Pak. j. life soc. Sci. (2016), 14(3): 135-143 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences
www.pjlss.edu.pk

RESEARCH ARTICLE

Seed Priming Improves Emergence Potential, Growth Behaviour and Nutritional Quality of *Capparis decidua* (Forssk.) Edgew. under Drought Stress

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ARTICLE INFO

Received: Jul 25, 2016
Accepted: Nov 30, 2016
Online: Dec 05, 2016

Keywords
Ascorbate
Capparaceae
Kinetin
PEG-8000
Seed priming
Thermo-hardening

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ABSTRACT

Capparis decidua is an edible shrub for livestock due to its good nutritional quality. Its seeds exhibit very low emergence rate under drought stress. The present study was conducted to improve the germination traits of *C. decidua* by different pre-sowing seed treatments i.e. hydropriming, osmopriming with 2.2% $CaCl_2$, -1.1 MPa PEG-8000, 50 mg L^{-1} ascorbate and 50 mg L^{-1} kinetin and thermo-hardening. Each seed treatment was applied for two different durations, i.e. 24 and 48 h separately in phase I for selection of suitable priming duration. In phase I, maximum final emergence percentage (80.00%) was observed when *C. decidua* seeds were treated with kinetin for 48 hours followed by kinetin and ascorbate priming for 24 h (76.67%). PEG priming also showed 60.0% emergence, while the least emergence (46.6%) was recorded in untreated seeds. Moreover, these treatments also improved early emergence of *C. decidua* seeds. On the basis of findings of Phase I; three pre-sowing seed treatments (PEG-8000, ascorbate and kinetin priming) for 48 h were selected to further investigate the improvement in emergence rate, stand establishment and nutritional quality under drought stress (70 and 40% field capacity). Beside these selected seed priming techniques, hydropriming and non-primed seeds were also used for comparison. In phase II, seedling emergence, plant height and biomass, and nutritional quality [calcium (Ca) and potassium (K) contents] of *C. decidua* were significantly reduced with increase in drought stress and ascorbate and kinetin priming proved effective in mitigating these adverse effects. It can be concluded here that emergence, biomass and Ca and K contents of *C. decidua* could be improved by priming the seeds with kinetin and ascorbate for 48 h.

INTRODUCTION

Capparis decidua (Forssk.) Edgew., (hereafter *C. decidua*) a multiple-branched shrub, is abundantly found in arid regions of Middle East, Africa and parts of South Asian countries including deserts of South Punjab of Pakistan. The dense growth of these bush like trees are substantially and extremely drought-resistant which can tolerate mild frost conditions and produce root suckers freely. Un-ripened *C. decidua* fruits (caper berries) are used for making prickles and dry vegetables. Pickled caper berries have been used as a condiment from ancient times due to a good source of protein, carbohydrates and vitamins (Ozcan, 2005; Gupta and Sharma, 2007). The branches are also edible being used by goats and cattle due to its palatability and good nutritional quality. As stated earlier that wild population of *C. decidua* can be found in Thal, Thar, Cholistan and Nara Deserts of Pakistan, this plant favours the areas where there has been acute shortage of water as reported by Gull et al. (2015a). There have been a few studies conducted on evaluating the emergence and growth performance of its sister species i.e. *C. spinosa* and *C. ovata* under drought stress mentioning decrease in emergence and biomass under drought conditions (Bhoyar et al., 2010; Heydariyan et al., 2014) but no study is available on *C. decidua*. No doubt, *Capparis* species are local to water deficit regions, but a serious decline in emergence percentage of its seeds have also been reported in earlier studies due to water deficit conditions (Soyler and Khawar, 2007). Such low emergence rate and percentage may result in a decrease in plant population, reduced plant vigour index and lower nutritional quality.

Drought stress affects plant metabolism which results in impaired plant growth resulting in reduced crop yield and economic loss. The mitigation of drought stress can be of different ways including plant breeding and plant engineering but these strategies are long term and a few are still unacceptable in some countries (Savvides et al., 2016). Beside these, a few strategies are used to prepare the plant for adjusting itself under stress conditions. In this perspective, one of the practicable strategies could be seed priming with plant growth regulators which have been successfully applied to many crops and rangeland grasses (native to water deficit areas) for improving seed emergence, stand establishment and nutritional quality (Hardegree et al., 2002; Farooq et al., 2009; Nouman et al., 2012; Savvides et al., 2016). Seed priming, a controlled aeration process is a simple, economical, easily adaptable and effective strategy for inducing drought tolerance in plants improving the activation of protection response and stronger when a stress pressure is encountered (Ellouzi et al., 2013; Filippou et al., 2013; Sani et al. 2013).

The emergence rate and percentage, plant biomass and nutritional quality of plants under drought stress have been improved by different strategies as devised by plant scientists. One of these strategies is pre-sowing seed treatments. For example, seed treatments with gibberellic acid and salicylic acid have been reported as effective agents improving seed emergence of *C. spinosa* and *C. ovata* (Fernandez et al., 2002; Pupalla and Fowler, 2002; Basbag et al., 2009; Bhoyar et al., 2010) but no study is available for improving emergence rate, plant growth and nutritional quality of *C. decidua*. For this, the present study was designed aiming at evaluating the seed priming and thermo-hardening techniques to assess the germination, stand establishment and nutritional quality response of *C. decidua* under drought stress.

MATERIALS AND METHODS

Experimental site

The effect of seed priming on the emergence potential, seedling vigor and nutritional quality of *C. decidua* was evaluated in the wire-house of the Department of Forestry & Range Management, Faculty of Agricultural Sciences & Technology, Bahauddin Zakariya University, Multan, Pakistan.

Plant material

Seeds of *C. decidua* were collected manually from Lal Suhanra National Park Bahawalpur, located in southern Punjab (Pakistan) in May, 2014.

Seed priming treatments

C. decidua seeds were subjected to different seed priming techniques for two durations i.e. 24 and 48 h. Seed priming techniques included hydropriming (with distilled water), osmopriming with 2.2% $CaCl_2$ (Basra et al., 2004), PEG-8000 priming (-1.1 MPa) (Ruan et al., 2002), ascorbate priming (50 mg L^{-1}) (Sundstrom et al., 1987) and kinetin priming (50 mg L^{-1}) (Iqbal and Ashraf, 2006). In addition to these, seeds were also subjected to thermo-hardening at 40°C for 24 and 48 h and non-primed seeds were considered as control. Treatment combinations and their codes (as used further in the article) are mentioned in Table 1.

After 24 and 48 h of priming durations in the priming solutions, primed seeds were rinsed with distilled water, dried in shade and kept at room temperature (25-30°C) in polythene bags till further use.

Phase I: Emergence and seedling vigor evaluation

The primed and non-primed seeds were sown in plastic pots having 10 inches surface diameter, filled with acid washed sand. Twenty seeds in each pot were sown with three replications and daily emergence count was recorded according to Association of Official Seed Analysts (AOSA, 1990). For exploring emergence potential, time taken to 50% emergence (E_{50}) [days]

Table 1: Seed treatments applied to *C. decidua* seeds in phase I

Sr. No.	Treatment Codes	Treatments
1	HP24	Soaked in aerated distilled water for 24 h
2	HP48	Soaked in aerated distilled water for 48 h
3	$CaCl_2$ 24	Soaked in aerated solution of 2.2% $CaCl_2$ for 24 h
4	$CaCl_2$ 48	Soaked in aerated solution of 2.2% $CaCl_2$ for 48 h
5	PEG 24	Soaked in aerated solution of PEG-8000 (-1.1 MPa) for 24 h
6	PEG 48	Soaked in aerated solution of PEG-8000 (-1.1 MPa) for 48 h
7	TH24	Kept in oven at 40°C for 24 h
8	TH48	Kept in oven at 40°C for 48 h
9	Ascorbate-24	Soaked in aerated solution of ascorbate (50 mg L^{-1}) for 24 h
10	Ascorbate-48	Soaked in aerated solution of ascorbate (50 mg L^{-1}) for 48 h
11	Kinetin-24	Soaked in aerated solution of kinetin (50 mg L^{-1}) for 24 h
12	Kinetin-48	Soaked in aerated solution of kinetin (50 mg L^{-1}) for 48 h

(Farooq et al., 2005), mean emergence time (MET) [days] (Ellis and Roberts, 1981), emergence index (EI) (AOSA, 1983) and final emergence percentage (FEP) [%]. Accumulative speed of emergence (AS) and speed of emergence (S) were calculated by using formulae adopted by Anjum and Rukhsana (2005). Further, after 10 days of final emergence, plumule and radical lengths (cm) were also measured.

PHASE II

In phase II, two drought levels i.e. 70 and 40% field capacities were maintained in the soil. The field capacity was maintained on the basis of soil water contents by measuring fresh and dry soil weights. For phase II, seeds of *C. decidua* were subjected to three seed priming treatments i.e. PEG, ascorbate and kinetin for 48 h based on phase I findings. Emergence, growth behavior and nutritional quality of *C. decidua* plants were studied under the above mentioned field capacities for three weeks. After completion of the phase, *C. decidua* plants were harvested and their fresh and dry weights shoot and root lengths were measured according to standard procedures.

Mineral analyses

Calcium and potassium are important macro-minerals contributing to nutritional quality of plants being essential for livestock, if being used as fodder. So, *C. decidua* shoots were oven dried at 60 ºC after harvesting to a constant weight and ground to pass 2 mm sieve. The samples were digested by using concentrated nitric and perchloric acid (2:1) by following the procedure adopted by (Rashid 1986). Flame photometer (Jenway PEP-7) was used to determine potassium (K) contents while Calcium (Ca) contents were determined by atomic absorption spectrophotometer (Model: Z-8200) (Chapman and Pratt 1961).

Statistical analysis

The replicated data was statistically analyzed in software and two factor factorial completely randomized design was applied for analysis of variance (ANOVA). Significance of variance ($p<0.05$) was found for determining difference among seed priming treatments, field capacity levels and interaction of field capacity levels and seed priming treatments. Least significance difference test (LSD @ 5% probability level) was used to compute the differences among the mean values (Steel et al. 1997).

RESULTS

Phase I: Seed emergence test

Among all seed priming treatments, PEG-48 and kinetin-24 were found as the most effective treatments for improving MET and E50, while kinetin-48 performed well for improving FEP (80.00%) followed by kinetin-24 and ascorbate-24 (76.67%) which were statistically at par with each other (Table 2). So, an increase of 72 and 64% in FEP was recorded when the seeds were subjected to kinetin and ascorbate priming in comparison to control. A two-fold increase in EI was also found in *C. decidua* seeds when these were subjected to kinetin-24 and kinetin-48 in comparison to unprimed seeds (Table 2). Regarding other emergence parameters i.e. AS and S, kinetin-24 was recorded as a promising priming treatment followed by kinetin-48 and PEG-48 (Table 2). Maximum plumule length (13.73, 13.67 and 11.97 mm) was recorded when the seeds were subjected to ascorbate-48 and kinetin-48 followed by kinetin-24, respectively. Moreover, maximum radical length (13.67 mm) was found in *C. decidua* seedlings when seeds were subjected to kinetin-24 followed by kinetin-48 (11.67 mm) while the least was recorded in unprimed and hydroprimed seeds (Table 3). Moreover, among all the applied treatments, kinetin-48 and kinetin-24 performed well for improving SVI (2035.3 and 1992.4, respectively) followed by ascorbate-48 and ascorbate-24 (1592.1 and 1443.3, respectively) (Table 3).

Table 2: Effect of seed treatments on mean emergence time (MET), time taken for 50% emergence (E50), final emergence percentage (FEP), emergence index (EI), Speed of accumulated emergence speed (AS) and Speed of emergence (S) of *C. decidua* seeds

Treatments	MET (Days)	E50 (Days)	FEP (%)	EI	AS	S
Control/ Non-primed	16.16^{ab}	13.53^{ab}	46.6^{e}	4.75^{f}	4.18^{f}	6.44^{g}
HP24	15.98^{ab}	12.75^{abc}	46.67^{e}	5.09^{ef}	4.56^{ef}	6.77^{fg}
HP48	15.88^{abc}	13.50^{ab}	45.00^{e}	5.35^{ef}	4.76^{ef}	7.05^{fg}
$CaCl_2$ 24	15.81^{abc}	13.17^{abc}	63.33^{cd}	6.94^{cde}	6.15^{cde}	9.22^{de}
$CaCl_2$ 48	15.75^{abcd}	12.75^{abc}	56.67^{d}	6.58^{def}	5.79^{def}	8.65^{ef}
PEG 24	15.23^{cd}	11.33^{c}	60.00^{cd}	8.19^{bcd}	7.18^{bcd}	10.07^{cde}
PEG 48	15.07^{d}	12.42^{abc}	68.33^{bc}	9.43^{ab}	8.23^{ab}	11.40^{abc}
TH24	16.26^{a}	13.47^{ab}	65.00^{cd}	6.56^{def}	5.87^{def}	9.15^{de}
TH48	16.13^{ab}	13.08^{abc}	63.33^{cd}	6.71^{def}	5.96^{def}	9.30^{de}
Ascorbate-24	15.55^{bcd}	13.81^{a}	76.67^{ab}	8.81^{abc}	7.87^{abc}	11.26^{bc}
Ascorbate-48	15.68^{abcd}	12.83^{abc}	68.33^{bc}	8.25^{bcd}	7.28^{bcd}	10.70^{cd}
Kinetin-24	15.10^{d}	11.56^{bc}	76.67^{ab}	10.79^{a}	9.50^{a}	13.25^{a}
Kinetin-48	15.62^{abcd}	12.29^{abc}	80.00^{a}	9.85^{ab}	8.78^{ab}	12.80^{ab}
LSD (0.05)	0.68	2.08	9.59	2.09	1.82	1.91

Means showing different letters are statistically ($P<0.05$) different with each other.

Table 3: Effect of seed treatments on plumule length (mm), radical length (mm) and seedling vigour index (SVI) of *C. decidua* seeds

Treatments	PL (mm)	RL (mm)	SVI
Control/ Non-primed	3.97^{g}	2.76^{h}	310.90^{e}
HP24	6.00^{f}	3.67^{h}	452.07^{e}
HP48	7.77^{def}	3.73^{h}	518.70^{e}
$CaCl_2$ 24	6.60^{ef}	6.37^{fg}	823.57^{cd}
$CaCl_2$ 48	7.27^{def}	6.70^{efg}	786.05^{d}
PEG 24	8.20^{de}	8.29^{cd}	988.53^{cd}
PEG 48	7.97^{de}	7.23^{def}	1033.3^{c}
TH24	8.30^{de}	5.28^{g}	880.53^{cd}
TH48	8.83^{cd}	7.51^{def}	1035.7^{c}
Ascorbate-24	10.77^{bc}	8.08^{de}	1443.3^{b}
Ascorbate-48	13.67^{a}	9.67^{c}	1592.1^{b}
Kinetin-24	11.97^{ab}	13.67^{a}	1992.4^{a}
Kinetin-48	13.73^{a}	11.67^{b}	2035.3^{a}
LSD (0.05)	1.96	1.49	225.67

Means showing different letters are statistically ($p<0.05$) different with each other

Phase II: Seed emergence and seedling vigour evaluation under drought stress

Seed emergence of *C. decidua* was evaluated under water deficit with the application of screened seed priming techniques i.e. PEG-8000, ascorbate and kinetin. Maximum FEP (60.67%) was recorded under moderate stress and decreased to 46.93% under severe water deficit. Moreover, it was noted that seed emergence speed and final emergence percentage reduced with increase in drought stress. Early emergence was noted when *C. decidua* seeds were primed with PEG-8000 and kinetin while non-primed seeds took maximum time to emergence. Ascorbate and kinetin primed seeds performed better for improving emergence speed and FEP even under severe water deficit. Under severe stress, unprimed seeds exhibited only 31.67% seed final emergence which was increased upto 61.67 and 56.33% when seeds were primed with kinetin and ascorbate, respectively (Table 4).

The growth behaviour and nutritional quality of *C. decidua* plants were also investigated under water deficit. Vigorous seedlings were recorded at moderate drought conditions followed by sever water deficit while the seedlings exhibited maximum root length under severe water shortage (40% field capacity). Moreover, when *C. decidua* seeds were primed with ascorbate, the seedlings provided maximum fresh and dry plant weight (47.03 and 28.93 g, respectively) followed by kinetin priming at moderate and severe drought stress (Table 5). So, a 52% increase in plant fresh and dry weight was found with the application of ascorbate priming while kinetin primed seeds exhibited 36% increase in these attributes at moderate water deficiency (Table 5). A likewise trend was observed in shoot length expression by primed *C. decidua* seeds. Maximum shoot length (22.33 cm) was recorded in ascorbate primed seeds followed by kinetin primed ones (18.67 cm) under moderate drought while under severe water deficiency, both ascorbate and kinetin priming improved shoot length under in comparison with unprimed ones while a significant reduction was observed among shoot length of plants exposed to moderate and severe stress (Table 6). Moreover, maximum root length was exhibited under severe water deficit especially when *C. decidua* seeds were primed with ascorbate > kinetin > PEG-8000 (16.33, 14.67 and 13.33 cm, respectively) (Table 6). In present study, a significant reduction in calcium and potassium contents was recorded with increasing water deficiency (Table 7). Unprimed *C. decidua* seedlings exhibited 283.76 and 267.52 mg kg^{-1} calcium contents under moderate and severe drought, respectively while an increase of 32 and 19% in calcium contents was recorded in ascorbate and kinetin primed seedlings under moderate drought conditions while a negligible increase was observed under severe water deficit (Table 7). Ascorabte and kinetin priming also performed well form improving potassium contents under moderate drought (17 and 11% increase in comparison to control, respectively) while a significant decrease in potassium contents was found under severe water deficit which was a little increased in primed seedlings (Table 7).

DISCUSSION

Pre-sowing seed treatments like those of seed priming, seed scarification and seed hardening have been reported effective in improving seed emergence, seedling vigour and inducing tolerance against environmental odds like heat, cold, salinity or drought stress. Besides, these seed treatments have also rendered positive impacts on growth behavior, yield and various quality traits in field crops, vegetables, fruits, trees and rangeland grasses (Welbaum et al., 1998; Brancalion et al., 2008; Nouman et al., 2012). In this study, various seed priming treatments were applied to *C. decidua* seeds to improve their emergence rate. A significant decrease in emergence percentage with increase in drought stress was observed in the present study while an increase in emergence percentage was recorded when the seeds were subjected to ascorbate, kinetin and PEG priming (Table 2-3). Decrease in emergence percentage and rate under drought conditions is a usual phenomenon for many crops and other plants. Even, *C. decidua* and its sister species are not exceptions. No doubt, the emergence and growth behavior of *C. decidua* was first time investigated, the likewise trends have been recorded and reported for *C. spinosa* and *C. ovata* (Heydariyan et al., 2014). In these both species, emergence rate potential was improved by applying sulfuric acid, nitric acid, gibberellic acid and salicylic acid seed treatments as effective agents (Fernandez et al., 2002; Pupalla and

Table 4: Effect of seed treatments on mean emergence time (MET), time taken for 50% emergence (E50), final emergence percentage (FEP) and emergence index (EI) of *C. decidua* seeds under drought conditions

Treatments	MET (Days)			E50 (Days)		
	Moderate	Severe	Mean	Moderate	Severe	Mean
Control	16.52^{b}	17.29^{a}	16.90^{A}	13.25^{bcd}	13.92^{abc}	13.58^{A}
Hydropriming	15.94^{c}	16.59^{b}	16.27^{B}	14.17^{ab}	14.92^{a}	14.54^{A}
PEG-8000	15.21^{e}	15.74^{cd}	15.48^{C}	11.42^{e}	12.08^{de}	11.75^{B}
Ascorbate	15.35^{de}	15.67^{cde}	15.51^{C}	12.00^{de}	12.58^{cde}	12.29^{B}
Kinetin	15.22^{e}	15.49^{cde}	15.35^{C}	11.50^{e}	12.00^{de}	11.75^{B}
Mean	15.65^{B}	16.15^{A}		12.47	13.10	
	FEP (%)			EI		
	Moderate	Severe	Mean	Moderate	Severe	Mean
Control	41.67^{cd}	31.67^{e}	36.67^{D}	4.23^{ef}	2.85^{f}	3.54^{C}
Hydropriming	48.33^{c}	38.33^{de}	43.33^{C}	5.47^{de}	3.74^{f}	4.58^{C}
PEG-8000	61.67^{b}	46.67^{c}	59.17^{B}	8.28^{bc}	6.94^{cd}	7.61^{B}
Ascorbate	75.00^{a}	56.33^{bc}	70.66^{A}	8.92^{ab}	8.29^{bc}	8.60^{B}
Kinetin	76.67^{a}	61.67^{b}	74.17^{A}	10.31^{a}	9.76^{ab}	10.03^{A}
Mean	60.67^{A}	46.93^{B}		7.43^{A}	6.30^{B}	

Means showing different letters are statistically ($p<0.05$) different with each other, LSD (0.05) value for MET: Field Capacity: 0.23, Treatment: 0.36, Field Capacity × Treatments: 0.51, LSD (0.05) value for E50: Field Capacity: 0.69, Treatments: 1.09, Field Capacity × Treatments:1.53, LSD (0.05) value for FEP: Field Capacity: 3.33, Treatments: 5.27, Field Capacity × Treatments: 7.46, LSD (0.05) value for EI: Field Capacity: 0.74, Treatments: 1.18, Field Capacity × Treatments:1.67.

Table 5: Effect of seed treatments on plant fresh and dry weights (g) of *C. decidua* under drought conditions

Treatments	Plant Fresh Weight			Plant Dry Weight		
	Moderate	Severe	Mean	Moderate	Severe	Mean
Control	31.10^{cd}	21.67^{e}	26.38^{C}	18.90^{c}	13.33^{d}	16.10^{C}
Hydropriming	31.77^{cd}	22.03^{e}	26.90^{C}	19.93^{c}	13.64^{d}	16.78^{C}
PEG-8000	41.50^{b}	26.30^{d}	33.90^{BC}	23.43^{bc}	16.20^{cd}	19.81^{B}
Ascorbate	47.03^{a}	31.63^{cd}	39.33^{A}	28.93^{a}	20.53^{c}	24.73^{A}
Kinetin	42.37^{ab}	29.80^{d}	36.08^{B}	26.60^{ab}	20.40^{c}	23.50^{A}
Mean	38.75^{A}	30.29^{B}		23.56^{A}	16.82^{B}	

Means showing different letters are statistically ($p<0.05$) different with each other, LSD (0.05) value for Plant Fresh Weight: Field Capacity: 2.21, Treatment: 3.49, Field Capacity × Treatments: 4.94, LSD (0.05) value for Plant Dry Weight: Field Capacity: 1.66, Treatments: 2.63, Field Capacity × Treatments: 3.72.

Table 6: Effect of seed treatments on shoot length and root length (cm) of *C. decidua* under drought conditions

Treatments	Shoot Length (cm)			Root Length (cm)		
	Moderate	Severe	Mean	Moderate	Severe	Mean
Control	11.00^{e}	7.33^{f}	9.16^{C}	6.33^{d}	6.33^{d}	6.33^{C}
Hydropriming	11.67^{de}	9.67^{ef}	10.67^{C}	7.33^{d}	8.33^{d}	7.83^{C}
PEG-8000	15.00^{cd}	13.67^{bc}	14.33^{B}	9.33^{cd}	13.33^{ab}	11.33^{B}
Ascorbate	22.33^{a}	19.33^{b}	20.83^{A}	12.00^{bc}	16.33^{a}	14.17^{A}
Kinetin	18.67^{b}	16.33^{bc}	17.50^{AB}	13.67^{ab}	14.67^{ab}	14.17^{A}
Mean	15.73^{A}	13.27^{B}		9.73^{B}	11.80^{A}	

Means showing different letters are statistically ($p<0.05$) different with each other, LSD (0.05) value for Shoot Length: Field Capacity: 1.49, Treatments: 2.37, Field Capacity × Treatments: 3.35, LSD (0.05) value for Root Length: Field Capacity: 1.44, Treatments: 2.28, Field Capacity × Treatments: 3.23.

Table 7: Effect of seed treatments on calcium and potassium contents ($mg\ kg^{-1}$) of *C. decidua* under drought conditions

Treatments	Calcium ($mg\ kg^{-1}$)			Potassium ($mg\ kg^{-1}$)		
	Moderate	Severe	Mean	Moderate	Severe	Mean
Control	283.76^{def}	267.52^{f}	275.64^{B}	1363.70^{cd}	1081.30^{f}	1222.50^{B}
Hydropriming	298.46^{bcd}	272.89^{ef}	285.67^{B}	1392.00^{c}	1083.70^{f}	1237.80^{B}
PEG-8000	314.86^{bc}	298.33^{bcde}	306.60^{A}	1567.00^{ab}	1247.30^{e}	1407.20^{A}
Ascorbate	341.97^{a}	293.19^{cde}	317.58^{A}	1600.30^{a}	1301.70^{de}	1451.00^{A}
Kinetin	319.20^{ab}	290.66^{cdef}	304.93^{A}	1514.00^{b}	1333.30^{cd}	1423.70^{A}
Mean	311.65^{A}	284.52^{B}		1487.40^{A}	1209.50^{B}	

Means showing different letters are statistically ($p<0.05$) different with each other, LSD (0.05) value for Calcium Contents: Field Capacity: 11.44, Treatments: 18.08, Field Capacity × Treatments: 25.57, LSD (0.05) value for Potassium Contents: Field Capacity: 33.81, Treatments: 53.46, Field Capacity × Treatments: 75.60.

Fowler, 2002; Bhoyar et al., 2010). Soyler and Khawar (2007) reported that low and late emergence in *C. decidua* seeds might owe to its hard coat. The hard coat contains mucilage, so when seeds come in contact with water the mucilaginous substance inhibits oxygen diffusion which ultimately prevents seed emergence. The scientists reported the increase in emergence rate and final emergence percentage in *C. spinosa* seeds when these were primed with different plant growth regulators (Nun et al., 2003; Ramezani-Gask et al., 2008; Bhoyar et al., 2010). It has been observed that the presence of mucilaginous substance in seed coat hinder water adsorption by seeds and the plant growth regulators enable the plants to absorb water for emergence (Ramezan-Gask et al., 2008). In present investigation, thermo-hardening also improved emergence rate of *C. decidua* seeds (Table 2-3).

Poor seed germination and retarded seedling growth are the primary consequences of drought on plants (Harris et al., 2002; Kaya et al., 2006). It has been reported that seed emergence rate determines seedling vigour and plant growth behavior especially under water deficit conditions. Early and synchronized emergence results in healthy and vigorous stand establishment (Khaninejad, 2012). It has been reported that hard seed coat is not the only responsible factor for low emergence rate as was observed in other sister species of *C. decidua*, since there may possibly be other physical and physiological restrictions that might hinder emergence. Beside these, poor soil condition with less water holding capacity and less availability of water are also physical constraints (Pascual et al., 2004). In such cases, seed priming is an important tool to induce tolerance in *C. decidua* seeds and plants to survive under water deficit conditions. In present investigation, a significant decrease in emergence rate and early emergence was recorded with increase in drought stress. Moreover, kinetin and ascorbate primed seeds resulted in early, synchronized and higher emergence in comparison with unprimed ones (Table 4).

Plant growth is dependent on cell division, elongation and differentiation involving various genetic, physiological and morphological procedures and their complexities which are affected by drought stress (Farooq et al., 2009). Drought tolerant plants avoid water deficit through modified physiological and morphological adaptations like extensive and prolific root growth (Turner et al., 2001). In present investigation, *C. decidua* plants exhibited extended root length under severe water deficiency while a significant decrease in shoot length was recorded at the same drought level (Table 6). Root growth in length and proliferation are key attributes determining plant adaptability to drought conditions being the only source to uptake water and nutrients (Kavar et al., 2007). Root parameters are also used as indicator or selection criteria for plants' drought tolerance. Under drought conditions, plants have morphological adaptation lengthening their roots (Basal et al., 2005). The similar drought avoidance mechanism was observed in *C. decidua* plants in the present study. Plant growth regulators induce drought tolerance in plants when applied at a very low concentration. Seed priming through PGRs or other agents can improve plant growth and development (Savvides et al., 2016). Similar observations were recorded in *C. decidua* plants when its seeds were primed with ascorbate and kinetin (Table 6). Root proliferation plays a vital role in drought stress mitigation which is controlled by auxins and cytokinins. In case of drought stress, the exogenous application of these regulators or seed priming with these ones can improve root growth (Farooq et al., 2009; Li et al., 2014). Similar observations were recorded in the present investigation as stated earlier.

The nutrients and water uptake is also affected with the decrease in water availability to plants (Garg, 2003). *C. decidua* is a good source of calcium and potassium contents as Gull et al. (2015b) reported 211.80 mg kg^{-1} and 5139.0 mg kg^{-1} calcium and potassium contents in *C. decidua* shoots, respectively. In present investigation, a significant decrease in potassium contents was observed in comparison with earlier studies (Gull et al., 2015b) while no change was observed in calcium contents under drought stress. In present study, *C. decidua* plants exhibited 283.76 and 267.52 mg kg^{-1} calcium contents at moderate and severe drought, respectively. Jodral-Segado et al. (2006) reported that calcium uptake efficiency by plant roots under drought stress has no significant change. Even an increase in calcium contents has been reported in *Cynodon dactylon* under water deficit (Utrillas et al., 1995). As in present investigation an increase in calcium contents was recorded when *C. decidua* seeds were primed with ascorbate and kintin. Garg (2003) reported that nutrient and water uptake is closely related to each other which can be improved by PGRs. Calcium is an imperative macro-element for plant growth and development. Moreover, calcium uptake by *C. decidua* plants can be enhanced by the application of ascorbate or kinetin priming as evident for the present study. Furthermore, a reduction in potassium contents was recorded in *C. decidua* plants under drought conditions while a significant increase was observed when *C. decidua* seeds were primed with ascorbate and kinetin (Table 7). Potassium is responsible for regulating water status, protein synthesis, photosynthesis (Farooq et al., 2009). Moreover, drought stress affects potassium accumulation in plants which ultimately influences stomatal opening and closure mechanism (Mengel, 2007). It has been reported that under water deficit conditions, stomata close which might be controlled by significant reduction in potassium contents (Silva et al., 2003; Larcher, 2006). On these bases, it can safely be concluded that reduction in potassium accumulation in plants cause stomatal closure reducing transpiration losses.

Conclusion

Drought extent in arid and semi-arid regions is being expected to increase with global climate change which may cause food security risks to farmers and environmentalists. The usage of drought tolerant plants of good nutritional quality is a possible alternative approach to cope with the situation. *C. decidua* is one of drought tolerant plants being consumed by livestock for its nutrition but it has low emergence rate and percentage under drought conditions. Seed priming is a better approach to induce tolerance in *C. decidua* plants to improve and synchronize the emergence under water deficit. Based on the findings on the present investigation, it can safely be concluded that ascorbate and kinetin priming can improve drought tolerance in *C. decidua* plants. A significant increase in emergence, seedling vigour and calcium and potassium contents of *C. decidua* plants was recorded when its seeds were subjected to seed priming which revealed that ascorbate and kinetin priming for 48 hours can be applied to *C. decidua* seeds for getting early and synchronized emergence, better plant growth and improved nutritional quality. This study can be further enhanced for studying anatomical modifications and investigating the physiological mechanism involved in the growth of *C. decidua* under drought conditions and how plant growth regulators alter plants' physiological response under these conditions.

Authors' contributions

HMY performed the experiments and analysis as MPhil student, WN conceived the idea, planned and supervised the research as supervisor and wrote the article, MZ co-supervised the research and wrote the article, SAM and IA assisted the student in mineral analyses and provided seed material and chemicals and wrote the article.

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