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Research Article

Evaluation of Salinity Tolerance of Some Egyptian Faba Bean Varieties During the Germination Stage

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Abstract

A germination laboratory experiment was conducted at Cell Research Department, FCRI, ARC to study the effect of different salinity levels 0, 1000, 3000, 5000, 7000, and 9000 mg L^{-1} NaCl on twelve faba bean varieties that were arranged in a CRBD in three replications. Results of ANOVA showed that the effect of variety, salt concentration, and their interactions were significant (LSD at the level of $p < 0.05$) for the different germination parameters i.e. germination rate index (GRI), germination index (GI), germination velocity (GV), the last day of germination (LDG), the first day of germination (FDG), final germination % (FG%), time spread of germination (TSG), as well as, the relative salt damage rate (RSDR). The increase in salinity level led to a decrease in germination percentage in all varieties. Giza- 40 and Misr-1 varieties were the highest salinity tolerant varieties according to the RSDR% estimation. Increasing salinity concentration in up to 9000 NaCl mg L^{-1} retard germination percentage of Wadi-1, Sakha-1, and Sakha-3 varieties (0, 6.67, and 6.67 %, respectively), while Misr-1 and Nubaria-5 varieties were able to germinate under relatively high NaCl concentration (9000 mg L^{-1}), their germination percentage recorded 80 and 66.67 %, respectively. According to the RSDR values, results suggested that faba bean varieties Misr-1 and Giza-40 could be recommended to grow under salt-affected soil, as those faba bean varieties were highly tolerant to salinity stress. In contrast, Sakha-1 variety is salt susceptible.

Keywords: Vicia faba L; abiotic stress; germination parameters

Introduction

Legumes (Leguminosae) are the third largest family of dicotyledons. Faba bean (Vicia faba L.) belongs to the Fabaceae family and has many public names. Legumes come second only to cereals in their importance to human beings (Graham and Vance [1]). Faba bean is the most important legumes crop cultivated in Egypt due to the affluence of seed protein content. Moreover, it is used for both human consumption and animal feed. The importance of faba bean in Egypt lies not only in its multiple uses in preparing diverse local dishes but also in its importance in crop rotation due to fixing atmospheric nitrogen that enriches the soil with nitrogen and organic matter and improving the water use efficiency of the cropping system (Pala et al., [2]). Several environmental factors adversely affect plant growth and development and the final yield performance of a crop. Drought and salinity, are among the major environmental constraints to crop productivity worldwide. Salinity is one of the most important environmental factors that severely affects crop production worldwide (Kumar et al., [3], El -Menshawi et al., [4], Keshta et al., [5], Ashraf and Foolad, 2013; Morsi et al., [6], Abdrabou et al., [7], Dobeie et al., [8], Ismael et al., [9,10], Azzam et al., [11,12] Abbas et al., [13]).

Seed germination is usually the most critical factor determining the success or failure of plant establishment. Initial species establishment in saline habitats depends on their seed germination response to thermal and saline regimes and it is the level of this response that usually determines whether a population can persist until reproductive maturity or not (Kader and Julzi, [14]). Germination is one of the most critical periods for a crop faced salinity stress. Germination failures on saline soils are often the result of high salt concentrations in the seed planting zone because of upward movement of soil solution and subsequent evaporation

at the soil surface (Bernstein, [15]) and were negatively correlated by salinity stresses (Zhu [16]). Furthermore, screening for legumes that can grow and provide economic yield under saline conditions has a dual ecological benefit: (i) less nitrogen fertilization needed; (ii) ability to grow in a saline environment would reduce the effects of the saline irrigation water. Legumes are either salt susceptible or moderately salt tolerant. Vicia faba is moderately tolerant to salinity (Al–Tahir and Al–Abdulsalam, [17]). The weakened germination of seeds under salt stress might lead to uneven plant cover and a reduction in crop yield. Nevertheless, the salt response during germination can be manipulated as a reliable rapid test for the salt response of the plant. Generally, assessment of plant response to salinity is based on two parameters: the threshold, and the critical salinity levels. A large genetic variability has been recognized in V. faba in terms of seed size and composition in addition to tolerance to numerous biotic and abiotic stresses (Duc et al., [18]; Khoufi et al., [19]). More research is therefore needed to characterize the traits of different V. faba cultivars related to environmental adaptation and stress tolerance. Therefore, this study was conducted to explore the role of genotypic variability among twelve Egyptian V. faba cultivars concerning salt tolerance at the germination stage, as well as, to select the most salt-tolerant verities and the most susceptible ones.

Material and Methods

This study was carried out in the laboratories of Cell Research Department, Field Crops Research Institute, ARC. The combination between twelve faba bean varieties and six saltwater concentrations was arranged in a complete randomized block design in three replications. Table 1 shows the pedigree of the faba bean verities that were kindly obtained from Legume Crops Research Department, FCRI, ARC. Water salinity levels were 1000, 3000, 5000, 7000, and 9000 mg L^{-1} NaCl in addition to control treatment, i.e. distilled water.

Ten seeds of each faba bean variety were germinated in 15 cm Petri plates above Whatman filter paper with 10 ml of NaCl solution for each concentration and repeated 3 times. The plates were arranged at random in an incubator at 25±1°C for 14 days under a 16/8 hr's light/dark photoperiodic regime (1000-Lux), till both the plumule and the radical were extended to more than 2 mm length. After 14 days, the germination percentage was calculated to estimate the salinity tolerance of each variety. Germination was determined using the international rules of seed testing (ISTA [20]). The germination indices correlated to seed vigor were evaluated such as:

Table 1: Faba bean varieties names, origins, Pedigree, and seed size categories.

Parent	Origin	Pedigree	Seed Size
Nubaria-1	Spain	Individual plant selection from Spanish variety (Rena Blanka)	Major
Nubaria-3	Egypt	Selection in Ahnasiaz	Equina
Nubaria-4	Egypt	Selected from landrace Hammam-3	Equina
Nubaria-5	Egypt	Selected from landrace Hammam-10	Equina
Sakha-1	Egypt	Giza-716 X 620/283/85	Equina
Sakha-3	Egypt	Promising line 716/402/2001 derived from cross 716 (Giza-461/842/83 x 503/453/83)	Equina
Sakha-4	Egypt	Sakha-1 x Giza-3	Equina
Misr-1	Egypt	Single cross (Giza-3 × A123/45/76)	Equina
Giza-40	Egypt	Individual Plant Selection from Repaya-40	Minor
Giza-716	Egypt	461 \ 842 \ 83 × 503 \ 453 \ 83	Equina
Giza-843	Egypt	561/2076/85 Sakha x461/845/83	Equina
Wadi-1	Egypt	Rena Blanka x Triple white	Equina

- The First Day of Germination (day) (FDG): FDG=Day on which the first germination event occurred, according to Kader et al. [21].

-The Last Day of Germination (day) (LDG): LDG=Day on which the last germination event occurred, according to Kader et al. [21].

- Germination velocity (GV): percentage of seeds sprouted at the first count, 7 days after incubation, and was considered as an indicator for germination speed (Maguire, 1962).

-Time Spread of Germination (day) (TSG): The time in days between the first, and last germination events occurring in a seed lot, according to Kader et al. [22].

- Final Germination percent (%) (FG%): percentage of the normal seedling at the final day of counting (14 days after incubation) according to Scott et al. [23].

-Germination rate index (%/day) (GRI)): The GRI reflects the percentage of germination on each day of the germination period. According to Esechi (1994) after modification as follow:

$$GRI=G1/1 + G2/2 +\cdots+ Gx/x$$

G1=Germination percentage × 100 on the first day after sowing,

G2=Germination percentage × 100 on the second day after sowing

- **Germination index (GI):** In the GI, the maximum value is specified to the seeds germinated on the first day, and less to those germinated afterward. The lowest value would be for seeds germinated on the 10th day. Consequently, the GI underlines both the germination % and its speed. A higher GI value represents a higher percentage, and rate of germination. According to Bench et al. [24].

GI= (10×n1) + (9×n2) +· · · + (1×n10)

n1, n2 . . . n10 = No. of germinated seeds on the first, second, and subsequent days until the 10th day; 10, 9 . . ., and 1 are value specified to the number of germinated seeds on the first, second, and subsequent days, respectively.

- **Relative salt damage rate (RSDR%):** Evaluation of the tolerance of seeds to salt during germination was carried out as the protocol described by Chinese Crop Germplasm Resources. The salt tolerance was evaluated by RSDR, which was calculated according to Yang et al. [25] in the following formula

RSDR% = (GRc - GRt)/GRc.

While GRc represents the number of germinated seeds under control condition, and

GRt is the number of germinated seeds under salt treatment.

The salt tolerance can be classified into five rankings based on the RSDR, viz., high tolerance (RSDR < 20%), tolerance (20% ≤ RSDR < 40%), mediate tolerance (40% ≤ RSDR < 60%), sensitive (60% ≤ RSDR < 80%), high sensitive (RSDR ≥ 80%). All Data were exposed to proper statistical analysis of a completely randomized design (CRBD) and were subjected to two-factor of analysis of variance (ANOVA) as published by Gomez and Gomez (1984). The differences between treatment means were compared by LSD at the level of 0.05 by the use of MSTAT-C computer programs (Waller and Duncan, [26].

Results and discussions

The first day of germination (day) FDG

Data show that increasing of NaCl concentration from 0 up to 5000, 7000, and 9000 mg L^{-1} led to a significant increase in the first day of germination overall varieties; it recorded 3.3, 4.2, and, 4.7 days for the above-mentioned concentrations, respectively (Table 2). Lower FDG values indicate a faster initiation of germination Kader [27]). Similar results were reported by Wajid et al. [28] and Abayechaw and Wulchafo [29]. FDG varied significantly when NaCl concentration increased, at 9000 mg L^{-1} concentration. The Increasing salinity concentration in germination media often causes a delay in germination initiation (Abayechaw and Wulchafo, [29]). Giza-843 and Nubaria-5 varieties recorded the highest FDG being 11.0, and 8.33 days, respectively. While at free NaCl concentration, the FDG was after one day of cultivation in Giza-843 variety, as well as, Sakha-4 under 1000, and 3000 mg L^{-1} salt concentration, and Nubaria-4 under 1000 mg L^{-1} NaCl, whereas Nubaria-5 started its germination after 1 day under 3000 mg L^{-1} NaCl concentration. The different response of faba bean varieties to salinity was also reported by many researchers like Al–Tahir and Al–Abdulsalam (1997), who stated that the ability of seed germination of crop under salt stress conditions is an indication of salt tolerance of the crop, at least in the early stage of growth.

Table 2: Effect of six NaCl concentrations (0, 1000, 3000, 5000, 7000, and 9000 mgL-1) and their interaction on the first day of germination (FDG) of 12 faba bean varieties.

Variety	NaCl mg L-1						X`
	Control	1000	3000	5000	7000	9000	
Nubaria-1	5.67	6	5.67	5.67	9.67	6.67	6.56
Nubaria-3	3	3.67	4.33	5	6	7.33	4.89
Nubaria-4	1.33	3.67	4.67	5.67	6	6	4.56
Nubaria-5	2	3.67	3.33	3	7.67	8.33	4.67
Sakha-1	3.33	3.33	5	5.33	7.33	3.67	4.67
Sakha-3	3.33	1	4.67	6.33	6	2.33	3.94
Sakha-4	2.67	4	4	5	6	8	4.94
Misr-1	3.33	1	2.67	3	8.33	6.67	4.17
Giza-40	3	3	2.67	5.67	7	7.33	4.78
Wadi-1	4.67	2.33	3.67	3.33	6	0	3.33
Giza-716	2	2	6	4.33	6.33	2	3.78
Giza-843	7	6	7.67	9.33	10	11	8.5
X`	3.44	3.31	4.53	5.14	7.19	5.78	
LSD at 0.05 level	Genotypes (G) = 1.34		Salt treatment (ST) = 0.95		ST X G = 3.29		

Germination velocity (GV %):

Germination velocity is considered an indicator of germination speed. Our results indicated that GV% significantly and generally decreased with each increase in NaCl concentration above 3000 mg L^{-1} (Table 3). The increase in salinity concentration of media solution above 3000 mg L^{-1} resulted in a marked decrease in germination velocity. The highest reduction of germination speed was recorded at 9000 mg L^{-1} NaCl concentration, as it recorded 8.33 %. Faba bean varieties differed significantly in overall salinity levels. Giza-40 and Sakha-4 varieties were faster in germination than others. They showed the highest value of GV%, which recorded 63.33 and 60.00 %, respectively. While the lowest GV% values were 16.67 and 32.22 % were recorded with Giza-843 and Sakha-1 varieties, respectively. Our results indicated that the reactions of faba bean varieties were significantly differed by increasing NaCl concentrations, but Junior (2018) reported that significant differences were not seen in the interaction effect of salinity and priming on the coefficient of velocity. The GV% varied significantly when NaCl concentration increased under 1000 mg L^{-1} NaCl concentration. Wadi-1 and Giza-40 recorded the highest GV% that equal to 100 and 100 %, respectively, while Sakha-3, Misr-1, and Giza-40 recorded the highest value of GV% under 3000 mg L^{-1} NaCl concentration, it recorded 93.33, 93.33, and 93.33 %, respectively. On the other hand, Nubaria-1, Sakha-1, Wadi-1 and Giza-843 recorded 0 % under 9000 mg L^{-1} NaCl concentration. The Increasing salinity concentration in germination media often causes a delay in germination initiation (Abayechaw and Wulchafo [29]). This means that high levels of NaCl not only decreased germination percentage but also delayed seed germination.

Table 3: Effect of six NaCl concentrations (0, 1000, 3000, 5000, 7000, and 9000 mgL-1) and their interaction on germination velocity (GV%) of 12 faba bean varieties.

Variety	NaCl mg L-1						X`
	Control	1000	3000	5000	7000	9000	
Nubaria-1	53.33	86.67	40	46.67	0	0	37.78
Nubaria-3	60	73.33	66.67	40	26.67	26.67	48.89
Nubaria-4	73.33	86.67	60	40	33.33	6.67	50
Nubaria-5	86.67	60	73.33	80	13.33	6.67	53.33
Sakha-1	60	33.33	33.33	33.33	33.33	0	32.22
Sakha-3	80	86.67	93.33	26.67	20	6.67	52.22
Sakha-4	60	73.33	86.67	73.33	60	6.67	60
Misr-1	70	80	93.33	20	20	26.67	51.67
Giza-40	86.67	100	93.33	66.67	20	13.33	63.33
Wadi-1	60	100	80	60	53.33	0	58.89
Giza-716	80	73.33	46.67	66.67	26.67	6.67	50
Giza-843	46.67	46.67	6.67	0	0	0	16.67
X`	68.06	75	64.44	46.11	25.56	8.33	
LSD at 0.05 level	Genotypes (G) = 14.40		Salt treatment (ST) = 10.18		ST X G = 35.26		

The last day of germination (day) LDG

Data show that increasing NaCl concentration from 0 up to 1000, 3000, and 9000 mg L^{-1} led to a significant decrease of LDG overall varieties; it recorded 10.11, 7.31, 7.92, and 7.25 days for the above-mentioned concentrations, respectively (Table 4). Similar results were reported by Wajid et al. [28] and Abayechaw and Wulchafo [29]). Kader (2005) reported that lower LDG values indicate a faster ending of germination. LDG among the most faba bean varieties overall NaCl concentrations was significant. The varieties differed in their response to salt stress and the effect can easily be observed. The highest value of LDG was recorded with Giza-843, and Nubaria-3, it recorded 10.39, and 9.78 days respectively. While Wadi-1 and Sakha-3 recorded the lowest last day of germination value it recorded 6.50, and 7.06 days respectively. Our results indicated that the reactions of faba bean varieties were significantly differed by increasing NaCl concentrations. The highest last day of germination was recorded 12 days for Nubaria-1 and Nubaria-3 under control condition free of salt, while also, Misr-1 (under 7000 mg L^{-1}) ended their germination after 12 days of cultivation Wadi-1 and Giza-716 terminated their germination after 0, and 2 days, respectively. The different response of faba bean varieties to salinity was also reported by many researchers such as Al–Tahir and Al–Abdulsalam (1997), who stated that the ability of seed germination of crop under salt stress conditions is an indication of salt tolerance of the crop, at least in the early stage of growth.

Table 4: Effect of six NaCl concentrations (0, 1000, 3000, 5000, 7000, and 9000 mg L^{-1}) and their interaction on the last day of germination (LDG) of 12 faba bean varieties.

Variety	NaCl mg L^{-1}						X`
	Control	1000	3000	5000	7000	9000	
Nubaria-1	12	7	9	8	11	7.33	9.06
Nubaria-3	12	7.67	8.67	9.33	10	11	9.78
Nubaria-4	10	6.33	9.33	9	10.67	7.33	8.78
Nubaria-5	10.33	9.33	7	8	8.67	11	9.06
Sakha-1	10	5.67	6.33	8.67	8.33	3.67	7.11
Sakha-3	8	7	7	8.67	9.33	2.33	7.06
Sakha-4	10.33	7	8.33	7.33	10	10	8.83
Misr-1	9.33	7.67	7.67	7	12	10	8.94
Giza-40	8.33	6.33	6.67	9.33	10.67	11	8.72
Wadi-1	11	6	8	4.67	9.33	0	6.5
Giza-716	10	8.67	7	8.33	6.67	2	7.11
Giza-843	10	9	10	11	11	11.33	10.39
X`	10.11	7.31	7.92	8.28	9.81	7.25	
LSD at 0.05 level	Genotypes (G) = 1.60		Salt treatment (ST) = 1.13		ST X G = 3.91		

Time spread of germination (day) TSG

The higher the TSG value, the greater the difference in germination speed between the 'fast' and 'slow' germinating members of a seed lot (Kader, 2005). Means of TSG of faba bean as affected by NaCl concentrations are presented in Table 5. Data show that increasing NaCl concentration from 0 up to 1000, 3000, 5000, 7000, and 9000 mg L^{-1} led to a significant decrease in TSG overall varieties; it recorded 6.70, 4.00, 3.39, 3.14, 2.61, and 1.47 for the above-mentioned concentrations, respectively. Such harmful effect of NaCl salinity may be due to the toxic effect of accumulated ions of this salt on the embryonic activity. Similar results were reported by Ahmad and Sharma [30] and EL-Katony et al. [31]. TSG among the most faba bean varieties (overall NaCl concentrations) was highly significant. The varieties differed in their response to salt stress and the effect can easily be observed. The highest TSG was recorded with Nubaria-3, and Misr-1, it recorded 4.89, and 4.78 days, respectively. While Giza-843 and Sakha-1 recorded the lowest time spread of germination, they recorded 1.89, and 2.44 days, respectively. Our results indicated that the reactions of faba bean varieties were significantly differed by increasing NaCl concentrations. Nubaria-3 and Nubaria-4 recorded the highest time spread of germination, it recorded 9.00, and 9.00 days under the control treatment conditions (Free of NaCl). Meanwhile, Sakha-1, Sakha-3, Wadi-1, and Giza-716 varieties recorded the lowest TSG being 0, 0, 0, and 0 days under the salt concentration of 9000 NaCl mg L^{-1}, respectively. Our results are in harmony with those obtained by EL-Katony et al. [31].

Table 5: Effect of six NaCl concentrations (0, 1000, 3000, 5000, 7000, and 9000 mgL-1) and their interaction on time spread of germination (TSG) of 12 faba bean varieties.

Variety	NaCl mg L-1						X`
	Control	1000	3000	5000	7000	9000	
Nubaria-1	6.33	1	3.33	2.33	1.33	0.67	2.5
Nubaria-3	9	4	4.33	4.33	4	3.67	4.89
Nubaria-4	9	2.67	4.67	3.33	4.67	1.33	4.28
Nubaria-5	8.33	5.67	3.67	5	1	2.67	4.39
Sakha-1	6.67	2.33	1.33	3.33	1	0	2.44
Sakha-3	4.67	6	2.33	2.33	3.33	0	3.11
Sakha-4	7.67	3	4.33	2.33	4	2	3.89
Misr-1	6	6.67	5	4	3.67	3.33	4.78
Giza-40	5.33	3.33	4	3.67	3.67	3.67	3.94
Wadi-1	6.33	3.67	4.33	1.33	3.33	0	3.17
Giza-716	8	6.67	1	4	0.33	0	3.33
Giza-843	3	3	2.33	1.67	1	0.33	1.89
X`	6.69	4	3.39	3.14	2.61	1.47	
LSD at 0.05 level	Genotypes (G) = 1.49		Salt treatment (ST) = 1.05		ST X G = NS		

Final germination % (FG%):

Final germination % only reflects the final percentage of germination attained and provides no picture of the speed or uniformity of germination. The higher the FG% value the greater the germination of a seed population. Means of the FG% of faba bean as affected by NaCl concentrations are presented in Table 6. Data show that increasing of NaCl concentration from 0 up to 1000, 3000, 5000, 7000, and 9000 mg L^{-1} led to a significant decrease in germination percentages overall varieties; it recorded 100, 87.22, 86.11, 76.67, 68.89, and 33.89 % for the above-mentioned concentrations, respectively. Such harmful effect of NaCl salinity may be due to the toxic effect of accumulated ions of this salt on the embryonic activity. Similar results were reported by Ahmad and Sharma [30] and EL-Katony et al. [31]. The FG% among the most faba bean varieties (overall NaCl concentrations) was highly significant. The varieties differed in their response to salt stress and the effect can easily be observed. The highest FG% was recorded with Giza-40, and Misr-1, it recorded 87.78, and 85.56 %, respectively. While Sakha-1 and Giza-716 recorded the lowest final germination percentage, they recorded 50.00, and 61.11 %, respectively.

Table 6: Effect of six NaCl concentrations (0, 1000, 3000, 5000, 7000, and 9000 mgL-1) and their interaction on final germination percent (FG %) of 12 faba bean varieties.

Variety	NaCl mg L^{-1}						X`
	Control	1000	3000	5000	7000	9000	
Nubaria-1	100	100	93.33	93.33	73.33	40	83.33
Nubaria-3	100	80	93.33	86.67	66.67	60	81.11
Nubaria-4	100	86.67	73.33	80	73.33	20	72.22
Nubaria-5	100	80	80	93.33	53.33	66.67	78.89
Sakha-1	100	40	40	60	53.33	6.67	50
Sakha-3	100	93.33	100	73.33	60	6.67	72.22
Sakha-4	100	80	100	80	86.67	40	81.11
Misr-1	100	93.33	100	40	100	80	85.56
Giza-40	100	100	100	100	80	46.67	87.78
Wadi-1	100	100	100	66.67	93.33	0	76.67
Giza-716	100	93.33	53.33	80	33.33	6.67	61.11
Giza-843	100	100	100	66.67	53.33	33.33	75.56
X`	100	87.22	86.11	76.67	68.89	33.89	
LSD at 0.05 level	Genotypes (G) = 11.75		Salt treatment (ST) = 8.31		ST X G = 28.78		

Our results indicated that the reactions of faba bean varieties were significantly differed by increasing NaCl concentrations. The FG% of all varieties was 100 % under the control treatment conditions (Free of NaCl). However, it varied significantly when NaCl concentration increased, at 9000 mg L^{-1} concentration. Wadi-1, Sakha-1, Sakha-3, and Giza-716 varieties recorded the lowest germination percentages being 0.00, 6.67, 6.67, and 6.67 % respectively. Increasing salinity concentration in germination media often causes osmotic and/or specific toxicity that may decrease or retard germination % (Munns and Tester [32]). Misr-1 and Nubaria-5 varieties were able to germinate under relatively high NaCl concentration (9000 mg L^{-1}), their germination percentage recorded 80.00 and 66.67 %, respectively. The different response of faba bean varieties to salinity was also reported by many researchers such as Al–Tahir and Al–Abdulsalam [17] stated also that the ability of seed germination of crop under salt stress conditions is an indication of salt tolerance of the crop, at least in the early stage of growth.

Germination index (GI)

The GI appears to be the most comprehensive measurement parameter combining both germination percentage and speed (spread, duration, and 'high/low' events). It magnifies the variation among seed lots in this regard with an easily compared numerical measurement. In the GI, maximum weight is given to the seeds germinated on the first day and less to those germinated afterward.

The lowest weight would be for seeds germinated on the 10th day. Thus, the GI highlights both the germination% and its speed. A higher GI value signifies a higher percentage and degree of germination Kader [27]. Our results reveal that salinity concentrations significantly affected GI Table 7. Data show that an increase of NaCl concentration from1000 up to 3000, 5000, 7000, and 9000 mg L^{-1} led to a significant decrease in germination percentages overall varieties; it recorded 328.33, 256.56, 181.28, 99.83, and 34.06 for the above-mentioned concentrations, respectively. The highest GI was recorded with Giza-4, and Wadi-1, it recorded 260.00, and 232.44, respectively. While Giza-843 and Sakha-1 recorded the lowest germination index, they recorded 83.44, and 141.22, respectively. Each increase in salinity concentration was associated with a marked decrease in germination index. Our results indicated that the reactions of faba bean varieties were significantly differed by increasing NaCl concentrations. The highest values recorded by Wadi-1, and Giza-716, as it recorded 448.00, and 428.00 (under 1000 mg L-1), while Wadi-1 and Sakha-1 recorded the lowest values, it recorded 0.00, and 2.00 (under 9000 mg L^{-1}), respectively. Similar observations were reported by Mass and Hoffman [33], Puppala et al. [34], and Houle et al. [35]. Seed germination at 9000 mg L^{-1} NaCl and more was substantially delayed. It was quite probable that the delay and reduction in seed germination under these circumstances were equivalently due to osmotic or toxicity effects or a combination of both.

Table 7: Effect of six NaCl concentrations (0, 1000, 3000, 5000, 7000, and 9000 mgL^{-1}) and their interaction on germination index (GI) of 12 faba bean varieties.

Variety	NaCl mg L^{-1}						X`
	Control	1000	3000	5000	7000	9000	
Nubaria-1	188.67	290	190	192.67	32	18	151.89
Nubaria-3	306	294.67	246	192	114	78.67	205.22
Nubaria-4	353.33	318	202.67	180	118	18	198.33
Nubaria-5	402.67	252.67	284.67	314.67	68.67	46	228.22
Sakha-1	270	205.33	126.67	129.33	114	2	141.22
Sakha-3	290.67	419.33	310	131.33	85.33	14	208.44
Sakha-4	294.33	274.67	313.33	228.67	186	44.67	223.61
Misr-1	319.33	429.33	404	88.67	92.67	116	241.67
Giza-40	408	392.67	388	230.67	97.33	43.33	260
Wadi-1	233.33	448	339.33	190	184	0	232.44
Giza-716	422	428	180.67	258.67	80	18.67	231.33
Giza-843	146	187.33	93.33	38.67	26	9.33	83.44
X`	302.86	328.33	256.56	181.28	99.83	34.06	
LSD at 0.05 level	Genotypes (G) = 52.69		Salt treatment (ST) = 37.26		ST X G = 129.06		

Germination rate index (%/day) GRI

GRI calculations simply show the germination% per day, so the higher the percentage and the shorter the duration, the higher the GRI. This parameter lacks any correlation with the 'high' and 'low' germination days as it spreads the percentage evenly across the time spread. The GRI reflects the percentage of germination on each day of the germination period. Higher GRI values specify higher and faster germination (Kader[22]). Means of GRI of faba bean as affected by NaCl concentrations are presented in Table 8. Data show that increasing NaCl concentration from 0 up to 1000, 3000, 5000, 7000, and 9000 mg L^{-1} led to a significant decrease in GRI overall varieties; it recorded 21.69, 25.10, 16.59, 12.30, 8.46, and 3.77 % for the above-mentioned concentrations, respectively. Such harmful effect of NaCl salinity may be due to the toxic effect

of accumulated ions of this salt on the embryonic activity. Similar results were reported by Ahmad and Sharma [30] and EL-Katony et al. [36]. The GRI among the most faba bean varieties (overall NaCl concentrations) was highly significant. The varieties differed in their response to salt stress and the effect can easily be observed. The highest GRI was recorded with Giza-40, and Misr-1, it recorded 19.39, and 18.66 %, respectively. Where as, Giza-843 and Sakha-1 recorded the lowest GRI, 8.67, and 10.34 %, respectively.

Table 8: Effect of six NaCl concentrations (0, 1000, 3000, 5000, 7000, and 9000 mgL^{-1}) and their interaction on germination rate index (GRI %) of 12 faba bean varieties.

Variety	NaCl mg L^{-1}						X`
	Control	1000	3000	5000	7000	9000	
Nubaria-1	14.23	17.29	13.39	13.53	6.91	3.82	11.35
Nubaria-3	26.88	17.71	15.84	13.07	8.9	7.2	14.93
Nubaria-4	27.05	21.84	13.66	12.23	9.55	2.17	14.42
Nubaria-5	24.68	16.16	18.67	20.37	6.37	6.82	15.51
Sakha-1	19.71	17.5	7.41	9.05	7.8	0.61	10.34
Sakha-3	19.8	36.3	18.12	10.03	7.46	0.95	15.44
Sakha-4	20.89	16.19	19.62	13.75	12.69	4.57	14.62
Misr-1	21.8	36.9	25.95	6.22	11.16	9.96	18.66
Giza-40	27.44	35.21	23.83	15.35	9.41	5.08	19.39
Wadi-1	15.79	36.89	20.87	11.4	13.15	0	16.35
Giza-716	29.49	34.76	10.73	15.96	5.12	1.11	16.2
Giza-843	12.42	13.93	10.93	6.6	5.15	3.01	8.67
X`	21.69	25.1	16.59	12.3	8.64	3.77	
LSD at 0.05 level	Genotypes (G) = 4.30		Salt treatment (ST) = 3.04		ST X G = 10.52		

Our results indicated that the reactions of faba bean varieties were significantly differed by increasing NaCl concentrations. The highest GRI was recorded with Misr-1 and Wadi-1, it recorded 36.90 and 36.89, respectively (under 1000 mgL^{-1}). While, Wadi-1 and Sakha-1 varieties recorded the lowest GRI, 0.00 and 0.61 % respectively (under 9000 mgL^{-1}). Increasing salinity concentration in germination media often causes osmotic and/or specific toxicity that may reduce or retard germination percentage (Munns and Tester [32]). The different response of faba bean varieties to salinity was also reported by many researchers such as Al–Tahir and Al–Abdulsalam [17] stated also that the ability of seed germination of crop under salt stress conditions is an indication of salt tolerance of the crop, at least in the early stage of growth.

Relative salt damage rate (RSDR %):

Data show that increasing NaCl concentration from 1000 up to 3000, 5000, 7000, and 9000 mg L^{-1} led to a significant decrease in RSDR% overall varieties; it recorded 12.8, 13.9, 23.3, 31.1, and 66.1 % for the above-mentioned concentrations, respectively. Such harmful effect of NaCl salinity may be due to the toxic effect of accumulated ions of this salt on the embryonic activity Similar results were reported by Ahmad and Sharma [30] and EL-Katony et al. [36-38]. The FG% among the most faba bean varieties (overall NaCl concentrations) was highly significant. The varieties differed in their response to salt stress and the effect can easily be observed in Table 9 and Figure 1. The highest RSDR was recorded with Giza-40, and Misr-1, it recorded 14.7, and 17.3 %, respectively. While Sakha-1 and Giza-716 recorded the lowest RSDR, they recorded 60.0, and 46.7 %, respectively. High tolerant variety (RSDR < 20%), tolerant variety (20% ≤ RSDR < 40%), mediate tolerant variety (40% ≤ RSDR < 60%), susceptible variety (60% ≤ RSDR < 80%), high susceptible variety (RSDR ≥ 80%).

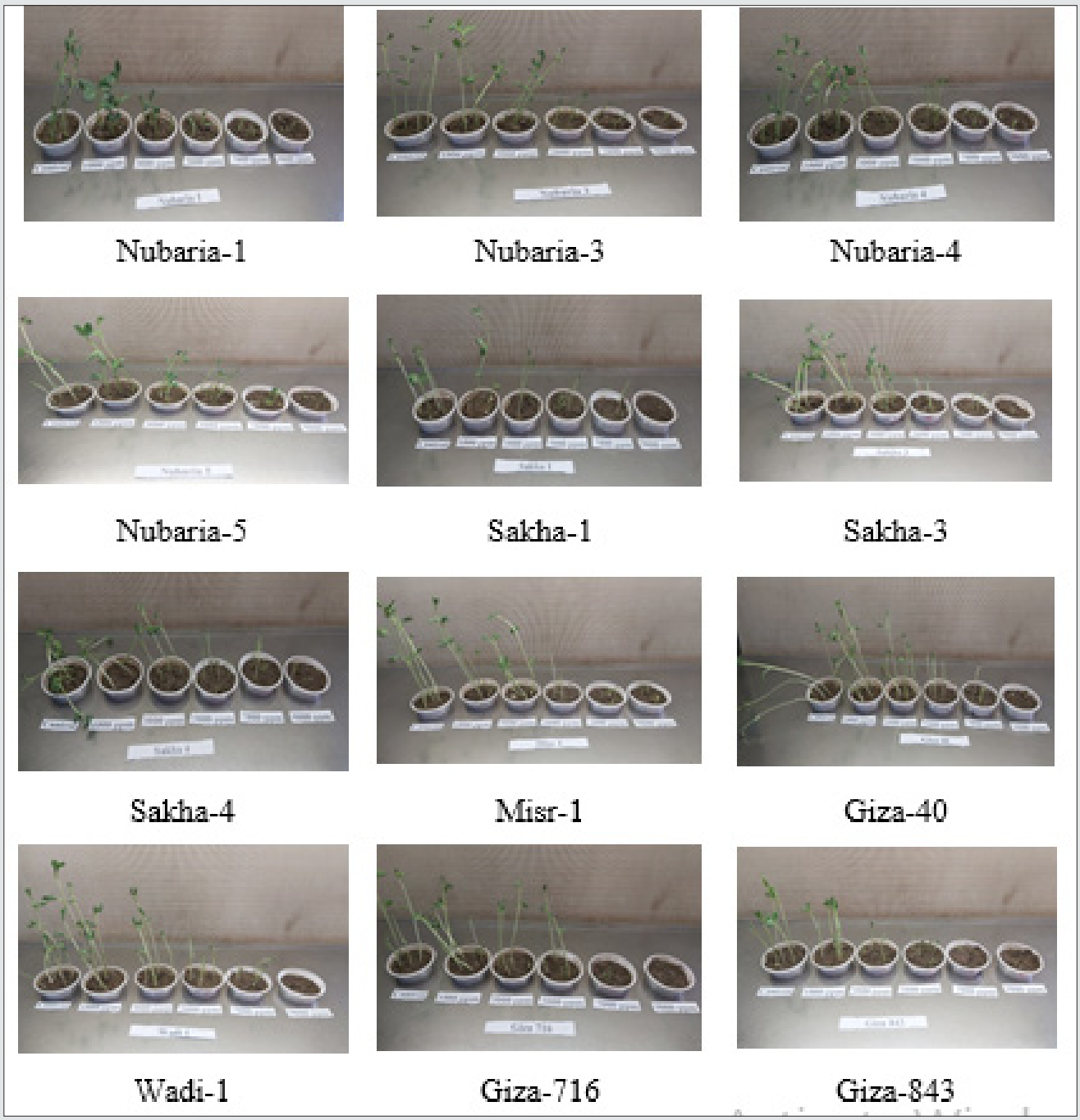

Figure 1: The response of twelve faba bean varieties against six different NaCl concentrations: 0, 1000, 3000, 5000, 7000, and 9000 mgL^{-1} in Lab experiment.

Table 9: Effect of six NaCl concentrations (0, 1000, 3000, 5000, 7000, and 9000 mgL^{-1}) and their interaction on relative salt damage rate (RSDR %) of 12 Faba bean varieties.

Variety	NaCl mg L^{-1}					X`
	1000	3000	5000	7000	9000	
Nubaria-1	0	6.7	6.7	26.7	60	20
Nubaria-3	20	6.7	13.3	33.3	40	22.7
Nubaria-4	13.3	26.7	20	26.7	80	33.3
Nubaria-5	20	20	6.7	46.7	33.3	25.3
Sakha-1	60	60	40	46.7	93.3	60
Sakha-3	6.7	0	26.7	40	93.3	33.3
Sakha-4	20	0	20	13.3	60	22.7
Misr-1	6.7	0	60	0	20	17.3
Giza-40	0	0	0	20	53.3	14.7
Wadi-1	0	0	33.3	6.7	100	28
Giza-716	6.7	46.7	20	66.7	93.3	46.7
Giza-843	0	0	33.3	46.7	66.7	29.3
X`	12.8	13.9	23.3	31.1	66.1	
LSD at 0.05 level	Genotypes (G) = 14.1	Salt treatment (ST) = 9.1		ST X G = 31.6		

Our results indicated that the reactions of faba bean varieties were significantly differed by increasing NaCl concentrations. The RSDR of almost all varieties was about 100% under control. However, it varied significantly when NaCl concentration increased, at 7000 mg L^{-1} concentration. Misr-1 variety recorded the highest RSDR being 0 %. Increasing salinity concentration in germination media often causes osmotic and/or specific toxicity that may reduce or retard germination percentage (Munns and Tester[32]). Our results reveal that there were significant differences among the twelve evaluated faba bean varieties in RSDR. The highest RSDR was observed Giza-40, and Misr-1 varieties have markedly surpassed all varieties, their germination rates were 14.7 % and, 17.3 %, respectively. Meanwhile, Sakha-1 and Giza-716 gave the lowest values in germination rate, it recorded 60.0 %, and 46.7 %, respectively. The interaction between faba bean varieties and NaCl concentrations had a significant effect on the RSDR. Data show that the highest reduction was observed when salinity concentration was increased (9000 mg L^{-1} NaCl). The germination rate of all evaluated faba bean varieties significantly varied in response to salinity concentrations. Wadi-1, Sakha-1, Sakha-3, and Giza-716 have surpassed all other varieties in germination rate under the highest salinity concentration. They recorded 100.0, 93.3, 93.3, and 93.3 %, respectively. Meanwhile, Misr-1 variety was the lowest in this concern. It recorded 0 %. Other interactions were insignificant on germination rate.

Changes % in different growth parameters in 12 faba bean varieties due to salt stress with 6 NaCl concentrations are shown in Table 10. Three color scale heat map, yellow as the midpoint of parameters values compared to control, red for changes above control values, and blue for changes below control values. At all faba bean varieties, the change % increased significantly while increasing salinity levels of NaCl, the lowest values in almost all varieties were noted in 7000 and 9000 mg L^{-1} of NaCl. In general increasing salinity levels led to a significant decreasing in different growth parameters.

Table 10: Changes % in different growth parameters in 12 faba bean varieties due to salt stress with 6 NaCl concentrations. Three color scale heat map, yellow as the midpoint of parameters values compared to control, red for changes above control values, and blue for changes below control values.

varieties	parameter	0 mgL^{-1}	1000 mgL^{-1}	3000 mgL^{-1}	5000 mgL^{-1}	7000 mgL^{-1}	9000 mgL^{-1}	varieties	parameter	0 mgL^{-1}	1000 mgL^{-1}	3000 mgL^{-1}	5000 mgL^{-1}	7000 mgL^{-1}	9000 mgL^{-1}
Nubaria-1	FDG	5.67	5.82	0	0	70.55	17.64	Sakha-4	FDG	2.67	49.81	49.81	87.27	124.72	199.63
Nubaria-1	LDG	12	-41.67	-25	-33.33	-8.33	-38.92	Sakha-4	LDG	10.33	-32.24	-19.36	-29.04	-3.19	-3.19
Nubaria-1	TSG	6.33	-84.2	-47.39	-63.19	-78.99	-89.42	Sakha-4	TSG	7.67	-60.89	-43.55	-69.62	-47.85	-73.92
Nubaria-1	GV	53.33	62.52	-25	-12.49	-100	-100	Sakha-4	GV	60	22.22	44.45	22.22	0	-88.88
Nubaria-1	GI	188.67	53.71	0.7	2.12	-83.04	-90.46	Sakha-4	GI	294.33	-6.68	6.46	-22.31	-36.81	-84.82
Nubaria-1	GRI	14.23	21.5	-5.9	-4.92	-51.44	-73.16	Sakha-4	GRI	20.89	-22.5	-6.08	-34.18	-39.25	-78.12
Nubaria-1	FG%	100	0	-6.67	-6.67	-26.67	-60	Sakha-4	FG%	100	-20	0	-20	-13.33	-60
Nubaria-3	FDG	3	22.33	44.33	66.67	100	144.33	Misr-1	FDG	3.33	-69.97	-19.82	-9.91	150.15	100.3
Nubaria-3	LDG	12	-36.08	-27.75	-22.25	-16.67	-8.33	Misr-1	LDG	9.33	-17.79	-17.79	-24.97	28.62	7.18
Nubaria-3	TSG	9	-55.56	-51.89	-51.89	-55.56	-59.22	Misr-1	TSG	6	11.17	-16.67	-33.33	-38.83	-44.5
Nubaria-3	GV	60	22.22	11.12	-33.33	-55.55	-55.55	Misr-1	GV	70	14.29	33.33	-71.43	-71.43	-61.9
Nubaria-3	GI	306	-3.7	-19.61	-37.25	-62.75	-74.29	Misr-1	GI	319.33	34.45	26.51	-72.23	-70.98	-63.67
Nubaria-3	GRI	26.88	-34.11	-41.07	-51.38	-66.89	-73.21	Misr-1	GRI	21.8	69.27	19.04	-71.47	-48.81	-54.31
Nubaria-3	FG%	100	-20	-6.67	-13.33	-33.33	-40	Misr-1	FG%	100	-6.67	0	-60	0	-20
Nubaria-4	FDG	1.33	175.94	251.13	326.32	351.13	351.13	Giza-40	FDG	3	0	-11	89	133.33	144.33
Nubaria-4	LDG	10	-36.7	-6.7	-10	6.7	-26.7	Giza-40	LDG	8.33	-24.01	-19.93	12	28.09	32.05
Nubaria-4	TSG	9	-70.33	-48.11	-63	-48.11	-85.22	Giza-40	TSG	5.33	-37.52	-24.95	-31.14	-31.14	-31.14
Nubaria-4	GV	73.33	18.19	-18.18	-45.45	-54.55	-90.9	Giza-40	GV	86.67	15.38	7.68	-23.08	-76.92	-84.62
Nubaria-4	GI	353.33	-10	-42.64	-49.06	-66.6	-94.91	Giza-40	GI	408	-3.76	-4.9	-43.46	-76.14	-89.38
Nubaria-4	GRI	27.05	-19.26	-49.5	-54.79	-64.7	-91.98	Giza-40	GRI	27.44	28.32	-13.16	-44.06	-65.71	-81.49
Nubaria-4	FG%	100	-13.33	-26.67	-20	-26.67	-80	Giza-40	FG%	100	0	0	0	-20	-53.33
Nubaria-5	FDG	2	83.5	66.5	50	283.5	316.5	Wadi-1	FDG	4.67	-50.11	-21.41	-28.69	28.48	-100
Nubaria-5	LDG	10.33	-9.68	-32.24	-22.56	-16.07	6.49	Wadi-1	LDG	11	-45.45	-27.27	-57.55	-15.18	-100
Nubaria-5	TSG	8.33	-31.93	-55.94	-39.98	-88	-67.95	Wadi-1	TSG	6.33	-42.02	-31.6	-78.99	-47.39	-100
Nubaria-5	GV	86.67	-30.77	-15.39	-7.7	-84.62	-92.3	Wadi-1	GV	60	66.67	33.33	0	-11.12	-100
Nubaria-5	GI	402.67	-37.25	-29.3	-21.85	-82.95	-88.58	Wadi-1	GI	233.33	92	45.43	-18.57	-21.14	-100
Nubaria-5	GRI	24.68	-34.52	-24.35	-17.46	-74.19	-72.37	Wadi-1	GRI	15.79	133.63	32.17	-27.8	-16.72	-100
Nubaria-5	FG%	100	-20	-20	-6.67	-46.67	-33.33	Wadi-1	FG%	100	0	0	-33.33	-6.67	-100
Sakha-1	FDG	3.33	0	50.15	60.06	120.12	10.21	Giza-716	FDG	2	0	200	116.5	216.5	0
Sakha-1	LDG	10	-43.3	-36.7	-13.3	-16.7	-63.3	Giza-716	LDG	10	-13.3	-30	-16.7	-33.3	-80
Sakha-1	TSG	6.67	-65.07	-80.06	-50.07	-85.01	-100	Giza-716	TSG	8	-16.63	-87.5	-50	-95.88	-100
Sakha-1	GV	60	-44.45	-44.45	-44.45	-44.45	-100	Giza-716	GV	80	-8.34	-41.66	-16.66	-66.66	-91.66
Sakha-1	GI	270	-23.95	-53.09	-52.1	-57.78	-99.26	Giza-716	GI	422	1.42	-57.19	-38.7	-81.04	-95.58
Sakha-1	GRI	19.71	-11.21	-62.4	-54.08	-60.43	-96.91	Giza-716	GRI	29.49	17.87	-63.61	-45.88	-82.64	-96.24
Sakha-1	FG%	100	-60	-60	-40	-46.67	-93.33	Giza-716	FG%	100	-6.67	-46.67	-20	-66.67	-93.33
Sakha-3	FDG	3.33	-69.97	40.24	90.09	80.18	-30.03	Giza-843	FDG	7	-14.29	9.57	33.29	42.86	57.14
Sakha-3	LDG	8	-12.5	-12.5	8.38	16.63	-70.88	Giza-843	LDG	10	-10	0	10	10	13.3
Sakha-3	TSG	4.67	28.48	-50.11	-50.11	-28.69	-100	Giza-843	TSG	3	0	-22.33	-44.33	-66.67	-89
Sakha-3	GV	80	8.34	16.66	-66.66	-75	-91.66	Giza-843	GV	46.67	0	-85.71	-100	-100	-100
Sakha-3	GI	290.67	44.26	6.65	-54.82	-70.64	-95.18	Giza-843	GI	146	28.31	-36.08	-73.51	-82.19	-93.61
Sakha-3	GRI	19.8	83.33	-8.48	-49.34	-62.32	-95.2	Giza-843	GRI	12.42	12.16	-12	-46.86	-58.53	-75.76
Sakha-3	FG%	100	-6.67	0	-26.67	-40	-93.33	Giza-843	FG%	100	0	0	-33.33	-46.67	-66.67

Conclusion

Our findings confirmed that germination percentage, germination velocity, and germination rate, as well as, all other germination parameters were significantly affected by all concentrations of NaCl (1000, 3000, 5000, 7000, and 9000 mgL-1). All studied traits were decreased with increasing salinity concentrations beyond 1000 mg L^{-1} NaCl, with a sharp drop at 7000 mg L^{-1} NaCl concentration and preventing germination of faba bean seeds at the concentration of 9000 mg L^{-1} NaCl. We could conclude that all faba bean varieties were affected significantly by the high salt concentrations. Misr-1 and Giza-40 varieties markedly surpassed all varieties concerning FG%, GI, GRI traits; meanwhile, Giza-40 variety markedly surpassed all varieties concerning germination velocity trait, while, Giza-843 variety markedly surpassed all varieties concerning FDG and LDG. Whereas, Nubaria-3 markedly surpassed all varieties concerning TSG. According to the RSDR values, results suggested that faba bean varieties Misr-1 and Giza-40 could be recommended to grow under salt-affected soil, as those faba bean varieties were highly tolerant to salinity stress. In contrast, Sakha-1 variety is salt susceptible, meanwhile, Giza-716 could be considered as a mediate tolerant variety.

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