatively greater proportion than that under NaCl. BR-90 exhibited rapid germination (mean GVI = 17.26 ± 2.30) followed by BR-2/1 (15.83 ± 2.04) and S-5742 (13.32 ± 0.76). Mean GVI of BR-99 was almost equal to that of S-5742 in magnitude (13.21 ± 1.68). The lowest magnitude of GVI was exhibited by BR-2017 (8.48 ± 1.49**)** (Table 5b). The remaining germplasms had mean GVI varying from 10.20 to 12.57. Osmotic potential which retards the uptake of water necessary for mobilization of nutrients disturb the metabolism due to stress resulting in delay and inhibition of germination (Cicek and Cakirlar, 2002; Hassan *et al.*, 2018). Our germplasms appeared to be more sensitive to sulphate salinity.

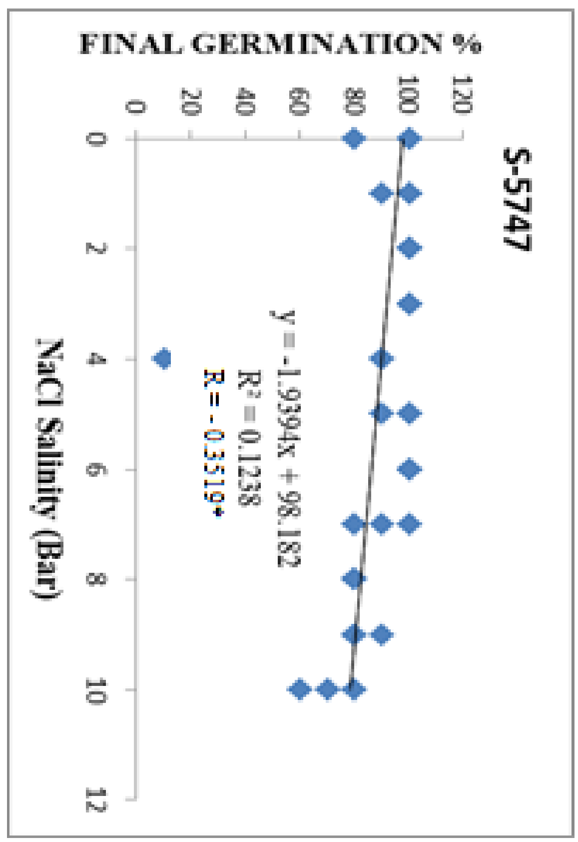

BR-2/1
y = -0.8485x + 96.667
R² = 0.1184
R = -0.3441, NS
FINAL GERMINATION %
NaCl Salinity (Bars)

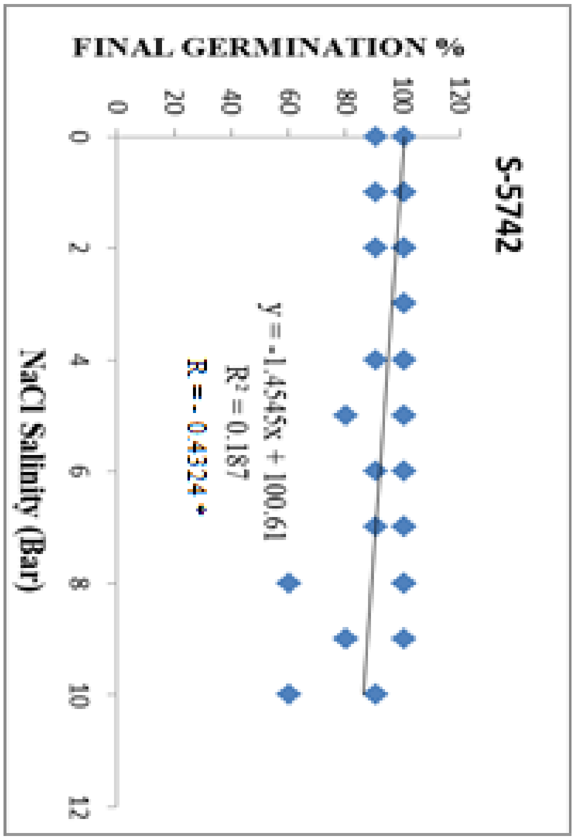

BR-99
y = -0.5152x + 99.545
R² = 0.0976
R = - 0.3124, NS
FINAL GERMINATION %
NaCl Salinity (Bars)

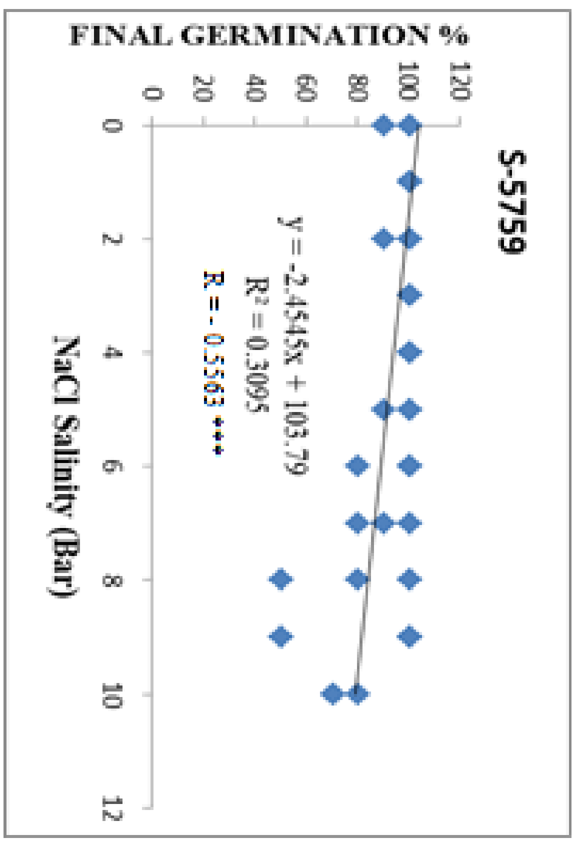

BR-90
y = -0.9394x + 101.67
R² = 0.1535
R = -- 0.3917*
FINAL GERMINATION %
NaCl Salinity (Bars)

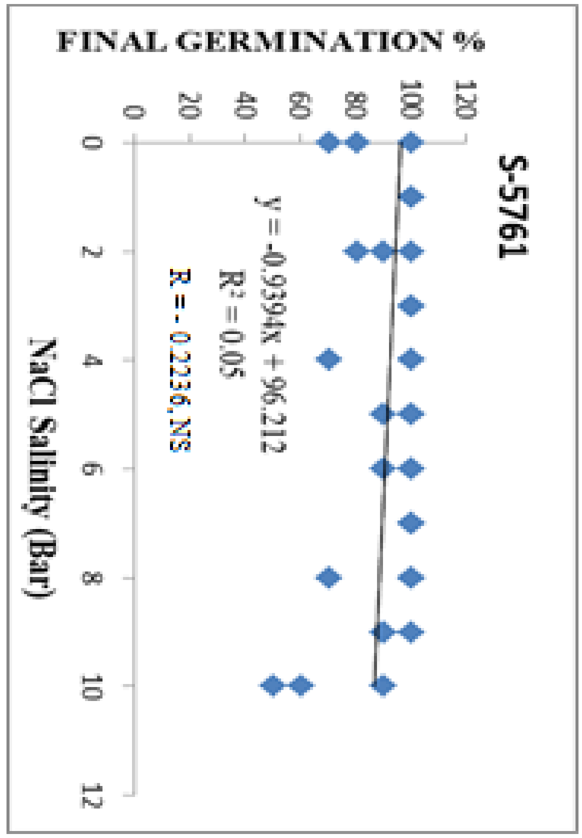

BR-2017
y = -3.9091x + 106.52
R² = 0.4311
R = - 0.6566 ***
FINAL GERMINATION %
NaCl Salinity (Bars)

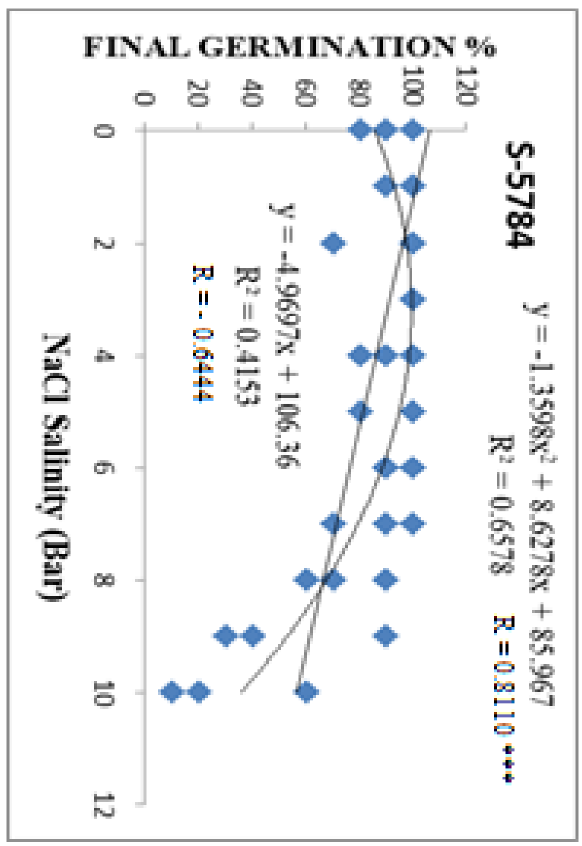

S-5733
FINAL GERMINATION %
y = -1.3939x + 101.52
R² = 0.2891
R = - 0.5377 ***
NaCl Salinity (Bar)

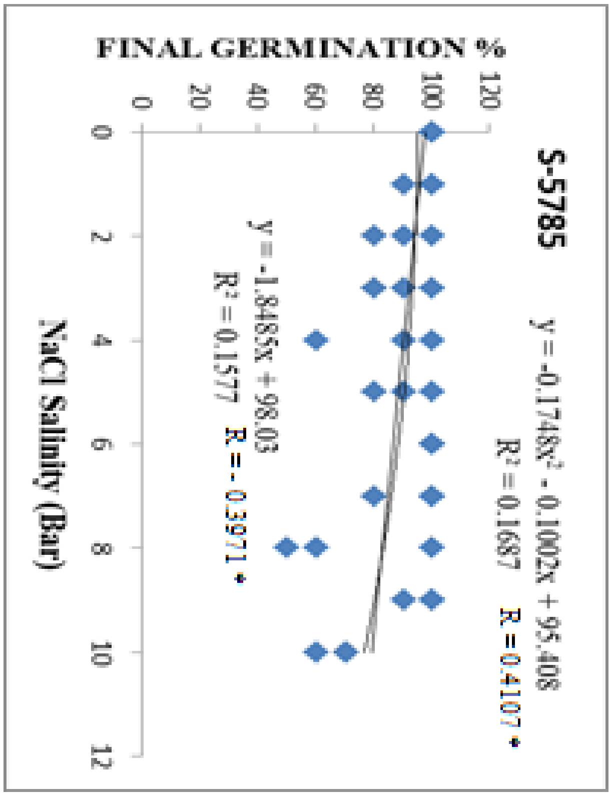

S-5747
FINAL GERMINATION %
y = -1.9394x + 98.182
R² = 0.1238
R = - 0.3519*
NaCl Salinity (Bar)

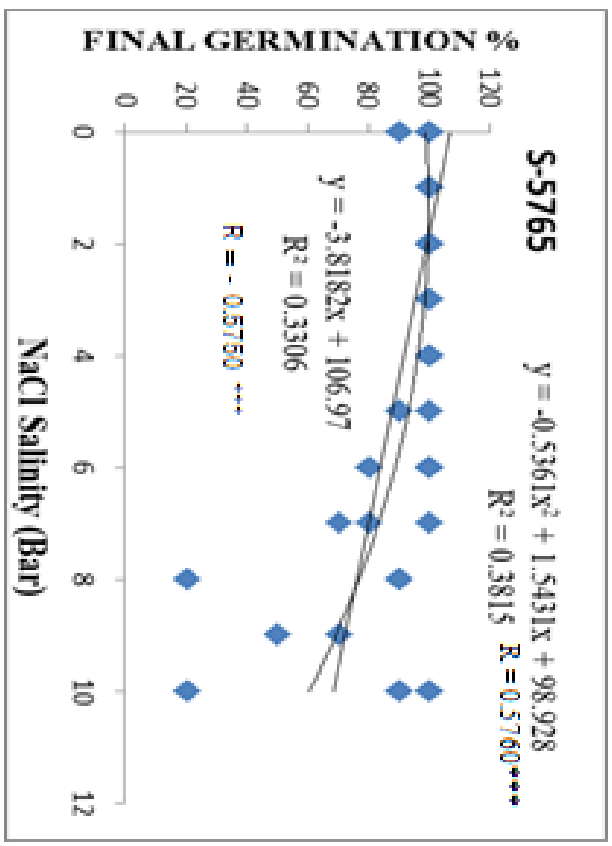

S-5742
FINAL GERMINATION %
y = -1.4545x + 100.61
R² = 0.187
R = - 0.4324 *
NaCl Salinity (Bar)

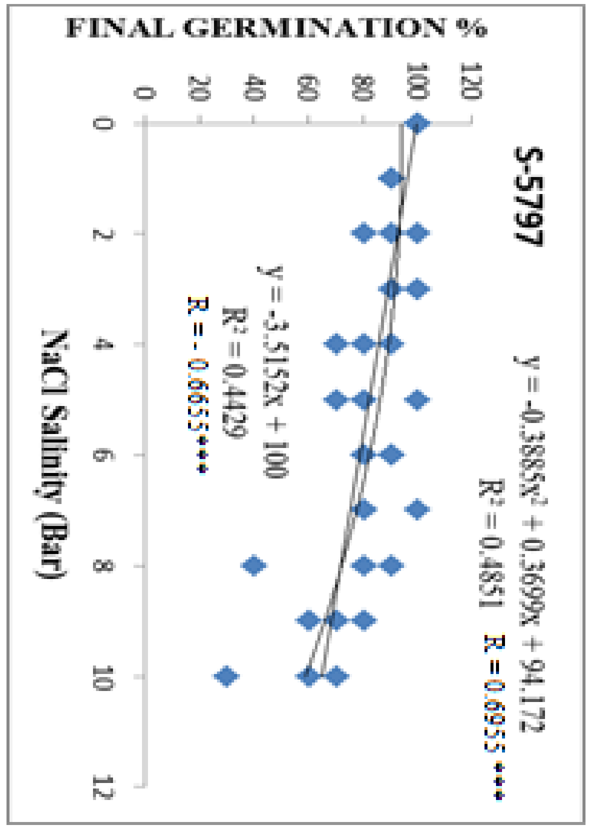

S-5759
FINAL GERMINATION %
y = -2.4545x + 103.79
R² = 0.3095
R = - 0.5563 ***
NaCl Salinity (Bar)

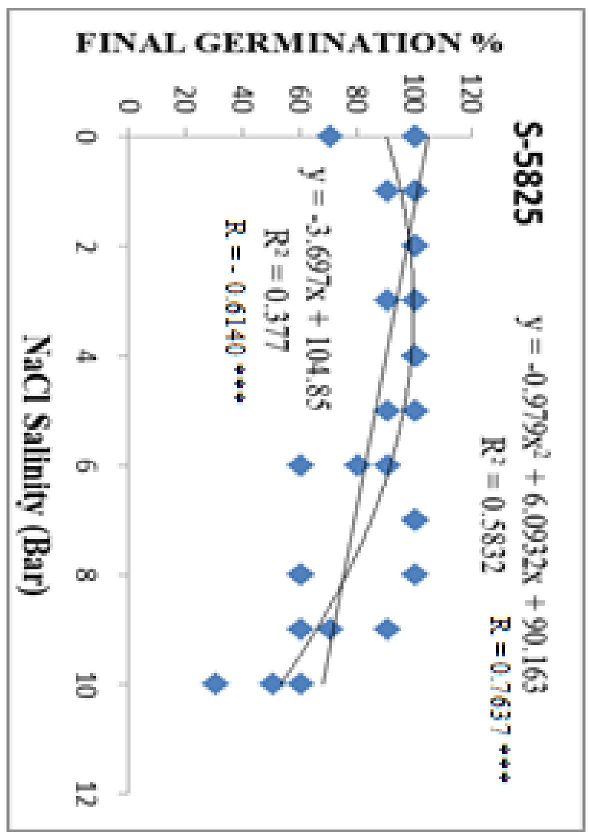

S-5761
FINAL GERMINATION %
y = -0.9394x + 96.212
R² = 0.05
R = - 0.2236 NS
NaCl Salinity (Bar)


S-5784
FINAL GERMINATION %
y = -1.3598x² + 8.6278x + 85.967
R² = 0.6578 R = 0.8110 ***
y = -4.9697x + 106.36
R² = 0.4153
R = - 0.6444
NaCl Salinity (Bar)


S-5785
FINAL GERMINATION %
y = -0.1748x² - 0.1002x + 95.408
R² = 0.1687 R = 0.4107 *
y = -1.8485x + 98.03
R² = 0.1577 R = - 0.3971 *
NaCl Salinity (Bar)


S-5765
FINAL GERMINATION %
y = -0.5361x² + 1.5431x + 98.928
R² = 0.3815 R = 0.5760***
y = -3.8182x + 106.97
R² = 0.3306
R = - 0.5750 ***
NaCl Salinity (Bar)





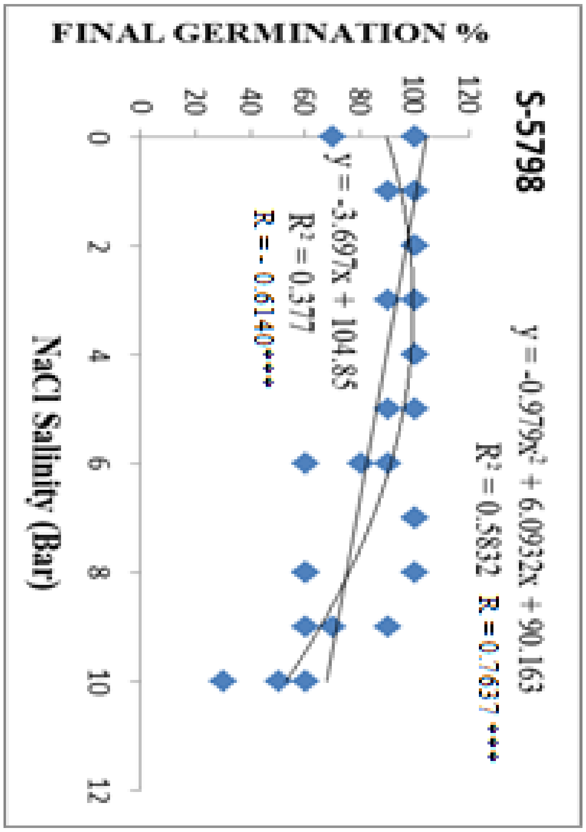


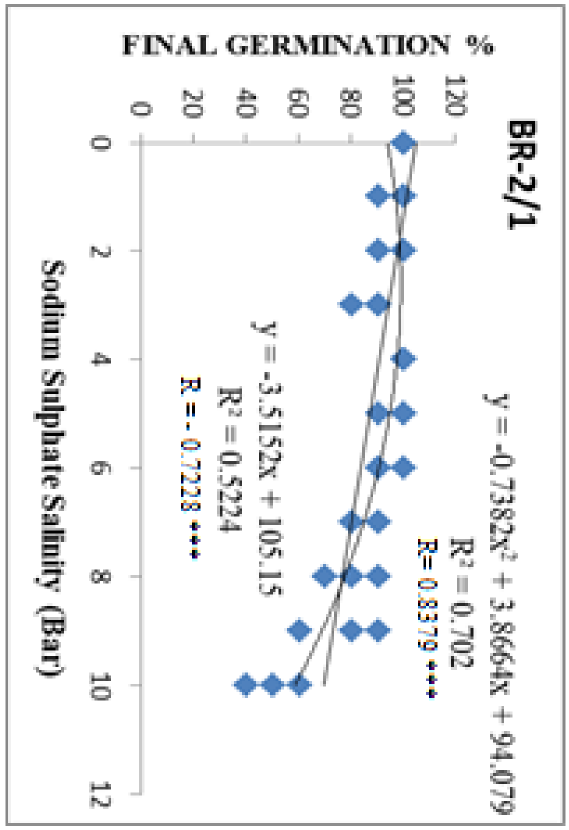
Fig 7. Behaviour of % final germination (replicated data) under NaCl salinity (1-10 Bar) and control. Trend lines for linear and / or polynomial regression are shown with R2. The scatter of data faciltated in reading out the threshold NaCl salinity above which the germination declined.

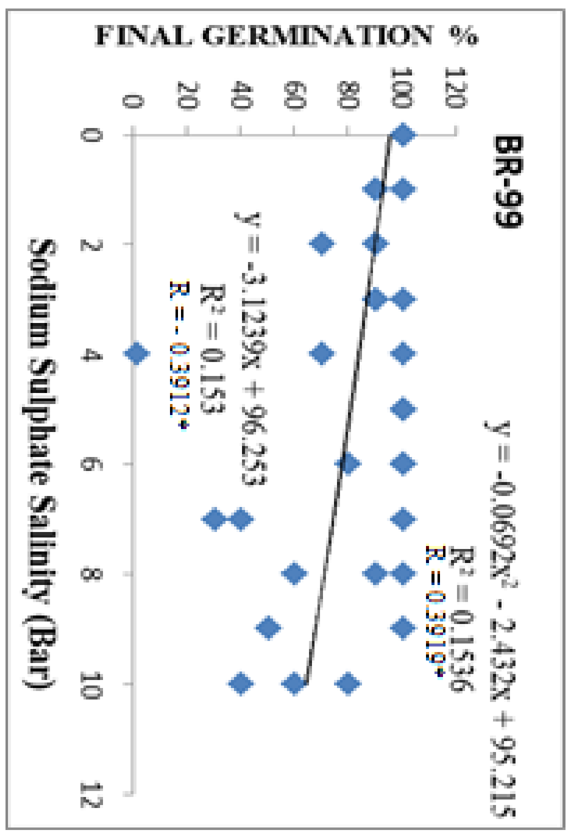
NS, Non-significant.

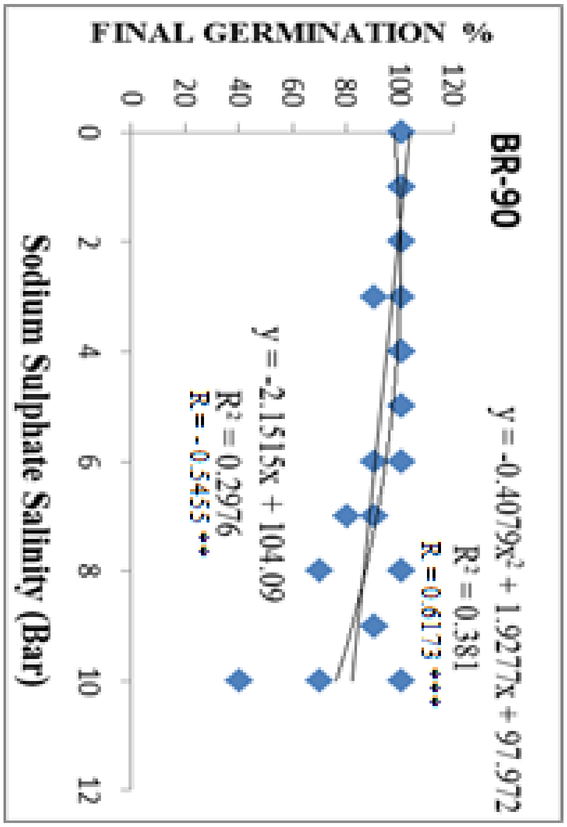
*, $p < 0.05$

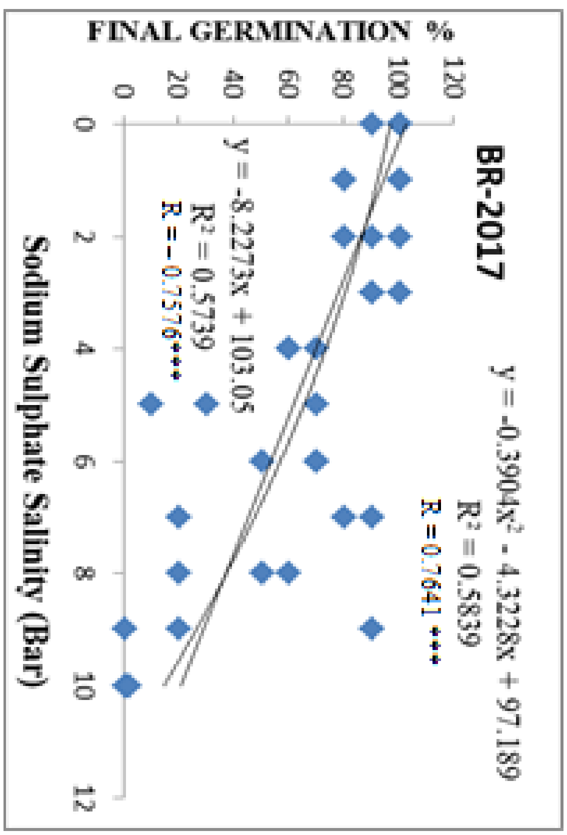
**, $p < 0.01$

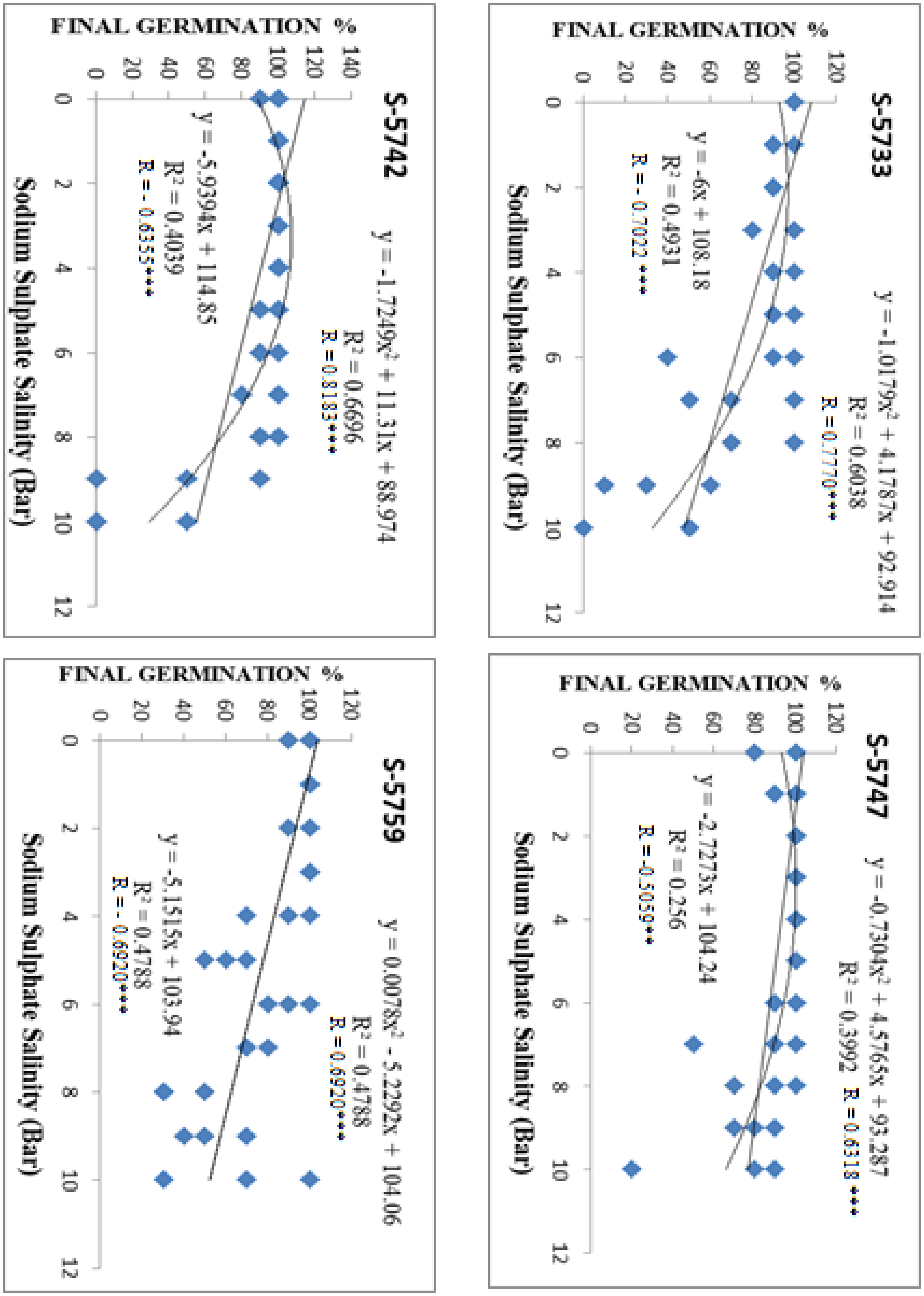
***, $p < 0.0011$

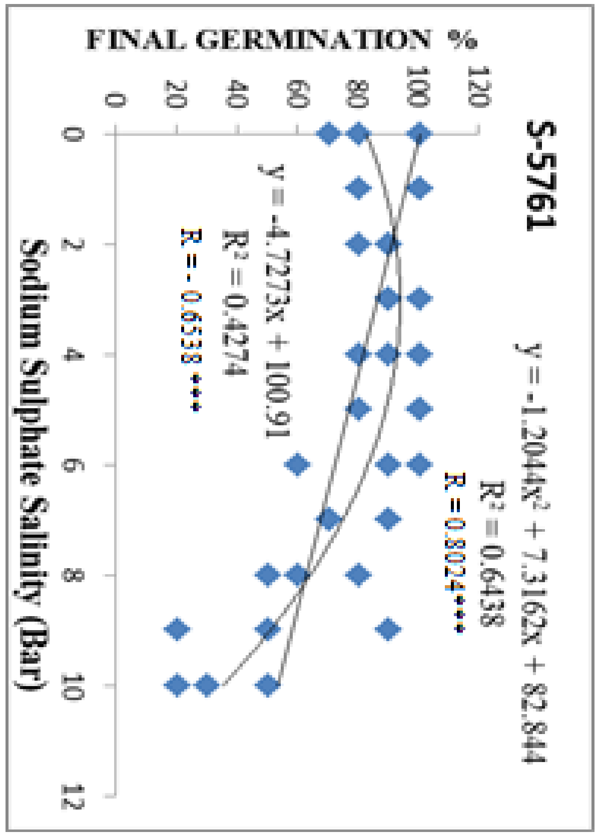

BR-2/1
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)
y = -0.7382x² + 3.8664x + 94.079
R² = 0.702
R= 0.8379 ***
y = -3.5152x + 105.15
R² = 0.5224
R = - 0.7228 ***

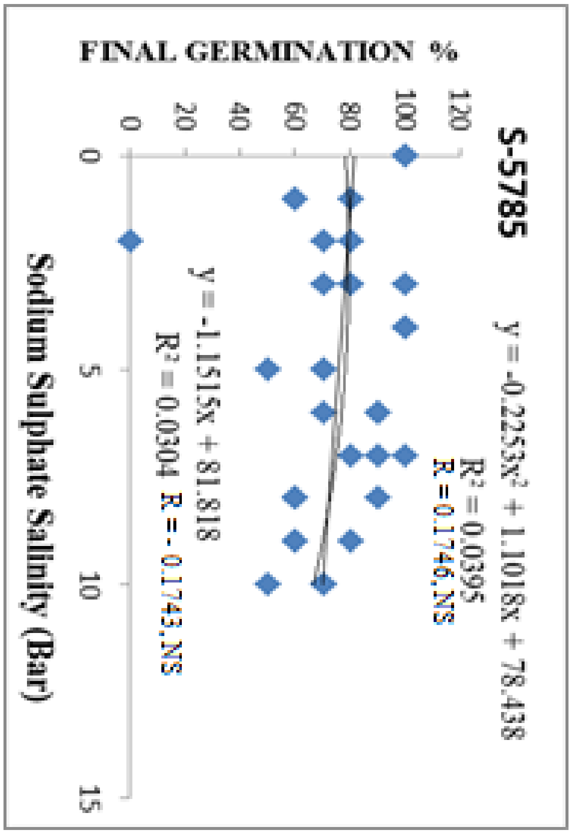

BR-99
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)
y = -0.0692x² - 2.432x + 95.215
R² = 0.1536
R = 0.3919*
y = -3.1239x + 96.253
R² = 0.153
R = - 0.3912*

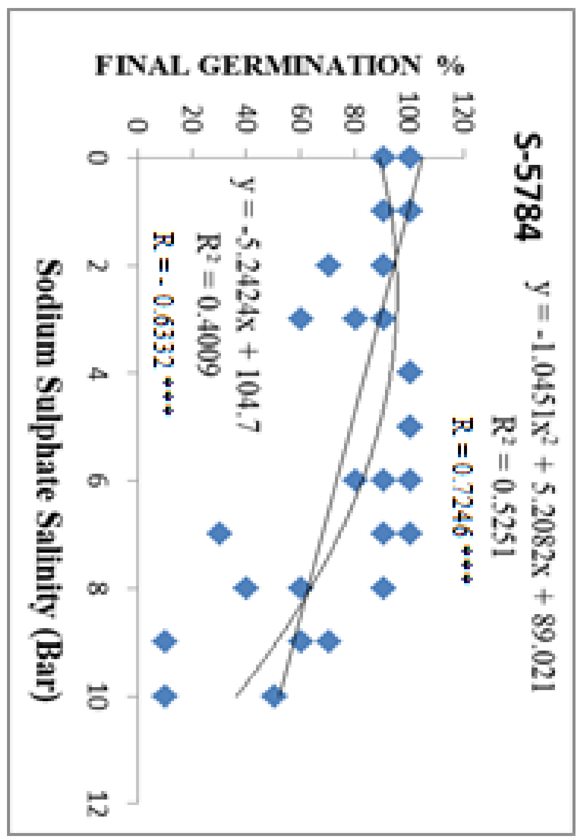

BR-90
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)
y = -0.4079x² + 1.9277x + 97.972
R² = 0.381
R = 0.6173 ***
y = -2.1515x + 104.09
R² = 0.2976
R = - 0.5455 **

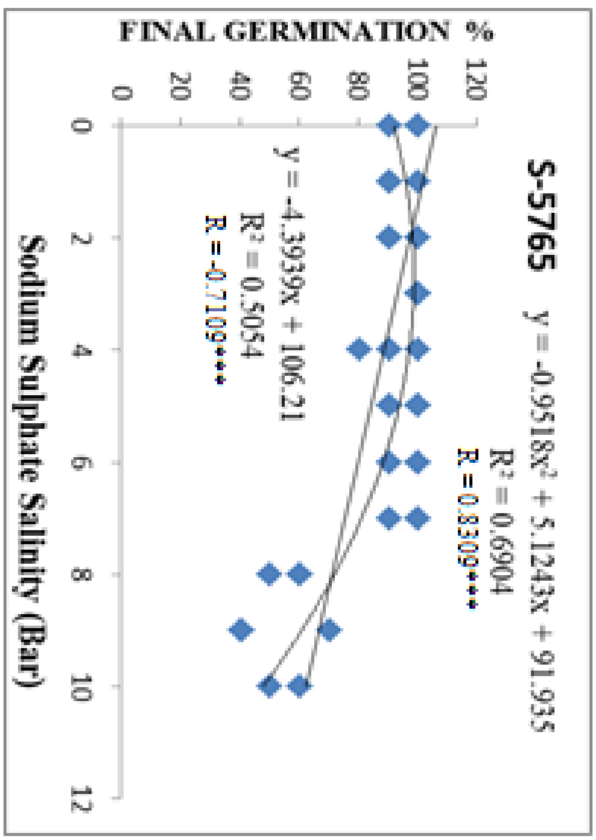

BR-2017
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)
y = -0.3904x² - 4.3228x + 97.189
R² = 0.5839
R = 0.7641 ***
y = -8.2273x + 103.05
R² = 0.5739
R = - 0.7576***

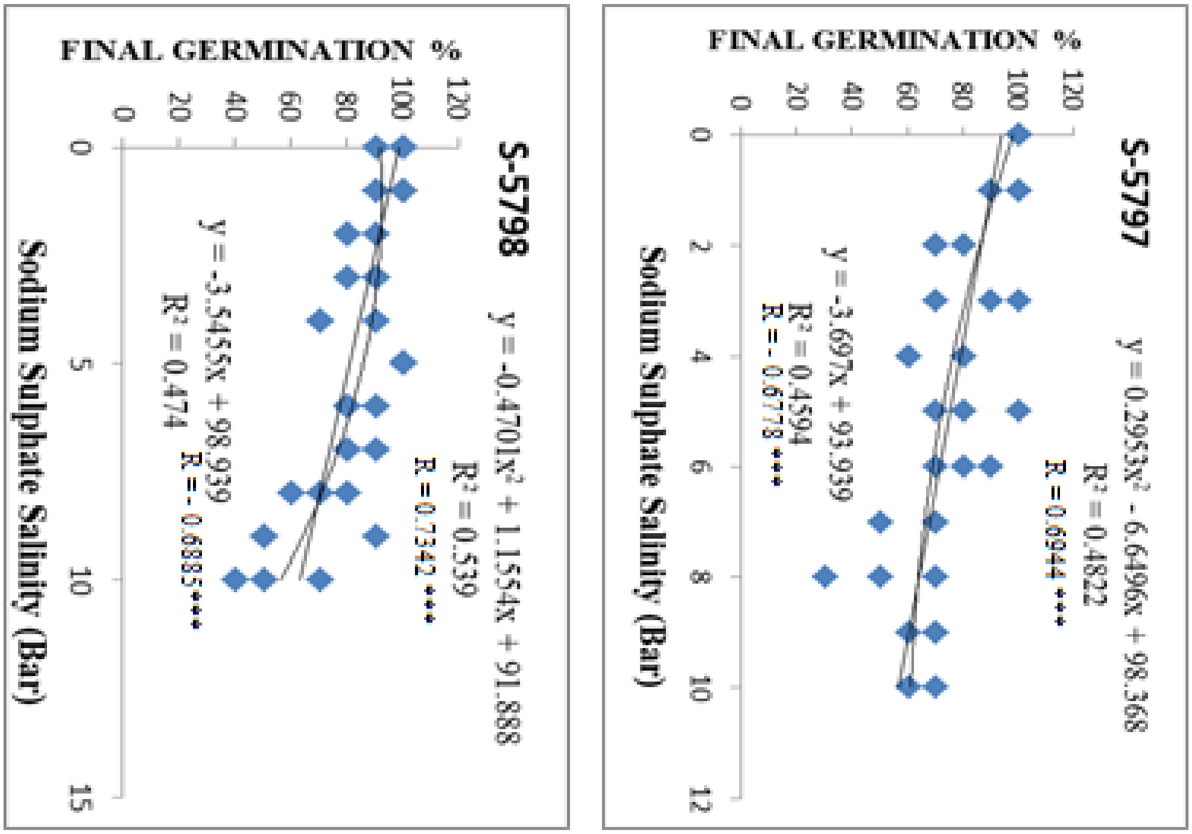

S-5733
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)
y = -1.0179x² + 4.1787x + 92.914
R² = 0.6038
R = 0.7770***
y = -6x + 108.18
R² = 0.4931
R = - 0.7022 ***
S-5742
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)
y = -1.7249x² + 11.31x + 88.974
R² = 0.6696
R = 0.8183***
y = -5.9394x + 114.85
R² = 0.4039
R = - 0.6355***
S-5747
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)
y = -0.7304x² + 4.5765x + 93.287
R² = 0.3992 R = 0.6318 ***
y = -2.7273x + 104.24
R² = 0.256
R = -0.5059**
S-5759
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)
y = 0.0078x² - 5.2292x + 104.06
R² = 0.4788
R = 0.6920***
y = -5.1515x + 103.94
R² = 0.4788
R = - 0.6920***


S-5761
y = -1.2044x² + 7.3162x + 82.844
R² = 0.6438
R = 0.8024***
y = -4.7273x + 100.91
R² = 0.4274
R = - 0.6538 ***
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)


S-5785
y = -0.2253x² + 1.1018x + 78.438
R² = 0.0395
R = 0.1746,NS
y = -1.1515x + 81.818
R² = 0.0304 R = - 0.1743,NS
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)


S-5784
y = -1.0451x² + 5.2082x + 89.021
R² = 0.5251
R = 0.7246 ***
y = -5.2424x + 104.7
R² = 0.4009
R = - 0.6332 ***
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)


S-5765
y = -0.9518x² + 5.1243x + 91.935
R² = 0.6904
R = 0.8309***
y = -4.3939x + 106.21
R² = 0.5054
R = -0.7109***
FINAL GERMINATION %
Sodium Sulphate Salinity (Bar)



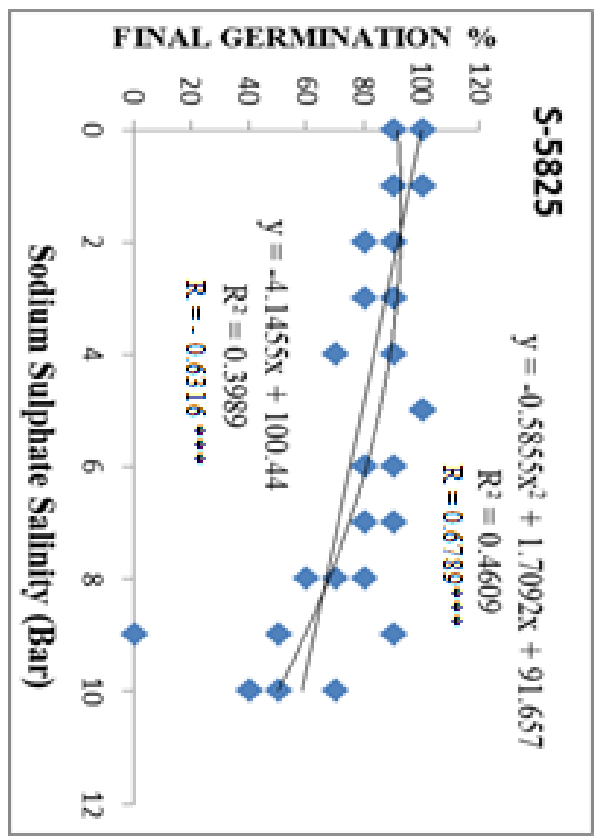


Fig.8. Behaviour of % final germination (in replicate data) under Na_2SO_4 salinity (1-10 Bar) and control. Trend lines for linear and / or polynomial regression are shown with R^2. The scatter of data facilitated in reading out the threshold Na_2SO_4 salinity above which the germination declined substantially.

NS, Non-significant

*, $p < 0.05$

**, $p < 0.01$

***, $p < 0.001$.

Table 6. The relationships of Germination velocity index (GVI, Y) with NaCl salinization (X = bar) for 15 guar varieties / lines.

Varieties / Lines	Best fit regression equations	
BR-2/1	Y = 27.907 – 1.179 (Bar) ± 1.969; ta = 25.13 (p < 0.0001), tb = - 6.28 (p < 0.0001) R = 0.902, R^2 = 0.814, F = 39*.43 (p < 0.0001)	*Eq. 1*
BR-90	Y = 28.516 – 0.700 (Bar) ± 1.321; ta = 38.27 (p < 0.0001), tb = - 5.557 (p < 0.0001) R = 0.884, R^2 = 0.781, F 30.882 (p < 0.0001)	*Eq.2*
BR -99	Y = 25.591 – 0.049 (bar) ± 1.192; ta = 38.07 (p < 0.0001), tb = - 0.434 (p < 0.675) R = 0.141, R^2 = 0.020, F = 0.188 (NS)	*Eq. 3*
BR-2017	Y = 14.290 + 0.572 (Bar) – 0.143 (Bar) ^{2} ± 1.623, ta = 11.56 (p ,0.0001), tb1 = 0.994 (p < 0.3498), tb2 = -2.59 (p < 0.032); R = 0.908, R^2 = 0.824, F = 18.84 (p < 0.001)	*Eq. 4*
S-5733	Y = 27.089 – 1.805 (Bar) ± 2.20; ta = 21.83 (p < 0.0001), tb = - 9.87 (p < 0.0001) R = 0.944, R^2 = 0.892, F = 74.11 (p < 0.0001)	*Eq. 5*
S- 5742	Y = 19.840 – 1.108 (Bar) ± 1.177; ta = 29.87 (p < 0.0001), tb = - 9.87 (p < 0.0001) R = 0.957, R^2 = 0.915, F = 97.38 (p < 0.0001)	*Eq. 6*
S-5747	Y = 16.200 – 0.598 (Bar) ± 1.289; ta = 22.28 (p < 0.0001), tb = - 4.86 (p < 0.0001) R = 0.851, R^2 = 0.724, F = 23.613 (p < 0.0001)	*Eq. 7*
S-5761	Y = 16.481 – 0.920 (Bar) ± 1.338; ta = 21.84 (p < 0.0001), tb = - 7.20 (p < 0.0001) R = 0.934, R2 = 0.872, F = 52.06 (p < 0.0001)	*Eq. 8*
S – 5765	Y = 14.217 + 0.503 (Bar) – 0.135 $(Bar)^2$ ± 0.743; ta = 25.52 (p ,0.0001) tb1 = 1.911 (p < 0.097), tb2 = - 0.503 (p , 0.001), R = 0.977, R^2 = 0.944, F = 84.67 (p < 0.0001)	*Eq. 9*
S-5784	Y = 14.107 – 1.059 (Bar) ± 0.856; ta = 29.22 (p < 0.0001), tb = - 12.98 (p < 0.0001) R = 0.974, R^2 = 0.949, F = 168.56 (p < 0.0001)	*Eq. 10*
S-5785	Y = 13.838 – 0.590 (bar) ± 1.385, ta = 17.71 (p < 0.0001), tb = - 4.470 (p < 0.002) R = 0.830, R2 = 0.689, F = 19.984 (p < 0.002)	*Eq. 11*
S-5797	Y = 16.549 – 0.834 (Bar) ± 1.188, ta = 24.694 (P , 0.0001), tb = - 7.37 (p , 0.00001) R = 0.926, R2 = 0.858, F = 54.25 (p < 0.0001)	*Eq. 12*
S-5798	Y = 13.782 + 0.633 (Bar) -0.150 (Bar) ^{2} ± 1.927; ta = 9.39 (p < 0.0001), tb1 = 0.926 (p < 0.3810), tb2 = - 2.28 (p < 0.050), R = 0.880, R^2 = 0.774, F = 13.73 (P < 0.003)	*Eq. 13*
S-5759	Y = 15.992 – 0.644 (Bar) ± 1.212, ta = 23.30 (p < 0.0001), tb = - 5.57 (p < 0.0001) R = 0.880, R^2 = 0.775, F = 31.01 (p < 0.0001)	*Eq. 14*
S-5825	Y = 18.931 – 0.484 (Bar) ± 2.077, ta = 15.87 (p < 0.0001), tb = - 5.224 (p <, 0.0001) R = 0.867, R^2 = 0.752, F = 27.29 (p < 0.0001)	*Eq. 15*

The relationship of GVI with NaCl and Na_2SO_4 salinization is presented in Table 6 and 7 in form of best fit regression equations and values of correlation coefficients ‘r’, F, and t.

Most of the germplasms exhibited linear inverse relationship but three germplasms viz. S-5765, S-5798 and Br-2017 exhibited curvilinear (polynomial) relationship. Germplasm BR-99 showed non-significant linear correlation as given above and exhibited promotion by 6.25% in GVI almost throughout the treatment range over control (Fig. 9).

The order of salinity tolerance of germplasms against NaCl, based on the decreasing magnitude of ‘b’ of linear regression between GVI and NaCl salinity (expressed as bar value) is as follows.

S-5733 (b = - 1.805) < BR- 2/1 (b = -1.179) < S-5742 (b = -1.108) < S-5784 (b = -1.059) < S-5761 (b = - 0.920) < S-5797 (b = - 0.834) < BR- 90 (b = -0.700) < S-5759 (b = - 0.644) < S – 5747 (b = - 0.598) < S – 5785 (b = - 0.590) < S-5825) (b = - 0.488) (excluding BR-99 showing no correlation and Br-2017, S-5765 and S-5798 showing polynomial relationship).

That is to say that S-5733, BR-2/1, S5742 and S-5784 were more sensitive accessions as regards to the GVI decline. The sequential order of salinity tolerance against NaCl in terms of 50% reduction in germination velocity (GVI) as predicted on the basis of above equations (see Table 8) appeared to be as given below (50% reduction in

GVI for BR-2017, S-5765 and S-5798 was calculated on the basis of their curvilinear equations (bar values shown in parenthesis):

NaCl salinity:

S-5784 (6.66 bar) < S-5733 (7.50 bar) < S-5798 (8.55 bar) ≈ S-5742 (8.95 bar) = S-5761 (8.95 bar) < BR-2017 (9.36 bar) < S-5797 (9.92 bar) < S-5765 (10.02 bar) < S-5785 (11.73bar) < S- BR-2/1 (11.83 bar) < S-5759 (12.42 bar) < S-5747 (13.55 bar) < S-5825 (19.56 bar) < BR-90 (20.36 bar) < BR-99 (exhibited promotion by 6.25% in 10 bar NaCl).

Clearly, BR-99 showed the best germination rate and was the most tolerant to NaCl salinity as regards to the germination velocity.

The sequential order of salinity tolerance of germplasms against Na_2SO_4, based on the decreasing magnitude of 'b' of linear regression between GVI and Na_2SO_4 salinity is given below. The order excludes two germplasms viz. S-5765 and S-5785 which exhibited curvilinear relationship:

Na_2SO_4 salinity:

S-5733 (-2.765) < BR-90 (-2.284) < BR-2/1 (- 2.024) < S-5742 (- 1.759) < BR-99 (- 1.606) < S-5761 (- 1.575) < S-5759 (-1.255) < S-5784 (-1.123) < BR-2017 (-1.140) < S-5797 (-1.1062) < S-5747 (-1.070) < S-5825 (-0.902) **> S-5798 (-0.562).**

Table 7. The relationships of Germination velocity index (GVI) over 0-10 bar of Na_2SO_4 salinization as obtained with linear regression between GVI (Y) and salinity in bar (X). .

Varieties / Lines	Best fit regression equations	
BR-2/1	Y = 25.945 – 2.024 (Bar) ± 0.901; ta = 51.08 (p < 0.0001), tb = - 23.58 (p < 0.0001) R = 0.992, R^2 = 0.984, F = 555.77 (p < 0.0001)	*Eq. 1*
BR-90	Y = 28.678 –2.284 (Bar) ± 0.846; ta = 60.084 (p < 0.0001), tb = - 28.31 (p < 0.0001) R = 0.994, R^2 = 0.0.989 F = 326.0.882 (p < 0.0001)	*Eq. 2*
BR -99	Y = 21.238 – 1.606 (bar) ± 1.765; ta = 21.33 (p < 0.0001), tb = - 9.547 (p < 0.0001) R = 0.954, R^2 = 0.989, F = 91.14 ((p < 0.0001)	*Eq. 3*
BR-2017	Y = 15.481 - 1.140 (Bar) ± 1.736, ta = 15.81 (p ,0.0001), tb1 = - 8.457 (p < 0.0001) R = 0.0.938, R^2 = 0.888, F = 71.51 (p < 0.001)	*Eq. 4*
S-5733	Y = 28.686 – 2.765 (Bar) ± 2.143; ta = 25.17 (p < 0.0001), tb = - 14.34 (p < 0.0001) R = 0.979, R^2 = 0.958, F = 91.43 (p < 0.0001)	*Eq. 5*
S- 5742	Y = 22.112 – 1.759 (Bar) ± 2.429; ta = 16.13 (p < 0.0001), tb = - 7.59 (p < 0.0001) R = 0.930, R^2 = 0.865, F = 57.67 (p < 0.0001)	*Eq. 6*
S-5747	Y = 16.616 – 1.07 (Bar) ± 0.806; ta = 36.54 (p < 0.0001), tb = -13.92 (p < 0.0001) R = 0.978, R^2 = 0.956, F = 193.89 (p < 0.0001)	*Eq. 7*
S-5761	Y = 18.260 – 1.575 (Bar) ± 1.922; ta = 16.84 (p < 0.0001), tb = - 8.59 (p < 0.0001) R = 0.944, R^2 = 0.891, F = 73.823 (p < 0.0001)	*Eq. 8*
S – 5765	Y = 13.328 + 0.875 (Bar) – 0.179 (Bar) ^{2} ± 1.586; ta = 11.028 (p ,0.0001) tb1 = 1.555 (p < 0.158), tb2 = - 3.304 (p , 0.011), R = 0.925, R^2 = 0.856, F = 23.75 (p < 0.0001)	*Eq. 9*
S-5784	Y = 16.494 – 1.123 (Bar) ± 2.081; ta = 14.05 (p < 0.0001), tb = - 5.660 (p < 0.0001) R = 0.884, R^2 = 0.781, F = 32.04 (p < 0.0001)	*Eq. 10*
S-5785	Y = 11.376 + 1.087 (Bar) – 0.160 (Bar) ^{2} ± 1.466, ta = 10.188 (p , 0.0001), tb1 = 2.093 (p < 0.070), Tb2 = - 3.20 (p < 0.013), R = 0.865, R^2 = 0.748, F = 11.88 (p < 0.0001)	*Eq. 11*
S-5797	Y = 15.840 – 1.062 (Bar) ± 2.091, ta = 13.427 (p , 0.0001), tb = - 5.33 (p , 0.00001) R = 0.871, R^2 = 0.759, F = 28.36 (p < 0.0001)	*Eq. 12*
S-5798	Y = 14.044 – 0.562 (Bar) ± 1.242; ta 20.05 (p < 0.0001), tb = - 4.75 (p < 0.3810) R = 0.845, R^2 = 0.715, F = 22.59 (P < 0.001)	*Eq. 13*
S-5759	Y = 16.481 – 1.255 (Bar) ± 2.077, ta = 14.07 (p < 0.0001), tb = - 6.339 (p < 0.0001) R = 0.904, R^2 = 0.817, F = 4018 (p < 0.0001)	*Eq. 14*
S-5825	Y = 17.080 – 0.902 (Bar) ± 2.013, ta = 15.0 (p < 0.0001), tb = - 4.688 (p <, 0.0001) R = 0.842, R^2 = 0.709, F = 21.98 (p < 0.0001)	*Eq. 15*

The sequential order of salinity tolerance against Na_2SO_4 in terms of 50% reduction in germination velocity (GVI) as predicted from these equations (see Table 8) appeared to be as follows (50% reduction in GVI for S-5765 and S-5785 was calculated on the basis of their curvilinear equations (bar values corresponding to 50% reduction in parenthesis):

Na_2SO_4 salinity:
S-5733 (5.18) < S-5761 (5.79) < BR-2/1 (6.16) ≈ BR-90 (6.27) ≈ S-5742 (6.29) ≈ S-5759 (6.57) ≈ BR-99 (6.61) ≈ BR-2017 (6.69) < S-5784 (7.34) ≈ S-5797 (7.46) ≈ S-5747 (7.76) < S-5765 (8.74) < S-5825 (9.47) < S-5785 (10.25) < S-5798 (12.49)

Clearly, line S-5798 was the most tolerant to Na_2SO_4 salinization as regards to GVI.

The reduction or promotion of GVI over control, under NaCl and Na2SO4 environment for various germplasms is presented in Fig. 9. GVI reduction for most germplasms was clearly higher in Na_2SO_4 as compared to that in NaCl. The % reduction in GVI averaged to **52.85 ± 3.86** (CV: 32.44%) (Excluding variety BR-99 which showed promotion) under NaCl. *Per cent* reduction of GVI of the germplasms tested averaged to **71.80 ± 3.86** (CV: 20.8%) in Na_2SO_4.

Seven germplasms under NaCl salinity viz. BR-2/1, BR-90, S-5759, S-5765, S-5785, S-5797 and S-5825 showed GVI reduction in lesser magnitude than the average GVI reduction of the germplasms. Germplasms, BR-2017, S-5733, S-5742, S-5761, S-5784 and S-5798 had larger decline than the average GVI. S-5747 had reduction nearly equal to the average GVI reduction.

Reduction of GVI under Na_2SO_4 environment was of higher order than in NaCl. Seven germplasms (S-5759, S-5747, S-6765, S-5785, S-5797 and S-5825) showed lesser than the average reduction where as germplasms, BR-2/1, BR-90, BR-99, BR-2017, S-5733, S-5742 and S-5761 showed larger reduction than the average reduction. Germplasm S-5784 exhibited GVI decline nearly equal to the quantum of average decline.

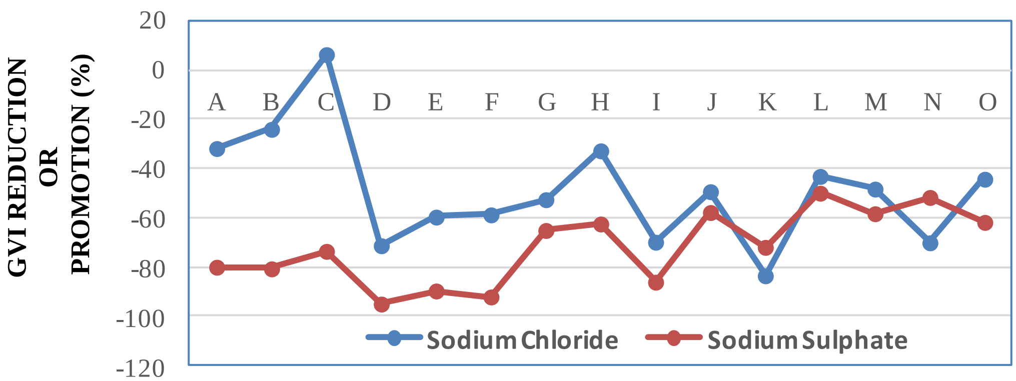


Fig. 9. *Per cent* reduction or promotion (%) of germination velocity index (GVI) in highest salt concentration of over control. Acronyms (A-O): A, BR-2/1; B, BR-90; C, BR-99; D, Br-2017, E; S-5733, F, S-5742; G, S-5747; H, S-5759; I, S-5761; J, S-5765; K, S-5784, L, S-5785; M, S-5797; N, S-5798 and O, S-5825.

Fifty *per cent* reduction in GVI of the germplasms in NaCl and Na_2SO_4 environment is presented in Table 8. Excluding BR-99 which showed promotion (6.25%) even in 10 bar NaCl the magnitude of NaCl salinity causing 50% re4duction in GVI varied differentially amongst the germplasms – the lowest in S-5784 (6.66 bar) and the highest in BR-90 (20.36 bar) followed by S-5825 (19.56 bar). It is, however, apparent that NaCl salinity associated with 50% reduction was although differentially varying with germplasms but in all cases it was of quite high order. In terms of EC corresponding to 50 % reduction it ranged from 14.91 to 44.16dS.m^{-1}.

In Na_2SO_4, fifty per cent decline in GVI occurred in comparatively lower salinities varying from 5.79 bar in S-5761 to 12.49 bar in S-5798. All varietal genotypes (BR-2/1, BR-90, Br-99 and BR-2017) showed relatively higher sensitivity to sulphate salinity which narrowly varied among these genotypes (6.16 to 6.69 bar i.e. 15-16 dS.m^{-1}). These genotypes were more resistant to NaCl salinity. As regards to GVI, lines S-5785 and S-5798 were comparatively more resistant to sulphate salinity than the four varietal genotypes.

Table 8. NaCl and Na_2SO4 concentrations, in terms of bar values and EC ($dS.m^{-1}$) corresponding with 50% reduction in Germination velocity index.

Germplasms	NaCl	Na_2SO_4
BR-2/1	11.83 (25.95)*	6.16 (15.35)*
BR-90	20.36 (44.16)	6.27 (15.60)
BR-99	-	6.61 (16.37)
BR-2017	9.36 (20.68)	6.69 (16.55)
S-5733	7.50 (16.71)	5.18 (13.12)
S-5742	8.95 (19.80)	6.29 (15.64)
S-5747	13.55 (29.62)	7.76 (18.03)
S-5761	8.95 (19.80)	5.79 (14.50)
S-5765	10.02 (22.08)	8.74 (21.21)
S-5784	6.66 (14.91)	7.34 (18.03)
S-5785	11.73 (25.74)	10.25 (14.65)
S-5797	9.92 (21.87)	7.46 (18.30)
S-5798	8.55 (18.95)	12.49 (29.74)
S-5759	12.42 (27.20)	6.57 (16.28)
S-5825	19.56 (42.45)	9.47 (22.87)

EC values in parenthesis. The values for BR-2017, S-5785 and S-5798 in case of NaCl salinity and for S-5765 and S-5798 in case of Na_2SO_4 salinity were calculated on the basis of curvilinear equations.

Agglomeration of guar germplasms on the basis of germination and GVI:

The agglomeration of germplasms was done by cluster analysis of Ward (1963) on the basis of germination and GVI data of germplasms using Euclidean distances among the germplasms. The results are presented in form of cluster diagrams (Fig. 10-13).

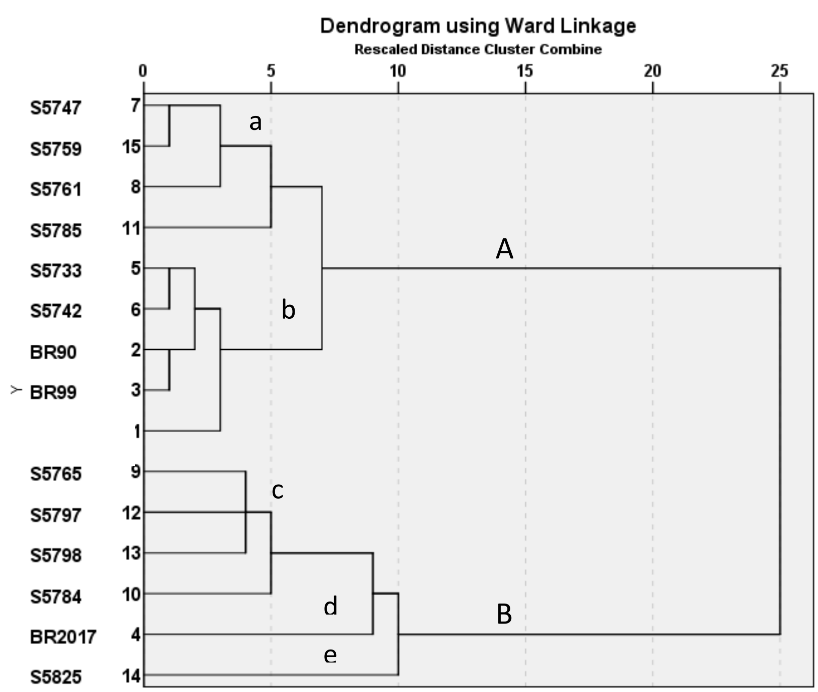


Fig. 10. Agglomerative clustering of guar germplasms on the basis of mean final % germination under NaCl salinization.

Germplasms agglomeration on the basis of germination under NaCl

Fig. 10 presents the cluster diagram of germplasms under NaCl. On the basis 0f 5% distance amongst the germplasm five discrete (all differentially salt tolerant) groups may be observed and on a distance of 10% only two groups (both salt tolerant) were observed as given below for their composition and their germination potentials.

Dissimilarity Distance: 5%

Group a: S-5747, S-5759, S-5761 and S-5785

(N = 44, mean final germination: **90.682 ± 1.5156**, 66.67-100, CV = 11.09%) –Rank II

Group b: S-5733, S-5742, BR-90, BR-99 and BR-2/1

(N = 55, mean final germination: **95.041 ± 0.78485**, 80-100, CV= 5.85%) – Rank I

Group c: S-5765, S-5797, S-5798 and S-5784

(N = 44, mean final germination: **84.69 ± 2.505**, 30-100, CV: 19.62%) – Rank III

Group d: BR-2017

(N = 11, final germination: **75.46 ± 4.8886,** 43.33 – 90.0, CV: 21.49) –Rank V

Group e: **S-5825**

(N = 11, final germination: **80.91 ± 3.9204**, 46.67 – 93.33, CV: 16.07%) – Rank IV

All groups of germplasms were considerably tolerant at germination phase but groups a and b predominated the germplasms for germinability.

Dissimilarity Distance: 10%

Group A: S-5747, S-5759, S-5761, S-5785, S-5733, S-5742, BR-90, BR-99 and BR-2/1

N = 99, mean final germination: **93.898 ± 0.8168**, 66.67 -100.0, CV: 8.13%) –Rank I

Group B: **S-5765, S-5797, S-5798, S-5784, BR-2017 and S- 5825**

(N = 66, mean final germination: **82.526 ± 3.920**, 30.-100, CV: 19.59%) --- Rank II

These two groups were significantly different from each other on the basis their germination behaviour as indicated by the t-test ($t = 4.92$, $p < 0.0001$). Group A had higher germination potential under NaCl salinity than the group B.

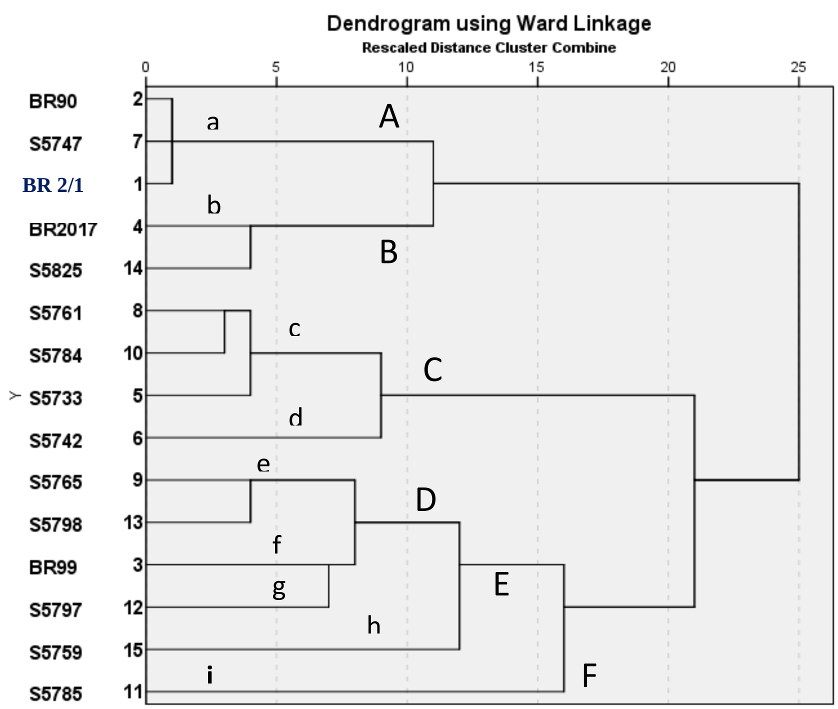


Fig. 11. Agglomerative clustering of guar germplasms on the basis of mean final germination under Na_2SO_4 salinization.

Germplasms agglomeration on the basis of germination under Na_2SO_4

Fig. 11 presents the cluster diagram of germplasms under Na_2SO_4. On the basis 0f 5% distance amongst the germplasm nine discrete and differentially tolerant groups may be observed and on a distance of 10% six groups were apparent as given below for their composition and their germination behaviour.

Dissimilarity Distance 5%

Group a: BR-90, S-5747 and BR-2/1

N = 33, mean final germination: **90.00 ± 2.298,** 50-100, CV: 14.66% -- Rank I

Group b: Br-2017, S-5825

(N = 22, mean final germination: **83.79 ± 2.475**, 53.33-100, CV: 13.85%) – Rank III

Group c: S-5761, S-5784 and S-5733

(N = 33, mean final germination: **77.98 ± 3.661,** 33.33-100, CV: 26.97%) – Rank VII

Group d: S-5742

(N = 11, mean final germination: **85.15 ± 8.269,** 16.7-100, CV: 32.20%) – Rank II

Group e: S-5765 and S-5798

(N = 22, mean final germination: **82.72 3.581**, 50.0-100, CV: 20.30%) – Rank V

Group f: BR-99

(N = 11, mean final germination: **83.34 ± 4.669,** 56.67-100, CV: 18.59%) – Rank IV

Group g: S-5797

(N = 11, mean final germination: **75.46 ± 4.633,** 50.0-100, CV: 20.37%) – Rank IX

Group h: S-5759

(N =11, mean final germination: **78.18 ± 6.5198,** 36.0-100, CV: 27.66%) – Rank VI

Group i: S-5785

(N = 11, mean final germination: **76.06 ± 4.919**, 50-100, CV: 16.32%) – Rank VIII

Dissimilarity Distance 10%

Group A: BR-90, S-5747 and BR-2/1

(N =33, mean final germination: **90.00 ± 2.298,** 50.0-100, CV: 14.69%) – Rank I

Group B: BR-2017 and S-5825

(N = 22, mean final germination: **83.78 ± 2.2747,** 53.33-100, CV: 13.85%) – Rank II

Group C: S-5761, S-5784, S-5733 and S-5742

(N = 44, mean final germination: **79.77 ± 36.417**, 16.67-100, CV: 28.42%) – Rank IV

Group D: S-5785, S-5798, BR-99 and S-5797

(N = 44, mean final germination = **81.06 ± 2.427,** 50-100, CV: 20.29%) – Rank III

Group E: S-5759

(N = 11, mean final germination: **78.18 ± 6.519,** 36.67-100, CV: 29.66%) – Rank V

Group F: S-5785

(N = 11, mean final germination: **76.06 ± 4.919**, 36.67-100, CV: 21.45%) – Rank VI

Germplasms agglomeration on the basis of mean GVI under NaCl

Fig. 12 presents the GVI- based cluster diagram of germplasms under NaCl. On the basis of 5% distance amongst the germplasm two discrete groups were observed as given below for their composition and their germination behaviour.

Dissimilarity Distance: 5%

Group A: BR-2017, S-5798, S-5797, S- 5759, S-5747, S-5761, S-5765, S-5785, S- 5742, S-5825 and S-5784

Mean GVI over the treatment range and the control = 12.13 ± 0.79176, CV: 11.89% -- Rank II

Group B: BR-90, BR-99, BR-2/1 and S-5733

(Mean GVI over the treatment range and the control: 22.628 ± 1.502, CV: 11.89% -- Rank I

The group B of germplasms composed of BR -90, BR -99, BR-2/1 and S-5733 was fast- germinating than germplasms of group A.

Germplasms agglomeration on the basis of mean GVI under Na_2SO_4

Fig. 13 presents the GVI-based cluster diagram of germplasms under Na_2SO_4. On the basis of 5% distance amongst the germplasm five discrete groups were observed and on the basis of 10% distance two groups were apparent as given below for their composition and their germination behaviour. The first ranking group was composed of BR-2/1, BR-99 and S-5733 followed by the second-ranking group composed of BR-99 and S-5742.
The clustering was more dispersive under Na_2SO_4.

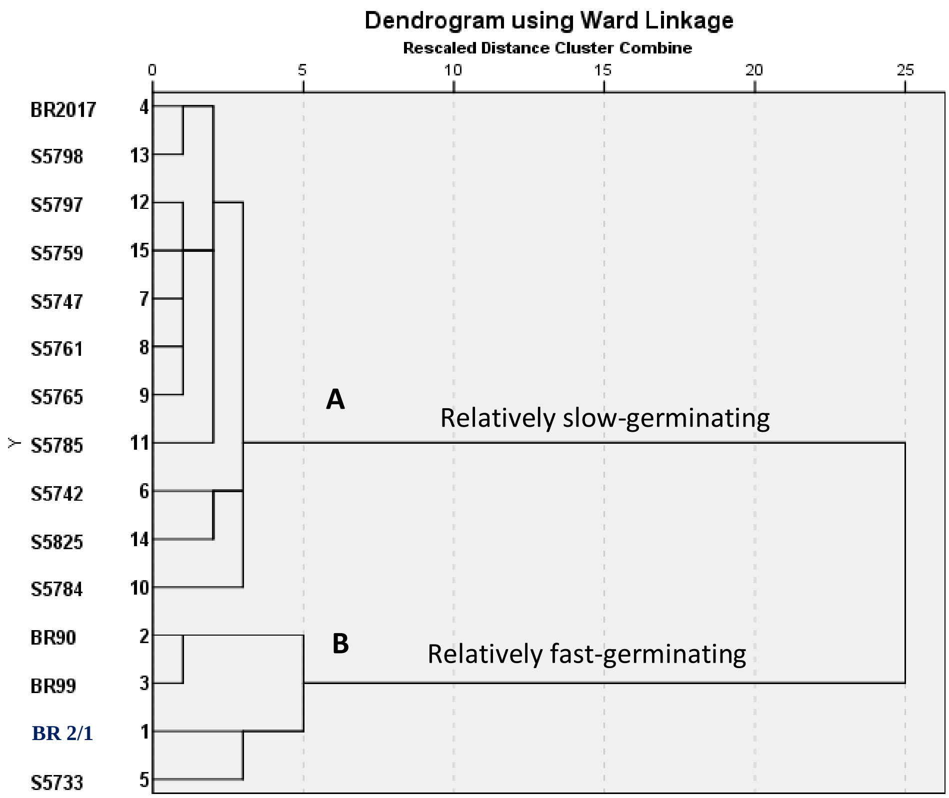


Fig. 12. Agglomerative clustering of guar germplasms based on GVI under NaCl salinization.

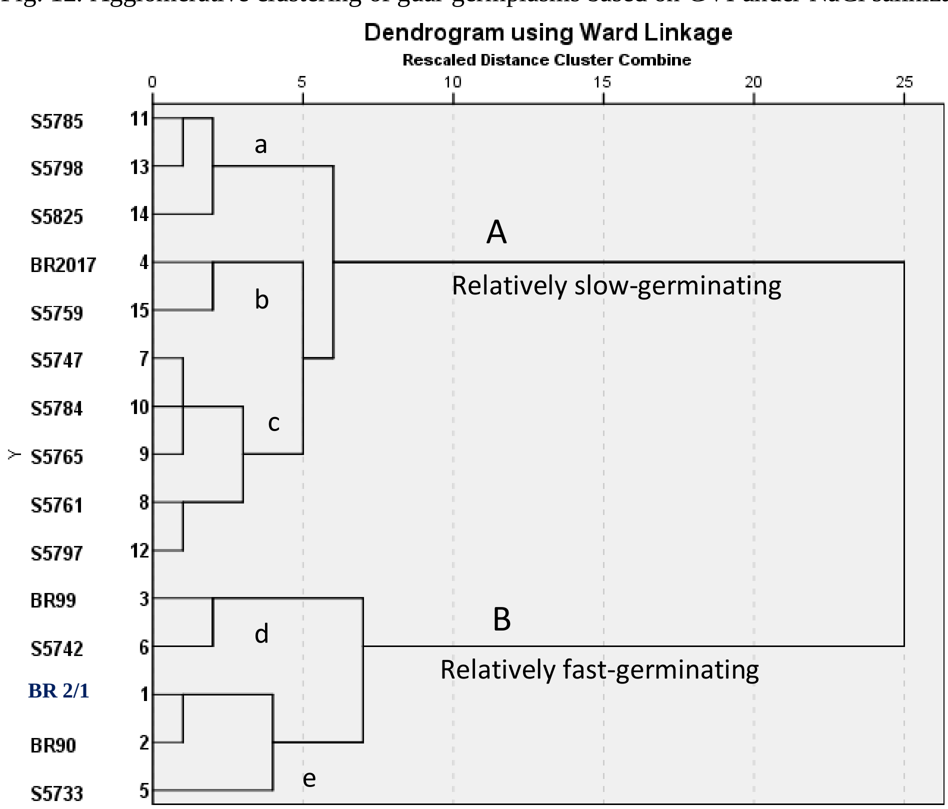


Fig. 13. Agglomerative clustering of guar germplasms based on GVI under Na_2SO_4 salinization.

Dissimilarity Distance: 5%

Group a: S-5785, S-5798 and S-5825

Mean GVI over the treatment and control: 11.64 ± 0.45, CV: 6.68% -- Rank III

Group b: BR-2017 and S-5759

Mean GVI over the treatment range and the control: 9.37 ± 0.86, CV: 13.02% -- Rank V

Group c: S-5747, S-5784, S-5765, S-5761 and S-5797

Mean GVI over treatment range and the control: 10.90 ± 0.2032, CV: 4.96 – Rank IV

Group d: BR-99, S-5742,

Mean GVI over the treatment range and the control: 13.23 ± 0.0270, CV: 0.30% --Rank II

Group e: BR-2/1, BR-90 and S-5733

Mean GVI over the treatment range and the control: 15.99 ± 0.6944, CV: 7.52% -- Rank I

Dissimilarity Distance: 10%

Group A: S-5785, S-5798, S-5825, BR-2017, S-5759, S-5742, S-5784, S-5765, S-5761 and S-5797

Mean GVI over the treatment range and the control: 10.82 ± 0.3351, CV: 9.79% --Rank II

Group B: BR-99, S-5742, BR-2/1, BR-90 and S-5733

Mean GVI over the treatment range and the control: 14.84 ± 0.7607, CV: 11.38% -- Rank I

Group B composed of BR-99, BR-2/1, S-5742 and S-5733 was comparatively more rapid in germination.

Seedling growth

Under significant germination delaying conditions under salinity as seen in the present work, seedling growth *in vitro* experiment of short period of time (four days) appears to be somewhat dubious due to disparity of age amongst the seedlings. However, since this age disparity is caused by differential response of the germplasms to salinity, seedling behaviour is often described in such studies. It is given below.

Seedling growth in the present work was assessed on three parameters – root length, shoot length and cummulative seedling dry weight after four days of incubation. Two-way ANOVA for these parameters is presented in Table 9-14. Analysis of variance for the component sources of variation of the root length under NaCl and Na_2SO_4 salinities is presented in Table 9 and 10. The both components sources significantly influenced germination under two types of salinities and the nature of varieties and their interactions were also significant.

During growth phase, salt stress is first perceived by the root. Both, NaCl and Na_2SO_4 regularly reduced the root length. The root length of various germplasms varied differentially. Root length was maximum in line in BR-99 and S-5765 and minimum in line S-5797. Root length varied between 2 to 3 cm in six germplasms (S-5825, BR-2/1, S-5742, BR-90, S-5747 and S-5759). Genotypes such as BR-2017, S-5761, S-5784, S-5785, S-5733 and S-5798 had root varying between 1 and 2 cm in length. Under Na_2SO_4 environment, the maximum root length was observed in S-5825 (2.44 cm) followed in S-5797 (0.56 cm). The root length of BR-99 was more affected under Na_2SO_4 salinity (Table 10). Generally, Na_2SO_4 salinity was more suppressive to root length than NaCl. The component sources of variation (salt concentration and nature of varieties) significantly affected the shoot growth and their interaction was also found to be significant. Under this interactive system, like NaCl salinity regularly declined shoot elongation in Na_2SO_4 (0 to 10 bar) but comparatively in larger magnitude than under NaCl i.e. Na_2SO_4 salinity was more detrimental to shoot growth than NaCl. Still BR-2/1 (2.81cm), BR-90 (2.51cm), S-5733 (2.28cm) S-5825 (2.19 cm) and BR-99 (2.09 cm) had root length larger or equal to 2 cm under sulphate salinity. Other germplasms showed root elongation between 1 and 1.7 cm (Table 11 and 12).

Analysis of variance for seedling growth under chloride and sulphate salinities is presented in Table 13 and 14, respectively. The salt concentration and varietal nature presented a highly interactive system as regard to the cummulative dry seedling mass under NaCl and Na_2SO_4 salinities. On four- day- interaction, seedling dry mass was observed to be the maximum in 7 bar NaCl followed by 5 bar salinity. In most germplasms seedling dry mass was higher in all treatments of NaCl as compared to control – only except that in 10 bar salinity (Table 13).

The sequential order of seedling mass productivity under two types of salinity (Table 13 and 14) indicated that seedling biomass was the highest in S-5784 (0.2115g) and the minimum in S-5761 (0.1216g). Under sulphate salinity, maximum seedling dry mass was represented by S-5733 (0.1933g) followed by S-5742 (0.1924g). Seedling mass was minimum in BR-99 (0.1199g). Like root and shoot lengths, seedling mass was more suppressed in sulphate salinity (Table 14). *Prosopis juliflora* (a known salt tolerant plant; Khan *et al.*, 1987) showed increase in shoot growth over control up to 8 bar NaCl and only up to 5 bar Na_2SO_4 concentration. In seedlings of this species, root length was larger up to 7 bar NaCl and was maximum at 4 bar (Khan *et al.*, 1984).

Table 9. Analysis of variance for root length data (cm) of 15 guar varieties tested against 11 concentrations of NaCl.

Source	SS	df	MS	F	p
NaCl concentrations	278.218	10	27.82	68.19	0.00001 ***
Varieties	200.572	14	14.33	35.12	0.00001 ***
Concentration x varieties	185.859	140	1.33	3.250	0.00001 **
Error	134.633	330	0.408	-	-
Total	799.282	494	-	-	-

NaCl Concentrations LSD 0.0-5:0.268134					Varieties or lines, LSD 0.05: 0.309329				
Rank	TRT	Mean	n	NSR	Rank	TRT	Mean	n	NSR
1	Control	3.344	45	a	1	Br-99	3.200	33	a
2	1 bar	2.856	45	b	2	S-5765	3.119	33	a
3	2 bar	2.669	45	bc	3	S-5825	2.560	33	b
4	3bar	2.651	45	bc	4	BR-2/1	2.510	33	b
5	4 bar	2.517	45	cd	5	S-5742	2.440	33	b
6	5 bar	2.273	45	d	6	Br-90	2.396	33	b
7	6 bar	1.923	45	e	7	S-5747	2.361	33	b
8	7 bar	1.779	45	e	8	S-5759	2.297	33	bc
9	8 bar	1.366	45	f	9	BR-2017	1.988	33	cd
10	9 bar	1.0584	45	g	10	S-5761	1.864	33	de
11	10 bar	0.885	45	g	11	S-5785	1.842	33	de
TRT, Treatments (salt concentrations or varieties; NSR, NS ranges					12	S-5733	1.571	33	ef
					13	S-5784	1.435	33	fg
					14	S-5798	1.210	33	gh
					15	S-5797	0.936	33	h

Table 10. Analysis of variance of root length data (cm) of 15 guar varieties tested against 11 concentrations of Na_2SO_4.

Source	SS	df	MS	F	p
Na_2SO_4 concentrations	403.84	10	40.384	118.111	0.00001 ***
Varieties	117.53	14	8.395	24.553	0.0000 ***
Concentration x varieties	205.09	140	1.465	4.284	0.0000 ***
Error	112.83	330	0.342	-	
Total	839.289	494	-	-	

Na_2SO_4 Concentrations LSD 0.0-5: 0.2424994					Varieties or lines, LSD 0.05: 0.283178				
Rank	TRT	Mean	n	NSR	Rank	TRT	Mean	n	NSR
1	Control	3.344	45	a	1	S-5825	2.437	33	a
2	1 bar	2.837	45	b	2	S-5747	2.385	33	a
3	2 bar	2.083	45	c	3	S-5742	1.962	33	b
4	4 bar	2.018	45	c	4	S-5765	1.911	33	bc
5	3 bar	1.662	45	d	5	BR-2017	1.862	33	bc
6	5 bar	1.516	45	d	6	S-5785	1.687	33	bcd
7	6 bar	1.167	45	e	7	S-5759	1.637	33	cde
8	7 bar	1.013	45	e	8	BR-90	1.503	33	def
9	8 bar	0.594	45	f	9	BR-2/1	1.446	33	defg
10	9 bar	0.552	45	f	10	S-5733	1.356	33	efg
11	10 bar	0.535	45	f	11	S-5761	1.303	33	fg
TRT, Treatments (salt concentrations or varieties; NSR, NS ranges					12	Br-99	1.212	33	fgh
					13	S-5798	1.175	33	gh
					14	S-5784	0.992	33	h
					15	S-5797	0.561	33	h

The average seedling dry mass of various germplasms and within germplasms seedling-mass-variation in terms of Coefficient of Variation (CV) under the treatment range (0 to10 bar) salinities is presented in Table 15. Maximum variation in seedling mass under NaCl was exhibited by S-5733 (40.68%) followed by S-5761 (39.83%), S-5765 (34.91%) and S-5797 (31.23%). The minimum variation was found in S-5798 (4.70%) followed by S-5747 (6.68%). Seedling mass variation was around 20% in S-5785, S-5784 and BR-90. Low order variation (below 15%) was exhibited in BR-2/1, BR-99, S-5742 and S-5825. Under sulphate salinity, variation of seedling mass was generally of higher order- maximum in S-5761 (53.77%) followed by S-5784, BR-2017, S-5733, S-5784 and S-5798 (fluctuating between 30-35%). Variation was minimal in S-5765 (10.10%) followed by S-5747 and BR-2/1 (around 12%).

Table 11. Analysis of variance for shoot length data (cm) of 15 guar varieties tested against 11 concentrations of NaCl.

Source	SS	df	MS	F	p
NaCl concentrations	372.322	10	37.23	124.88	0.00001 ***
Varieties	397.398	14	28.39	95.206	0.00001 ***
Concentration x varieties	301.9313	140	2.159	7.233	0.00001 ***
Error	98.3891	330	0.29814	-	-
Total	1170.0471	494	-	-	-

NaCl Concentrations LSD 0.0-5: 0.22645					Varieties or lines, LSD 0.05: 0.264435				
Rank	TRT	Mean	n	NSR	Rank	TRT	Mean	n	NSR
1	Control	3.765	45	a	1	BR-2/1	4.30	33	a
2	I bar	3.271	45	b	2	BR-90	4.05	33	ab
3	2bar	3.243	45	b	3	BR-99	3.88	33	b
4	3 bar	3.207	45	b	4	S-5733	2.72	33	c
5	4 bar	2.574	45	c	5	S-5765	2.24	33	d
6	5bar	2.358	45	c	6	S-5825	2.21	33	d
7	6 bar	1.873	45	d	7	S-5759	1.99	33	de
8	7 bar	1.778	45	d	8	S-5797	1.97	33	def
9	8 bar	1.537	45	e	9	S-5742	1.86	33	ef
10	9 bar	1.372	45	e	10	S-5784	1.84	33	ef
11	10 bar	1.090	45	f	11	S-5785	1.76	33	ef
TRT, Treatments (salt concentrations or varieties; NSR, NS ranges					12	BR-2017	1.72	33	ef
					13	S-5747	1.70	33	ef
					14	S-5798	1.69	33	ef
					15	S-5761	1.66	33	f

Table 12. Analysis of variance of shoot length data (cm) of 15 guar varieties tested against 11 concentrations of Na_2SO_4.

Source	SS	df	MS	F	p
Na_2SO_4 concentrations	382.81	10	38.28	159.15	0.00001 ***
Varieties	122.54	14	8.753	36.39	0.0000 ***
Concentration x varieties	282.91	140	2.020	8.40	0.0000 ***
Error	79.399	330	0.24054	-	
Total	867.642	494	-	-	

Na_2SO_4 Concentrations LSD 0.0-5: 0.203399					Varieties or lines, LSD 0.05: 0.237519				
Rank	TRT	Mean	n	NSR	Rank	TRT	Mean	n	NSR
1	Control	3.79	45	a	1	BR-2/1	2.81	33	a
2	1 bar	2.73	45	b	2	BR-90	2.51	33	b
3	2 bar	2.26	45	c	3	S-5733	2.28	33	bc
4	3 bar	2.04	45	d	4	S-5825	2.19	33	c
5	4bar	1.72	45	e	5	BR-99	2.09	33	c
6	5 bar	1.69	45	e	6	S-5747	1.70	33	d
7	6 bar	1.43	45	f	7	S-5759	1.699	33	d
8	7 bar	1.22	45	g	8	S-5742	1.664	33	de
9	8 bar	0.909	45	h	9	S-5785	1.606	33	de
10	9 bar	0.819	45	h	10	S-5765	1.504	33	de
11	10 bar	0.717	45	h	11	BR-2017	1.443	33	def
TRT, Treatments (salt concentrations or varieties; NSR, NS ranges					12	S-5798	1.399	33	efg
					13	S-5784	1.210	33	fgh
					14	S-5761	1.180	33	gh
					15	S-5797	1.050	33	h

Table 13. Analysis of variance for collective seedling dry wt. (g) data of 15 guar varieties tested against 11 concentrations of NaCl.

Source	SS	df	MS	F	p
NaCl concentrations	0.14784	10	0.0147839	5.268	0.00001 ***
Varieties	0.387463	14	0.384626	9.7908	0.00001 ***
Concentration x varieties	0.65837	140	0.004703	1.6759	0.00001 ***
Error	0.92598	330	0.002806	-	-
Total	2.11681	494	-	-	-

NaCl Concentrations LSD 0.0-5: 0.021968					Varieties or lines, LSD 0.05: 0.025653				
Rank	TRT	Mean	n	NSR	Rank	TRT	Mean	n	NSR
1	7 bar	0.1941	45	a	1	S-5784	0.21150	33	a
2	5 bar	0.1855	45	ab	2	S-5765	0.20924	33	a
3	4 bar	0.1788	45	ab	3	S-5759	0.19739	33	a
4	3bar	0.1747	45	ab	4	S-5747	0.19045	33	ab
5	6 bar	0.1680	45	bc	5	S- 5733	0.18969	33	ab
6	1 bar	0.1680	45	bc	6	S-5742	0.18854	33	ab
7	2 bar	0.1680	45	bc	7	Br-2017	0.16363	33	bc
8	8bar	0.1628	45	cd	8	S-5798	0.15785	33	cd
9	bar	0.1499	45	cd	9	S-5825	0.15627	33	cd
10	Control	0.1459	45	cd	10	BR-2/1	0.15303	33	cd
11	10 bar	0.1328	45	d	11	BR-99	0.14848	33	cde
TRT, Treatments (salt concentrations or varieties; NSR, NS ranges					12	S-5797	0.14833	33	cde
					13	BR-90	0.13758	33	cde
					14	S-5785	0.12894	33	de
					15	S-5761	0.12164	33	e

Table 14. Analysis of variance of collective seedling dry wt. (g) data of 15 guar varieties tested against 11 concentrations of Na_2SO_4.

Source	SS	df	MS	F	p
Na_2SO_4 concentrations	0.172829	10	0.017283	4.4093	0.00001 ***
Varieties	0.284342	14	0.020310	5.1816	0.0000 ***
Concentration x varieties	0.87435	140	0.006245	1.5933	0.0000 ***
Error	1.293495	330	0.0039196	-	
Total	2.6250	494	-	-	

Na_2SO_4 Concentrations LSD 0.0-5: 0.025964					Varieties or lines, LSD 0.05: 0.0303198				
Rank	TRT	Mean	n	NSR	Rank	TRT	Mean	n	NSR
1	5 bar	0.1885	45	a	1	S-5733	0.1933	33	a
2	4bar	0.1780	45	ab	2	S-5742	0.1924	33	ab
3	2 bar	0.1679	45	abc	3	S-5747	0.1874	33	ab
4	3 bar	0.1663	45	abc	4	S-5761	0.1757	33	abc
5	1 bar	0.1659	45	abc	5	S-5784	0.1744	33	abc
6	6 bar	0.1624	45	abc	6	S-5759	0.1742	33	abc
7	7bar	0.1509	45	bc	7	BR- 90	0.1655	33	abcd
8	8 bar	0.1508	45	bc	8	S-5825	0.1576	33	bcde
9	Control	0.1459	45	c	9	BR-2017	0.1445	33	cdef
10	9 bar	0.1393	45	cd	10	S-5765	0.1436	33	cdef
11	10 bar	0.1172	45	d	11	S-5797	0.1416	33	cdef
TRT, Treatments (salt concentrations or varieties; NSR, NS ranges					12	BR-2/1	0.1367	33	def
					13	S-5798	0.1301	33	ef
					14	S-5785	0.1257	33	ef
					15	BR-99	0.1199	33	f

The variation of germination and seedling growth as observed here with germplasms, nature of salt and their concentrations are also reported to occur with genotypic nature of species and varieties and salt and its concentrations by Asana and Kale (1965) in wheat, Maliwal and Paliwal (1970) in Bajra, Kumar and Bhardwaj (1981) in mung and Bafeel (2014) in Sorghum.

Table15. Seedling dry weight (mg) of guar cultivars and lines over the treatments range (0 to 10 bar).

Rank (NaCl Based)	Genotype	Seedling Dry Weight (mg) over treatments range (0-10 bar) – mean ± SE, % CV		Rank (Na_2SO_4 based)
		NaCl	Na_2SO_4	
10	BR-2/1	153.09 ± 6.26, 13.55	136.82 ± 11.93, 12.01	12
13	BR-90	137.45 ± 8.78, 21.19	143.55 ± 11.93, 27.55	10
11	BR-99	148.55 ± 6.28, 14.01	119.91 ± 10.39, 28.74	15
7	Br-2017	165.00 ± 13.01, 26.15	145.64 ± 14.75, 33.60	9
5	S-5733	189.52 ± 28.25, 40.68	193.27 ± 19.98, 34.29	1
6	S-5742	188.45 ± 6.74, 11.86	192.45 ± 11.63, 20.04	2
4	S-5747	190.45 ± 3.84, 6.68	187.27 ± 7.11, 12.59	3
3	S-5759	197.45 ± 6.86, 11.53	174.18 ± 12.68, 24.15	6
15	S-5761	121.64 ± 14.61, 39.83	175.73 ± 20.49, 53.77	4
2	S-5765	209.18 ± 22.02, 34.91	165.55 ± 5.04, 10.10	7
1	S-5784	211.18 ± 19.92, 21.86	175.27 ± 18.20, 34.47	5
14	S-5785	129.00 ± 8.16, 20.98	125.73 ± 9.22, 24.32	14
12	S-5797	148.36 ± 13.97, 31.23	141.64 ± 10.04, 23.51	11
8	S-5798	157.82 ± 16.52, 4.70	130.09 ± 13.06, 33.06	13
9	S-5825	156.18 ± 6.44, 13.68	157.73 ± 20.28, 42.64	8

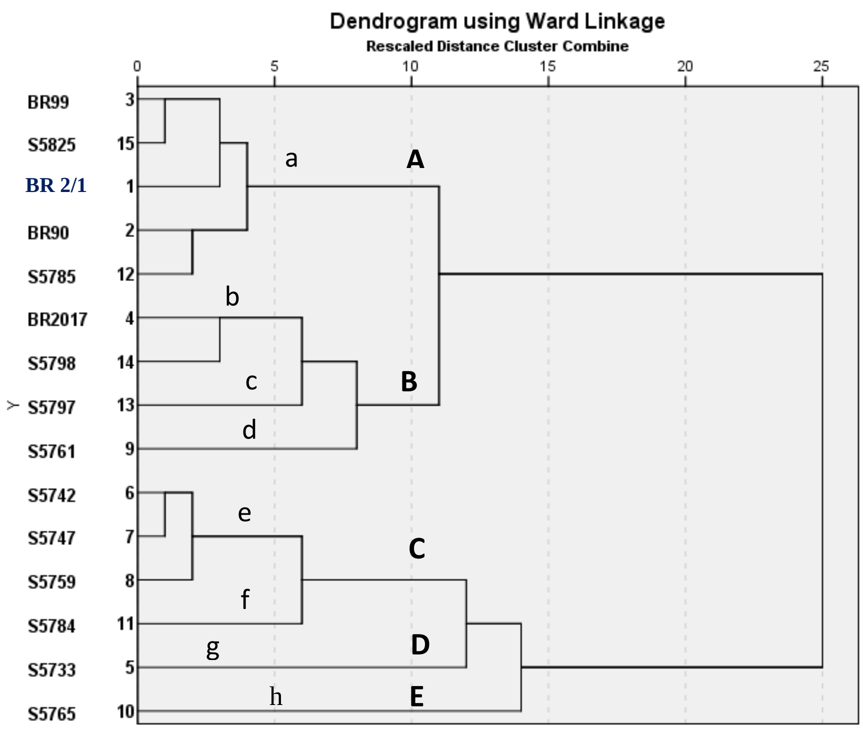


Fig. 14. Agglomerative clustering of guar germplasms on the basis of the seedling mass under NaCl salinity.

Our results on seedling growth are quite different than that reported for 25 guar germplasms (CG-1, HGS-25, HGS-18, CG-4, PLG-174, HFG-314, DSE-IJ, HGS -46, PLG-85, PLG-119, HGS-47, DSE – 16J, HFG-156, PNB, FS-277, HGS-43, HFG-119, Guara, HG-182, HGS-75, HFG-189, Suvidha, HGS-3, HG-17-1 and Hg-258) under mixed salt salinity by Datta and Dayal (1988). Under increasing mixed salinity while root elongation consistently increased, the shoot length decreased with salinity. Cotyledonary fresh weight was reported to increase markedly by 12 and 16dS.m^{-1}. Dry weights of shoot and root did not differ appreciably. Of cultivar studied, PLG-119 and HGS-18 were found relatively salt tolerant. Decline in root and shoot growth with salinity is, however, manifest in several studies (Cramer *et al*., 1994, Mansour *et al.*, 2005, Chowdhury *et al*., 2018). The presence of salt is reported to reduce vegetative and reproductive growth parameters of guar by Kumar *et al.* (1988). Garg *et al.* (1997) have also reported reduction in dry matter production of guar at seedling stage under salinity. Kumar and Bhardwaj (1981) have reported genotypic differences in *Vigna radiata* seedling growth under salinity. Such reduction of growth may primarily be related to the limited supply of metabolic energy for the maintenance of normal growth processes (O'Leary, 1986). The amount of work to combat ionic and osmotic effects is increased and in consequence relatively less energy is available for growth (Nieman and Maas, 1978). The growth of even halophyte *Salicornia* is reported to be adversely affected by salinity (Hoffman and Sachert, 1967).

Relationship of cummulative seedling dry weight with NaCl and Na_2SO_4 salinities

NaCl salinity:

Table 16 portrays the relationship in terms of simple linear correlation coefficients of seedling dry weights of various germplasms to NaCl and Na_2SO_4 salinities (0 to 10 bars). Under NaCl, all germplasms exhibited non-significant relationships except S-5733 which exhibited significant positive correlation ($r = 0.755$, $p < 0.007$) and S-5798 which exhibited significant negative correlation (-0.828, $p < 0.002$).

S-5733 – Seedling weight (mg) = 102.091 + 17.545 NaCl in bar ± 53.31
t =3.40 t = 3.45
p < 0.008 p < 0.007, r = + 0.755, F = 11.92 (p < 0.007)

S-5798 – Seedling weight (mg) = 226.230 – 13.682 NaCl in bar ± 32.34
t = 12.40 t = - 4.44
p < 0.0001 p < 0.002, r = - 0.828, F = 19.69 (p < 0.002)

Table 16. Linear correlation Coefficient "r" between Seedling dry mass (mg) and NaCl and Na_2SO_4 salinities.

Germplasms	NaCl		Na_2SO_4	
	"r"	Significance, p	"r"	Significance, p
BR- 2/1	0.333	0.318, NS	0.079	0.818, NS
BR-90	0.218	0.519, NS	0.186	0.584, NS
BR-99	0.021	0.953, NS	0.234	0.489, NS
BR-2017	0.491	0.126, NS	0.312	0.351, NS
S-5733	**0.755**	**0.007 *****	**0.851**	**0.001*****
S-5742	0.274	0.415, NS	0.281	0.402, NS
S-5747	0.275	0.414, NS	**-0.692**	**0.018 ****
S-5759	0.248	0.463, NS	**-0.761**	**0.007 *****
S-5761	0.368	0.265, NS	-0.345	0.298, NS
S-5765	0.498	0.119, NS	-0.139	0.684, NS
S-5784	0.204	0.548, NS	-0.403	0.218, NS
S-5785	0.203	0.550, NS	-0.274	0.415, NS
S- 5797	0.054	0.805, NS	-0.366	0.269, NS
S-5798	**- 0.828**	**0.002*****	**-0.869**	**0.001 *****
S-5825	0.319	0.339, NS	0.331	0.320, NS

Table. 17. Promotion / reduction of cummulative seedling dry weight in -10 bar NaCl and Na_2SO_4 over control.

Germplasms	Promotion / Reduction (%)	
	NaCl	Na_2SO_4
BR- 2/1	+14.38	-7.29
BR-90	-23.08	-5.98
BR-99	+21.95	-21.19
BR-2017	-62.15	-49.72
S-5733	+163.33	+192.22
S-5742	+21.74	-22.46
S-5747	-9.18	-30.61
S-5759	-8.24	-30.77
S-5761	-57.30	-20.22
S-5765	-17.68	-12.71
S-5784	-39.39	-61.04
S-5785	+51.16	+12.79
S- 5797	-18.60	-17.83
S-5798	-70.19	-74.04
S-5825	+28.57	+6.72

S-5742, S-5761and S-5825 exhibited curvilinear relationships of cummulative seedling mass with NaCl salinity.

S-5742 - Seedling wt. (mg) = 148.336 + 22.44 bar – 2.059 bar^2 ± 11.07
t= 17.58 t = 5.72 t =-5.05
P < 0.0001 p < 0.0001 p < 0.0001; R = 0.896, F = 16.36 (p < 0.0001)

S- 5761 - Seedling wt. (mg) = 99.210 + 27.509 bar – 3.289Bar^2 ± 37.01
t = 3.51 t = 2.09 t = -2.59
p < 0.008 p < 0.032 p < 0.070; R 0.729, F = 4.53 (p < 0. 070)

S- 5825 – Seedlintg wt. (mg) = 121.119 + 18.581 bar – 1.653 bar^2 ± 14.81
t = 10.74 t = 3.54 t = - 3.27
p < 0.0001 p < 0.008 p < 0.011; R = 0.785, F = 6.404 (p < 0.022)

Na_2SO_4 salinity:

Under Na_2SO_4 salinity, seedling weight of only four germplasms exhibited significant linear correlation with salinity, of which one (S-5733) showed positive correlation and three (S-5747, S-5759 and S-5798) showed negatively correlation. Br-90 and Br-5742 showed curvilinear relationship between seedling weight and sodium sulphate salinity. The best fit equation for these germplasms are as follows:

Linear Equations:

S-5733 – Seedling wt. (mg) = 108.273 + 17.00 bar ± 36.70
t = 5.23 t = 4.86
p < 0.001 p < 0.001, r = + 0.851, F = 23.60 (p < 0.001)

S-5747 – Seedling wt. (mg) = 211.864 – 4.9187 bar ± 17.936
t = 20.88 t = -2.88
p < 0.0001 p < 0.018, r = - 0.692, F = 8.27 (p < 0.018)

S- 5759 – Seedling wt. (mg) = 222.409 – 9.645 bar ± 28.378
t = 13.38 t = -3.51
p < 0.0001 P < 0.007, r = - 0.761, F = 12.36 (0.007)

S-5798 – Seedling wt. (mg) = 186.864 – 11.355 bar ± 22.586
t = 14.67 t = -5.27
p < 0.0001 p < 0.001, r = - 0.869, F = 27.80 (p < 0.001)

Curvilinear Equations:

BR-90 – Seedling wt. = 86.645 + 32.824 bar – 3.06 bar^2 ± 31.41
t = 3.82 t = 3.12 t = -3.02
p < 0.005 p < 0.014 p < 0.017. R = 0.740, F = 4.86 (p < 0.042)

S-5742 – Seedling wt. (mg) = 156.41 + 31.609 bar – 3.494 bar^2 ± 20.08
t = 10.23 t = 4.45 t =- 5.10
p < 0.0001 p < 0.002 p < 0.001, R = 0.855, F = 14.45 (p < 0.002)

Promotion / Reduction in seedling wt. In 10 bar salinities of NaCl and Na_2SO_4 over the respective controls
NaCl salinity:

Following sequence of germplasms describe their salt tolerance in terms of the promotion or reduction in seedl;ing dry wt. In 10 bar NaCl and Na2SO4 salinities over the respective control. In NaCl, six germplasms showed promotion and three germplasms showed quite higher reduction in seedling mass.

S-5733 (+163.33%) > S-5785 (+51.16%0 > S-5825 (+ 28.57%) > BR-99 (+21.95%) ≈ S-5742 (+ 21.74%) > BR-2/1 (+14. 38%) > S-5759 (-8.24%) > S-5747 (-9.18%) > S- 5765 (-17.68%) > S-5797 (-18.60%) > BR-90 (-23.08%) > S-5784 (-39.39%) > S-5761 (-57.30%) > BR-2017 (-62.15%) > S-5798 (-70.19%)

Na_2SO_4 salinity:

Under Na_2SO_4 salinity, three germplasms (S-5733, S-5785 and S-5825) showed promotion in seedling weight in 10 bar over control and three germplasms (BR-2017, S-5784 and S-5798 exhibited reduction near 50% or above 50 % as given below. Three germplasms (S- 5761, BR-99 and S-5742) were almost equally tolerant with reduction in seedling wt. Fluctuating around 20 – 22%.

S-5733 (+ 192.22%) > S-5785 (+12.79%) > S-5825 (+6.72%) > BR- 90 (-5.98%) > BR- 2/1 (-7.29%) > S-5765 (-12.71%) > S-5797 (-17.83) > S-5761 (-20.22%) ≈ BR-99 (-21.19%) ≈ S-5742 (-22.46%) > S- 5747 (-30.61%) ≈ S-5759 -30.77%) > BR-2017 (-49.72%) > S-5784 (-61.04 > S-5798 (-74.04%).

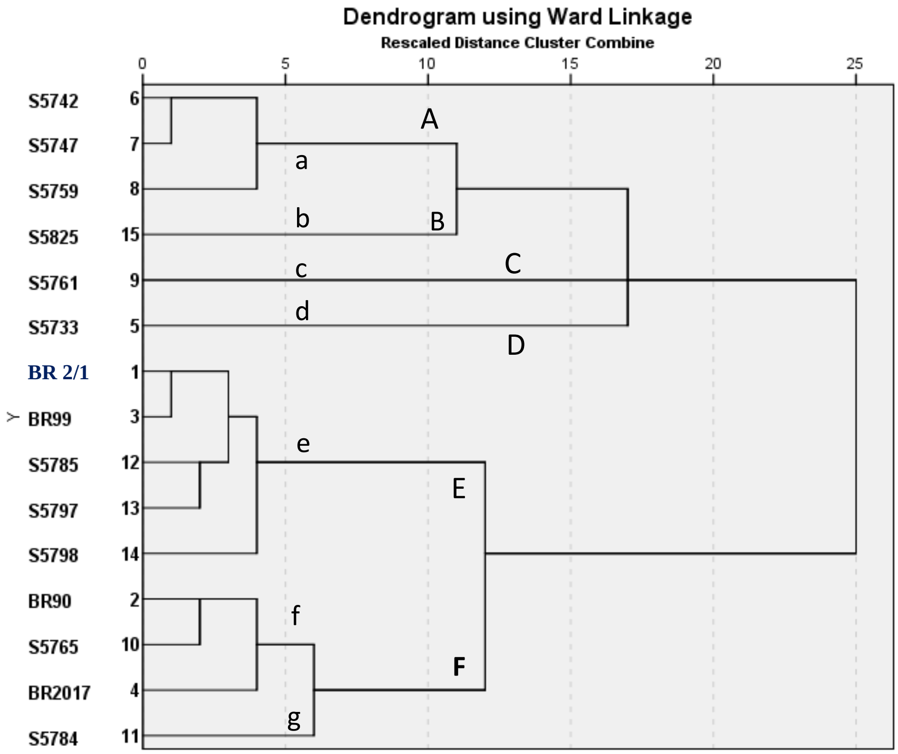


Fig.15. Agglomerative clustering of guar germplasms based on seedling dry weight under Na_2SO_4 salinization.

Germplasms agglomeration on the basis of cummulative seedling dry mass under NaCl

Fig. 14 presents the cluster diagram of germplasms based on seedling mass under NaCl. On the basis of 5% distance amongst the germplasm eight discrete groups were observed and on the basis of 10% distance five groups were discretely seen in the figure. They are described below for their composition and their seedling dry mass. Biomass production was much higher in group-f, S-5784 (211.18 mg) followed by group h, S-5765 (209.18mg).

Dissimilarity Distance: 5%

Group a: BR-99, S-5825, BR-2/1, BR-90, and S-5785

Mean seedling mass over the treatment range: 150.85 ± 6.292mg, CV: 9.32% -- Rank VI

Group b: BR-2017 and S-5798

Mean seedling mass over the treatment range: 161.41 ± 3.590mg, CV: 3.15% --Rank V

Group c: S-5797

Mean seedling mass over the treatment range: 148.36mg – Rank VII

Group d: S-5761

Mean seedling mass over the treatment range 121.46mg – Rank VIII

Group e: S-5742, A-5747 and S-5759

Mean seedling mass over the treatment range: 192.11 ± 2.74mg, CV: 2.47% -- Rank III

Group f: S-5784

Mean seedling mass over the treatment range: **211.18mg – Rank I**

Group g: S-5733

Mean seedling mass over the treatment range: 189.52mg – Rank IV

Group h: S-5765

Mean seedling mass over the treatment range: **209.18mg – Rank II**

BR-99 occupied group-a (BR-99, S-5825, BR- 2/1, BR- 90 and S-5785) was relatively low biomass producer. Group-f (S-5784) was the highest biomass accumulator followed by group h (S-5765). S- 5761 represented the lowest seedling biomass accumulation.

Dissimilarity Distance: 10%

Group A: **BR-99, S-5825, BR-2/1, BR-90, and S-5785**

Mean seedling mass over the treatment range: 150.85 ± 6.292mg, CV; 9.32% --Rank IV

Group B: BR-2017, S-5798, S-5797and S-5761

Mean seedling mass over the treatment range: 143.28 ± 7.75 mg, CV: 10.82% --Rank V

Group C: S-5742, S-5747, S-5759 and S-5784

Mean seedling mass over the treatment range: 196.88 ± 5.145 mg, CV: 5.27% --Rank III

Group D: S-5733

Mean seedling mass over the treatment range: **198.52mg – Rank II**

Group E: S-5765

Mean seedling mass over the treatment range: **209.18mg – Rank I**

Germplasms agglomeration on the basis of mean seedling dry mass under Na_2SO_4

Fig. 15 presents the cluster diagram of germplasms based on seedling mass under Na_2SO_4. On the basis of 5% distance amongst the germplasm seven discrete groups were observed and on the basis of 10% distance six groups were discretely observed. These groups are described below for their composition and their mean seedling dry mass.

Dissimilarity Distance: 5%

Group a: S-5742, S-5747 and S-5759

Mean seedling mass over the treatment range: **184.63 ± 5.44 mg, CV: 5.10% -- Rank II**

Group b: S-5825

Mean seedling mass over the treatment range: 156.18mg – Rank IV

Group c: S-5761

Mean seedling mass over the treatment range: 121.64 mg – Rank VII

Group d: S-5733

Mean seedling mass over the treatment range: **189.52 mg –Rank I**

Group e: BR-2/1, BR-99, S-5785, S-5797 and S-5798

Mean seedling mass over the treatment range: 130.84 ± 0.0663 mg, CV: 6.60% -- Rank VI

Group f: BR-90, S-5765 and BR-2017

Mean seedling mass over the treatment range: 151.58 ± 7.011 mg, CV: 8.01% -- Rank V

Group g: S-5784

Mean seedling mass over the treatment range: 175.28 mg – Rank III

This cluster diagram was predominated by group-d (S-5733) (189.52mg) followed by group-a (S-5742, S-5747 and S-5759) (184.63 ± 5.44mg)

Dissimilarity Distance: 10%

Group A: S-5742, S-5747 and S-5759

Mean seedling mass over the treatment range: **184.63 ± 5.436 mg, CV: 5.10% -- Rank II**

Group B: S-5825

Mean seedling mass over the treatment range: 156.18mg – Rank IV

Group C: S-5761

Mean seedling mass over the treatment range: 121.64 mg – Rank IV

Group D: S-5733

Mean seedling mass over the treatment range: **189.52 mg – Rank I**

Group E: BR-2/1, BR-99, S-5785, S-5797 and S-5798

Mean seedling mass over the treatment range: 130.84 ± 0.0663mg, CV: 6.60% -- Rank V

Group F: BR-90, S-5765, BR-2017, S-5784

Mean seedling mass over the treatment range: 157.50 ± 7.724 mg, CV: 9.81% -- Rank III

Group-D (S-5733) (189.52mg) and group-A (S-5742, S-5747 and S-5759) (184.63 ± 5.44mg) predominated the cluster diagram based on seedling biomass production.

Threshold salinities in relation to germination and Germination velocity Index

From the scatter diagrams presented in Fig. 7 and 8, threshold salinities of NaCl and Na_2SO_4 were approximated. The threshold salinity was defined here as the maximum salinity beyond which visible decline, greater or smaller, began to set in germination (and not the salinity corresponding with 50% reduction in a germination parameter). Such threshold salinities for various germplasms are presented in Table 17. In this respect BR-2017 was the most sensitive variety with threshold NaCl salinity c. 3 to 4 bar. In S-5797, threshold NaCl salinity was 4 to 5 bar and in S-5798 and S-5825 it was 5 bar NaCl. In six germplasms (S-5733, S-5742, S-5747, S-5784, S-5785 and S-5759, threshold salinity was c. 7 bar NaCl. The threshold salinity was quite high (9 bar) in S-5761 and BR-90. BR- 2/1, and BR-99 had Threshold salinity much above 10 bar NaCl. There is a generalization that growth reduction in many plants occurs at osmotic potentials of 2 to 4 bar NaCl (Wilcox, 1959).

In comparison, threshold salinity in Na_2SO_4 was quite low i.e., 3 bar in S-5797, S-5759 and Br-2017. In some other germplasms it was relatively higher, 5 bar in S-5798, S-5784, S-5761, S-5742, and S-5733 and 6 bar in BR-2/1, BR-90, BR-99 and S-5747. Two germplasms, S-5765 and S-5825 had maximum threshold salinity of 7 bar Na_2SO_4. It was obvious that performance of guar germplasms was comparatively somewhat lower in sulphate salinity than that in NaCl.

Table 17. Threshold salinities* for guar germplasms on the basis of germination and GVI under NaCl and Na_2SO_4 salinities. Threshold salinity of germination based on data behaviour in the scatter diagrams for the linear correlation and regression of final germination (for day 4) with salinity (see Fig.7 and 8), using replicate data (N = 33). Threshold salinity for GVI was approximated on the basis of data given in Table 5a and b.

Genotype	GERMINATION		GVI	
	NaCl	Na_2SO_4	NaCl	Na_2SO_4
	Threshold salinity in bar			
BR-2/1	>10 bar	6 bar	3 bar	1 bar
BR-90	c. 9 bar	6 bar	4 to5 bar	2 bar
BR-99	> 10 bar	6 bar	**Promotion = 6.25%; threshold above -10 bar i.e. EC > 22.2 $dS.m^{-1}$.	1 bar
Br-2017	3 to 4 bar	5 bar	2 bar	1 bar
S-5733	7 bar	5 bar	2 to 3 bar	2 to 3 bar
S-5742	7 bar	5 bar	2 bar	2 bar
S-5747	7 bar	5 to 6 bar	1 bar	4 bar
S-5759	7 bar	3 bar	2 bar	2 to 3 bar
S-5761	9 bar	5 bar	1 bar	1 bar
S-5765	5 to 6 bar	7 bar	4 bar	6 bar
S-5784	7 bar	5 to 6 bar	1 bar	1 bar
S-5785	7 bar	6 to 7 bar	2 bar	4 to 5 bar
S-5797	4 to 5 bar	3 bar	3 bar	2 bar
S-5798	5 bar	5 bar	5 to bar	1 bar
S-5825	5 bar	7 bar	2 bar	1 bar

*, Threshold salinity referred to the salinity above which decline in germination began. .
**, Promotion of GVI was recorded in even 10 bar NaCl-treatment over control in this germplasm (BR – 99).

Table 18. Approximated salinities (NaCl and Na_2SO_4 in bar associated with 50% reduction in final germination based on scatter of the replicated final germination data plotted against salinities (0to 10 bar). See Figure 7 and 8).

Germplasms	Approximated 50 % Reduction	
	NaCl (bar)	Na_2SO_4 (bar)
BR-2/1	Above 10 bar	10 bar
BR-90	Above 10 bar	Above 10 bar
BR-99	Above 10 bar	c. 9 bar
BR-2017	Variable, Above 10 bar	c. 5 bar, High behavioural dispersion
S-5733	Above 10 bar	9 bar, behavioural dispersion
S-5742	Above 10 bar	9 bar
S-5747	Above 10 bar	10 bar
S-5759	10 bar (Behavioural dispersion)	8 bar
S-5761	10 bar	8 to 9 bar
S-5765	8 to 9 bar	8 bar
S-5784	9 bar	8 bar, behavioural dispersion
S-5785	9 to 10 bar	6 bar, behavioural dispersion
S-5797	Above 10 bar	7 to 8 bar
S-5798	10 bar	9 to 10 bar
S-5825	10 bar	10 bar

It is obvious from Table 18 that in hand germplasms, on the basis of approximate levels of salinity causing 50 % reduction in final germination were comparatively more tolerant to NaCl than Na2SO4 salinity. All germplasms exhibited moderate to high level of salt tolerance as regard to the final germination achieved after four days of incubation. Germination velocity is impeded, however quite early even in much lower salinities. The germplasms somehow cope up with salinity and restore germination in appreciable proportion reaching the fourth day of incubation.

Table 19. Values of Composite Performance Index (CPI) of various guar germplasms for NaCl and Na_2SO_4.

Germplasms	Composite Performance Index	
	NaCl	Na_2SO_4
BR-2/1	89.30	79.41
BR-90	84.91	84.21
BR-99	90.29	72.15
BR-2017	84.20	78.34
S-5733	100.80	95.44
S-5742	98.71	96.97
S-5747	98.29	96.38
S-5759	100.56	87.52
S-5761	75.00	87.79
S-5765	103.03	87.08
S-5784	100.70	88.21
S-5785	76.12	71.00
S-5797	80.06	75.87
S-5798	85.29	74.18
S-5825	83.50	85.66

CPI

Composite Performance Index = CPI = (Mean seedling dry mass (mg) after four days of incubation + Mean GVI over the treatment range (0 to 10 bar) + Mean final germination over the treatment range (0 to 10 bar)) /3.

Threshold salinities in case of GVI were approximated on the basis of data given in Table 5a and 5b. The decline in GVI was comparatively set in NaCl salinities (1 to 2 (- 3) in most of the germplasms except S-5798 (5 to 6 bar NaCl). BR-99 was, however, the only germplasms showing promotion in GVI over control even under 10 bar NaCl and threshold salinity was somewhere above 10 bar (Table 17). GVI began to decline in magnitude in lower salinities of 1 or 2 bar Na_2SO_4 except S-5733 (2 to 3 bar), S-5747 (4bar), S-5785 (4 to 5 bar) and S-5765 (6 bar). Francois and Kleiman (1990) have reported threshold ECe of guar to be 8.8 $dS.m^{-1}$ (around 3 bar). Inhibition of the seeds of all varieties tested (S1538, S2378, S 2395, S-2381, S-2376, S-196, S-287 and S-212) by Yadava *et al.* (1974), germinated up to 2.0 EC but only three varieties S 23765, S-196 and S- 287) showed 100 % germination at 4.0 EC. In 11 EC, germination ranged from 7.5 to 26.62% and more than 50% germination was observed by 6.0 EC. The germination in *Rhynchosia minima* was reported only up till 8 bar NaCl (Shaukat and Burhan, 2000).

Performance of germplasms on the basis of a composite index of performance

Since the performance of various germplasms varied with respect to germination, germination velocity and seedling growth, Composite Performance Index (CPI) was calculated as described above with this contention that higher is the CPI, higher the salt tolerance of a germplasm. On the basis of CPI (Table 19), there were three groups of germplasms evident in NaCl.

NaCl salinity:

1. Germplasms with CPI: 70-80 (S-5761, S-5785 and S-5797)
2. Germplasms with CPI: 81-90 (S-5825, BR-2017, BR-90, S-5798, BR- 2/1, and BR-99)
3. Germplasms with CPI: 98-103 (S-5747, S- 5742, S-5784, S- 5759, S-5733 and S-5765)

All germplasms were definitely but differentially tolerant to NaCl salinity. Group I was comparatively lesser tolerant, group II moderately tolerant and group III comparatively highly tolerant to salinity.

There were three groups of germplasms discernible in Na_2SO_4 salinity as follows (Table 18) as follows:

Na_2SO_4 salinity:

I. Germplasms with CPI: 71-79 (S-5785, BR-99, S-5798, S-5797, BR-2017, BR- 2/1). All varietal germplasms except BR-90 entered the composition of this group.
II. Germplasms with CPI: 84-88 (BR-90, S-5825, S-5765, S-5761, S-5784
III. Germplasms with CPI: 95-96 (S-5733, S-5747, S-5742)

Obviously, group III was relatively more tolerant.

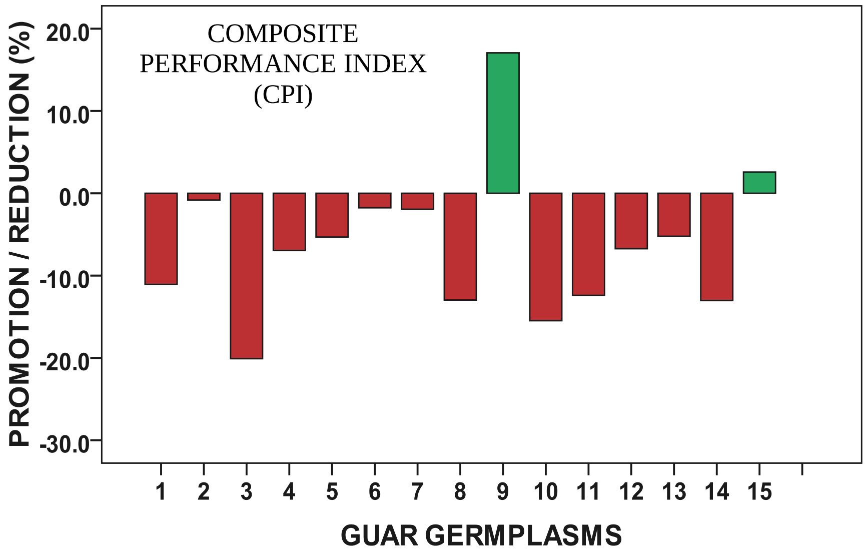


Fig. 16. *Per cent* promotion or reduction in composite performance index (CPI) under Na_2SO_4 salinity relative to the NaCl. **Germplasms acronyms**: 1, BR-2/1; 2, BR-90; 3, BR-99; 4, BR-2017; 5, S-5733; 6, S-5742; 7, S-5747; 8, S- 5759; 9, S- 5761; 10, S-5765; 11, S-5784; 12, S-5785; 13, S-5797; 14, S-5798; and 15, S-5825. Promotion / Reduction in CPI = ($CPI_{Na2SO4} - CPI_{NaCl\,/}\, CPI_{NaCl}$) * 100.

Comparison of germplasms performance in NaCl and Na_2SO_4 on the basis of CPI

Per cent promotion or reduction of CPI in Na_2SO_4 relative to NaCl is presented in Fig. 16. The germplasms under study tended to form five groups as regards to the CPI.

CPI reduction / promotion in Na_2SO_4 over NaCl:

The data of promotion/ reduction in the CPI behaviour of the germplasms in Na_2SO_4 relative to NaCl on the basis of three germination related parameters (Final mean germination over the treatment range, mean velocity of germination over the treatment range and the seedling dry mass at the last day of incubation in the treatment range (0 to 10 bar) is presented in Fig. 16. Following generalization may be made from this data.

a. Germplasms showing CPI reduction: - 0.82 to -1.95% (BR- 90, S-5742 and S-5747). These germplasms were more or less equally tolerant to NaCl and Na_2SO_4 salinities.
b. Germplasms with CPI reduction: -5.23 to - 6.95% (S-5797, S-5733, S-5785, and BR-2017)
c. Germplasms with CPI reduction: -11.08 to – 15.48% (BR- 2/1, S-5784, S-5759, S- 5798 and S-5765) – more sensitive to Na_2SO_4 than above groups.
d. Germplasms with CPI reduction: -20.99% (BR-99) – most sensitive to Na_2SO_4 amongst the tested germplasms.
e. Germplasms with CPI promotion: + 2.58 to +17.06% (S-5825 and S-5761, respectively) – Quite tolerant to Na_2SO_4 salinity which was promotory to them over NaCl- particularly S-5761.

CPI reduction / promotion in NaCl over Na_2SO_4:

The results were obtained on the basis of CPI promotion / reduction in NaCl over Na_2SO_4.
Following generalizations could be made:

A) Germplasms showing CPI promotion: 0.83 to 1.94% (BR-90, S-5742 and S-5747) – More or less equally tolerant to NaCl and Na_2SO_4.
B) Germplasms with CPI promotion: 4.9 to 7.48% (BR- 2/1, S-5747, S-5733, S- 5785 and BR-2017).
C) Germplasms with CPI promotion: 14.17-18.32% (S-5784, S-5759, S-5798 and S-5765) - moderate promotion.
D) Germplasm with CPI promotion: 25.14% (BR-99) – Maximum promotion in NaCl.
E) Germplasms with CPI reduction: -2.52 to -14.31% (S-5825 and S-5761) – Less tolerant to NaCl than to Na_2SO_4 – particularly S-5761.

It follows from this data that BR-99 is although tolerant to NaCl, it is quite sensitive to Na_2SO_4 salinity at germination stage. AlShameri *et al.* (2017) have reported this germplasm to be less tolerant to drought than several other accessions from Pakistan viz. BWP-5595, 24320, Chiniot 1, Chiniot 2, Kaloorkot 2 and BWP 5599. The accessions 24320, BWP 5595, Chiniot 1, Chiniot 2 and 22159 were also rated as salt tolerant by them. Accession BWP 5595 is reported to perform better than accession 24320 when subject to multiple stresses of heat, drought and salinity combined (AlShameri *et al*., 2019).

It is apparent from the results given above regarding CPI reduction or promotion that germplasms were differentially tolerant to NaCl salinity and in any of the germplasms the reduction was not more than 21% in Na_2SO_4 salinity. Besides the varietal germplasms, especially BR-99 which is known for its salt tolerance (Rasheed *et al*., 2015), some lines such as S-5747, S- 5742, S-5784, S- 5759, S-5733 and S-5765 are also of the interest particularly on the basis of the magnitude of their composite performance index. The germplasms in hand were also tolerant to Na_2SO_4 salinity but at somewhat reduced level. The germplasms, S-5733, S-5747, S-5742, were however, quite tolerant to Na_2SO_4. The germplasms, especially S-5761 and to some extent S-5825 showed promotion in their composite performance in Na_2SO_4 salinity than that in NaCl salinity. Germplasm S-5733, which is rated as an advance line and is currently under trial at Bahawalpur Agricultural Research Station, deserves special attention of researchers as regards to its salinity tolerance under field conditions. Several local guar germplasms that are also reported to be salt tolerant may be listed such as BR-99, 5597, 41671, Khushab white, Mardan white, Shianwali white (Rasheed *et al.,* 2015), accessions 281/ 3 from Balochistan (Ashraf *et al.* (2005), and Lines S- 5881, S 5932, S-6067 (Sudhar *et al.,* 2018b) are salt tolerant guar germplasms from Pakistan. Cultivar Kinman is a salt tolerant exotic germplasms (Andrade, 1985). Guar is reported to cope with salinity by accumulation of sugar and proline as osmoticum adjustment. Decline in protein and starch, however, takes place (Gulati and Dhingra (2014). The genotypes RGC-1002 and RGC-197 are reported by Soni *et al.* (2017) to respond to salt stress (*in vitro)* by modifying various biochemical pathways to prevent salt-induced oxidative damage i.e., by rapid accumulation of protective anti-oxidative enzymes (peroxidase and catalase) There is a need to investigate the physiological mechanism of salt tolerance of Pakistan germplasms of guar.

As regards to the sulphate sensitivity of some guar germplasms observed in the present studies as regards to their germination velocity or seedling growth, it may be mentioned that several plants have been reported to be more sensitive to SO_4^{2-} ion than Cl^- ion. Up to 4 bar NaCl (c. 9.77dS.m-1); there appeared almost no effect on germination of *Achyranthes aspera* seeds beyond which both germination and rate of germination regularly declined. Na_2SO_4 inhibited its germination more drastically (Khan *et al.,* 1984). *Peristrophe bicalyculata* (now *P. paniculata*) and *Cassia holosericea* were more sensitive – their germination was greatly reduced at 3 bar concentration of NaCl and Na_2SO_4. In case of *Prosopis juliflora,* no effect on germination was recorded up to 8 bar NaCl. However, rate of germination was much impeded in Na_2SO_4. The shoot growth declined in all these species with salinity but more under the influence of Na_2SO_4 (Khan *et al.,* 1984). Strogonov (1964) reported white lupin, wheat, sorghum and cotton to be more sensitive to sulphate salinity.

Germination assays for salt tolerance do not predict plant growth and yield in saline soils (Teolis *et al.* (2009). It may be emphasized that salt tolerance at germination and other phases of life cycle of a plant are not necessarily correlated (Ayers, 1952; Khan, 1987; Khan and Ahmad, 1998). The results reported in literature are, however, controversial. Mayer and Poljakoff-Meyber (1975) observed that adult plants are more salt tolerant than the seeds. Ungar (1974) reported that seed germination in *Hordeum jubatum* was more resistant process than the later growth of seedlings. Azizov (1974) reported that seeds of *Limonium meyeri* cannot germinate in salinity above 1.5 % salt, yet the mature plant can grow even in the presence of 10% salt solution. The Ec_{iw} corresponding to 50% reduction in seed germination (10.03 $dS.m^{-1}$) in *Indigofera oblongifolia* was more or less comparable to that inducing 50% reduction in growth (12.05 $dS.m^{-1}$) (Khan and Ahmad, 1998). It was stressed by Angevine and Chabot (1979) that the germination of seeds and the subsequent early growth of seedlings represent the period of maximum vulnerability to changes in the environment and minimal potential for homeostatic response. Salinity studies should include, therefore, both germination and plant trials in field.

Three varieties of guar (PI 217923, PI 340246 and ARS Lewis) were studied by Liu (2003). Seed coat colour in guar ranges from black to dull white. The seeds of above accessions were sorted into light, dark gray and black and their germination was tested at 22 ^oC in dark. During germination seeds of black and dark gray colour had higher water absorption after 24 h and had higher germination rate than light coloured seeds of any accessions. After 72 h, black or dark gray seeds had higher germination percentage. Research with local germplasms is needed on this aspect also.

Seedling mortality

Seedling mortality in NaCl salinity

In our experimentation, no mortality except one seedling was recorded in NaCl salinity.

Seedling mortality in Na_2SO_4 salinity

There was substantial degree of seedling mortality in Na_2SO_4 salinity (Table 20). The germplasms tested behaved differentially in this respect. There was no mortality up to 3 bar Na_2SO_4 in any germplasms. Seedling mortality due to decay and burning began to take place from 4 bar (EC: 11.1 $dS.m^{-1}$) onwards in S-5742, S-5747, S-5759, S-5797 and S- 5798 more or less regularly along the increase in salt level. Seedling mortality began from 5 bar (EC: 13.33$dS.m^{-1}$) in S-5733 and S-5785 and from 6 bar (EC: 15.9 $dS.m^{-1}$) in S-5765, S-5825 and BR-2017. The varietal germplasms, BR- 2/1, BR-90 and BR-99 and the accessions S-5761 and S-5784 were relatively more tolerant and exhibited seedling mortality from 7 bar Na_2SO_4 (EC: 16.87 $dS.m^{-1}$) onwards. Obviously, S-5742, S-5747, S-5759, S-5797 and S- 5798 were relatively lesser tolerant and varietal germplasms (BR- 2/1, BR-90 and BR-99) were comparatively more tolerant to sulphate toxicity.

It is known that seedlings are particularly susceptible to harsh conditions. It is indeed the most vulnerable stage in the life of a plant (Stebbins, 1971; Fenner and Thompson, 2005). Na-salts, NaCl, Na_2SO_4, and Na_2CO_3 (Greenway and Munn, 1980) and NaF (Sabal *et al*., 2006) are reported for ionic and osmotic effects on plants. Under salinity, growth is first reduced by a decrease in the soil water potential (osmotic phase) and later a specific effect of salt causes injury. The seedlings die because of a rapid increase in salt in the cell wall or cytoplasm when the vacuole can no longer sequester incoming salt (ionic phase) (Acosta-Motos *et al*., 2017). According to Bernstein and Hayward (1958) and Strogonov (1946) deleterious effects of saline conditions on plant growth may be attributed to two main factors namely, increase in osmotic pressure of the rooting medium and specific ions. The crop plants cannot grow in the presence of high salt levels their growth is inhibited or completely prevented at 100-200 mM NaCl (Munns and Termaat (1986). There may be several factors which may cause seedling mortality. Green house studies of onion at diurnal temperature of 15 -25 ^{o}C induced hypocotyl and root mortality under high salinity. The salinity tolerance at seed germination stage was much higher than that of seedlings in comparison (Miyamoto, 1988). Seedling mortality under salinity is the phenomenon not only associated with glycophytes or salt tolerant plants, many halophytes are known to show seedling mortality in higher salinities. Only, 2 *per cent* of the seedlings of *Limonium emarginatum* could survive in 2 *per cent* salinity (Rodondo-Gomez *et al.,* 2006). In our *in vitro* experimental set up, seedling death of guar may probably be attributed to the ionic reasons due to Na_2SO_4.

Table 20. Seedling mortality of guar germplasm under Na_2SO_4 salinity (Bar).

	Seedling mortality (%)										
Germplasms	0	1	2	3	4	5	6	7	8	9	10
BR-2/1	-	-	-	-	-	-	-	16. 7± 6.7	43.3 ± 3.3	76.7 ± 8.8	50.0 ± 7.7
BR-90	-	-	-	-	-	-	-	76.7 ± 6.7	13.3 ±3.3	26.7 ± 14.5	30.0 ± 5.8
BR-99	-	-	-	-	-	-	-	20.0 ± 0.0	20.0 ± 0.0	16.7 ± 13.3	23.3 ± 13.3
BR-2017	-	-	-	-	-	-	6.7 ± 3.3	36.7±20.3	30.0±15.3	70.0 ±23.3	30.0 ± 11.6
S-5733	-	-	-	-	-	13.3± 3.3	13.3 ± 6.7	46.7±3.3	33.3 ± 6.7	23.3 ± 6.7	66.7±16.7
S-5742	-	-	-	-	6.7 ± 3.3	10.0± 0.0	10.0 ± 0.0	20.0±0.0	33.3±3.3	43.3 ± 3.3	50.0 ± 0.0
S-5747	-	-	-	-	23.3±3.3	20.0±10.0	13.3±6.7	36.7±8.8	26.7±3.3	30.0±0.0	33.3±6.7
S-5759	-	-	-	-	46.7±3.3	60.0±5.8	43.3±3.3	43.3±3.3	86.7±8.8	40.0±5.8	46.7±3.3
S-5761	-	-	-	-	-	-	-	23.3±3.3	33.3±3.3	26.7±8.8	23.3±3.3
S-5765	-	-	-	-	-	-	13.3±3.3	20.0±0.0	26.7±3.3	33.3±3.3	36.7±6.7
S-5784	-	-	-	-	-	-	-	53.3±13.3	20.0±0.0	26.7±3.3	20.0±0.0
S-5785	-	-	-	-	-	10.0±0.0	20.0±5.8	23.3±3.3	23.3±3.3	26.7±3.3	30.0±0.0
S-5797	-	-	-	-	20.0±0.0	16.7±3.3	16.7±3.3	20.0±0.0	23.3±3.3	23.3±3.3	33.3±3.3
S-5798	-	-	-	-	20.0±0.0	13.3±3.3	26.7±3.3	50.0±5.8	56.7±8.8	26.7±3.3	33.3±3.3
S-5825	-	-	-	-	-	-	13.3±3.3	13.3±3.3	16.7±3.3	13.3±3.3	23.3±3.3

C = control (0 bar); 1 to 10 represent the concentration on Na_2SO_4 in bar. -, denotes zero mortality of seedlings.

Salt tolerance of germplasms to NaCl salinity at germination phase relative to variety BR-99

Our studies indicated that BR-99 was the most tolerant variety to NaCl salinity amongst the tested germplasms. Considering BR-99 as an ideal local guar germplasm in NaCl salinity, other germplasms were graded for their tolerance relative to BR-99. For this purpose a parameter was generated through summation of FGP and GVI for each germplasms in extreme salinity of 10 bar NaCl. According to this parameter Variety BR-99 appeared to dominate over other germplasms. The degree of tolerance of each germplasm was then calculated relative to BR-99, as percent proportion of FGP + GVI of a germplasm to the FGP + GVI of BR-99.

Fig. 17 presents the salt tolerance of all germplasms relative to Variety BR-99. The results indicated that varietal germplasms BR-2/1 and BR-90 were nearly as tolerant as BR-99. Germplasms S-5733, S-5742, S-5747, S-5759, S-5761, S- 5785, S-5785 and S-5825 were 60-75% tolerant compared to the tolerance of BR-99. S-5797 showed nearly 50% relative tolerance compared to BR-99. Varietal germplasm BR-2017 and S-5798 exhibited tolerance as low as 40% of BR-99. Germplasm S-5784 was much sensitive to NaCl in comparison to BR-99.

Germplasms S-5733, S-5742, S-5747, S-5759, S-5761, S- 5785, S-5785 and S-5825 may further be investigated through pot culture experimentation. Moreover, there is need to evaluate all in-hand germplasms for their responses to other salts like $CaCl_2$, KCl, $NaHCO_3$, etc. and the mixed salts salinity to get them fully screened for tolerance to various salts. Furthermore, it is necessary that these germplasms should be tested in green house and under the field conditions of salinity. In Pakistan, the salinity-affected areas are largely due to NaCl: the studied germplasms are potentially tolerant to NaCl salinity and deserve further large scale studies.

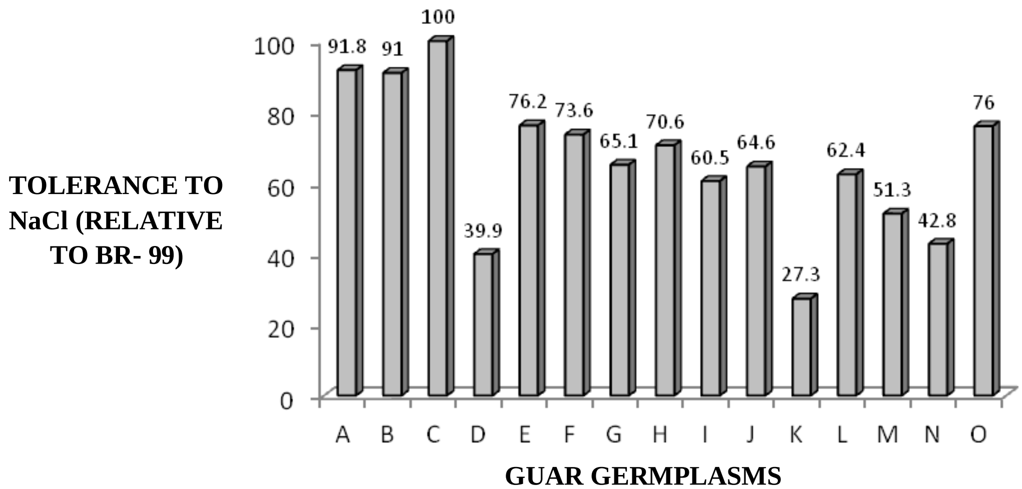


Fig.17. Showing degree of tolerance of germplasms to NaCl in comparison to BR-99 (the most salt tolerant local variety) based on an additive parameter of FGP and GVI in extreme salinity of 10 bar NaCl Data labels show the percent tolerance relative to the germplasm BR-99. Acronyms for Varieties / Lines: A, BR-2/1, B, BR-90, C, BR-99, D, BR-2017, E, S-5733, F, S-5742, G, S-5747, H, S-5759, I, S-5761, J, S-5765, K, S-5784, L, S-5785, M, S-5797, N, S-5798 and O, S-5825.

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