Chemistry Research Journal, 2020, 5(5):105-116

Available online www.chemrj.org

Research Article

ISSN: 2455-8990
CODEN(USA): CRJHA5

Effect of NaCl salinity on germination of *Trigonella foenum-graecum*

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Abstract Salinization is increasing on a global scale, and tolerance to salinity during germination is critical for the establishment of plants and growing in saline soil. Seed was investigated. Laboratory experiment with completely randomized design comprising three replicates in Petri dishes was conducted. In each petri-dish fifty seeds were placed. to determine the salt effects on A laboratory experiment was carried out to assess the germination and early seedling growth response to salinity stress of, which are common medicinal species in Libya. Seeds of fenugreek (Trigonella foenum-graecum L.) were treated with various concentrations of NaCl (0, 50, 100, 150,200 and 300 mM L1). control was moistened with ten milliliters of distilled water. The salt stress decreased seed germination the response of *Trigonella foenum-graecum* to salt stress and water stress was evaluated at the germination stage. The severe reduction in germination percentage and particularly germination speed with prolonged lag period by moderate salinity level of 100 mM NaCl, suggests that Fenugreek is a salt-sensitive species during germination. Salinity reduced germination uniformity and germination synchrony and might delay start of germination but accelerates its termination with a consequent shortening of the time spread of germination. The recovery percentage was lower but speed of recovery was higher compared with the corresponding parameters of non-treated seeds. Recovery percentage was slightly improved with the increase in the level of salinity pretreatment.

Keywords Trigonella foenum-graecum, germination, salinity stress, sodium chloride (NaCl)

Introduction

The interest in using herbs to treat illness has grown considerably worldwide due to the fact that many herbal medications are free of side effects. Medicinal plants belong to the essential crop category used in conventional disease prevention and treatment [1]. Salinity is one of the major limiting factors for seed germination, plant growth and development, as well as the quantity and quality of plant production in arid and semi-arid regions. Germination of the eastern species is reduced and delayed with an increase in salinity, and plant reactions can differ greatly depending on the species [2]. The concentration of salts in surface soils is greater than that of the subsoil, and seeds may have a more intense environment compared to established the plant [2]. The high rate of salt accumulation due to high cell growth rates is one of the main reasons for vulnerability to salt stress during the germination stage [3]. Germination and seedling establishment are therefore the essential stages of plant life history [4]. The mechanism by which a plant tolerates salt is complex, and it varies between species [5-6]. Salt has osmotic effects on seed germination [3]. Osmotic stress can inhibit water absorption, which is essential for enzyme activation, breakdown and translocation of seed reserves [5], In addition, ionic stress can inhibit essential metabolic steps in cell division and expansion, and can be toxic at high concentrations [5]. Fenugreek is an erect, strongly scented annual herb that

is widely grown as a food crop in India, the Mediterranean region, North Africa and Yemen. Indigenous people use both the leaves and seeds of this plant to treat diabetes mellitus, Fenugreek leaves are widely consumed in India as a green, leafy vegetable and are a rich source of vegetables and are a rich source of calcium, iron, B-carotene, and vitamin K [7]. This medicinal herbs has been extensively used in traditional medicine and sometimes cultivated in arid and semiarid regions with salinity problem [8-9]. The seeds are used for various dishes as a flavoring agent and a seasoning agent is also used. The sprouted seeds are used as salads while the fresh stems and leaves are used for pakodas and lentil curry [10-11]. Fenugreek seeds are used in baking bread in Egypt and Ethiopia, while in Switzerland they are used as a flavoring agent in cheese making [10-12], Fenugreek has been used for centuries in European countries as a spice [10-11].. Its use in the USA was, however, very recent and is primarily used as a spice for soups and stews,the young plants and the leaves are a very valuable vegetable source and have been used in different cuisines [10-11]. Information about the level of plant salt tolerance is needed as an aid in selecting species most likely to succeed cultivation in salt affected areas. This study was initiated to determine the effect of a range of salinity levels on germination and early seedling growth of some common medicinal plant's species in the arid and semiarid regions of Libya.

Materials and Methods

Germination conditions

This experiment aimed to characterize the range of salinity tolerated by Trigonella foenum-graecum at the germination stage. Seeds, selected for homogeneity, were germinated at 25 ^{o}C in the dark in 12-cm Petri dishes lined with filter paper moistened with five levels of NaCl: 0, 50, 100, 200 and 300 mM prepared in distilled water; 50 seeds per dish and four dishes per treatment. At intervals seeds and emerging seedlings were transferred under dim light to new dishes lined with filter papers, saturated with the experimental solutions to prevent buildup of salt. Germination was monitored daily for 6 days from sowing and seeds were considered germinating when the radical was emerged to a length of 2 mm. After approaching steady germination percentage in the test solutions, the non-germinated seeds were transferred from the high salt solutions to distilled water to monitor recovery of germination from salt stress, and the number of seeds germinating after transfer was counted daily for 6 days.

Definitions, calculations and statistical analysis

Final cumulative germination percentage and final percentage recovery of germination from salinity stress were arcsine transformed before performing statistical analysis to ensure homogeneity of variance. Data were analyzed using SPSS version 22. The effect of temperature on seed germination in the first experiment and the effect of salinity on plant growth and composition in the fourth experiment were assessed by using one-way ANOVA. The effects of main factors: osmoticum, nutrients and water potential and their interaction in the second experiment and of nutrients and salinity and their interaction on seed germination in the third experiment were assessed using three-way and two-way ANOVA respectively. Mean separation was performed using the Duncan's multiple range test at $p < 0.05$.

According to Rahimi et al. [13] the germination parameters estimated in this work were grouped into five categories - taking into account the different notations and expressions in the literature. These are the germinability or final germination percentage, rate or speed, times, uniformity and synchrony of germination.

Germinability or germination capacityit is the final cumulative germination percentage and was calculated as the total number of germinates at the end of germination period as a percentage of the total number of seeds.

Rate or speed of germination was estimated by using several calculations as follows:

Mean daily germination (MDG) or Daily germination speed (DGS) was calculated as:

$$MDG = \frac{\text{cumulative germination \% at time ti}}{\text{ti}}. \qquad (\% \, d^{-1})$$

The cumulative germination % is the number of germinant as a percentage of the total number of seeds.

Peak value (PV) is the maximum MDG, or the maximum quotient derived by dividing daily the accumulated number of germinants by the corresponding number of days; i.e., the mean daily germination of the most vigorous component of a seed lot.

Germination value (GV), also called the Czabator index of germination velocity, was calculated as:

$$GV = PV \times \text{final MDG} \qquad (\% \, d^{-1})$$

Timson index of germination velocity was calculated as:

$$\text{Timson index} = \frac{\sum G_i}{T} = \frac{G_1 + G_2 + G_3 + \cdots\ldots\ldots + G_n}{T} \quad (\% \, d^{-1})$$

Where G_1, G_2, G_3, G_i and G_n are the cumulative number of germinants at the first, second, third, i^{th} and final time respectively and T is the total germination period; that is to sum the cumulative germination % for certain intervals and divide by the final germination period.

Speed of accumulated germination (SAG) was calculated as:

$$SAG = \Sigma\frac{G_i}{t_i} = \frac{G_1}{t_1} + \frac{G_2}{t_2} + \frac{G_3}{t_3} + \ldots\ldots\ldots + \frac{G_n}{t_n} (\% \, d^{-1})$$

Germination rate index (GRI), also called speed of germination was calculated as:

$$GRI = \Sigma\frac{g_i}{t_i} = \frac{g_1}{t_1} + \frac{g_2}{t_2} + \frac{g_3}{t_3} + \ldots\ldots\ldots + \frac{g_n}{t_n} \qquad (\% \, d^{-1})$$

$$= \frac{G_1}{t_1} + \frac{(G_2 - G_1)}{t_2} + \frac{(G_3 - G_2)}{t_3} + \ldots\ldots\ldots + \frac{(G_n - G_{(n-1)})}{t_n}$$

The germination index (GI), also called the "germination rate" is a measure of both percentage and speed of germination and assigns maximum arithmetic weight to embryos or seeds that germinate first and less weight to those that germinate later. $GI = \Sigma g_i \times (T\text{-}j)$

Where g_i is the daily germination percentage or number of newly germinated seeds at time t_i, T is the total period of germination and j = i-1; that is $GI = \Sigma g_i \times (T\text{-}i+1)$

$$= g_1 \times T + g_2 \times (T-1) + G_3 \times (T-2) + \ldots\ldots + g_n \times 1 \qquad (\%.d)$$

The coefficient of germination (CG), also called the coefficient of velocity of germination (CVG), or Kotowski coefficient of germination was calculated using the following formula:

$$CVG = \frac{100 \times \Sigma g_i}{\Sigma (g_i \times t_i)} (d^{-1})$$

Where g_i is the number of newly germinates at times t_i.

It is the reciprocal of MGT multiplied by 100 = (1/MGT) ×100

This coefficient, which is the reciprocal of the mean germination time, was used to calculate the mean germination rate or $\bar{v}$, which in turn was used to calculate the weighted mean germination rate ($\bar{\bar{V}}$)

$$\bar{V} = \frac{CVG}{100} = \frac{1}{\bar{t}} \quad (d^{-1})$$

Weighted mean germination rate (WMGR or $\bar{\bar{V}}$) was calculated using the mean germination rate ($\bar{V}$) of each replicate and its variance (S^2_V) as follows:

$$\bar{\bar{V}} = \frac{\Sigma (W_j \times \bar{V}_j)}{\Sigma W_j} (d^{-1})$$

where $W_j = \frac{n_j}{S^2_j}$ $\quad S^2_j = (\bar{V})^4 \times S^2_t$ and $\quad n_j = \sum g_i$

Mean germination time (MGT or $\bar{t}$), also called mean emergence time (MET) or mean length of incubation time (MLIT) or mean days for germination (Mdays), is a measure of the average length of time required for maximum germination of a seed lot. It is one of the measures of time of germination and can be employed also as an inverse measure of speed of germination, and was calculated according to the following equation:

$$MGT = \frac{\sum g_i \times t_i}{\sum g_i} = \frac{\sum g_i \times t_i}{N} \quad (d)$$

Where g_i is the number of seeds newly germinated, or the daily germination percentage at time t_i from sowing, not the cumulative germination %, and N is the total number of germinants or the final cumulative germination percentage.

The variance of germination time (S^2_t) was calculated according to the following formula:

$$S^2_t = \frac{\sum g_i (t_i - \bar{t})^2}{\sum g_i - 1} (d^2)$$

S^2_t was used in the calculation of the coefficient of variation of germination time (CV_t); one of the measures of germination uniformity.

Germination times:

The first day of germination (FDG) is the time of first germination or the time of germination of the faster or most vigorous seeds.

The last day of germination (LDG) is the time of last germination or the time of germination of the slower or the least vigorous seeds.

Time spread of germination (TSG) is the time elapsing between FDG and LDG and was calculated as: TSG = (LDG - FDG) + 1

Mean germination time (MGT or $\bar{t}$), was mentioned above among the indices of rate of germination.

T_{10}or time to 10% germination is a measure of the lag period between imbibition and onset of germination.

Uniformity of germination:

The coefficient of uniformity of germination (CUG) measures the variability among seeds in relation to the mean germination time of the sample and was calculated as:

$$CUG = \frac{\Sigma g_i}{\Sigma (\bar{t} - t_i)^2 \times g_i} \quad (d^{-2})$$

Where g_i is the number of newly germinated seeds on time $t_i$from sowing and $\bar{t}$ is the mean germination time. High values would be associated with concentrated germination in time.

The coefficient of variation of the germination time (CV_t) is another measure of the germination uniformity or variability in relation to the mean germination time and was calculated as:

$$CV_t = \frac{(S_t) \times 100}{\bar{t}} \quad \%$$

Where S_t is the standard deviation of the germination time and $\bar{t}$ the mean germination time.

Synchrony of germination was estimated using the synchronization index ($\bar{E}$), calculated as:

$$\bar{E} = - \Sigma f_i \times \log_2 f_i \quad \text{(bit)} \qquad \text{and} \quad f_i = \frac{g_i}{\Sigma g_i}$$

where f_i is the relative frequency of germination and g_i the number of seeds germinated on day i. Low values of $\bar{E}$ indicate more synchronized germination.

The recovery from salinity stress was calculated using the following formula of Khan and Ungar (1984) [14]:

$$\text{Percent recovery} = \frac{(a-b) \times 100}{(c-b)}$$

where a is the total number of seeds germinated after being transferred to distilled water, b is the total number of seeds germinated in saline solution and c is the total number of seeds. In other words, the recovery percentage is the number of newly germinated seeds after transfer to water (a-b) as a percentage of the number of seeds transferred (those non-germinated in the saline solution (c-b).

The threshold and critical salinity levels for a specific process (germination index or embryonic growth) are defined as those levels leading to 5% and 50% reductions respectively.

Results

Salt response of Fenugreek during germination

This experiment aimed to specify the range of NaCl salinity tolerated by Fenugreek during germination and to characterize the effect of salinity stress on germination parameters of this species. A wide range of salinity has been examined in this experiment (0-300 mM NaCl). Time course of germination revealed progressive reduction in magnitude and speed, with prolonged lag of germination with the increase in salinity level from 0 to 200 mM NaCl (Figure 1). The FGP was reduced from 97% in non-salinized seeds to 2% in seeds treated with 300 mM NaCl and further to absolute cessation of germination at 300 mM NaCl. Similarly, speed of germination was sharply reduced under the impact of salinity. The speed of germination, in terms of GV and Timson index was sharply reduced from

571 and 89.9% d^{-1}, respectively in non-salinized seeds to 13.7 and 10.7 % d^{-1}, respectively in seeds treated with 200 mM NaCl (Table 1).

Uniformity and synchrony of germination exhibited a threshold of 50 mM NaCl, beyond which germination uniformity was sharply increased (CVt lowered by from 20.7% at 0 mM NaCl to14.1% at 300 mM NaCl) and germination synchrony was substantially increased ($\bar{E}$ lowered from 1.07 bit at 0 mM NaCl to 0.09 bit at 300 mM NaCl) (Table 1).

The first day of germination was High-significantly affected by increasing salinity up to 100 mM NaCl, but it was doubled as salinity level further increased to 150 mM NaCl. LDG was slightly increased (by 10%) with the increase in salinity from 0 to 200 mM NaCl, was non-significantly affected by increasing salinity from300 mM NaCl. TSG was non-significantly affected by increasing salinity from 0 to 50 mM NaCl but was doubled as salinity level further increased to 150 mM NaCl was reduced from in non-salinized in seeds treated with 300 mM NaCl.T10 was almost doubled with the increase in salinity from 0 to 100 mM NaCl, with substantial prolongation (germination percentage never attained 10%) with the increase in salinity from 150 to 300 mM NaCl (Table 1) (Figure 2).

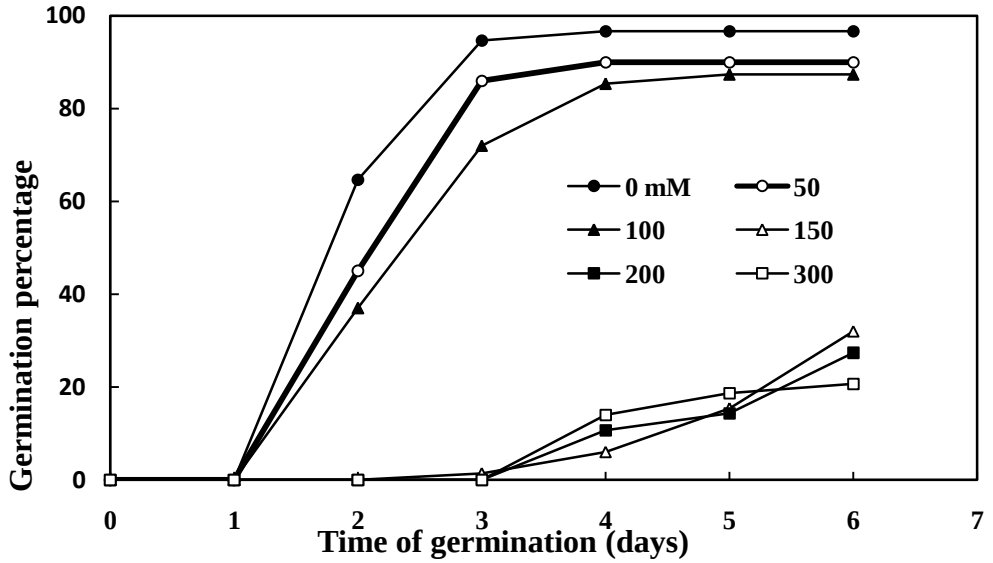

Figure 1: *Time course of germination of Fenugreek seeds under the impact of increasing levels of NaCl salinity. Each value is the mean of 3 replicates*

Table 1: Germination parameters of Fenugreek seeds under the impact of increasing levels of NaCl salinity. Each value is the mean of three replicates ± SE.

Parameter	**mM NaCl**					
	0	**50**	**100**	**150**	**200**	**300**
Germinability (%)	96.7±1.33^{a}	90.0±3.06^{ab}	76.7±6.36^{c}	45.0±4.62^{d}	27.3±1.76^{e}	20.7±1.76^{ef}
Timson index (%d^{-1})	89.9±1.19^{a}	76.0 ± 2.43^{b}	49.3±6.62^{c}	10.9±0.74^{d}	10.5±1.94^{d}	10.7±1.54^{d}
T_{10} (day)*	1.20	1.30	1.50	4.80	4.00	4.60
CV_t (%)	20.7±1.58^{ab}	21.0±2.17^{a}	21.4±3.22^{a}	18.0±4.84^{abc}	16.9±2.67^{abcd}	14.1±2.62^{abcde}
E (bit)	1.07±0.11^{abc}	1.60±0.08^{def}	1.50±0.24^{abde}	1.24±0.20^{abcd}	1.03±0.16^{ab}	0.09±0.27^{a}
FDG (day)	2.00±0.00^{a}	2.00±0.00^{a}	2.66±0.33^{ab}	4.00±0.58^{c}	4.00±0.00^{c}	4.00±0.00^{c}
LDG (day)	3.00±1.00^{a}	4.00±1.00^{ab}	5.66±0.33^{c}	6.00±0.00^{cd}	6.00±0.00^{cd}	5.66±0.33^{c}
TSG (day)	2.00±1.00^{a}	3.00±1.00^{ab}	4.00±0.58^{bc}	3.00±0.58^{ab}	3.00±0.00^{ab}	2.66±0.33^{a}

Means followed by the same letter are non-significantly different at $P \leq 0.05$.

*T_{10} was calculated using the mean germination percentages of the time course of germination curves; therefore, they are not followed by SE.

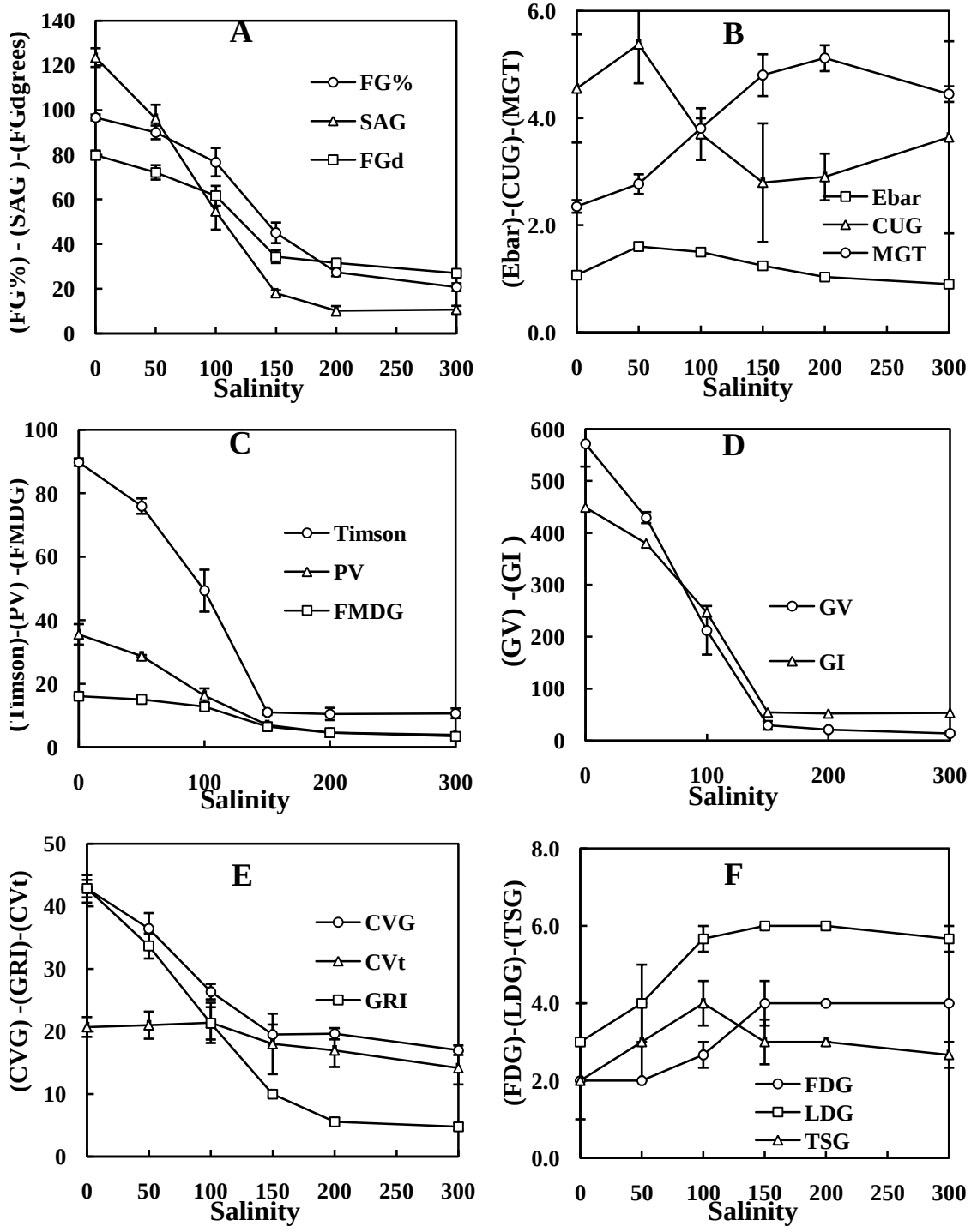

Figure 2: Germination parameters of Trigonella foenum-graecum seeds under the impact of increasing levels of NaCl salinity. Each value is the mean of three replicates ± SE.

A. Final germination percentage, CVG, Final germination degrees. FGd
B. Ebar. CUG, Mean germination time MGT.
C. Timson, index), Peak value , Final mean daily germination FMDG
D. Germination value GV, GI E. CVG, GRI, CVt. F. FDG, LDG, TSG.

Germination recovery from salt stress

Seeds of *Trigonella foenum-graecum*, non-germinated in saline solutions, exhibited instantaneous recovery upon release of salt stress, with lower magnitude but shorter lag period and faster speed compared with the native (non-treated) seeds (Figure 3). Final recovery percentage was non-significantly increased with the increase in salinity pre-treatment from 100 to 300 mM NaCl. Nevertheless, the speed of recovery, in terms of GV was progressively reduced by 46% upon increasing salinity pre-treatment from 100 to 200 mM NaCl, with no further reduction at 300 mM NaCl. The reduction in Timson index amounted to only 13% as salinity pretreatment exceeded a threshold of 100 mM NaCl up to 200 mM NaCl with no further change at 300 mM NaCl (Table 2).

Uniformity of recovery increased (CVt increased by 41%) as salinity pretreatment exceeded a threshold of 100 mM NaCl up to 300 mM NaCl. On the other hand, synchrony of recovery was reduced ($\overline{E}$ increased by 26%) upon increasing salinity pretreatment from 100 to 150 mM NaCl, with no further change at higher salinity pretreatment. Increasing salinity pretreatment from 100 to 300 mM doubled FDG without effect on LDG; consequently, TSG was maintained at 4 days across the range of salinity pretreatment from 100 to 200 mM NaCl but was shortened to 4 days (11% decrease) upon further increase in salinity pretreatment up to 300 mM NaCl (Table 2). (Figure 4).

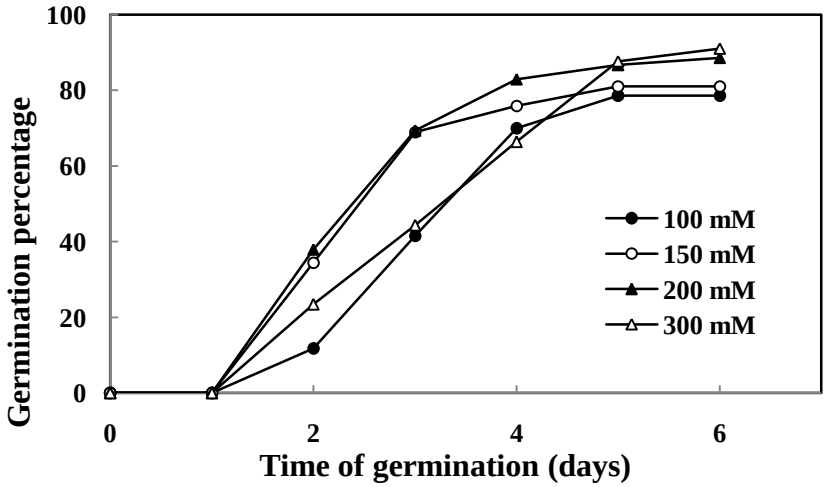

Figure 3: Time course of germination recovery from salt stress of Fenugreek seeds. Seeds were incubated with 100-300 mM NaCl for 6 days and non-germinated seeds were transferred to distilled water to monitor recovery from salt stress for a period of 6 days

Table 2: Parameters of germination recovery from salt stress of Fenugreek seeds. Seeds were incubated with 50-300 mM NaCl for 6 days and non-germinated seeds were transferred to distilled water to assess recovery from salt stress. Each value is the mean of four replicates ± SE

Parameter	**mM NaCl pretreatment**			
	100	**150**	**200**	**300**
Recovery %	78.7 ± 6.01^{a}	84.0 ± 2.89^{b}	88.3 ± 1.45^{bc}	91.0 ± 1.15^{bcd}
Timson index (% d^{-1})	25.5 ± 2.90^{a}	31.1 ± 1.47^{abc}	33.2 ± 1.62^{bcd}	28.4 ± 1.50^{ab}
T_{10} (d)*	1.80	1.20	1.60	1.40
CV_t (%)	21.7 ± 5.37^{a}	30.2 ± 2.51^{ab}	32.4 ± 2.87^{abc}	33.1 ± 1.30^{bcd}
E (bit)	1.45 ± 0.21^{a}	1.59 ± 0.09^{b}	1.69 ± 0.13^{bc}	2.09 ± 0.04^{cd}
FDG (day)	2.67 ± 0.33^{a}	2.00 ± 0.00^{b}	2.00 ± 0.0^{b}	2.00 ± 0.0^{b}
LDG (day)	4.67 ± 0.33^{ab}	3.67 ± 1.33^{a}	5.67 ± 0.33^{abc}	5.67 ± 0.33^{abc}
TSG (day)	3.00 ± 0.58^{a}	2.67 ± 1.33^{ab}	4.67 ± 0.33^{abc}	4.67 ± 0.33^{abc}

Means followed by the same letter are non-significantly different at $P \leq 0.05$.

*T_{10} was calculated using the mean germination percentages of the time course of germination curves; therefore, they are not followed by SE.

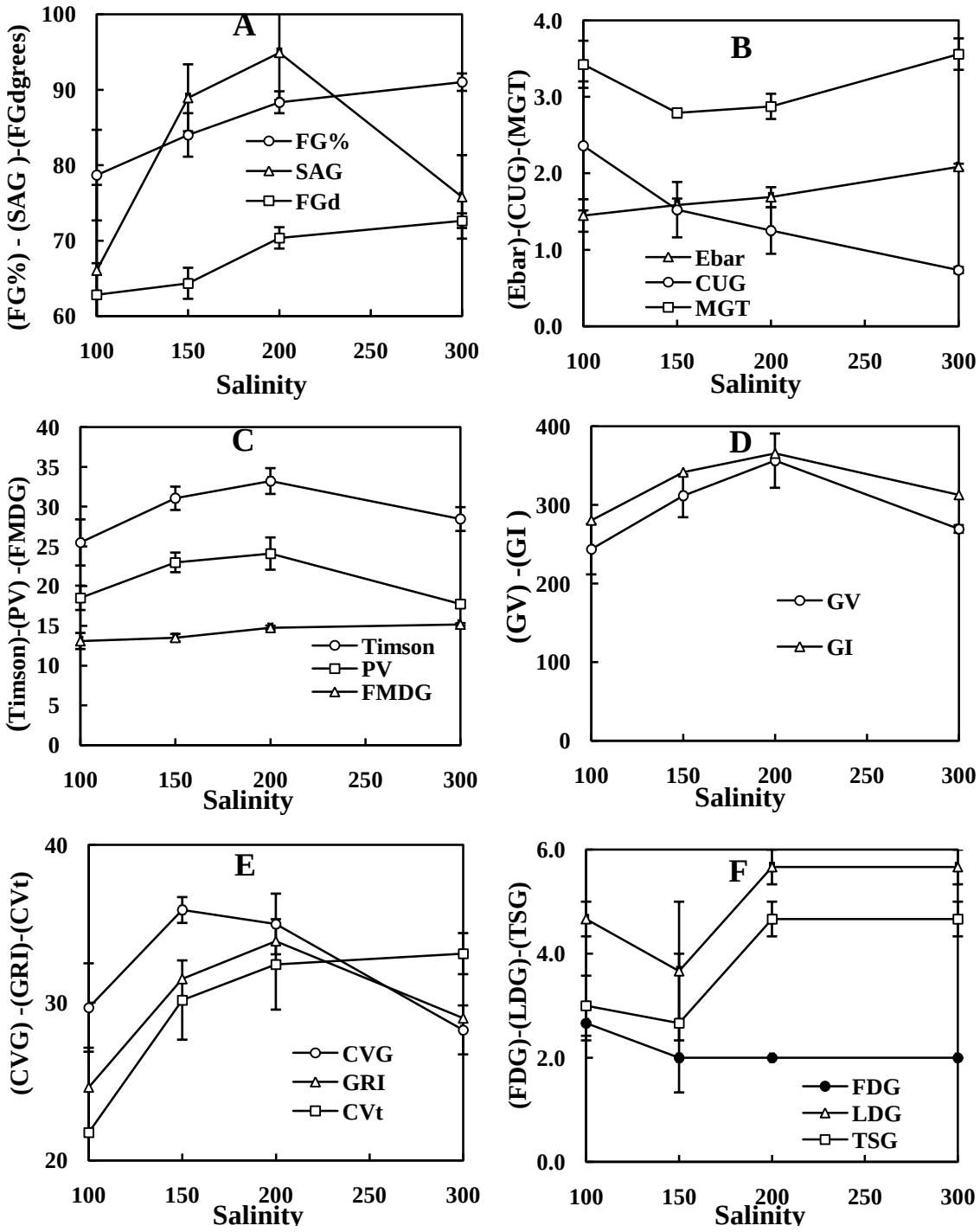

Figure 4: Parameters of germination recovery from salt stress of Fenugreekseeds. Seeds were incubated with 100-300 mM NaCl for 6 days and non-germinated seeds were transferred to distilled water to assess recovery from salt stress. Each value is the mean of four replicates ± SE.

E. Final germination percentage , CVG , Final germination degrees. FGd

F. Ebar. CUG, Mean germination time MGT.

G. Timson, index), Peak value , Final mean daily germination FMDG
H. Germination value GV, GI I.CVG, GRI, CVt. J. FDG, LDG, TSG.

Discussion

Effect of NaCl salinity on germination of Fenugreek

Salinity is one of the major factors limiting seed germination, plant growth and development as well as the quantity and quality of plant production in arid and semi-arid regions. Germination of most species is reduced and delayed with a salinity increase, and plant responses may vary greatly depending on species [2].

A range of salt-tolerant plant species can be considered to make profitable use of saline water and soil resources rather than neglecting these resources. The tolerant plant species, with an inherent ability to grow in high-salt conditions without a significant growth reduction, could be recommended for cultivation in salt-affected areas. Utilization of salt-tolerant plant species would help farmers to maintain regional production and local markets in salinized regions, where only poor-quality water for crop production is available. However, they varied in the degree of salt tolerance as salinity increased. The moderate salt tolerance of the fenugreek and dill at germination stage, is consistent with previous research [15-16]. However, in contrast to our result, Khalesro, et al. (2015) [17] reported that the savory and dragonhead are sensitive to salt stress during the germination stage. It has been reported that the degree of salt tolerance varies among plant species, and even for a given species [18-19]. When the seeds were transferred to distilled water after 20 days exposure to NaCl solutions, the recovery of germination enerally increased with an increase in pre-transfer salinity, as was observed in previous studies [3].

The concentration of salts in surface soils are more than that of the subsoil, and seeds may experience a more extreme environment compared to the established plant [2]. The high salt accumulation rate due to high rates of cell growth is one of the main reasons for sensitivity of the germination stage to salt stress [3]. Thus, germination and seedling establishment are the critical stages in the life history of plants [4]. The mechanism by which a plant tolerates salt is complex and it differs from species [5-6]. This is in agreement with the behavior of Viciafaba [20-21]. The results conclusion of germination speed represents a more reliable measure of salt injury during germination than does the magnitude of germination.

The reduced germination efficiency, expressed as reduced percentage and speed of germination, under the impact of salinity stress was associated with substantial lag of germination (increased T_{10}) and reduced germination uniformity (increased CV_t) and germination synchrony (increased $\bar{E}$). However, whereas germination percentage increased in proportion with the increase in germination speed in almost a linear pattern, the increases in CV_t and $\bar{E}$ (i.e. the reductions in germination uniformity and germination synchrony, respectively) approached a limit beyond germination speed of 23% day^{-1}. The effect of salinity on uniformity and synchrony of germination seems to be species specific and dose-dependent; leading either to non-significant changes e.g. in soybean [22]. and *Physalis peruviana* [23] or to reduction e.g. in *Moringa oleifera* [24] and *Senna spectabilis* [25] In *Elymus farctus*, moderate salinity led to limited lowering in germination uniformity, which was followed by sharp increase at high salinity, and this was accompanied with increased germination synchrony at high salinity [26].

The changes in times of germination of Fenugreek under salt stress suggest that salinity might delay start of germination but accelerates its termination with a consequent shortening of the time spread of germination. Similar response has been reported in *Elymus farctus*, particularly in absence of nutrients [26]. However, increasing salinity might delay both the onset and termination of germination, e.g. in wheat [27] and rice [28].

The lower recovery percentage, which was associated with higher speed of recovery compared with the corresponding parameters of non-treated seeds, along with the limited improvement in recovery percentage with the increase in the level of salinity pretreatment might refer to a toxic ion effect of the low salinity levels on seed viability but a priming effect of high salinity, probably via an osmotic effect. However, the recovery response to salt stress was affected by plant species, it was reported that seeds of some plant species exposed to salinities that inhibit germination will recover and germinate after they are transferred to distilled water [3]. The inhibition of germination under high salinity and then initiation of germination, when salt concentration decrease below the critical level, is

well known as a criterion of salt tolerance which distinguishes halophytes from glycophytes [29]. Inability of species to recovery could be either due to the death of the seeds or the induction of dormancy by salt stress [30].

In addition, these results suggest that salinity might exert a toxic effect on a portion of the seed population but the surviving portion will be kept ready to recover at higher speed and lower uniformity relative to their non-treated counterparts. The toxic ion effect on seed germination is expected at low salt levels, where the salt ions can diffuse into the seed and damage the embryo but the priming osmotic effect is expected at high salt levelsThe ability of seeds to exclude toxic Na+ from the developing embryo was critical for salt tolerance in Suaeda salsa, which is a medicinal halophyte [31].

Generally, restoration of germination efficiency after release of salt stress points to an osmotic effect, but low recovery means specific ion toxicity. Othman et al. (2006) [32] reported reduced germination recovery upon prolonged duration of seed soaking in saline medium which was related to uptake of Na+ and release of K+ from seeds under salt stress. The specific toxic effect of salt ions is likely to emerge in glycophytes whereas the osmotic effect is more likely in halophytes and salt-resistant species. Seeds of halophytes, due to their unique metabolic machinery, usually recover completely when salt stress is released indicating an osmotic effect [33-34]. On the other hand, the high recovery of seeds from abiotic stress compared with the original germinability means a priming effect of the stress pretreatment, which can be manipulated to enhance seed germination and plant growth, especially in poor quality seeds or under stressful environments [35]. In addition, the present finding suggests, that salinity pretreatment seems to enhance start of recovery upon release of stress, with marginal effect on its termination and consequent prolongation in the TSG during recovery.

Concisions

In conclusion, n summary, the results indicate that some genotypes of Trigonella foenum-graecum can tolerate high salinity at germination stage. The severe reduction in germination of Fenugreek, with prolonged lag period, by 100 mM NaCl, suggests that Fenugreek is salt-sensitive during germination. Salinity might delay start of germination but accelerates its termination with a consequent shortening of the time spread of germination. Removal of salt stress led to prompt recovery of non-germinated seeds, with higher speed and brief lag period, but lower final recovery percentage compared with non-treated seeds.

Acknowledgments

The author is grateful to Botany Department, Faculty of Science, Zintan University, Zintan City, Libya, and University, Zawia City, Faculty of Natural Resources Engineering.

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