*J. Indian Soc. Coastal Agric. Res. 42(1):73-87(2024) https://doi.org/10.54894/JISCAR.42.1.2024.147468*

# Germination Ability of Different Field Pea (*Pisum sativum* L.) Genotypes Under Salinity Stress

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Received: 15.01.2024 Accepted: 13.05.2024

**A laboratory experiment was conducted at the Pulses Research Sub-station, Bangladesh Agricultural Research Institute (BARI), during October to December 2019 to examine the establishment of field pea seedling under the effect of saline condition. The experimental was arranged in a completely randomized design (CRD) with three replications. The experiment induced two factors, first factors included 34 different field pea cultivars and second factor included four (4) salt concentration of NaCl including control (0 dS $m^{-1}$), 4 dS $m^{-1}$, 8 dS $m^{-1}$ and 12 dS $m^{-1}$. Experimental result revealed that BARI Motor 1 exhibited the highest germination (98.75%) in control situation (0 dS $m^{-1}$) and lowest germination percentage was recorded in Natore local 1 (68.75%). BARI Motor 3 gave the highest mean daily germination (27.93%) and seed germination 1.68 seed $day^{-1}$ under control. The lowest mean daily germination was observed in BD - 6944 (17.42%) genotype and seed germination was found in Natore local 1 (0.95 seed $day^{-1}$). The maximum germination value was observed in BARI Motor 1 (19.53) genotype and germination vigor index in BD-9047 (16.35 cm) genotype. On the other hand, minimum germination value was observed in Jhikorgasha local (10.0) and minimum germination vigor index was found in Natore local 1 (5.10 cm) and BARI Motorsuti 1 (3.64 cm) in control condition. In this study, it was observed that an increase in salinity stress significantly decreased all the germination parameters studied.**

(***Key words:*** *Field pea, Germination, NaCl, Salinity*)

Field pea (*Pisum sativum* L.), belongs to the Fabaceae family, accounts for approximately 27% of the world's crop production (Graham and Vance, 2003). Now-a-days, legumes provide one-third amount of total protein for human consumption (Smykal *et al.,* 2012). Besides the nutritional role for human being, field pea also improves soil fertility through $N_2$ fixation (Jensen *et al.,* 2020; Peoples *et al.,* 2009). Legumes are well-known for their capacity to establish symbiotic associations with $N_2$-fixing rhizobia bacteria, contributing to soil N budget via biological N fixation process (Zhang *et al.,* 2020). Field pea, like any other pulses, is comparatively more sensitive to abiotic stress factors, such as salinity, alkali-induced boron toxicity, frost, heat stress and water deficit (Dita *et al.,* 2006).

Salinity stress involves changes in various physiological and metabolic processes depending on severity and duration of stress and ultimately inhibits crop production (Rozema and Flowers, 2008). During the initial phases of salinity stress, water absorption capacity of root systems decreases and water loss from leaves is accelerated due to osmotic stress of high salt accumulation in soil. Hence, salinity stress can also be considered as hyper osmotic stress (Munns, 2005). The ability of plants to utilize water is reduced due to salinity thereby causing reduced growth rate and change of metabolic processes in plants (Munns, 2002; Yadav, 2010). Ionic imbalance occurs in the cells due to excessive accumulation of $Na^+$, $Cl^-$ and reduces uptake of other mineral nutrients such as $K^+$, $Ca^{2+}$ and $Mn^{2+}$ (Karimi *et al.,* 2005). Moreover high Na to K ratio due to accumulation of higher amounts of Na ions

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inactivates enzymes and affects metabolic processes in plants (Booth and Beardall, 1991).

Measures of saline tolerance based on germination and seedlings traits under controlled conditions and saline stress have been used by a few authors to identify candidate saline-tolerant genotypes (Shahid *et al.,* 2012). In addition, saline sensitivity indices based on the response of seedling traits under stress conditions compared to the control have been recently applied to evaluate field pea saline tolerance (Cerda *et al.*1982). Hence, our focus is on identifying salt tolerant field pea genotypes and to find out the effect of salt stress on selected field pea genotypes. We also aim to determine the critical level to salt tolerance in field pea.

## MATERIALS AND METHODS

### Experimental site

A laboratory experiment was carried out in Pulses Research Sub-station Laboratory, Bangladesh Agricultural Research Institute (BARI) during the period October to December, 2019.

### Treatment and experimental design

The experimental was arranged in a completely randomized design (CRD) with three replications. The experiment induced consisted of two factors, the first factor included 34 different field pea cultivars and the second factor included four (4) salt concentration of NaCl includes 0, 4, 8 and 12 dS $m^{-1}$.

### Experimental materials

Total 34 number of different field pea genotype seeds were received from Plant Genetics Resource Centre, BARI and Pulse Research Centre, Ishwardi, Pabna. Almost all the genotypes of unknown character were collected earlier from different regions of Bangladesh (Table 1). Three introduced field pea varieties namely BARI Motor 1, BARI Motor 2 and BARI Motor 3, developed by Pulse Research Centre, Ishwardi, Pabna of Bangladesh Agricultural Research Institute (BARI), were used as check variety for all the experiments.

### Seed treatment and sowing

Field pea seeds were first sterilized for 5 min with 5% commercial bleach and then thoroughly washed with distilled water. Germination tests were conducted in petridishes (containing one Whatman filter paper with 20 mL of respective test solutions) with four treatments by three replications (7 seeds per replication). Seeds were allowed to germinate at room temperature and in darkness for 10 days. During this period, the petridishes were maintained properly daily and 5 ml of distilled water was added to the petridishes daily. Electrical conductivity ($EC_e$) of different treatments was measured by using an electric conductivity meter (Water EC meter). A seed was considered to be germinated when the emerging radicle was 10 mm long (Cokkizgin, 2012). The germinated seeds counted daily starting at $3^{rd}$ day and the final count has been taken at $10^{th}$ days after sowing to calculate germination-related parameters (Table 1).

### Statistical analysis

The experiment was set up using completely randomized design (CRD) with two factors (salinity and genotypes). The statistical R - software version 4.01 was used to carried out a two - way analysis of variance (Table 2). The LSD test was used to determine significant difference between two mean value at P - value of $< 0.05$. The incomplete data obtained from these experiment had been excluded from the data set before analysis.

## RESULTS AND DISCUSSION

The present study was conducted to find out the effect of different levels of salinity on germination of different field pea genotypes. Most of the parameters studied in this experiment were influenced significantly by the different levels of salinity (NaCl). The effects of salinity (NaCl) on germination are presented in the following:

### Germination percentage

The different levels of salinity affected the germination percentage. Germination trend was found to increase at the lower salinity levels. The highest germination was found 97.91% in control solution and the lowest 78.67% was found in 12 dS $m^{-1}$ and the mean germination value is 90.25% (Fig. 1). Leonforte *et al.* (2013) stated that it has significant effects of salinity and moisture stress and their interactions on seed germination and seedling growth of field pea.

***Table 1.*** *The abbreviation, units of germination-related parameters and various equation calculations used*

| Sl. No. | Parameters | Ab. | Unit | Equation | References | Effect |
|---|---|---|---|---|---|---|
| 1. | Germination percentage | GP | % | GP = (No. of germinated seed / Total sown seeds) x 100 | Gairola *et.al.* (2011); Scott *et al.* (1984) | + |
| 2. | Germination initial time | GIT | Day | GIT = The number of days of first seed germination | Al-Mudaris (1998) | + |
| 3. | Maximum germination time | MTG | Day | MGT = Number of days until the highest Germination seed | Al-Mudaris (1998) | - |
| 4. | Germination duration time | GDT | Day | GDT = MTG - GIT | | - |
| 5. | Mean daily germination | MDG | % | MDG = GP/MGT | Fetouh and Hassan (2014); Gairola *et al.* (2011) | + |
| 6. | Mean germination time | MGT | Day | $MGT = (\Sigma n_i \times d_i)/N$ | Gairola *et al.* (2011); Matthews and Khajeh - Hosseini (2007); Zewdie and Welka (2015) | - |
| 7. | Speed of Germination | SP | Seed $Day^{-1}$ | $SP = (\Sigma n_i \times d_i)/N$ | Gairola (2011); Souza *et al.* (2017); Zewdie and Welka (2015) | + |
| 8. | Germination coefficient | GC | % | $GC = (N/(\Sigma n_i \times d_i) \times 100$ | Xu *et. al.* (2016) | + |
| 9. | Germination value | GV | - | GV = PV x MDG | Gairola *et.al.* (2011) | + |
| 10. | Germination vigor index | GVI | cm | GVI = Germination % x total seedling length (cm)/100 | Abdul - Baki and Anderson (1970) | + |

$n_i$ is the number of grains that germinated on the day (i); $d_i$ is the number of days counted from the beginning of germination; N is the total number of germinated seeds; PV is the peak value (PV = Cumulative germination %/ Respective time interval)

Germination percentage significantly varied with the different genotypes. Almost all the genotypes germinated at laboratory condition and maximum germination was observed in control non-saline solution. Germination trend decreased with increasing salinity levels. Maximum germination was found in the best genotype BARI Motor 1 (98.75%) in respect of salinity tolerance followed by BARI Motor 3 (97.5%), Ipsha Gardenpea 3, Sekim local BFP-11016, BD-9047 and BARI Motor 2 (96.25%). The lowest germination was recorded in Natore local 1 (68.75%) (Table 3).

**Germination initial time**

Germination initial time was significantly affected by different levels of salinity. Germination initial time increased with the increase in salinity level. Minimum initial time for seed germination was found in control condition (4.01 days) and maximum initial time for seed germination was required in 12 dS $m^{-1}$ (5.44 days) condition and the mean germination initial time was 4.63 days (Fig. 2). Seed germination may be affected by salinity through either creating external osmotic potential or toxic effect of $Na^+$ and $Cl^-$ ions as reported by (Yang *et al.,* 2007).

High accumulation of sodium and chloride ions produced an outside osmotic potential that prevents adequate water uptake or toxic effect of $Na^+$ and $Cl^-$ ions in saline environment resulted in poor activation of the hydrolytic enzymes which further reduced the seed germination (Khajeh *et al.,* 2003; Mohammed, 2007; Murillo *et al.,* 2002).

***Table 2.*** *Analysis of variance (ANOVA) of germination-related parameters under four-included salinity stress condition*

| Source of variation | | Rep | T | G | T x G | Error |
|---|---|---|---|---|---|---|
| Df | | 2 | 3 | 23 | 69 | 190 |
| Germination Parameters | GP% | 921*** | 4964*** | 602.0*** | 205*** | 59.06 |
| | SP | 0.010 | 2.50*** | 0.310*** | 0.109*** | 0.008 |
| | GIT | 79.71*** | 34.55*** | 1.83*** | 0.43 | 0.353 |
| | MTG | 71.01*** | 22.28*** | 8.33*** | 0.74*** | 0.48 |
| | GDT | 1.149 | 1.04*** | 3.23 | 0.55 | 0.44 |
| | MDG | 1167*** | 1477.0* | 84.64*** | 41.51** | 51.39 |
| | MGT | 53.68*** | 84.62*** | 3.35*** | 0.81*** | 0.86 |
| | GC | 1319*** | 1933.0* | 100.1*** | 52.48*** | 61.72 |
| | PL | 6314.7*** | 8379*** | 6268*** | 5989*** | 5869 |
| | RL | 40.98*** | 172.3*** | 92.05*** | 101.1*** | 89.20 |
| | PL:RL | 0.12*** | 11.4*** | 3.02*** | 0.27*** | 0.053 |
| | FW | 0.05*** | 8.75*** | 1.83*** | 0.22*** | 0.008 |
| | DW | 0.004*** | 1.13*** | 0.47*** | 0.13*** | 0.008 |
| | GV | 14366.0*** | 5472.1*** | 12581*** | 12959.3*** | 12893 |
| | GVI | 37.07*** | 2620*** | 149.54*** | 15.81*** | 1.047 |

*Significant at 0.05%, ** significant at 0.01%, *** significant at 0.001%; GP: Germination %, GIT: Germination initial time (day), MTG: Maximum germination time (day), GDT: Germination duration time (day), MDG: Mean daily germination (%), MGT: Mean germination time (day), SP: Speed of germination (seed day$^{-1}$), GC: Germination coefficient (%), PL: Plumule length (cm), RL: Radicle length (cm), FW: Fresh weight (g), DW: Dry weight (g), GV: Germination value and GVI: Germination vigor index (cm)

Germination initial time significantly varied in the different field pea genotypes. Maximum initial time for seed germination was found in Early-94 and BD-4193 (5.50 days) genotype followed by BD-4176 (5.08 days) and BFP-11015 (5.00 days) genotypes. Minimum initial time for seed germination was found in BARI Motor 3, Bagha local and BARI-Motor 2 (4.16 days) genotypes (Table 3).

**Maximum germination time**

Different levels of salinity affected the maximum germination time. Higher maximum germination time for field pea seed germination was required in 12 dS m$^{-1}$ condition (8.33 days) and lowest maximum germination time for seed germination was found in control (6.80 days) condition and the mean maximum germination time was 7.58 days (Fig. 2). Mudgal *et al.* (2009)

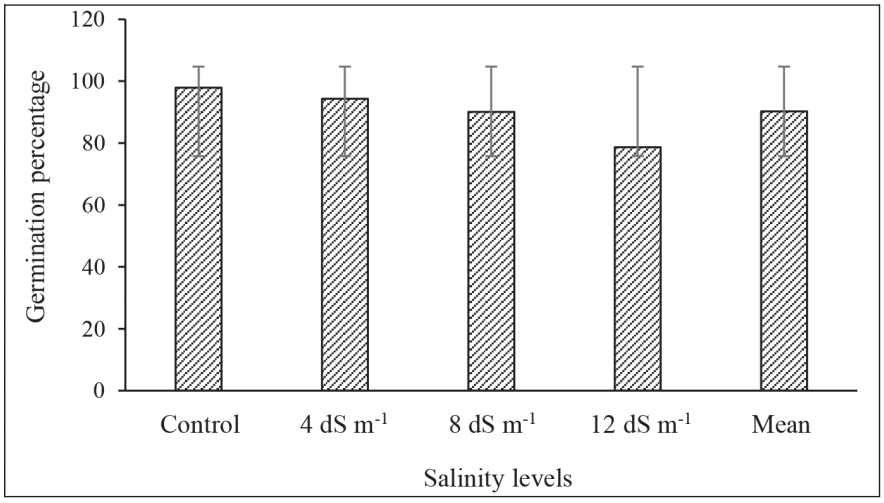


***Fig. 1.*** *Effect of salinity stress on germination percentage (GP)*

reported that during germination under saline conditions, high osmotic pressure of saline water is created due to capillary rise leading to more salts density at seed depth than at lower soil profile, which reduces time and rate of germination.

Significant differences were observed in maximum germination time of seed germination in different field pea genotypes. Highest maximum germination time was observed in BD-9047 (9.08 days) followed by BARI Motorsuti 1 (8.83 days). Lowest maximum germination time was observed in BFP-11016, BD-6944 and BARI Motor 2 (6.58 days) genotypes (Table 4).

**Germination duration time**

Significant differences were observed in maximum germination time of seed germination among the different field pea genotypes. Highest maximum germination time was observed in BD-9047 (9.08 days) genotype followed by BARI Motorsuti 1 (8.83 days) genotype. The lowest maximum germination time was observed in BFP-11016, BD-6944 and BARI Motor 2 (6.58 days) genotypes (Fig. 2).

Different ranges of salinity affected the germination duration time of field pea. Higher salinity levels was found to increase the germination duration time. Maximum germination duration time was found in 12 dS $m^{-1}$ condition (3.46 days) and the minimum germination duration time was found in control condition (2.58 days) and mean germination duration time was 2.97 days.

Germination duration time was significantly affected by different genotypes (Table 4). Maximum duration time for seed germination was found in BARI Motorsuti 1 (3.92 days) genotype followed by Nator local 2 (3.83 days) and BD-4175, BD-4176 (3.66 days) genotypes. Minimum duration time for seed germination was found in BARI Motor 1 (2.08 days) genotype.

**Mean daily germination**

Different levels of salinity affected the mean daily germination. Higher salinity levels reduced the mean daily germination percentage. Higher mean daily germination for field pea seed germination was required in control condition (27.69%) and lowest maximum mean daily germination for seed germination was required in 12 dS $m^{-1}$ (17.36%) condition and the average mean daily germination was 21.66% (Fig. 3). The results demonstrated genotypic variation in seed mean daily germination and seedling growth responses to salinity stress. The negative effects of NaCl increased with the increase in salt concentrations (Chakma and Hossain, 2019). These results have implications on the parameters of germination such as total germination percentage, germination index and the coefficient of velocity which are badly affected. Also, germination is

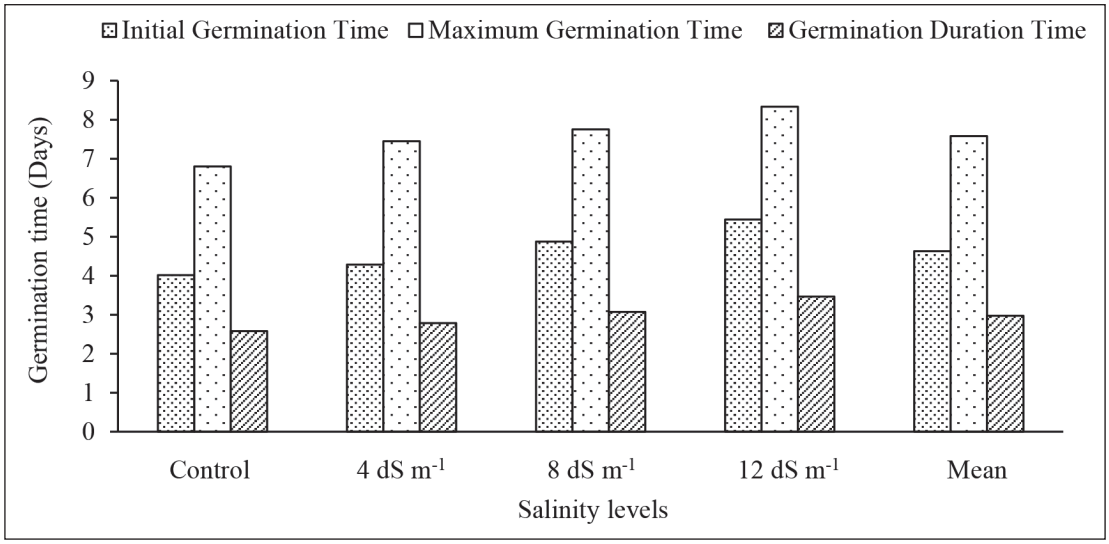


***Fig. 2.*** *Effect of salinity stress on initial germination time (GIT), maximum germination time (MTG) and germination duration time (GDT)*

***Table 3.*** *Germination percentage and germination initial time (GIT) of tested field pea genotypes as influenced by varied salinity conditions*

| Sl. No. | Genotypes | Salinity level | | | | Mean | Salinity level | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Control | 4 dS $m^{-1}$ | 8 dS $m^{-1}$ | 12 dS $m^{-1}$ | | Control | 4 dS $m^{-1}$ | 8 dS $m^{-1}$ | 12 dS $m^{-1}$ | |
| | | Ger. (%) | Ger. (%) | Ger. (%) | Ger. (%) | | GIT | GIT | GIT | GIT | |
| 1 | BD-4209 | 100 | 100 | 86 | 67 | 88.25 | 3.67 | 3.67 | 4.67 | 5.67 | 4.41 |
| 2 | Early-94 | 90 | 86 | 86 | 71 | 83.25 | 5.33 | 5.33 | 5.33 | 6.00 | 5.50 |
| 3 | BD-4181 | 100 | 100 | 90 | 62 | 88.00 | 3.67 | 3.67 | 5.00 | 5.33 | 4.41 |
| 4 | BARI Motor 1 | 100 | 100 | 100 | 95 | 98.75 | 3.67 | 3.67 | 5.00 | 5.67 | 4.50 |
| 5 | BARI Motor 3 | 100 | 100 | 95 | 95 | 97.5 | 4.00 | 4.67 | 4.33 | 5.33 | 4.16 |
| 6 | BFP-11015 | 90 | 90 | 90 | 81 | 87.75 | 4.00 | 4.33 | 4.67 | 5.00 | 4.50 |
| 7 | Faridpur local | 100 | 95 | 95 | 90 | 95.00 | 4.33 | 4.67 | 5.00 | 5.33 | 4.83 |
| 8 | Nator local 2 | 100 | 100 | 90 | 81 | 92.75 | 4.00 | 5.00 | 5.00 | 6.00 | 5.00 |
| 9 | Ipsha gardenpea 3 | 100 | 100 | 95 | 90 | 96.25 | 4.00 | 4.00 | 5.00 | 5.67 | 4.66 |
| 10 | Sekim local | 100 | 95 | 95 | 95 | 96.25 | 4.33 | 4.67 | 5.00 | 5.00 | 4.75 |
| 11 | BFP-11016 | 100 | 95 | 95 | 95 | 96.25 | 4.33 | 5.00 | 5.00 | 5.33 | 4.91 |
| 12 | Bagha local | 95 | 86 | 81 | 81 | 85.75 | 3.67 | 3.67 | 4.67 | 4.67 | 4.16 |
| 13 | BD-9047 | 100 | 95 | 95 | 95 | 96.25 | 3.67 | 3.67 | 4.67 | 5.33 | 4.33 |
| 14 | BD-4142 | 95 | 95 | 95 | 90 | 93.75 | 3.67 | 3.67 | 4.33 | 6.00 | 4.41 |
| 15 | BD-7211 | 100 | 100 | 95 | 86 | 95.25 | 3.67 | 3.67 | 5.00 | 5.67 | 4.50 |
| 16 | BD-4175 | 100 | 100 | 95 | 86 | 95.25 | 4.00 | 4.00 | 4.67 | 5.00 | 4.41 |
| 17 | BD-4176 | 100 | 100 | 86 | 52 | 84.5 | 4.00 | 4.67 | 5.67 | 6.00 | 5.08 |
| 18 | BD-4193 | 100 | 100 | 90 | 67 | 89.25 | 4.67 | 5.00 | 5.67 | 6.67 | 5.50 |
| 19 | BD-6944 | 100 | 95 | 86 | 76 | 89.25 | 3.67 | 4.33 | 5.00 | 5.33 | 4.58 |
| 20 | BD-4182 | 100 | 95 | 90 | 38 | 80.75 | 5.00 | 5.00 | 5.00 | 5.67 | 5.16 |
| 21 | BARI-Motor 2 | 100 | 95 | 95 | 95 | 96.25 | 3.33 | 3.67 | 4.67 | 5.00 | 4.16 |
| 22 | Natore local 1 | 90 | 71 | 71 | 43 | 68.75 | 4.00 | 4.00 | 4.67 | 5.00 | 4.41 |
| 23 | BARI Motorsuti 1 | 100 | 81 | 76 | 71 | 82.00 | 4.00 | 4.67 | 4.67 | 5.00 | 4.75 |
| 24 | Jhikorgasha local | 90 | 90 | 90 | 86 | 89.00 | 3.67 | 4.00 | 4.33 | 5.00 | 4.33 |
| | Mean | 97.91 | 94.33 | 90.08 | 78.67 | 90.25 | 4.01 | 4.28 | 4.87 | 5.44 | 4.63 |
| | LSD (0.05%) | T | G | T x G | | | T | G | T x G | | |
| | | 1.19 | 1.36 | 8.81 | | | 2.77 | 3.64 | 0.137 | | |

***Table 4.*** *Maximum germination time (MTG) and germination duration time (GDT) of tested field pea genotypes as influenced by varied salinity conditions*

| Sl. No. | Genotypes | Salinity level | | | | Mean | Salinity level | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Control | 4 dS $m^{-1}$ | 8 dS $m^{-1}$ | 12 dS $m^{-1}$ | | Control | 4 dS $m^{-1}$ | 8 dS $m^{-1}$ | 12 dS $m^{-1}$ | |
| | | MTG | MTG | MTG | MTG | | GDT | GDT | GDT | GDT | |
| 1 | BD-4209 | 5.67 | 7.00 | 7.33 | 8.00 | 7.00 | 2.00 | 2.33 | 2.33 | 3.00 | 2.42 |
| 2 | Early-94 | 7.33 | 8.87 | 8.67 | 9.00 | 8.46 | 3.00 | 3.00 | 3.33 | 4.00 | 3.33 |
| 3 | BD-4181 | 6.00 | 7.00 | 7.67 | 8.33 | 7.25 | 2.33 | 2.67 | 3.00 | 3.00 | 2.75 |
| 4 | BARI Motor-1 | 6.00 | 6.67 | 7.00 | 7.76 | 6.85 | 2.00 | 2.00 | 2.00 | 2.33 | 2.08 |
| 5 | BARI Motor 3 | 6.67 | 6.67 | 6.67 | 8.00 | 7.00 | 2.67 | 2.67 | 3.00 | 3.33 | 2.92 |
| 6 | BFP-11015 | 7.00 | 7.33 | 7.33 | 8.33 | 7.49 | 2.33 | 3.33 | 3.33 | 3.33 | 3.08 |
| 7 | Faridpur local | 6.67 | 6.67 | 7.00 | 9.33 | 7.41 | 2.00 | 2.00 | 2.33 | 3.33 | 2.42 |
| 8 | Nator local 2 | 6.00 | 6.67 | 7.33 | 7.33 | 6.83 | 3.67 | 3.67 | 4.00 | 4.00 | 3.83 |
| 9 | Ipsha gardenpea 3 | 6.67 | 7.33 | 7.67 | 8.67 | 7.58 | 2.33 | 2.33 | 3.00 | 3.33 | 2.75 |
| 10 | Sekim local | 7.00 | 8.67 | 9.00 | 9.00 | 8.41 | 2.33 | 2.67 | 3.00 | 3.33 | 2.83 |
| 11 | BFP-11016 | 5.33 | 6.33 | 7.33 | 7.33 | 6.58 | 2.33 | 2.67 | 2.67 | 3.00 | 2.66 |
| 12 | Bagha local | 8.00 | 8.33 | 8.33 | 10.00 | 8.65 | 2.67 | 2.67 | 3.00 | 3.67 | 3.00 |
| 13 | BD-9047 | 8.33 | 9.00 | 9.33 | 9.67 | 9.08 | 1.67 | 2.00 | 2.57 | 2.57 | 2.20 |
| 14 | BD-4142 | 6.33 | 6.67 | 7.00 | 7.33 | 6.83 | 2.33 | 2.67 | 2.67 | 3.00 | 2.66 |
| 15 | BD-7211 | 6.33 | 6.33 | 6.67 | 7.67 | 6.75 | 3.00 | 3.33 | 4.00 | 4.00 | 3.58 |
| 16 | BD-4175 | 6.67 | 7.00 | 7.33 | 7.33 | 7.08 | 3.67 | 3.67 | 3.33 | 4.00 | 3.66 |
| 17 | BD-4176 | 8.33 | 8.67 | 9.00 | 9.00 | 8.75 | 3.33 | 3.67 | 3.67 | 4.00 | 3.66 |
| 18 | BD-4193 | 7.33 | 7.33 | 7.33 | 8.00 | 7.49 | 2.67 | 2.67 | 3.67 | 3.67 | 3.17 |
| 19 | BD-6944 | 5.67 | 6.67 | 6.67 | 7.33 | 6.58 | 2.33 | 2.33 | 3.00 | 3.33 | 2.74 |
| 20 | BD-4182 | 8.00 | 8.33 | 8.87 | 9.00 | 8.55 | 2.00 | 2.33 | 2.33 | 3.57 | 2.55 |
| 21 | BARI-Motor 2 | 5.67 | 6.67 | 6.67 | 7.33 | 6.58 | 2.33 | 2.33 | 3.00 | 3.00 | 2.66 |
| 22 | Natore local 1 | 8.00 | 8.33 | 9.00 | 9.00 | 8.58 | 2.00 | 2.37 | 3.33 | 3.67 | 2.84 |
| 23 | BARI Motorsuti 1 | 7.33 | 9.00 | 9.33 | 9.67 | 8.83 | 3.67 | 3.67 | 3.67 | 4.67 | 3.92 |
| 24 | Jhikorgasha local | 7.00 | 7.33 | 7.67 | 7.67 | 7.41 | 3.33 | 3.67 | 3.50 | 4.00 | 3.62 |
| | Mean | 6.80 | 7.45 | 7.75 | 8.33 | 7.58 | 2.58 | 2.78 | 3.07 | 3.46 | 2.97 |
| | LSD (0.05%) | T | G | T x G | | | T | G | T x G | | |
| | | 2.09 | 5.36 | 0.012 | | | 0.07 | 2.26 | 0.106 | | |

delayed and mean germination time increased with salt stress. The same results were reported by Chartzoulakis and Klapaki (2000) and Zapata *et al.* (2003).

Significant differences were observed in mean daily germination of seed germination affected by different field pea genotype (Table 3). Highest mean daily germination was observed in BARI Motor 3 (27.93%) genotype followed by Sekim local (25.93%) and BD-9047 (25.49%) genotype. Lowest mean daily germination was observed in BD-6944 (17.42%) genotype.

**Mean germination time**

Different ranges of salinity also affected mean germination time. The maximum mean germination time was found in 12 dS $m^{-1}$ (5.82 days) salinity condition. The minimum mean germination time was found in control (3.45 days) condition and the average mean germination time was 4.56 days (Fig. 3). It could probably be due to the facilitation of cytokinin penetration in the testa and neutralization of inhibitors present in the embryo, thus enabling the embryo to rupture the seed coat (Çetinbaş and Koyuncu, 2006; Dhoran and Gudadhe, 2012; Noori *et al.,* 2008).

Mean germination time varied significantly among the genotypes. Maximum mean germination time for field pea seed germination was found in BD-4193 (5.89 days) genotype followed by Jhikorgasha local (5.65 days) and BD-6944 (4.60 days) genotypes. Minimum mean germination time for seed germination was found in Nator local 2 (3.60 days) genotype (Table 5).

**Speed of germination**

Speed of germination was significantly influenced by different levels of salinity. Seed of germination decrease with salinity level increased. Highest seed of germination was found in control condition (1.64 seed $day^{-1}$) and lowest seed of germination was required in 12 dS $m^{-1}$ (1.19 seed $day^{-1}$) condition and the mean seed of germination was 1.46 seed $day^{-1}$. Salt stress caused low intra-cellular water potential and water scarcity around the root zone due to which roots failed to absorb sufficient water and nutrients for adequate plant growth (Noori *et al.,* 2008).

Speed of germination also varied significantly among the genotypes (Fig. 4). Highest speed germination for field pea was found in BARI Motor 3 (1.68 seed $day^{-1}$) genotype followed by BARI Motor 1 (1.66 seed $day^{-1}$) and BFP-11015 (1.63 seed $day^{-1}$) genotypes. Lowest

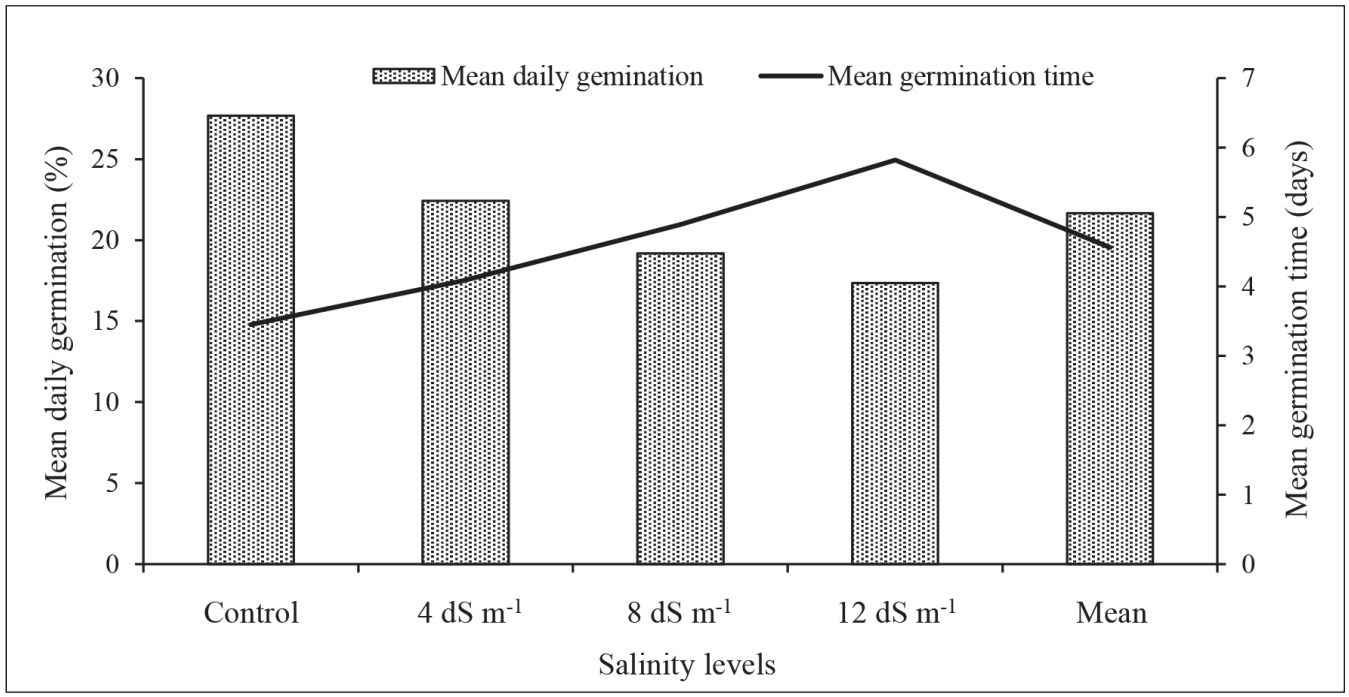


***Fig. 3.*** *Effect of salinity stress on mean daily germination and mean germination time*

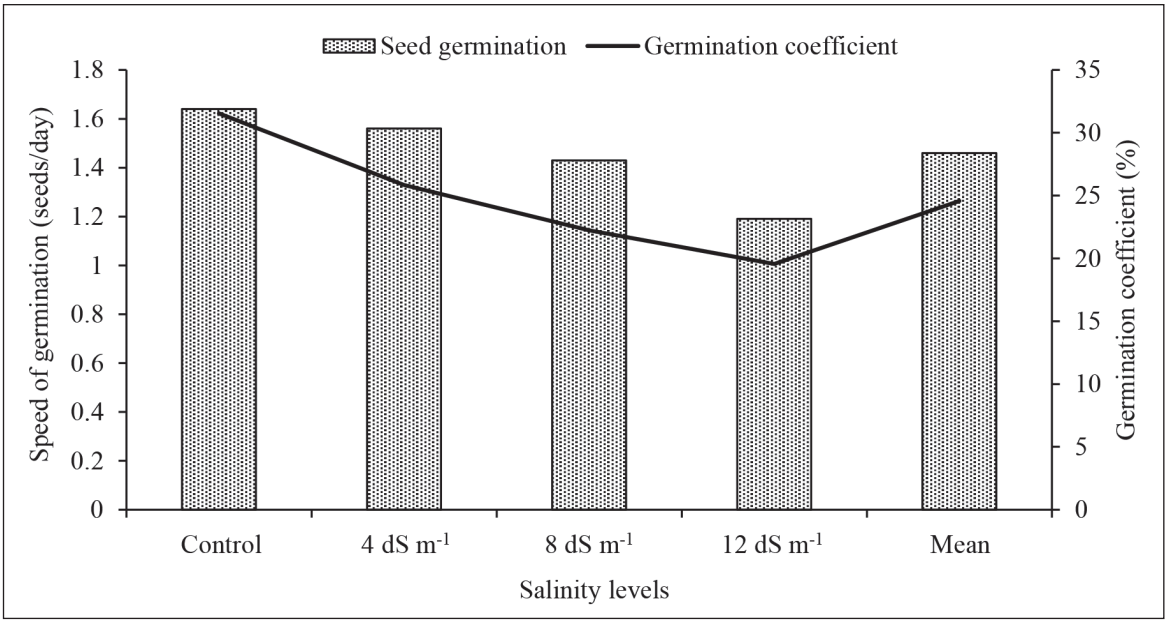


***Fig. 4.*** *Effect of salinity stress on speed of germination and germination coefficient*

speed of germination for seed germination was found in Natore local 1 (0.95 seed day$^{-1}$) (Table 6).

**Germination coefficient**

Germination coefficient of field pea seed decreased with the increase in salinity levels. Highest germination coefficient was found in control condition (31.54%) and lowest germination coefficient was found in 12 dS m$^{-1}$ (19.56%) condition and the mean germination coefficient was 24.58% (Fig. 4).

Germination coefficient varied significantly among the field pea genotype. Highest germination coefficient for field pea seed germination was found in BFP-11015 (29.35%) genotype followed by BARI Motor 3 (29.18%) and Nator local 2 (29.13%) genotypes. Lowest germination coefficient for seed germination was found in the genotype BD-6944 (19.39%) (Table 6).

**Germination value**

Different salinity levels had a significant effect on germination value of field pea seed. Germination value is an important characteristic of seed. The maximum germination value was found in control (20.63) salinity condition. The minimum germination value was found in 12 dS m$^{-1}$ (9.65) condition and the average mean germination value was 14.92 (Fig. 5).

The germination value of field pea seed varied significantly among the different field pea genotypes (Table 7). The maximum germination value was observed in BARI Motor 1 genotype (19.53) followed by BARI Motor 3 (18.03) and BFP-11015 (17.26). The minimum germination value was observed in Jhikorgasha local genotype (10.0) (Table 7).

**Germination vigor index**

Germination vigor index significantly varied between the different levels of salinity. Germination vigor index decrease as the salinity level increased. Highest germination vigor index was found in control condition (17.00 mg) and lowest germination vigor index was noticed in 12 dS m$^{-1}$ (3.59 mg) condition and the mean germination vigor index was 9.96 mg (Fig. 5). All the growth parameters discussed above may be varied due to the genetic characteristics of the different genotypes. The vigor index of the seedlings decreased as salinity levels rose, indicating that increased salt concentrations had a negative impact on the vigor index and seed germination percentage of common beans (*Phaseolus vulgaris* L.) (Cokkizgin, 2012). Under stressful circumstances, water absorption decreases both during imbibition and seedling establishment. Under salt stress, this could be followed by an increase in ion uptake (Prisco and Vieira, 1976). Additionally, it has been noted that salt inhibits the absorption of vital

***Table 5.*** *Mean daily germination (MDG) and mean germination time (MGT) of tested field pea genotypes as influenced by varied salinity conditions*

| Sl. No. | Genotypes | Salinity level | | | | Mean | Salinity level | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Control | 4 dS $m^{-1}$ | 8 dS $m^{-1}$ | 12 dS $m^{-1}$ | | Control | 4 dS $m^{-1}$ | 8 dS $m^{-1}$ | 12 dS $m^{-1}$ | |
| | | MDG% | MDG% | MDG% | MDG% | | MGT | MGT | MGT | MGT | |
| 1 | BD-4209 | 31.67 | 20.79 | 18.80 | 15.25 | 21.62 | 2.95 | 4.90 | 5.43 | 5.76 | 4.76 |
| 2 | Early-94 | 32.23 | 24.60 | 17.67 | 15.74 | 22.56 | 3.92 | 4.42 | 5.33 | 7.00 | 5.17 |
| 3 | BD-4181 | 24.50 | 21.17 | 17.89 | 14.48 | 19.51 | 3.14 | 3.71 | 5.14 | 7.00 | 4.74 |
| 4 | BARI Motor-1 | 30.00 | 27.41 | 18.07 | 17.06 | 23.13 | 2.62 | 3.76 | 3.66 | 5.81 | 3.96 |
| 5 | BARI Motor 3 | 55.02 | 20.97 | 17.39 | 18.36 | 27.93 | 2.81 | 3.09 | 3.80 | 5.57 | 3.81 |
| 6 | BFP-11015 | 23.32 | 19.43 | 18.84 | 18.62 | 20.05 | 4.28 | 4.28 | 4.28 | 4.52 | 4.34 |
| 7 | Faridpur local | 23.67 | 21.79 | 19.58 | 16.67 | 20.42 | 3.28 | 5.33 | 6.38 | 6.38 | 5.34 |
| 8 | Nator local 2 | 26.79 | 25.63 | 23.13 | 23.98 | 24.87 | 2.38 | 2.28 | 3.99 | 5.76 | 3.60 |
| 9 | Ipsha gardenpea 3 | 24.20 | 20.70 | 20.16 | 19.11 | 21.04 | 3.86 | 4.52 | 5.42 | 6.57 | 5.09 |
| 10 | Sekim local | 28.11 | 27.40 | 24.98 | 23.32 | 25.93 | 2.99 | 3.04 | 3.62 | 5.33 | 3.74 |
| 11 | BFP-11016 | 29.99 | 23.83 | 22.42 | 21.43 | 24.41 | 2.85 | 3.47 | 4.18 | 5.28 | 3.94 |
| 12 | Bagha local | 30.61 | 24.08 | 17.85 | 15.48 | 22.00 | 3.61 | 3.76 | 4.90 | 5.24 | 4.37 |
| 13 | BD-9047 | 28.46 | 27.40 | 23.09 | 23.02 | 25.49 | 4.14 | 4.67 | 5.14 | 4.90 | 4.71 |
| 14 | BD-4142 | 26.93 | 21.27 | 19.40 | 18.26 | 21.46 | 3.14 | 3.86 | 4.00 | 4.00 | 3.75 |
| 15 | BD-7211 | 25.30 | 21.95 | 20.85 | 16.93 | 21.25 | 3.47 | 5.09 | 5.47 | 6.57 | 5.15 |
| 16 | BD-4175 | 29.73 | 20.31 | 18.65 | 16.42 | 21.27 | 3.42 | 4.85 | 5.67 | 6.19 | 5.03 |
| 17 | BD-4176 | 21.97 | 21.41 | 19.00 | 13.69 | 19.01 | 2.85 | 4.40 | 5.14 | 6.33 | 4.68 |
| 18 | BD-4193 | 20.42 | 21.09 | 18.07 | 14.88 | 18.61 | 7.38 | 4.76 | 5.33 | 6.09 | 5.89 |
| 19 | BD-6944 | 20.57 | 20.01 | 14.64 | 14.47 | 17.42 | 4.47 | 5.13 | 5.62 | 6.38 | 5.40 |
| 20 | BD-4182 | 26.73 | 18.26 | 16.73 | 15.24 | 19.24 | 2.28 | 3.80 | 5.43 | 5.81 | 4.33 |
| 21 | BARI-Motor 2 | 28.87 | 24.74 | 23.48 | 19.25 | 24.08 | 2.95 | 3.28 | 4.52 | 5.14 | 3.97 |
| 22 | Natore local 1 | 27.67 | 24.19 | 13.69 | 11.16 | 19.17 | 3.05 | 4.00 | 4.47 | 5.61 | 4.28 |
| 23 | BARI Motorsuti 1 | 23.67 | 19.46 | 18.67 | 17.77 | 19.88 | 2.80 | 3.62 | 4.04 | 4.95 | 3.85 |
| 24 | Jhikorgasha local | 24.19 | 20.55 | 17.31 | 16.30 | 19.54 | 4.04 | 4.33 | 6.56 | 7.67 | 5.65 |
| | Mean | 27.69 | 22.43 | 19.18 | 17.36 | 21.66 | 3.45 | 4.09 | 4.89 | 5.82 | 4.56 |
| | LSD (0.05%) | T | G | T x G | | | T | G | T x G | | |
| | | 2.25 | 0.037 | 0.84 | | | 2.34 | 9.6 | 0.61 | | |

***Table 6.*** *Speed of germination (SP)and germination coefficient (GC) of tested field pea genotypes as influenced by varied salinity conditions*

| Sl. No. | Genotypes | Salinity level | | | | Mean | Salinity level | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Control | 4 dS $m^{-1}$ | 8 dS $m^{-1}$ | 12 dS $m^{-1}$ | | Control | 4 dS $m^{-1}$ | 8 dS $m^{-1}$ | 12 dS $m^{-1}$ | |
| | | SP | SP | SP | SP | | GC% | GC% | GC% | GC% | |
| 1 | BD-4209 | 1.67 | 1.64 | 1.31 | 1.06 | 1.42 | 32.07 | 31.67 | 20.76 | 17.77 | 25.56 |
| 2 | Early-94 | 1.73 | 1.61 | 1.45 | 1.37 | 1.54 | 27.67 | 24.03 | 21.86 | 17.47 | 22.75 |
| 3 | BD-4181 | 1.75 | 1.66 | 1.47 | 0.63 | 1.46 | 26.83 | 24.67 | 19.96 | 19.56 | 22.75 |
| 4 | BARI Motor-1 | 1.66 | 1.66 | 1.66 | 1.66 | 1.66 | 26.87 | 24.09 | 24.03 | 15.23 | 22.55 |
| 5 | BARI Motor 3 | 1.70 | 1.70 | 1.70 | 1.63 | 1.68 | 37.90 | 27.33 | 26.63 | 24.87 | 29.18 |
| 6 | BFP-11015 | 1.67 | 1.67 | 1.67 | 1.54 | 1.63 | 57.20 | 22.97 | 20.0 | 17.27 | 29.35 |
| 7 | Faridpur local | 1.57 | 1.57 | 1.57 | 1.50 | 1.55 | 30.83 | 23.10 | 16.32 | 15.83 | 21.52 |
| 8 | Nator local 2 | 1.63 | 1.49 | 1.49 | 1.34 | 1.48 | 33.70 | 33.00 | 27.67 | 22.17 | 29.13 |
| 9 | Ipsha gardenpea 3 | 1.68 | 1.56 | 1.26 | 1.46 | 1.49 | 25.47 | 23.77 | 23.67 | 18.09 | 22.74 |
| 10 | Sekim local | 1.62 | 1.59 | 1.49 | 1.48 | 1.54 | 31.50 | 30.33 | 25.27 | 24.72 | 27.95 |
| 11 | BFP-11016 | 1.65 | 1.50 | 1.46 | 0.55 | 1.29 | 32.47 | 30.93 | 20.40 | 17.67 | 25.36 |
| 12 | Bagha local | 1.33 | 1.33 | 1.32 | 1.04 | 1.25 | 29.67 | 25.27 | 20.83 | 19.17 | 23.73 |
| 13 | BD-9047 | 1.67 | 1.62 | 1.63 | 1.57 | 1.62 | 30.93 | 27.43 | 26.23 | 25.57 | 27.54 |
| 14 | BD-4142 | 1.53 | 1.53 | 1.53 | 1.38 | 1.49 | 31.87 | 26.70 | 25.27 | 25.40 | 27.30 |
| 15 | BD-7211 | 1.69 | 1.67 | 1.59 | 1.28 | 1.55 | 27.33 | 26.60 | 24.67 | 15.23 | 23.45 |
| 16 | BD-4175 | 1.60 | 1.57 | 1.47 | 1.47 | 1.52 | 29.67 | 20.29 | 19.40 | 16.97 | 21.58 |
| 17 | BD-4176 | 1.70 | 1.53 | 1.49 | 1.00 | 1.43 | 35.53 | 23.77 | 21.67 | 21.17 | 25.53 |
| 18 | BD-4193 | 1.66 | 1.63 | 1.57 | 1.12 | 1.49 | 22.50 | 21.07 | 20.30 | 19.37 | 20.80 |
| 19 | BD-6944 | 1.57 | 1.46 | 1.35 | 1.13 | 1.37 | 21.07 | 20.50 | 19.17 | 16.83 | 19.39 |
| 20 | BD-4182 | 1.70 | 1.56 | 1.45 | 0.45 | 1.29 | 26.96 | 24.07 | 19.20 | 19.20 | 25.68 |
| 21 | BARI-Motor 2 | 1.77 | 1.66 | 1.56 | 1.51 | 1.62 | 26.60 | 19.19 | 18.40 | 18.40 | 27.09 |
| 22 | Natore local 1 | 1.66 | 1.26 | 0.87 | 0.00 | 0.95 | 30.00 | 22.97 | 18.97 | 18.96 | 21.90 |
| 23 | BARI Motorsuti 1 | 1.62 | 1.56 | 1.46 | 1.30 | 1.48 | 25.57 | 23.33 | 23.33 | 20.80 | 25.62 |
| 24 | Jhikorgasha local | 1.50 | 1.40 | 1.30 | 1.23 | 1.35 | 24.20 | 23.67 | 20.33 | 18.40 | 21.65 |
| | Mean | 1.64 | 1.56 | 1.43 | 1.19 | 1.46 | 31.54 | 25.84 | 22.24 | 19.56 | 24.58 |
| | LSD(0.05%) | T | G | T x G | | | T | G | T x G | | |
| | | 3.16 | 2.49 | 3.49 | | | 1.7 | 0.04 | 0.78 | | |

***Table 7.*** *Germination value (GV) and germination vigour index (GVI) of tested field pea genotypes as influenced by varied salinity conditions*

| Sl. No. | Genotypes | Salinity level | | | | Mean | Salinity level | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Control | 4 dS $m^{-1}$ | 8 dS $m^{-1}$ | 12 dS $m^{-1}$ | | Control | 4 dS $m^{-1}$ | 8 dS $m^{-1}$ | 12 dS $m^{-1}$ | |
| | | GV | GV | GV | GV | | GVI | GVI | GVI | GVI | |
| 1 | BD-4209 | 23.44 | 18.28 | 14.21 | 7.11 | 15.76 | 13.81 | 11.65 | 6.26 | 3.66 | 8.79 |
| 2 | Early-94 | 20.57 | 10.98 | 8.82 | 8.10 | 12.11 | 15.10 | 8.02 | 5.90 | 2.61 | 7.86 |
| 3 | BD-4181 | 20.48 | 19.04 | 13.08 | 7.63 | 15.05 | 14.09 | 13.48 | 5.55 | 2.16 | 8.83 |
| 4 | BARI Motor-1 | 33.01 | 17.61 | 14.78 | 12.75 | 19.53 | 19.79 | 19.78 | 6.41 | 4.33 | 12.57 |
| 5 | BARI Motor 3 | 22.10 | 19.89 | 18.49 | 11.65 | 18.03 | 24.80 | 18.66 | 13.16 | 7.70 | 16.08 |
| 6 | BFP-11015 | 18.19 | 17.98 | 17.18 | 15.69 | 17.26 | 24.48 | 19.16 | 12.31 | 6.83 | 15.53 |
| 7 | Faridpur local | 19.77 | 16.29 | 15.62 | 11.47 | 15.78 | 17.81 | 13.71 | 5.47 | 4.96 | 10.46 |
| 8 | Nator local 2 | 21.97 | 15.92 | 14.08 | 13.72 | 16.42 | 24.67 | 23.30 | 9.34 | 5.73 | 15.77 |
| 9 | Ipsha gardenpea 3 | 19.45 | 17.12 | 16.19 | 11.92 | 16.17 | 14.65 | 8.02 | 5.60 | 4.60 | 8.22 |
| 10 | Sekim local | 18.59 | 14.92 | 10.61 | 9.92 | 13.51 | 15.39 | 10.46 | 4.83 | 3.89 | 8.60 |
| 11 | BFP-11016 | 22.07 | 19.38 | 13.44 | 10.03 | 16.23 | 22.95 | 19.95 | 8.52 | 6.85 | 14.56 |
| 12 | Bagha local | 18.48 | 11.22 | 10.00 | 8.88 | 12.14 | 15.19 | 8.43 | 4.34 | 2.79 | 7.69 |
| 13 | BD-9047 | 19.71 | 17.43 | 14.84 | 12.77 | 16.18 | 25.44 | 22.97 | 13.46 | 3.57 | 16.35 |
| 14 | BD-4142 | 13.88 | 13.62 | 12.42 | 10.83 | 12.68 | 16.76 | 9.14 | 5.69 | 3.73 | 8.82 |
| 15 | BD-7211 | 28.65 | 15.49 | 11.62 | 7.06 | 15.70 | 14.88 | 11.09 | 5.93 | 4.69 | 9.16 |
| 16 | BD-4175 | 20.51 | 18.99 | 14.99 | 13.19 | 16.92 | 13.06 | 5.16 | 3.51 | 0.76 | 5.66 |
| 17 | BD-4176 | 22.97 | 16.86 | 13.40 | 8.95 | 15.54 | 18.64 | 15.55 | 5.14 | 2.43 | 10.38 |
| 18 | BD-4193 | 23.37 | 15.05 | 14.04 | 7.64 | 15.02 | 14.15 | 8.47 | 5.35 | 2.76 | 7.67 |
| 19 | BD-6944 | 16.91 | 12.60 | 10.69 | 6.47 | 11.66 | 16.51 | 8.92 | 4.90 | 2.05 | 8.05 |
| 20 | BD-4182 | 22.10 | 17.12 | 16.48 | 3.78 | 14.87 | 15.83 | 10.91 | 5.67 | 0.91 | 8.47 |
| 21 | BARI-Motor 2 | 20.52 | 18.96 | 16.41 | 12.58 | 17.11 | 17.97 | 17.55 | 7.01 | 3.64 | 11.53 |
| 22 | Natore local 1 | 19.01 | 14.78 | 13.95 | 6.41 | 13.53 | 10.05 | 6.08 | 4.30 | 0.0 | 5.10 |
| 23 | BARI Motorsuti 1 | 15.92 | 12.69 | 9.22 | 5.41 | 10.81 | 6.96 | 3.77 | 2.35 | 1.52 | 3.64 |
| 24 | Jhikorgasha local | 13.64 | 9.48 | 9.16 | 7.74 | 10.00 | 14.95 | 10.24 | 6.76 | 4.00 | 9.00 |
| | Mean | 20.63 | 15.90 | 13.48 | 9.65 | 14.92 | 16.99 | 12.68 | 6.57 | 3.59 | 9.96 |
| | LSD(0.05%) | T | G | T x G | | | T | G | T x G | | |
| | | 0.73 | 0.49 | 0.47 | | | 2.14 | 6.51 | 2.5 | | |

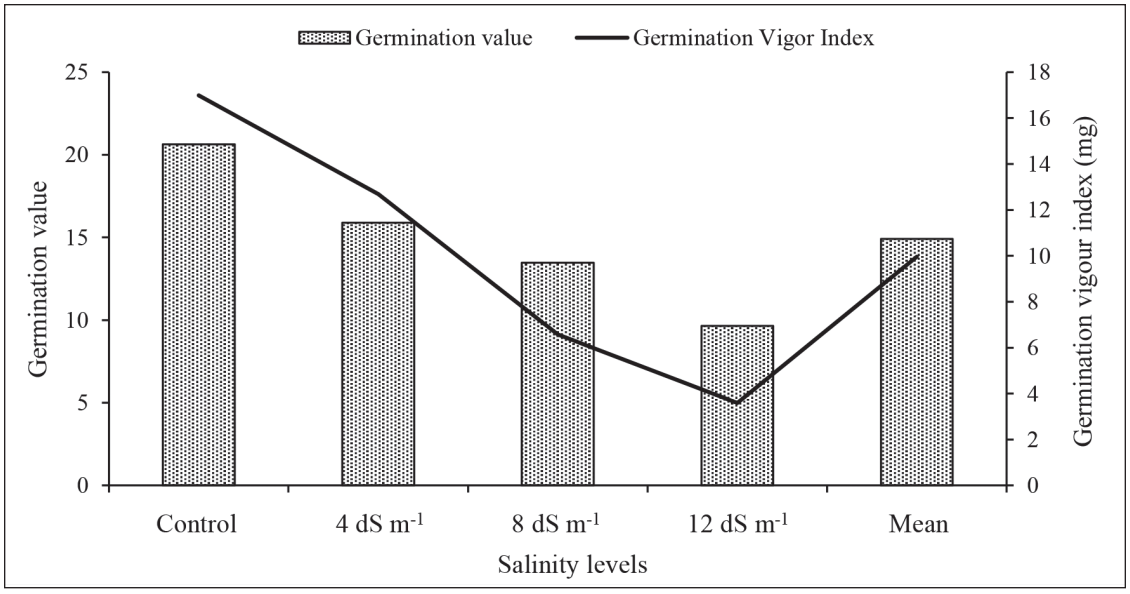


***Fig. 5.*** *Effect of salinity stress on germination value and germination vigor index*

nutrients like P and K, which may have a negative impact on seedling growth and vigor index (Nasim *et al.,* 2008).

Germination vigor index varied significantly among the genotypes. Highest germination vigor index for field pea seed was found in BD-9047 (16.35 mg) genotype followed by BARI Motor 3 (16.08 mg) and Nator local 2 (15.77 mg) genotypes. Lowest germination vigor index for seed germination was found in Natore local 1 (5.10 mg) and BARI Motorsuti 1 (3.64 mg) genotypes (Table 7).

## CONCLUSION

Wide variability was found for various germination traits of field pea genotypes and thus offer great scope for genetic improvement through selection process. However, based on the results of the present study it was observed that lower the salinity concentration, higher the chance of better seed germination and seedling establishment of field pea. The lowest salinity level was recorded to provide the best results in respect of all the parameters studied. BARI Motor 3 genotype showed better performance (in term of seed germination) in higher saline condition. Such screening of suitable genotypes may be helpful for determining better seed germination in salinity affected areas of Bangladesh.

## CONFLICTS OF INTEREST

We declare that the authors do not have any conflict of interest.

## ACKNOWLEDGEMENT

We thank Pulse Research Sub-station of Bangladesh Agricultural Research Institute (BARI) for their kind support in analyzing plant samples. We are also grateful to ACIAR-KGF project for helping us with necessary funds during the present study.

## REFERENCES

Abdul-Baki, A.A. and Anderson, J.D. (1970). Viability and leaching of sugars from germinating barley. *Crop Science* **10**(1): 31-34.

Al-Mudaris, M.A. (1998). Notes on various parameters recording the speed of seed germination. *Der Tropenlandwirt Journal of Agriculture in the Tropics and Subtropics* **99**(2): 147-154.

Booth, W.A. and Beardall, J. (1991). Effects of salinity on inorganic carbon utilization and carbonic anhydrase activity in the halotolerant alga *Dunaliella salina* (Chlorophyta). *Phycologia* **30**(2): 220-225.

Cerda, A., Caro, M. and Fernandez, F.G. (1982). Salt tolerance of two pea cultivars. *Agronomy Journal* **74**(5): 796-798.

Çetinbaş, M. and Koyuncu, F. (2006). Improving germination of *Prunus avium* L. seeds by gibberellic acid, potassium nitrate and thiourea.

*Horticultural Science* **33**(3): 119-123.

Chakma, P. and Hossain, M.M. (2019). Effects of salinity stress on seed germination and seedling growth of tomato. *Journal of the Bangladesh Agricultural University* **17**: 490-499.

Chartzoulakis, K. and Klapaki, G. (2000). Response of two greenhouse pepper hybrids to NaCl salinity during different growth stages. *Scientia Horticulturae* **86**(3): 247-260.

Cokkizgin, A. (2012). Salinity stress in common bean (*Phaseolus vulgaris* L.) seed germination. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* **40**: 177-182.

Dhoran, V.S. and Gudadhe, S.P. (2012). Effect of plant growth regulators on seed germination and seedling vigour in *Asparagus sprengeri*. *International Research Journal of Biological Sciences* **1**(7): 6-10.

Dita, M.A., Rispail, N., Prats, E., Rubiales, D. and Singh, K.B. (2006). Biotechnology approaches to overcome biotic and abiotic stress constraints in legumes. *Euphytica* **147**: 1-24.

Fetouh, M.I. and Hassan, F.A. (2014). Seed germination criteria and seedling characteristics of *Magnolia grandiflora* L. trees after cold stratification treatments. *International Journal Current Microbiology and Applied Science* **3**(3): 235-241.

Gairola, K.C., Nautiyal, A.R. and Dwivedi, A.K. (2011). Effect of temperatures and germination media on seed germination of *Jatropha curcas* Linn. *Advances in Bioresearch* **2**(2): 66-71.

Graham, P.H. and Vance, C.P. (2003). Legumes: importance and constraints to greater use. *Plant Physiology* **131**(3): 872-877.

Jensen, E.S., Carlsson, G. and Hauggaard-Nielsen, H. (2020). Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis. *Agronomy for Sustainable Development* **40**: 1-9.

Karimi, G., Ghorbanli, M., Heidari, H., Khavari Nejad, R.A., and Assareh, M.H. (2005). The effects of NaCl on growth, water relations, osmolytes and ion content in *Kochia prostrata*. *Biologia Plantarum* **49**(2): 301-304.

Khajeh H.M., Powell, A.A. and Bingham, I.J. (2003). The interaction between salinity stress and seed vigour during germination of soyabean seeds. *Seed Science and Technology* **31**: 715-725.

Leonforte, A., Sudheesh, S., Cogan, N.O., Salisbury, P.A., Nicolas, M.E., Materne, M. and Kaur, S. (2013). SNP marker discovery, linkage map construction and identification of QTLs for enhanced salinity tolerance in field pea (*Pisum sativum* L.). *BMC Plant Biology* **13**(1): 1-14.

Matthews, S. and Khajeh-Hosseini, M. (2007). Length of the lag period of germination and metabolic repair explain vigour differences in seed lots of maize (*Zea mays*). *Seed Science and Technology* **35**(1): 200-212.

Mohammed, A.H.M.A. (2007). Physiological aspects of mungbean plant (*Vigna radiata* L. Wilczek) in response to salt stress and gibberellic acid treatment. *Research Journal of Agriculture and Biological Sciences* **3**: 200-213.

Mudgal, V., Madaan N., Mudgal, A. and Mishra, S. (2009) Changes in growth and metabolic profile of Chickpea under salt stress. *Journal of Applied Bioscience* **23**: 1436-1446.

Munns, R. (2002). Comparative physiology of salt and water stress. *Plant*, *Cell and Environment* **25**(2): 239-250.

Munns, R. (2005). Genes and salt tolerance: Bringing them together. *New Phytologist* **167**(3): 645-663.

Murillo, A.B., Lopez, A.R., Kaya, C., Larrinaga M.J. and Flores H.A. (2002). Comparative effects of NaCl and polyethylene glycol on germination, emergence and seedling growth of cowpea. *Journal of Agronomy and Crop Science* **188**: 235-247.

Nasim, M. Qureshi, R. Aziz, T. Saqib, M. Nawaz, S. Sahi, S.T. and Pervaiz, S. (2008). Growth and ionic composition of salt stressed *Eucalyptus camaldulensis* and *Eucalyptus teretcornis*. *Pakistan Journal of Botany* **40**: 799-805.

Noori, I., Daoud, A.D. and Salman, A.M. (2008). Studies on seed germination, seedling growth and budding of some stone fruits (*Prunus* spp.). *Biological Plant* **23**: 144-159.

Peoples, M.B., Brockwell, J., Herridge, D.F., Rochester, I.J., Alves, B.J.R., Urquiaga, S., and Jensen, E.S. (2009). The contributions of nitrogen-fixing crop legumes to the productivity of agricultural systems. *Symbiosis* **48**: 1-17.

Prisco, J.T. and Vieira, G.H.F. (1976). Effects of NaCl salinity on nitrogenous compounds and proteases during germination of *Vigna sinensis* seeds. *Physiologia Plantarum* **36**: 317-320.

Rozema, J. and Flowers, T. (2008). Crops for a salinized world. *Science* **322**(5907): 1478-1480.

Scott, S.J., Jones, R.A. and Williams, W. (1984). Review of data analysis methods for seed germination. *Crop Science* **24**(6): 1192-1199.

Shahid, M.A., Pervez, M.A., Balal, R.M., Abbas, T., Ayyub, C.M., Mattson, N.S. and Iqbal, Z. (2012). Screening of pea (*Pisum sativum* L.) genotypes for salt tolerance based on early growth stage attributes and leaf inorganic osmolytes. *Australian Journal of Crop Science* **6**(9): 1324-1331.

Smykal, P., Aubert, G., Burstin, J., Coyne, C.J., Ellis, N., Flavell, A., Ford, R., Hybl, M., Macas, J., Neumann, P., Mcphee, K., Redden, R., Rubiales, D., Weller, J. and Warkentin, T. (2012): Pea (*Pisum sativum* L.) in the genomic era. *Agronomy* **2**: 74-115.

Souza, A.D.G., Spinelli, V.M., Souza, R.O.D., Smiderle, O.J. and Bianchi, V.J. (2017). Optimization of germination and initial quality of seedlings of *Prunus persica* tree rootstocks. *Journal of Seed Science* **39**: 166-173.

Xu, Y., Cai, N., He, B., Zhang, R., Zhao, W., Mao, J. and Woeste, K. (2016). Germination and early seedling growth of *Pinus densata* Mast. provenances. *Journal of Forestry Research* **27**: 283-294.

Yadav, S.K. (2010). Heavy metals toxicity in plants: An overview on the role of glutathione and phytochelatins in heavy metal stress tolerance of plants. *South African Journal of Botany* **76**(2): 167-179.

Yang, Y.W., Newton, R.J. and Miller, F.R. (2007). Salinity tolerance in *Sorghum bicolor*. I. Whole plant response in sodium chloride in *S. bicolor* and *S. halepense*. *Crop Science* **30**: 775-810.

Zapata, P.J., Pretel, M.T., Amorós, A. and Botella, M.Á. (2003). Changes in ethylene evolution and polyamine profiles of seedlings of nine cultivars of *Lactuca sativa* L. in response to salt stress during germination. *Plant Science* **164**(4): 557-563.

Zewdie, T. and Welka, K. (2015). Effect of micropyle orientation on germination of *Millettia ferruginea* and *Delonix regia. Ecological Processes* **4**(1): 1-7.

Zhang, N., Huang, Y., Wu, Z. and Xie, X. (2020). Artificial nitrogen fixation over bismuth-based photocatalysts: Fundamentals and future perspectives. *Journal of Materials Chemistry* **8**(10): 4978-4995.