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Original article

Hydrotime model: an indicator for assessing drought stress tolerance of different quinoa genotypes at the germination stage

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Extended abstract

Introduction#

Germination is the most vital period in the plant life cycle that is influenced by various environmental and genetic factors. Among environmental factors, drought stress can greatly affect the germination and emergence of seedlings. The tolerance to this stress in the early stages of plant development is very important and seeds that can germinate in these conditions will have a successful establishment, proper density and high yield. Therefore, knowing the drought tolerance threshold in different genotypes of a plant can be very useful in recommending their cultivation in different regions. The hydrotime model is one of the common experimental models in studying the effects of drought stress on seed germination. This model has three parameters including base water potential, hydrotime coefficient and sigma, which indicate drought tolerance, germination rate and germination uniformity, respectively. These coefficients, especially the base water potential, can be used to introduce genotypes for cultivation in areas with different drought levels. Therefore, this study was conducted to investigate the response of different quinoa genotypes to drought stress at the germination stage with the help of hydrotime model coefficients.

Material and Methods

To investigate the effect of drought stress on seed germination of different quinoa (Chenopodium quinoa Willd) genotypes, a factorial experiment was designed and conducted in a completely randomized design with four replications in the seed laboratory of Gorgan University of Agricultural Sciences and Natural Resources in 2019. For the germination test, 4 replicates of 25 seeds of each genotype were placed in a petri dish with a diameter of 8 cm on a layer of filter paper which added 3 ml of solutions prepared in different water potentials (0, -0.4, -0.8, -1.2 and -1.6 MPa) in an incubator at 25 °C. Depending on the germination rate, in the first days after the onset of germination, the number of germinated seeds was counted three to five times per day; with decreasing the germination rate, the number of counts was reduced to two times per day. The germination criterion was the radicle existence of one millimeter or more. The hydrotime model was used to investigate the germination response of quinoa genotypes to drought stress.

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Results and Discussion

The results showed that all genotypes had high germination up to -0.4 MPa and their average germination percentage was above 90%; But as the water potential became more negative, the difference between the germination percentage of genotypes increased. According to the hydrotime model, there was a significant difference between different quinoa genotypes in terms of base water potential for 50% germination (ψb50), hydrotime coefficient (θH) and germination uniformity (σψb). The value of the ψb50 parameter ranged from -1.58 in genotype2 to -1.95 in genotype3. This indicates that quinoa is drought tolerant at the germination stage compared to sunflower, barley, wheat, safflower and canola. The lowest and highest hydrotime coefficients were observed in genotypes2 and 3 with 16.83 and 26.08 MPa/h, respectively (with an average of 20.93 MPa/h). Quinoa hydrotime coefficient is lower than rapeseed, wheat and safflower; In other words, the germination rate of the seeds of this plant is higher compared to the mentioned crops. The reason for this may be related to the size of the seed. The lowest germination uniformity was in genotype 3 (0.68 MPa) and the highest value observed in genotype 7 (0.46 MPa). The hydrotime and sigma coefficients are considered as indicators of germination rate and uniformity. The lower values of these coefficients are indicated the higher the germination rate and uniformity of the genotype, the faster the canopy closure and the higher yield.

Conclusion

In general, the results of this study show that the seeds have a high germination rate and with a high tolerance to drought stress at the germination stage; This increases the chances of faster establishment in the water shortage conditions. Also, the ability to tolerate drought in the germination stage of quinoa reduces the need for water consumption in this stage, which can be very useful and practical in developing management plans that lead to increased water use efficiency.

***Keywords*:** Base water potential, Germination rate, Germination uniformity, Seed vigor

Table 1. Characteristics of different quinoa genotypes and cultivars in the present study (Bagheri et al., 2020)

Number of Genotype#	Genotype#	Growth type#	1000 seed weight#	Seed yield#	Protein#	Saponin content#
			g	$ton.ha^{-1}$	%	%
1	Titicaca	mid maturing	2.15	3.14	12.14	4.69
2	Red carina	mid maturing	2.63	2.84	12.20	5.23
3	Gza1	early maturing	2.80	2.15	11.99	4.95
4	Q12	late maturing	3.12	4.97	11.20	4.25
5	Q21	late maturing	2.76	3.10	11.34	5.31
6	Q22	late maturing	3.36	3.08	11.32	5.33
7	Q26	late maturing	2.69	3.74	12.33	5.74
8	Q29	late maturing	2.48	4.50	11.70	5.01
9	Q31	late maturing	2.84	4.07	11.83	5.14

Table 2. Mean square of maximum germination percentage of different genotypes of quinoa at different water potential levels

Sources of variance	dF	Mean Square
Genotype (G)	8	507**
Water potential (W)	5	47144**
G × W	40	117**
Error	178	18.89

**: significance at 0.01%

3. Maximum percentage of germination of different Quinoa genotypes at different water potential levels Table

Genotype	Water potential (MPa)					
	0	**-0.4**	**-0.8**	**-1.2**	**-1.6**	**-2**
Titicaca	97[abc]	94[ab]	78[d]	64[c]	32[e]	0
Red carina	94[c]	98[a]	87[c]	64[c]	45[d]	3[bc]
Gza1	95[bc]	94[ab]	92[abc]	64[c]	36[e]	0
Q12	100[a]	97[ab]	89[bc]	63[c]	56[c]	0
Q21	97[abc]	97[ab]	92[abc]	81[a]	74[a]	7[ab]
Q22	98[ab]	93[b]	89[bc]	71[b]	54[c]	4[abc]
Q26	100[a]	98[a]	94[ab]	81[a]	65[b]	8[a]
Q29	95[bc]	95[ab]	89[bc]	64[c]	51[cd]	7[ab]
Q31	99[a]	98[a]	95[a]	71[b]	56[c]	0

The letters indicate significant or non-significant of each genotype at different levels of water potential

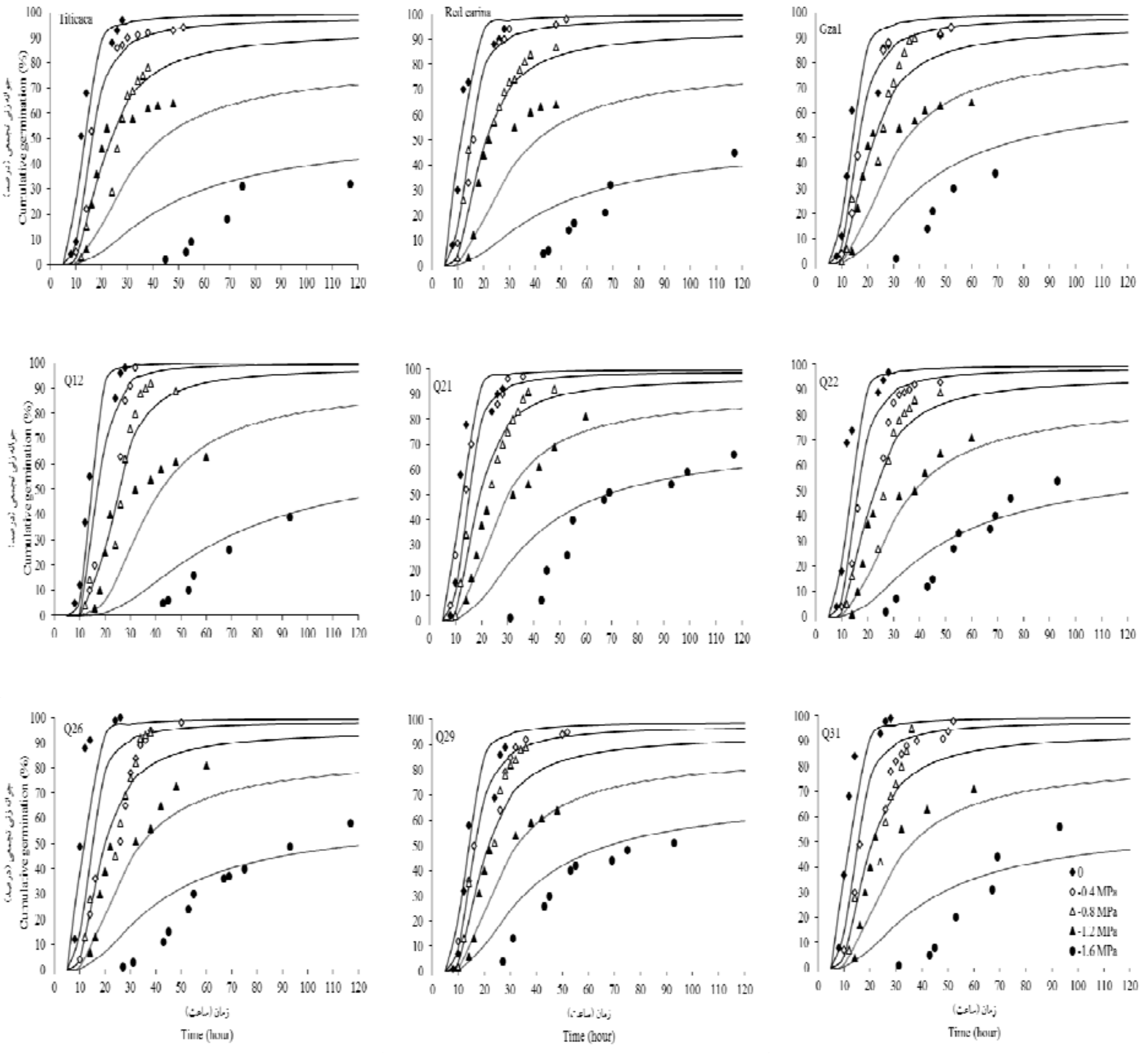

Fig.1. Fitting of hydrotime model with Logistic function to cumulative seed germination data of different Quinoa genotypes at different drought levels.

Table 4. Parameters estimated by the hydrotime model with Logistic function for different Quinoa genotypes.

Genotype	hydrotime coefficient #(θ_H)	base water potential for 50% germination ($\Psi b(50)$)#	sigma ($\sigma_{\psi b}$)	R^2
	MPa. h	-------------------------------MPa-----------------------------		
Titicaca	20.05±1.61	-1.66±0.07	0.32±0.04	0.83
Red carina	17.09±1.12	-1.62±0.05	0.29±0.03	0.87
Gza1	24.44±1.95	-1.90±0.09	0.37±0.05	0.86
Q12	24.11±1.28	-1.77±0.05	0.23±0.03	0.88
Q21	21.74±0.93	-1.92±0.04	0.32±0.02	0.91
Q22	21.68±1.17	-1.77±0.05	0.31±0.02	0.91
Q26	18.97±1.29	-1.75±0.06	0.31±0.04	0.84
Q29	25.07±1.57	-1.97±0.07	0.41±0.04	0.88
Q31	19.13±1.32	-1.72±0.07	0.33±0.03	0.87

#R^2 and SE represent the model coefficient of determination and the standard error, respectively.

Table 5. Hydrotime model parameters for sunflower, barley, canola, wheat and safflower based on different sources

Crop	base water potential for #50% germination ($\Psi_{b(50)}$) (MPa)			hydrotime coefficient (θ_H) (MPa. h)			sigma ($\sigma_{\psi b}$) (MPa)			Reference
	Min	**max**	**average**	**min**	**max**	**average**	**min**	**max**	**average**	
Sunflower	-0.632	-3.199	-1.208	-	-	-	-	-	-	Saux et al.. 2020
Barley	-1.343	-1.826	-1.591	-	-	-	-	-	-	Derakhshan and Gharineh. 2015
Canola	-0.23	-1.23	-0.814	22.76	50.93	32.617	0.326	0.801	0.497	Soltani et al.. 2017
Canola	-0.37	-1.32	-0.896	21.75	37.01	31.486	0.27	0.35	0.32	Tatari et al.. 2020
Canola	-0.22	-1.23	-0.783	22.76	50.93	33.008	0.326	0.892	0.517	Adeli et al.. 2017
Wheat	-1.27	-1.39	-1.326	70.32	83.76	78.672	0.22	0.28	0.242	Singh et al.. 2013
Safflower	-1.3	-1.33	-1.315	35.02	37.57	36.295	0.23	0.26	0.245	Eslampour et al.. 2014
Safflower†	-	-	-1.68	-	-	22.3	-	-	0.72	Ostadian Bidgoly et al.. 2018

† Hydrotime coefficients are related to the desired temperature (20 ° C)