International Journal of Traditional and Herbal Medicine

International Journal of Traditional and Herbal Medicine. Vol., 1 (5), 130-135, 2013
Available online at http://www.ijthmjournal.com
ISSN 2345-3249 ©2013 IJTHM

Regression analysis of salinity, hydropriming and their interaction effect on Fennel (*Foeniculum vulgare*) seeds germination

Samaneh Kiani[1], Morteza Eshraghi-Nejad[*1], Mahjoobeh Esmaeilzade-Moridani[2], Mohammad Hossain Gharineh[1]

Ramin University of Agriculture and Natural Resources, Khozestan, Iran.
Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.

Corresponding Author: Morteza Eshraghi-Nejad

Abstract

Fennel (*Foeniculum vulgare*) is an aromatic biennial plant with soft, feathery, almost hair-like foliage. Seed germination is a critical stage in the life of plants. Salinity can effect the germination and seedling growth. Hydropriming are commonly used methods to prime seeds. This study was done as factorial experiment based on completely randomized design with five levels of priming (0, 6, 12, 18, 24 and 30 hours hydropriming) and four levels of salinity (0, 50, 100 and 150 mmol NaCl). there are significant differences among treatments in maximum of germination (Gmax), rate of germination (R50), germination uniformity (GU), root length (RL), shoot length (SL) and seedling length (SEL). Increasing of salinity stress caused to linear decreasing in all traits. Based on segmented model the effect of hydropriming on traits was positive linearly till to "turning point" and after that, its effect was negative; and with increasing of hydropriming time, respective trait was decreased linearly. At salinity=0, germination rate was equaled to a=0.00708 (h^{-1}). With increasing of time of hydropriming to turning point (X0= 6 hours), R50 was increased with slope of b1=0.000388 per unit. The interaction effect of salinity×hydropriming was significant on maximum of germination (Gmax), germination uniformity (GU), root length (RL), and seedling length (SEL). Hydropriming effect on Gmax was significant at salinity level 50 and 100 mmol. Hence regression analysis by segmented model was done at these levels. Based on table 3, Gmax was equaled to 58% at hydropriming =0 (without hydropriming). With increasing hydropriming hours up to the 6 hours (x0), Gmax was increased (87%) with slope of 4.9%, linearly per unit; and after that was decreased with slope -1.5167% (R^2=0.9803). Hydro-priming treatment has no environmental pollution so it is better than two previous methods. The results obtained in this study can be used in the pharmacy, alimentary and sanitary industries.

Keywords: Segmented model; Germination rate; Salinity; Hydropriming; Medicinal plant; Fennel

Introduction

Fennel (*Foeniculum vulgare*) is an aromatic biennial plant with soft, feathery, almost hair-like foliage. It belongs to the Umbelliferae (Apiaceae) family, a medicinal plant used as anti-spasmodic, appetite stimulant, stomachic, diuretic, anti-inflammatory, anti-diarrheic, against colic and as a lactation promoter (Marotti et al., 1993; Piccaglia and Marotti, 1993,).

Seed germination is a critical stage in the life of plants (Yang et al., 2008). Seed germination is probably the most important life stage transition for annual plants in arid and semi-arid climates. Timing of emergence often determines whether a plant competes successfully with its neighbors, is consumed by herbivores, infected

with diseases. The timing of germination plays a critical role in seedling establishment in both natural ecosystems and cropping systems.

Nearly half of the irrigated land and 20% of the world's cultivated land are currently affected by salinity (Zhu, 2001). Salinity is one of the major abiotic stresses which adversely affect the crop growth and yield. According to Epstein *et al.* (1980), salt stress unfavorably affect plant growth and productivity during all developmental stages. Salinity can effect the germination and seedling growth either by creating an osmotic pressure that prevents water uptake of plant roots as well as decrease of germination of plant seeds by ionic toxicity of Na^+ and Cl^- (Almansouri *et al.*, 2001). In order to obtain fast and good establishment of seedling, high vigor seed is needed to provide essential nutrients for seedling until it becomes established and can photosynthesize independently (Bewley and Black, 1994). The vigor of seeds can be improved by techniques generally known as seed priming, which enhance the speed and uniformity of germination (Demir and Van De Venter, 1999).

A wide variety of priming treatment has been used to enhance seed germination. Hydropriming are commonly used methods to prime seeds (McDonald, 2000). Such a seed technology as priming has been developed and used extensively to improve germination and seedling emergence in a wide range of crop species (McDonald, 2000). Hydropriming is the simplest method to hydrate seeds and to minimize the use of chemical materials (McDonald, 2000). Hydropriming consists in soaking seeds in pure (distilled) water and redrying them before complete germination. This procedure is a cheap made because distilled water is just applied. hydropriming provides controlled hydration of seeds to a level that allows pre-germination metabolic activity to proceed, but prevents the actual emergence of the radicle after priming, the seeds can be dried back to the initial moisture content (Bradford, 1986). In hydropriming the metabolic process of germination is stimulated, therefore, the seeds treated before sowing germinate faster than nonprime controls.

It was observed that hydropriming practically ensured rapid and uniform germination accompanied with low abnormal seedling percentage (Singh, 1995; Shivankar et al., 2003). They underline that hydropriming has high potential in improving field emergence and ensures early flowering and harvest under stress conditions especially in dry areas. Hydrated seeds with higher germination percentage under salt stress or micronutrient application increased tolerance of seeds to salt stress. In addition, reported protocol is simple, cheap and does not require expensive chemicals and sophisticated equipment. The protocol has practical importance and could be recommended to farmers to achieve higher germination and uniform emergence under field conditions.

The objective of this study was to explore the effects hydropriming treatments and Determination of the best hydropriming time on germination of fennel seeds under salinity stress.

Materials and Methods

This study was done as factorial experiment based on completely randomized design with four replications at seed laboratory of Agriculture and natural Resources of Ramin University, Ahvaz, Iran, in 2013. Firs factor include five levels of priming (0, 6, 12, 18, 24 and 30 hours hydropriming). After that seeds were subjected with second factor include four levels of salinity (0, 50, 100 and 150 mmol NaCl). After the sterilization of seeds with sodium Hypochlorite (10%), 25 seeds of fennel in individual petri dishes were subjected with salt solution at 20 ºC in germinator. Seeds for 10 days were monitored daily; and each seeds were recorded as a germinated seed, if it had a radicle more than 2 mm. After 10 days, all germinated seeds were measured for shoot, root and seedling length. Maximum of Germination percent (Gmax), shoot length (SL), root length (RL), and Seedling length were measured.

Germination rate (R_{50}, h^{-1}) was calculated as (Soltani et al. 2001):

$$R_{50} = 1/D_{50} \quad (1)$$

Where D_{50} is the estimation of time taken for cumulative germination to reach 50% of maximum where interpolated from the germination progress curve versus time.

Analysis of variance for effects of hydropriming, Salinity and their interactions were done with "glm" procedure in SAS (SAS Institute 1992). In order to post Anova analysis of hydropriming and salinity effects for the traits that the respective interaction effect was not significant, regression analysis was run with "reg" procedure in SAS. This analysis method was done only in salinity levels that the effect of hydropriming was significant for the traits that the respective interaction effect was significant. For regression analysis, segmented model was used. All figures was drawn with excel.

Results and Discussion

As Table 1 indicates, there are significant differences among treatments in maximum of germination (Gmax), rate of germination (R50), germination uniformity (GU), root length (RL), shoot length (SL) and seedling length (SEL). The effect of salinity on all traits was significant (ρ≤0.01). Inhibition of germination due to salinity has been reported earlier in greegram cultivars (Abdul Jaleel et al. 2007). The decreasing germination due to increasing salinity can be correlated to the nature of salinity to reduce imbibition of water due to lowered osmotic potentials of the medium and causes changes in metabolic activity (Yupsanis et al., 1994). Moreover, salinity reduces the utilization of seed reserves (Ahmad and Bano,1992). High levels of NaCl decreased final germination percentages in wheat (Almansouri et al., 2001). Increasing of salinity stress caused to linear decreasing in all traits (Fig 1). At the control level of salinity (salinity = 0 mmol nacl, pure water), R50 was equaled to 0.0145 (h^{-1}); and with increasing of salinity in unit, R50 was decreased as slope of -0.00009 (R^2=0.9355). This slope was greater in RL (-0.0198), namely with increasing of salinity in unit from 0 to 150 mmol NaCl, length of shoot was decreased from 3.2094 Cm to 0 by slope= -0.0198). This result is agreement with El-Farash et al., (1993) who reported that has reported that salinity can affect plant or decrease its growth. Therefore, NaCl in this evaluation is the cause of plumule length decrease.

Table 1. Analysis of variance of salinity, hydropriming and their interaction on maximum of germination (Gmax), rate of germination (R50), germination uniformity (GU), root length (RL), shoot length (SL) and seedling length (SEL).

Source	DF	Means of Errors					
		Gmax	R50	GU	RL	SL	SEL
salinity	3	31308.67**	0.000821**	78192**	34.71208**	42.67549**	151.9271**
hydropriming	5	964.4**	0.0000171*	2428.991**	1.443869**	0.728462^{ns}	4.115664^{ns}
salinity*hydropriming	15	480.4**	0.00000628^{ns}	2228.161**	1.243015**	1.568647^{ns}	5.320386**
Error	72	91.4444	0.000006	974.0765	0.339793	1.113556	2.0337
Total	95						

** and * are significant at ρ≤0.01 and ρ≤0.05, respectively. ^{ns} is none significant at ρ≤0.05.

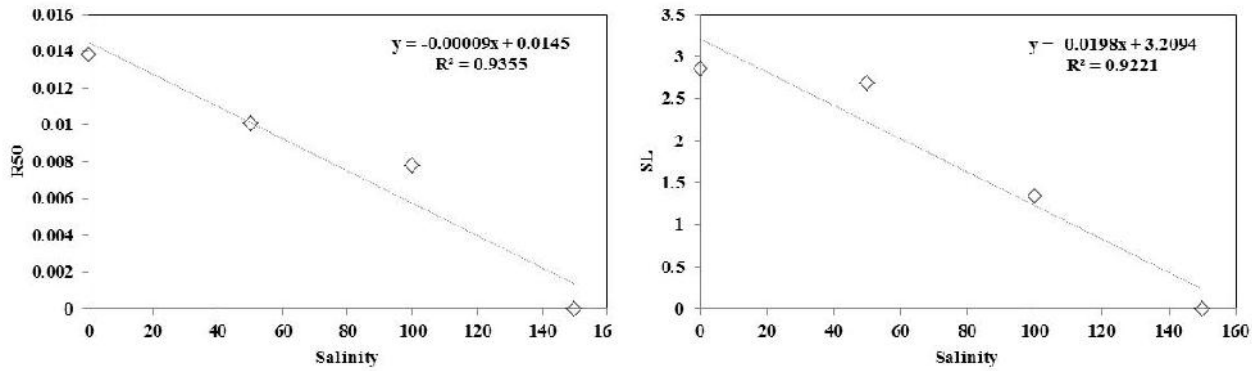

Fig. 1. Negative effect of salinity on germination rate (R50) and shoot length (SL). Salinity has the same effects on other traits, but because of the interaction effect was significant, that results are not discussed.

The results of ANOVA showed that the effect of hydropriming effect was significant on germination (Gmax), rate of germination (R50), germination uniformity (GU), root length (RL). The effect of hydropriming on these traits were not linearly. None-linearly regression model, “segmented” mode, was used to regression analysis. Based on this model the effect of hydropriming on traits was positive linearly till to “turning point” and after that its effect was negative; and with increasing of hydropriming time, respective trait was decreased linearly. Based on fig. 2. And table 2, at salinity=0, germination rate was equaled to a=0.00708 (h^{-1}). With increasing of time of hydropriming to turning point (X0= 6 hours), R50 was increased with slope of b1=0.000388 per unit. After that with increasing of hydropriming time for each hour, R50 was decreased as slope b2= -

0.00011, per unit (R^2= 0.95). Pahoja et al. 2013 reported that hydropriming improved the germination rate under salinity level.

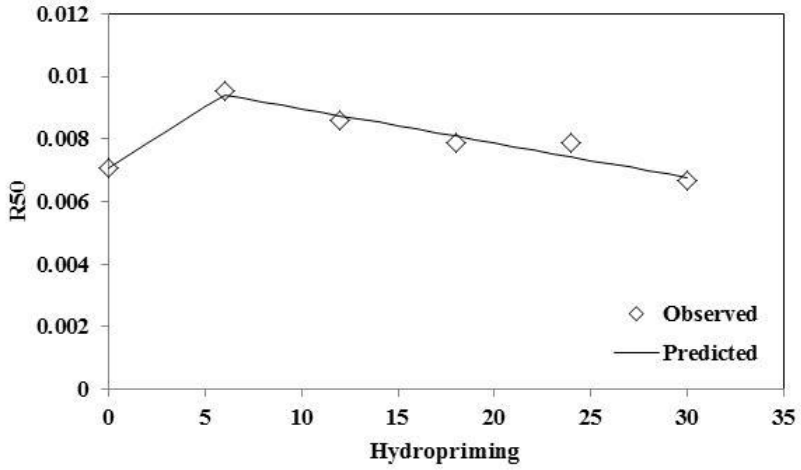

Fig 2. The effect of hydropriming on germination rate (R50). hydropriming has the same effects on other traits, but because of the interaction effect was significant, that results are not discussed.

Table 2. Parameters of regression analysis of hydropriming effect on rate of germination (R50), by segmented model. (Regression analysis was done only on traits that the respective effect of hydropriming was significant and there was not significant interaction effect)

Parameter	R50
Intercept (a)	0.00708±0.000299
Slope 1 (b1)	0.000388±0.000063
Slope 2 (b2)	-0.00011±0.000016
Turning point (x0)	6
R-Square	0.95

The interaction effect of salinity×hydropriming was significant on maximum of germination (Gmax), germination uniformity (GU), root length (RL), and seedling length (SEL) (Table 1). In order to regression analysis of interaction effect, effect of hydropriming was studied at different levels of salinity. Hydropriming effect on Gmax was significant at salinity level 50 and 100 mmol. Hence regression analysis by segmented model was done at these levels. Based on table 3, Gmax was equaled to 58% at hydropriming =0 (without hydropriming). With increasing hydropriming hours up to the 6 hours (x0), Gmax was increased (87%) with slope of 4.9%, linearly per unit; and after that was decreased with slope -1.5167% (R^2=0.9803) (Fig. 3). These trends was there at salinity=100 mmol NaCl with differences. Intercept was a= 9 % at this level of stress. With increasing of hydropriming time till to 8.4242 hours Gmax was increased with slope of b1=5.6667% and after that was decresed with slope of -0.2.5833. It seems that the effect of hydropriming was more than at this level of salinity compare to former. And also turning point of hydropriming positive effect was more than this level salinity. It means that for hydropriming of fennel seeds at higher levels of salinity, time of hydropriming must be higher (almost 8 hours not higher).

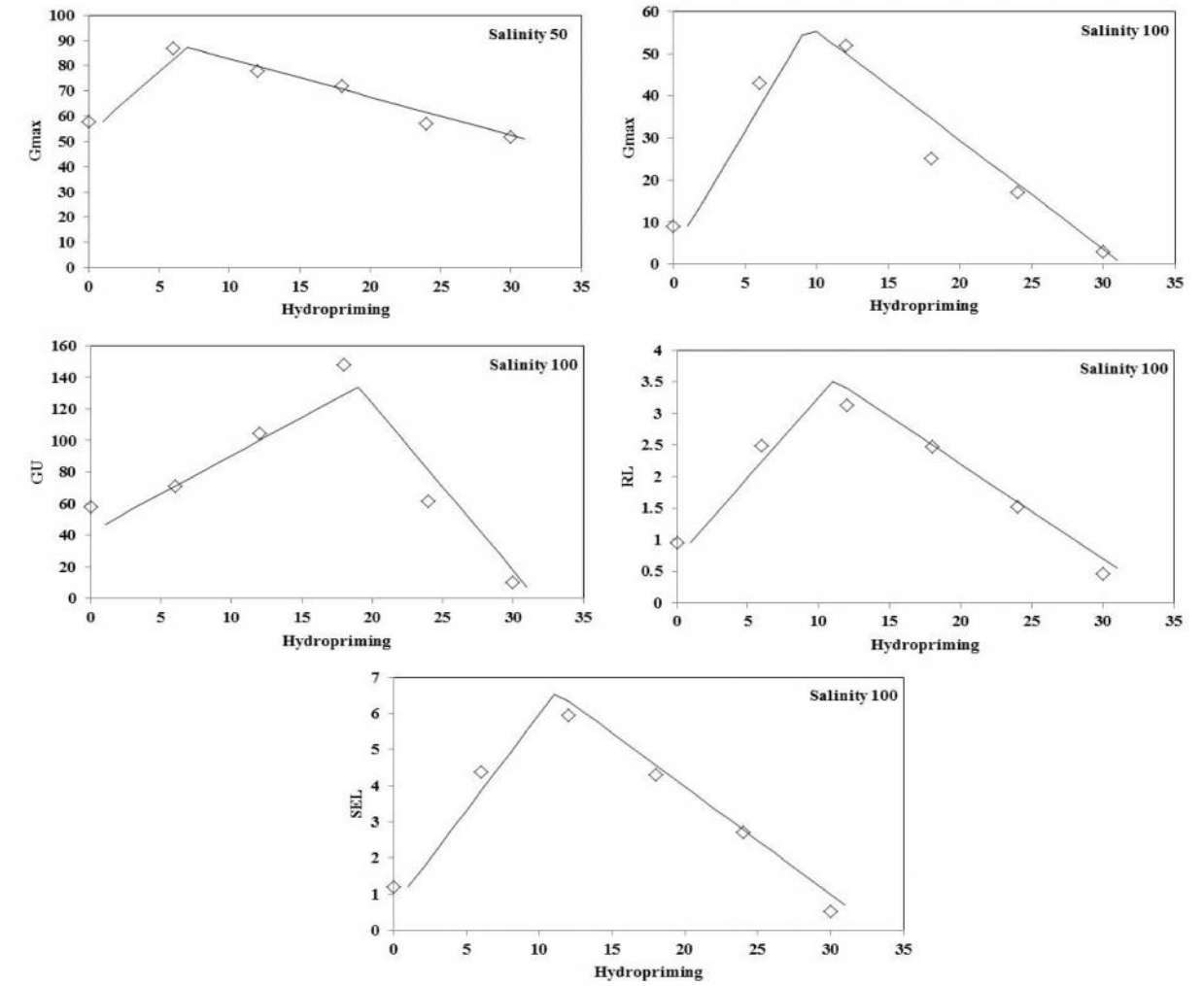

Fig. 3. The effect of hydropriming on maximum of germination (Gmax), germination uniformity (GU), root length (RL), and seedling length (SEL). hydropriming has the same effects on other traits, but because of the interaction effect was significant, that results are not discussed.

Table 3. Parameters of regression analysis of interaction of salinity× hydropriming effect on maximum of germination (Gmax), germination uniformity (GU), root length (RL), and seedling length (SEL).by segmented model. (Regression analysis was done on traits that the respective interaction effect was significant, also it was done between hydropriming levels only on salinity levels that the respective interaction effect of salinity× hydropriming was significant). S= salinity

Parameter	GMAX-S 50	GMAX- S 100	GU- S 100	RL- S 100	SEL- S 100
a	58±2.4967	9±6.0622	46.8092±11.4547	0.9625±0.1499	1.195±0.2152
b1	4.9±0.5263	5.6667±1.4289	4.8345±1.4788	0.2538±0.0353	0.5321±0.0507
b2	-1.5167±0.1316	-2.5833±0.4518	-10.5299±1.4788	-0.1498±0.0112	-0.2975±0.016
x0	6	8.4242±1.3274	18±1.4533	10.1193±0.7635	10.1615±0.5349
R-Square	0.9803	0.9505	0.9696	0.9915	0.9946

The effect of hydropriming on GU was significant only at salinity level=100. Base on segmented model, turning point of positive effect of hydropriming was 18 hours and after that with increasing of hydropriming time, GU was decreased with slope of -10.5299 hours per unit (R^2=0.9696). Germination uniformity is the uniformity of germination between time of 10 and 90 % germination. Based this definition, lower GU is better and indicated

that germination rate is more. For this reason respective turning point was the highest (Table 3 and Fig. 3). Root length and seedling length were same trends. The best time for hydro priming based on these traits were 10.1193 and 10.1615 hours, respectively (R^2=0.9915 and R^2=0.9946).

Hydro-priming clearly improved both rate of germination and mean germination time under salt stress conditions. Furthermore, hydro priming resulted in increase of normal germination. Results showed that the effect of hydro and osmo-priming on germination percentage of fennel were significant. Hydropriming clearly improved rate of germination and mean germination time under salt stress conditions. Furthermore, hydro-priming resulted in increase of normal germination percentage (Reddy and Vora, 1983). The efficiency of seed hydro-priming for better seedling establishment, also reported in barley, lentil and chickpea (Chinnusamy et al., 2006). Hydro-priming treatment has no environmental pollution so it is better than two previous methods. The results obtained in this study can be used in the pharmacy, alimentary and sanitary industries.

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