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Correlation among germination and seedling parameters of *Brassica juncea* under PEG 6000 and NaCl treatments

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Abstract

Brown mustard (*Brassica juncea* L.) has potential for industrial use because of the high erucic acid content of the oil. This study evaluated the association under stress treatments [PEG 6000 (0, –0.2, –0.4, –0.6, –0.8, –1.0 and –1.2 MPa) and NaCl (0, 5, 10, 15, 20, 25, 30 and 35 dSm^{-1})] among germination and early seedling growth of *B. juncea* originated from Izmir, Turkey. Germination and seedling parameters as ISTA method to evaluate eleven seed parameters viz. germination percentage, final germination percentage, mean germination time, germination index, root length, shoot length, root shoot ratio, root length reduction, shoot length reduction, seedling fresh weight, seedling dry weigh. Statistical techniques correlation between different parameters both NaCl and PEG 6000 were analysed. Results exhibited that positive and significant correlation was noted among several germination and seedling parameters subjected to stress excluding root–shoot ratio that showed negative correlation with shoot length under the influence of both stress. Similarly, significant and negative correlation of mean germination time was detected with germination speed and final germination percentage. The objective and aim of this study was to determined correlation coefficients among studies traits of *B. juncea* under PEG 6000 and NaCl treatments. Such information about differential responses over time may be useful for identifying critical parameters for screening this species. The present research can help to plant breeders and agronomist in deciding the selection criteria.

Key words
Brown mustard, Salt and drought stress, Correlation coefficient.

Introductıon

Brown mustard (*Brassica juncea* L.) from Brassicaceae family is an annual crop. It is cultivated as food, fodder, oil and as medicinal plants in different cultures and many parts of the World. It is generally grown as alternative feed crops. This species are used as a condiment and vegetable oil (Kayacetin, 2020).

Salinity and drought are major biotic stress detected (Serrano et al. 1999; Mitra, 2001; Blum, 2009). The plant's reaction to stress relies on the genotypes, the severity and duration of water deficit along with level of plant growth (Nezhadahmadi et al., 2013). Brown mustard behave differently under different under stress conditions. Water stress because of NaCl and PEG 6000 acts by declining the percentage germination and seedling growth parameters (Kayacetin, 2021). Evaluation of salt and drought tolerance may be attempted on control conditions and salt and drought stress. The correlation association among various germination traits on different crops have been reported previously (Fuller et al., 2012; Thabet et al., 2018; Ahmed et al., 2019).

Correlation coefficients define the level of relationship among treatments NaCl and PEG 6000. It is significant in plant breeding and give practical information providing evidence of the relationship between several desired traits. It provides a basic concept of the relationship between various germination traits useful for plant breeding in the selection of genotypes with desirable traits (Ghafoor et al., 2013; Ali et al., 2008). Information about correlation coefficients between the studied parameters influence in selection of superior genotypes (Afroz et al., 2004).

Current study targeted to screen germination and seedling parameters relevant to PEG 6000 and NaCl stress responses with an emphasis on the germination measure, investigating salt and drought stress responses in brown mustard. This study will help in understanding the differences between responses and adaptations to PEG 6000 and NaCl stress in *B. juncea* at the seed germination and early seedling growth. It help to correlate the assessed parameters with PEG 6000 and NaCl response of seed germination and seedling growth. The knowledge of association between parameters and their direct and indirect contribution towards expression of seed quality parameters are additional help to plant breeder in deciding the selection criteria.

Materials and Methods

The study was designed to at the Oilseed Crop Unit, Central Field Crops Research Institute Yeni–mahalle, Ankara, Turkey. The experiments were carried out using Completely Randomized Design, with 3 replications. Two experiments were performed. In the first experimental, factor was PEG levels (0.0, –0.2, –0.4, –0.6, –0.8, –1.0, and –1.2 MPa). In the second experiment, factor was NaCl levels [(0, 5 (–0.2 MPa), 10 (–0.5 MPa), 15 (–0.7 MPa), 20 (–1.0 MPa), 25 (–1.3 MPa), 30 (–1.5 MPa) and 35 dSm^{-1} (–1.8 MPa)] (Model WTW Cond. 314i, Germany). Distilled water used as a control in both experiments. Three replications of 20 seeds of each Petri dish® were germinated in two layered Whatman@qualitative filter paper, Grade 1 with 10 ml of respective test solutions in glass Petri dishes (100 × 10 mm) with respective concentrations of PEG and NaCl in separate experiments to induce drought and salt stress. The seeds were germinated at 22 ± 1 °C (Fallah–Toosi and Baki, 2013) in the dark for 10 days. Rate of germination was measured on daily basis. The filter papers and the Petri dishes in the experiment were replaced after every 2 days to prevent error and over accumulation of both PEG and NaCl. The percentage of germination was measured every day until no increase in count was was noted (ISTA, 1996). The seeds were counted germinated when ~2mm radicle emerged (Huang and Redmann, 1995). These seedlings from each replicate were measured at the end of tenth day of standard germination test and were evaluated for germination speed, mean germination time, final germination percentage, germination index, root length, shoot length, root/shoot ratio, root length reduction, shoot length reduction, and seedling fresh weight. The seedling dry weights were measured by drying the samples in an oven at at 70 °C for 48 h (Böhm, 1979) (Table 1).

Table 1. The names, and descriptions of measurement for *Brassica juncea*

Name	Abbreviation	Description of Measurement
Germination speed	GS	GS = $n_1/d_1+n_2/d_2+n_3/d_3+$ ...... nn/dn (Panuccio et al., 2014) n= count of the germinated seed; d= count of the days
Final germination percentage	FGP	FGP–%: (number of normal seedling/number of seedling)×100 (Kandil et al., 2012)
Mean germination time	MGT	MGT–day= $n_1 \times d_1 + n_2 \times d_2 + n_3 \times d_3 +$ ...... /Total number of days (Ellis et al., 1980) n= count of the germinated seed; d= count of the days
Germination index	GI	GI–%= (germination percentage in each treatment/germination percentage in the control) × 100 (Panuccio et al., 2014)
Root length	RL	was measured with a scale (in cm)
Shoot length	SL	was measured with a scale (in cm)
Root shoot ratio	R/S	was expressed as the percentage of the shoot length to root length
Root length reduction	RLR	root length in control treatment − root length under the influence of stress
Shoot length reduction	SLR	shoot length in control treatment − shoot length under the the influence of stress
Seedling fresh weight	SFW	was recorded in g using a sensitive balance
Seedling dry weight	SDW	was measured in mg with a sensitive balance soon after drying

Statistical analysis

Completely Randomized Design with three replications was used. Correlation analysis among treatments was done for both seed germination and growth parameters separately for PEG 6000 and NaCl treatments (p<0.05; p<0.01) using MINITAB.

Result and Discussion

PEG Treatments

Correlation coefficients among germination and seedling parameters of brown mustard under PEG 6000 treatments is detected in Table 2. Significant and positive correlation of final germination percentage was determined with germination speed (0.995). Significant and negative correlation of mean germination time was noted with germination speed (–0.981) and final germination time (–0.993). Similarly, germination index expressed positive and significant correlation with germination speed (r = 0.995) and final germination percentage (r = 1) and significant and negative correlation with mean germination time (–0.992). Root length expressed positive and significant correlation with germination speed (r = 0.973), final germination percentage (r = 0.984) and germination index (0.985) and significant and negative correlation with mean germination time (–0.966). Taking into account shoot length expressed significant and positive correlation with germination speed (r = 0.977), final germination percentage (r = 0.988), germination index (0.989) and root length (0.999) whereas parameter mean germination time (–0.972) was showed significant and negative correlation. Root shoot ratio expressed significant and positive correlation with germination speed (r = 0.879), final germination percentage (r = 0.92), germination index (0.92), root length (0.944) and shoot length (0.946); significant and negative correlation with mean germination time (0.932). Root length reduction expressed significant and negative correlation with germination speed (r = –0.973), final germination percentage (r = –0.984), germination index (–0.984), root length (–1), shoot length (–0.999) and root shoot ratio (r = –0.942) while root length reduction demonstrated significant and positive correlation with mean germination time (0.964). Shoot length reduction indicated significant and negative correlation with germination speed (r = –0.978), final germination percentage (r = –0.989), germination index (–0.989), root length (–1), shoot length (–1) and root shoot ratio (r = –0.944) whereas shoot length reduction showed significant and positive correlation with mean germination time (0.973) and root length reduction (0.999). Seedling fresh weight expressed significant and positive correlation with root length (0.919) and shoot length (0.906); significant and negative correlation with root length reduction (–0.921) and shoot length reduction (–0.907). Rest of the parameters showed non–significant correlation. Seedling dry weight possessed significant and positive correlation with germination speed (r = 0.957), final germination percentage (r = 0.978), germination index (0.978), root length (0.991), shoot length (0.993), root shoot ratio (r = 0.972) and seedling fresh weight (0.879). In other respects positive and significant correlation with mean germination time (–0.97), root length reduction (–0.99) and shoot length reduction (–0.992). These obtained results agreed with those obtained by Rauf et al., (2007) who finded a positive and significant correlation between germination rate, root length and shoot length but a negative and non significant and correlation between germination rate and root/shoot length ratio in 16 wheat varieties under PEG 6000 stress. And similar conclusions were displayed by Hellal et al. (2018) for barley genotypes under PEG 6000 stress, the correlation analysis expressed that root/shoot length were the correlated parameters. Wheat, root length, fresh weight, dry weight had positive and significant correlation among themselves under the influence of stress and under controlled conditions long–lived and not comprehensively possible with all the parameters studied while shoot length showed a non–significant correlation (Ahmed et al., 2019). In barley, root control options, but drought fresh weight and long and short time and germination percentage and fresh varieties are mandatory (Thabet et al., 2018).

NaCl Treatments

It is evident from Table 3 all the 11 parameters were significantly associated with germination and seedling parameters of brown mustard under NaCl treatments. Significant and positive correlation of final germination percentage was determined with germination speed (0.959). Significant and negative correlation of mean germination time was noted with germination speed (–0.967) and final germination time (–0.897). Similarly, germination index showed positive correlation with germination speed (r = 0.959) and final germination percentage (r = 1); significant and negative correlation with mean germination time (–0.898). Root length indicated significant and positive correlation with germination speed (r = 0.966), final germination percentage (r = 0.911) and germination index (0.912) whereas root length showed significant and negative correlation with mean germination time (–0.921). Shoot length expressed significant and positive correlation with germination speed (r = 0.976), final germination percentage (r = 0.956), germination index (0.956) and root length (0.988) while shoot length demonstrated significant and negative correlation with mean germination time (–0.914). Root shoot ratio expressed significant and positive correlation with germination speed (r = 0.892), root length (0.936) and shoot length (0.877); significant and negative correlation with mean germination time (0.903). Final germination percentage and germination index showed non–significant correlation. Root length reduction possessed significant and negative correlation with germination speed (r = –0.968), final germination percentage (r = –0.912), germination index (–0.912), root length (–1), shoot length (–0.988) and root shoot ratio (r = –0.938); significant and positive correlation with mean germination time (0.923). Shoot length reduction expressed significant and negative correlation with germination speed (r = –0.975), final germination percentage (r = –0.964), germination index (–0.964), root length (–0.981), shoot length (–0.999) and root shoot ratio (r = –0.859); significant and positive correlation with mean germination time (0.913) and root length reduction (0.981). Seedling fresh weight noted significant and positive correlation with germination speed (r = 0.983), final germination percentage (r = 0.944), germination index (0.944), root length (0.995), shoot length (0.997), root shoot ratio (r = 0.912); significant and negative correlation with mean germination time (–0.933), root length reduction (–0.996) and shoot length reduction (–0.993). Seedling dry weight showed significant and positive correlation with germination speed (r = 0.986), final germination percentage (r = 0.96), germination index (0.961), root length (0.987), shoot length (0.998), root shoot ratio (r = 0.885) and seedling fresh weight (0.997). Contrarily, negative and positive correlations with parameters mean germination time (–0.935), root length reduction (–0.987) and shoot length reduction (–0.998). Bae et al. (2006) detected a negative correlation between germination and salinity, root and shoot length and also significant positive correlation to germination percentage and root and shoot length germination and early pak–choi, amaranth, cabbage, and sugar beet seedling (p=0.01).

Under both salinity and drought stress, the significant positive association among germination and seedling growth parameters may lead to rapid and high improvement during selection because of correlated response as improvement in on characters may bring improvement in other character. These characters have also been identified as major direct contributors in germination and seedling growth parameters (Maurya et al., 2019).

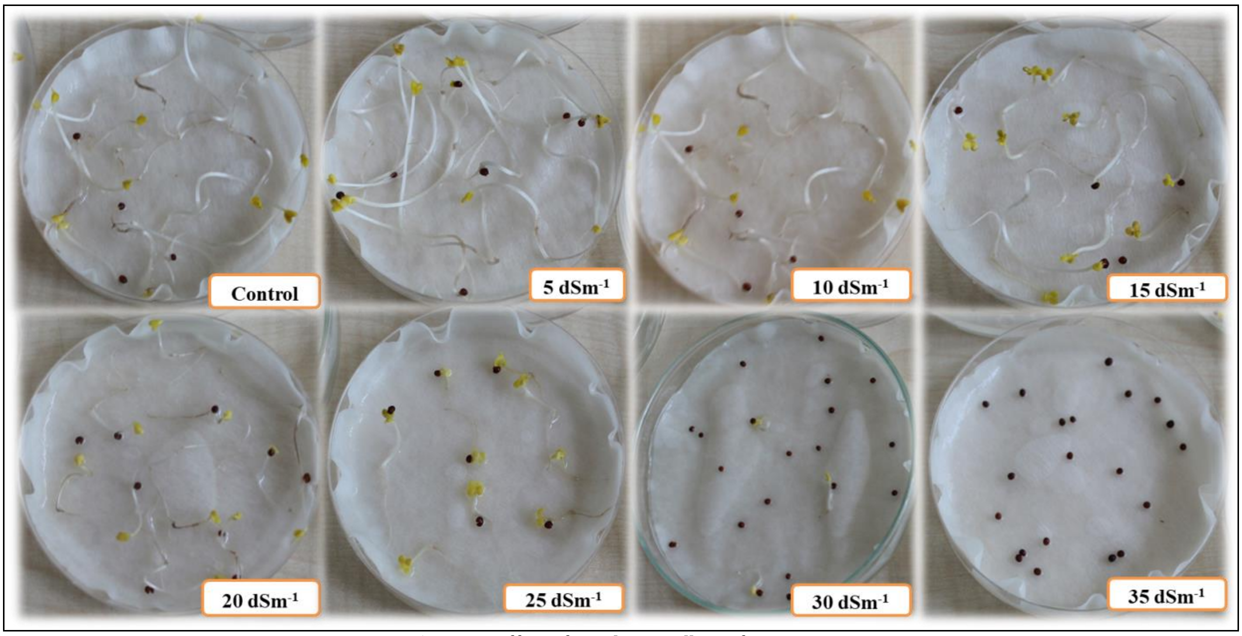

Figure 1. Effect of NaCl on seedling of *B. Juncea*

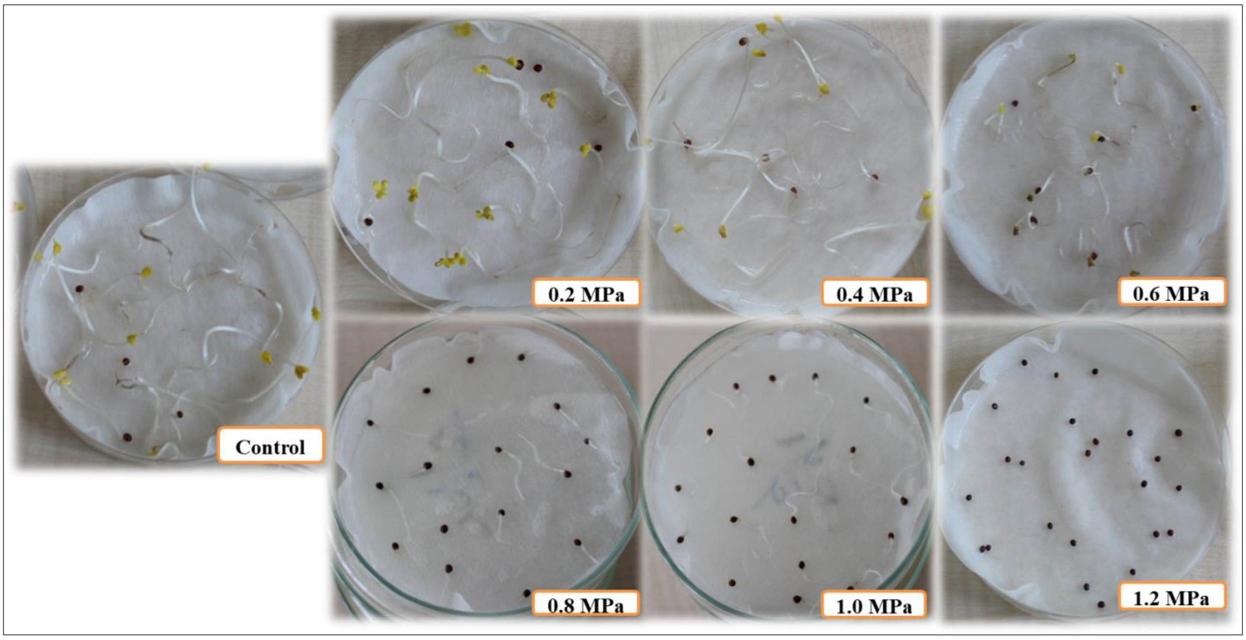

Figure 2. Effect of PEG 6000 on seedling of *B. juncea*

Table 2. Correlation coefficients among germination and seedling growth parameters observed in PEG 6000 treatments of *B. juncea*

	GS	FGP (%)	MGT (day)	GI (%)	RL (cm)	SL (cm)	R/S	RLR (%)	SLR (%)	SFW (mg)	SDW (mg)
GS	1	0.995**	–0.981**	0.995**	0.973**	0.977**	0.879*	–0.973**	–0.978**	0.838	0.957*
FGP (%)		1	–0.993**	1**	0.984**	0.988**	0.92*	–0.984**	–0.989**	0.843	0.978**
MGT (day)			1	–0.992**	–0.966**	–0.972**	–0.932*	0.964**	0.973**	–0.788	–0.97**
GI (%)				1	0.985**	0.989**	0.92*	–0.984**	–0.989**	0.845	0.978**
RL (cm)					1	0.999**	0.944*	–1**	–1**	0.919*	0.991**
SL (cm)						1	0.946*	–0.999**	–1**	0.906*	0.993**
R/S							1	–0.942*	–0.944*	0.825	0.972**
RLR (%)								1	0.999**	–0.921*	–0.99**
SLR (%)									1	–0.907*	–0.992**
SFW (mg)										1	0.879*
SDW (mg)											1

** $p<0.01$; * $p<0.05$

Table 3. Correlation coefficients among germination and seedling growth parameters observed in NaCl treatments of *B. juncea*

	GS	FGP (%)	MGT (day)	GI (%)	RL (cm)	SL (cm)	R/S	RLR (%)	SLR (%)	SFW (mg)	SDW (mg)
GS	1	0.959**	–0.967**	0.959**	0.966**	0.976**	0.892**	–0.968**	–0.975**	0.983**	0.986**
FGP (%)		1	–0.897**	1**	0.911**	0.956**	0.747	–0.912**	–0.964**	0.944**	0.96**
MGT (day)			1	–0.898**	–0.921**	–0.914**	–0.903**	0.923**	0.913**	–0.933**	–0.935**
GI (%)				1	0.912**	0.956**	0.747	–0.912**	–0.964**	0.944**	0.961**
RL (cm)					1	0.988**	0.936**	–1**	–0.981**	0.995**	0.987**
SL (cm)						1	0.877**	–0.988**	–0.999**	0.997**	0.998**
R/S							1	–0.938**	–0.859*	0.912**	0.885**
RLR (%)								1	0.981**	–0.996**	–0.987**
SLR (%)									1	–0.993**	–0.998**
SFW (mg)										1	0.997**
SDW (mg)											1

** $p<0.01$; * $p<0.05$

Conclusion

Correlation analyses showed that most of germination and seedling characters of *B. juncea* under salinity and drought stress and non stress conditions were significant and negatively or positively associated among themselves screening for these desired characters could be beneficial in breeding studies. Higher of values of above parameters, better is the seed quality. Generally mean germination time showed significant and negative association with studied characteristics. Negative and positive strong relationship among the parameters under the influence of drought and salinity condition showing the importance of these parameters for use in future breeding and plant improvement studies.

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Statement of Conflict of Interest

The author(s) declare no conflict of interest for this study.

Author's Contributions

The contribution of the authors is equal

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