COBISS Code 1.01

DOI: 10.2478/v10014-012-0003-6

**Agrovoc descriptors:** triticum aestivum, soft wheat, drought resistance, acquired characters, drought stress, pregermination, seed treatment, growth control

**Agris category code**: F03, F60

# Induction of drought tolerance with seed priming in wheat cultivars (*Triticum aestivum* L.)

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Received January 20, 2012; accepted February 21, 2012.
Delo je prispelo 20. januarja 2012, sprejeto 21. februarja 2012.

## ABSTRACT

Delay in sowing and low precipitation (<300mm annual) in wheat (*Triticum aestivum* L.) farming is the major problem in the irrigated and rainfall lands of Iran. A factorial experiment for evaluating the effects of seed priming on wheat cultivars was carried out under laboratory, greenhouse and at two field conditions during seasons of 2008-2010. Arrangement of treatments were Zarrin, Shariar, Sardary and Azar cultivars as A factor, and priming treatments including distilled water (DW), osmotic solutions (10% PEG, 2.5% KCl, 4% MN, 10% Urea, 5% NaCl W/V) and plant growth inducers (20 ppm IAA, 1000 ppm CCC) with non-primed seed as a control established B factor. During the second year of field experiment two separate treatments were done under drought stress and well watered conditions. Drought stress was withheld by irrigation at booting stage of plants. Maximum amount of absorbed water was determined in cultivar Shariar, 15.5 g DW. Seed weight of all cultivars increased the most when primed with CCC and IAA. Irrespective of the cultivar seedlings related traits revealed that treatment with CCC increased plumule and radical dry weights (11.5 and 8.0 mg) and their lengths (17.2 and 17.8 cm). In opposite, urea pretreatment had negative effects on seedlings growth. All priming treatments increased grain yield and its components, chlorophyll content and nitrogen absorbed under field and green house conditions in four cultivars in comparison to control. Plants arising from seeds primed with potassium chloride under drought stress had the lowest percentage of variation for traits such as relative water content (-9.3%), total dry matter (-10.7%) and grain yield (-4.0%) in comparison with well watered plants. Potassium chloride improved drought tolerance at all wheat cultivars. There were significant correlations between grain yield at primed with KCl and following wheat traits: number of spikes per square meter (0.91**), number of grains per spike (0.92**) and total dry matter (0.79*). Therefore, it seems that these traits could be used as indirect criteria for selection of high grain yield of cultivars for primed seed.

**Key words:** drought stress, hydro and osmo priming, plant growth inducers, common bread wheat

## IZVLEČEK

### INDUKCIJA TOLERANCE NA SUŠO S PREDSETVENIM TRETIRANJEM SEMEN PRI IZBRANIH SORTAH PŠENICE (*Triticum aestivum* L.)

Zakasnitev v setvi in majhna količina padavin (<300mm letno) sta glavna problema pri pridelavi pšenice (*Triticum aestivum* L.) v namakanih in nenamakanih območjih Irana. Izvrednotenje učinka predsetvenega tretiranja semena izbranih sort pšenice je bilo narejeno s faktorskim poskusom v laboratoriju, rastlinjaku in v dveh poljskih poskusih v sezonah 2008-2010. Poskus je bil zastavljen s štirimi sortami pšenice (Zarrin, Shariar, Sardary in Azar) kot faktorjem A in predsetvenimi tretmaji, ki so obsegali destilirano vodo (DW), raztopine osmotikov (0% Urea, 5% NaCl W/V) in rastlinske rastne regulatorje (20 ppm IAA, 1000 ppm CCC) primerjalno z netretiranimi semeni, kar je bila kontrola in faktor B. V drugem letu poljskega poskusa sta bili opravljeni še obravnavi s sušo in zadostnim zalivanjem. Sušni stres je bil preprečen z zalivanjem v fazi bilčenja. Največ absorbirane vode je bilo izmerjeno pri sorti Shariar, 15.5 g DW. Teža semen vseh sort se je povečala najbolj, kadar so bila semena pred setvijo tretirana s CCC in IAA. Ne glede na sorto se je pokazalo, da sta se suha teža mladega poganjka in korenine (11.5 in 8.0 mg) pri kalicah povečali kot tudi njuni dolžini (17.2 in 17.8 cm) kadar je bilo seme pretretirano s CCC. Nasprotno je imelo predtretiranje z ureo negativni učinek na rast kalic. Vsa predtretiranja so povečala pridelek zrnja in njegove komponente, vsebnost klorofila in privzetje dušika v poskusih v rastlinjaku in poljskem poskusu pri vseh sortah v primerjavi s kontrolo. Rastline, ki so zrasle iz semen predtretiranih s KCl v razmerah sušnega stresa so imele najmanjši odstotek variabilnosti v znakih kot so reletivna vsebnost vode (-9.3%), celokupna suha snov (-10.7%) in pridelek zrnja (-4.0%) v

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primerjavi z dobro zalivanimi rastlinami. Natrijev klorid je pri vseh sortah pšenice izboljšal prenašanje suše. Ugotovljene so bile značilne korelacije med pridelkom zrnja pšenice, ki je bila predtretirana s KCl in naslednjimi znaki pridelka: število klasov na kvdratni meter (0.91**), število zrn na klas (0.92**) in celokupno suho snov (0.79*). Zato izgleda, da bi lahko te znake uporabili kot posredni kriterij za izbor visokoproduktivnih sort pšenice, pri katerih se seme predtretira.

**Ključne besede:** sušni stres, vodno in osmotsko predtretiranje semen, rastlinski rastni regulatorji, krušna pšenica

## 1 INTRODUCTION

In irrigated lands, winter wheat and sugar beet fallow is the dominant rotation in 130.000 hectares of West Azerbaijan province of Iran. Planting of winter wheat is delayed after harvesting of sugar beet. In addition, low precipitation and inadequate moisture of seed zone under rainfall conditions reduces grain yield potential. Therefore, seed priming is a technology that enhances rapid (7-10 d) emergence and early establishment of wheat. Rapid and uniform field emergence is an essential prerequisite at two irrigated and rainfall conditions to reach the yield potential, quality, and ultimately profit in annual crops. Seed priming has been common pretreatment that reduces the time between seed sowing until emergence and synchronizes seedling emergence (Parera and Cantliffe 1994).

Seed priming can be accomplished through different methods such as hydro-priming (soaking in DW), osmo-priming (soaking in osmotic solutions such as PEG, potassium salts, e. g., KCl, $K_2SO_4$) and plant growth inducers (CCC, Ethephon, IAA) (Capron *et al.*, 2000; Chiu *et al.,* 2002; Harris *et al.,* 1999; Chivasa *et al.,* 1998).

Several investigations confirmed that seed priming has many benefits including early and rapid emergence, stand establishment, higher water use efficiency, deeper roots, increasing in root growth, uniformity in emergence, germination in wide range of temperature, break of seed dormancy, initiation of reproductive organs, better competition with weed, early flowering and maturity, resistance to environmental stresses (such as drought and salinity) and diseases (*Sclerotium rolfsii* L.): Higher grain yield in wheat (*Triticum aestivum* L.) (Ghana and Schillinger 2003), corn (*Zea mays* L.) (Subedi and Ma 2005) canola (*Brassica napus* L.) (Farhoudi and Sharifzadeh 2006), pearl millet (*Pennisetum glaucum* L.), chickpea (*Cicer arietinum* L.), rice (*Oriza sativa* L.) (Harris *et al.,* 1999 and 2005) lettuce (*Lactuca sativa* L.) (Cantliffe *et al.*, 1984) is reported from field and laboratory studies. Inversely, longevity of primed seed can be decreased (Bruggink *et al.,* 1999).

Singh and Agrawal (1977) found out that wheat which seeds were treated with DW for 12h increased nitrogen uptake for 11 kg/ha. Misra and Dwivedi (1980) reported that seed soaking in 2.5% KCl for 12 h before sowing increased wheat grain yield for 15%. Paul and Choudhury (1991) observed that seed soaking with 0.5 to 1% solutions with KCl or $K_2SO_4$ significantly increased plant height, grain yield and its components in wheat genotypes. Kulkarni and Eshanna (1988) stated that pre-sowing seed treatment with IAA at 10 ppm improved root length, rate of germination, and seedling vigor.

The objective of this study was to evaluate the effect of several priming solutions on early growth, grain yield and its components under laboratory and field conditions. Specific objective was to determine the effect of seed priming on improving the response of winter wheat cultivars to drought stress under field conditions.

## 2 MATERIALS AND METHODS

Responses of four wheat cultivars, Sardary and Azar for rainfall conditions and Zarrin and Shariar for irrigated conditions, to hydro, osmo-priming and plant growth inducers were studied. Seed from latest harvest was used. and treated with eight priming media: 1- hydropriming (DW), 2- osmopriming (2.5% KCl, 10% urea, 5% NaCl, 4% MN and 10% PEG 8000 W/V), 3- plant growth inducers (20 ppm IAA, and 1000 ppm CCC). Non-treated seeds of each cultivar were used as control. All priming media were prepared in distilled water and seeds soaked at 25°C. The duration of soaking for hydro, osmopriming and plant growth inducers were 16 h and 30 min, respectively. 500 g of seeds of each cultivar was placed in 36 one liter capacity bashers and immersed in liquid priming media. After soaking weight of seeds was recorded and rinsed three times with tap water. All seed sets were surface sterilized with 10% sodium hypochlorite solution for 10 minutes, then rinsed with sterilized water and air dried at room temperature (25°C) for 20 days. After air-drying, the weight of seed sets was recorded again, and amount of water absorbed during soaking was determined (Subedi and Ma 2005, Ghana and Schillinger 2003).

### 2.1 Laboratory experiment

Germination test of dried seed was measured in laboratory using a factorial experiment based on Completely Randomized Design for 36 combination treatments with five replications. Factor A and B included four wheat cultivars and nine priming media+control, respectively. For each treatment 100 seeds were placed on five 90 mm diameter petri dish. Two filter papers of Whatman No. 2 were moistened with 10 mL of distilled water. Seed was kept at germinator in 20°C for 10 days under 16/8 h day/night light. After this period plumule and radical lengths, and dry weights of them were measured.

### 2.2 Greenhouse experiment

Plants were grown in 0.5 L plastic pots (5 cm diameter) filled with a mixture of soil, peat moss, Vermiculite and Perlite (3:1:5:1 v/v). Decision for greenhouse treatments was based on germination performance from the laboratory experiment. Urea and NaCl had negative effect on germination therefore these treatments were removed. The experimental design was the same as in laboratory experiment. Three uniform seed sets of each treatment were sown on 25 February 2008. At seedling emergence (10 days after planting), one gram of NH4NO3 fertilizer was applied per pot at each irrigation. Pots were regularly watered. The temperature inside the greenhouse was maintained at 25/15°C (day/night regime ± 3°C) with 10 h photoperiod. At 60 days after planting, when plants were at five leaves stage, plants were removed and oven dried at 80°C for 24 h and then nitrogen uptake was measured (Bremner and Mulvaney 1982). Leaf chlorophyll content was measured with using SPAD-502.

### 2.3 Field Experiments

Field experiment was carried out in West Azerbaijan agricultural research center in 2009-10. The experimental field station was located in latitude 45º 22'N, 75º 32' 36° 58´, longitude 46° 6´ and altitude 1371 m, by a typical silty loam texture.

At the first year, seed lots used in the laboratory experiment were planted with factorial experiment based on randomized complete blocks design with five replications. Chemical fertilizers were applied pre-planting according soil analysis, therefore 100 kg per hectare $NH_4NO_3$ was applied before planting. At the booting stage, 1.5 $L.ha^{-1}$ of 2- 4-D was used for weed control.

In the second year the same treatments were carried out at two separate factorial experiments based on randomized complete blocks designs under drought and well-watered conditions. In drought experiment water was withheld at the booting stage and irrigation was done after 150 ± 5 mm evaporation from the Class A Pan. Well watered plots were irrigated after 75 ± 5 mm evaporation from the Class A Pan (Table 1). To determine above ground biomass, four central rows were harvested upon maturity. Total dry matter, grain yield, 1000-kernel weight, spike/m2, grain per spike, relative water content (Gonzalez 1999) and plant height were measured.

Analyses of variance for all data's of laboratory, greenhouse and field experiments were conducted by Mstat-c software. Treatments were considered significantly different at $p \leq 0.05$.

**Table 1.** General characteristics, summary of water inputs (rainfall and irrigation), class A pan evaporation and maximum and minimum temperatures in 2009-10 at field conditions.

| | | Month | Tmax (°C) | Tmin (°C) | Rain (mm) | Irr. (mm) | Evap. (mm) |
|---|---|---|---|---|---|---|---|
| Number of cultivars | 4 | | | | | | |
| Number of pretreatments | 7 | | | | | | |
| Number of combination treatments | 28 | October | 26.1 | 9.2 | 5.5 | | 124.1 |
| Total plots | 280 | November | 15.6 | 9.3 | 27.7 | | 45.2 |
| Density of plants | 400 | December | 8.9 | 1.5 | 32 | | |
| Internals between blocks | 1.3m | January | 7.7 | -0.7 | 38.4 | | |
| Intervals between rows | 0.2m | February | 5.9 | -3.8 | 16.6 | | |
| Rows per plot | 6 | March | 14.4 | -0.4 | 44.6 | | |
| Plot size | $1.2\times2m^2$ | April | 15.9 | 5.3 | 63.6 | 25 | 57.7 |
| Harvest area per plot | $1m^2$ | May | 20.2 | 6.9 | 34.1 | 33 | 130.9 |
| Replications per experiment | 5 | June | 28.6 | 10.7 | 3.8 | 110 | 232.3 |
| Ec of water irrigation | 0.024ds/m | July | 33 | 15.7 | 4.4 | 130 | 314.6 |

## 3 RESULTS AND DISCUSSION

### 3.1 Seed Soaking

The greatest amount of absorbed water within cultivars was observed for Shariar with DW and the lowest amount corresponded to Zarrin and Shariar with CCC pretreatment (Table 2). Priming with CCC and IAA pretreatments had the shortest time of imbibition and the lowest absorbed water to the other types, but the most increased seed weight. In general, increased weight of primed seed lots was due to activation of cell respiration (Bewley and Black 1994), repairs of macromolecules (Osborn 1993), movements of acquired materials (Gallardo *et al.,* 2001), activation of cell cycling (Vasquez-Ramos and Sanchez 2004) and weakening of seed coat structure for root emergence (Cantliffe *et al.*, 1984). Water absorption is the first stage of germination, at the second stage or retardation stage, seeds start the replication of DNA (Bray *et al.*, 1989), increasing of protein and RNA synthesis (Gallardo *et al.,* 2001), availability of more ATP (Mazor *et al.*, 1984), rapid embryo growth (Dahal *et al.*, 1990) than control seeds.

**Table 2.** Changes in weight and moisture content of wheat seed cultivars after soaking and air-drying for 20 days in 25°C.

| Cultivar | Seed weight (g) | Pretreatment DW | NaCl 5% | Urea 10% | KCl 2.5% | PEG 10% | MN 4% | IAA 20ppm | CCC 1000ppm |
|---|---|---|---|---|---|---|---|---|---|
| Sardary | water absorbed | 9.68 | 2.43 | 3.42 | 10.44 | 11.48 | 12.04 | 3.60 | 2.28 |
| | Increased seed weight | 0.42 | 0.33 | 0.32 | 0.96 | 1.12 | 1.02 | 1.20 | 1.12 |
| Azar | water absorbed | 13.32 | 2.55 | 2.96 | 9.52 | 7.76 | 12.40 | 4.4 | 3.68 |
| | Increased seed weight | 0.16 | 0.17 | 0.05 | 0.20 | 0.40 | 0.28 | 0.76 | 0.84 |
| Zarrin | water absorbed | 10.56 | 2.78 | 3.1 | 8.88 | 6.32 | 11.20 | 2.68 | 1.92 |
| | Increased seed weight | 0.52 | 0.22 | 0.25 | 0.80 | 1.16 | 0.52 | 0.96 | 1.20 |
| Shariar | water absorbed | 15.12 | 3.35 | 3.77 | 13.32 | 9.88 | 13.32 | 4.88 | 1.96 |
| | Increased seed weight | 0.4 | 0.12 | 0.15 | 0.60 | 0.88 | 0.44 | 0.96 | 1.24 |

## 3.2 Seedling Vigor and Plant Stand

Root lengths of Shariar and Zarrin seedlings at pretreatments with IAA and CCC were 22.3, 22.0, 22.0 and 22.5 cm, respectively (Fig. 1-A), which is much more than in other treatments. This effect could be related to CCC and IAA enhanced cell divisions at root tip (Farooq *et al.*, 2006; Fu *et al.*, 1988). The trend of variation between cultivars and pretreatments for plumule length was similar with root length, however, at urea pretreatment length of both decreased (Fig. 1-B). Irrespective of cultivar, pretreatments with CCC, IAA and DW with 8.1, 8.0, 8.1 g had bigger effect on radical dry weights (Fig. 1-C). Within pretreatments, potassium chloride had the most positive effect on plumule dry weight, 12.6 g, and urea treatment had the most negative effect, 7.1 g (Fig. 1-D). Increased plumule dry weight due to osmopriming was reported by Harris *et al.*, (2004). It caused rapid establishment of plants during germination and ultimately higher production of dry matter. Rapid germination in primed seeds was caused by increased enzyme activity, including of alfa amylase, higher levels of ATP, increased synthesis of RNA and DNA and increased number and efficiency of mitochondria (Bittencourt *et al.*, 2005).

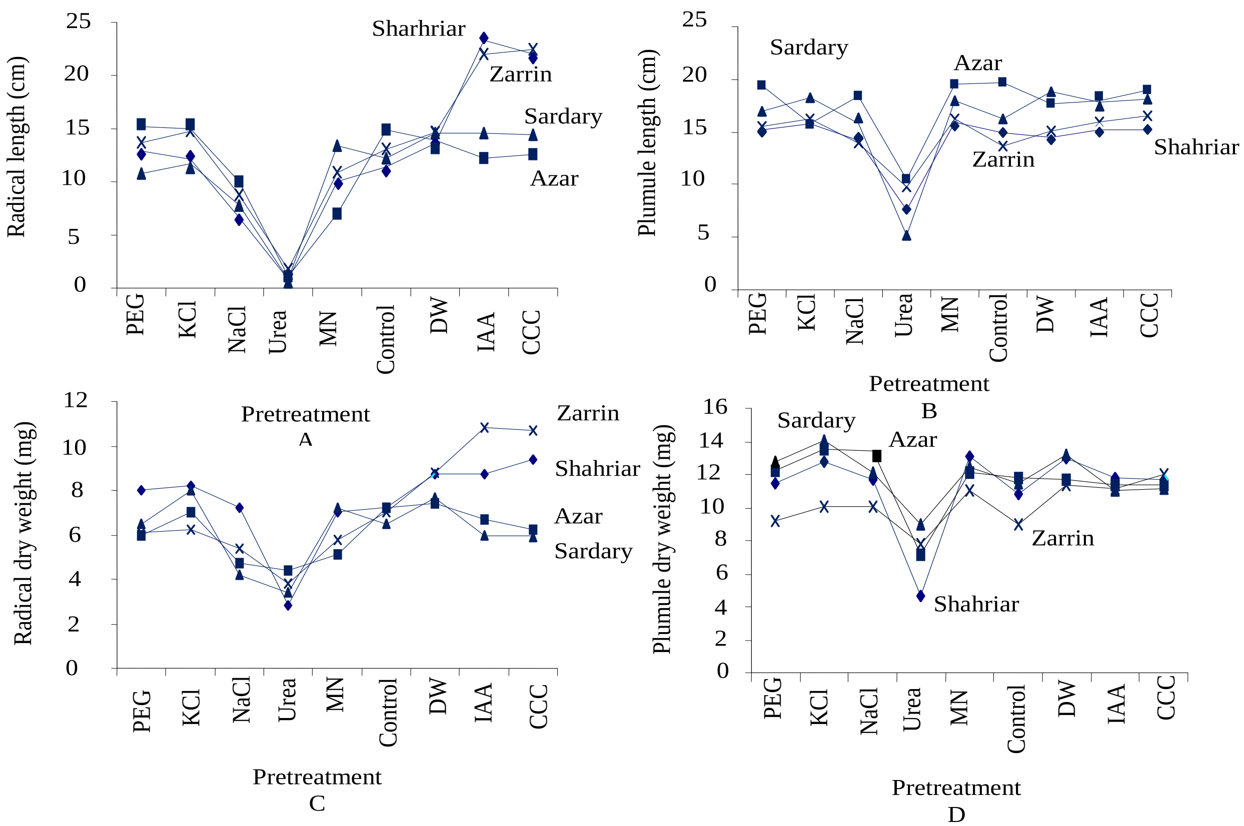


**Figure 1**. The effects of different seed pretreatments in wheat cultivars on seedling related traits.

### 3.3 Response to Nitrogen

Cultivars Azar and Sardary had the highest chlorophyll content at IAA pretreatment while the highest content of chlorophyll in cultivars Zarrin and Sharriar was determined in DW treatment (Fig. 2-B). All pretreatments in four cultivars had higher nitrogen absorption than control. The highest nitrogen absorption, 57.3% was measured in cultivar Shariar and the lowest in cultivar Sardary, 47.6% (Fig. 2-A). In all cultivars priming with CCC and IAA resulted in higher nitrogen absorption in comparison to the other pretreatments. The reason behind that is probably the increase of the root length, which was seen in the laboratory evaluation. The increase of nitrogen absorption at priming with plant growth inducers may finally cause improvement of grain yield. Absorbed nitrogen directly effects on leaf chlorophyll content, and, in turn, improves metabolism and photosynthesis (Kulkarni and Eshanna 1988).

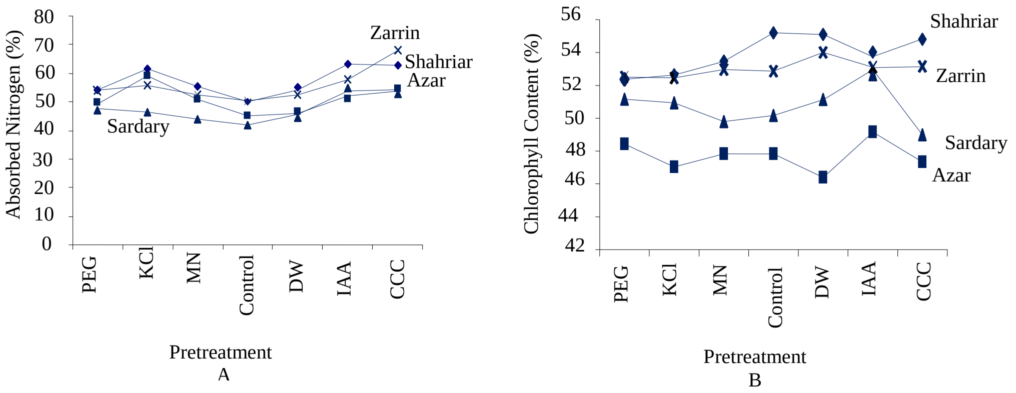


**Figure. 2.** The effects of different seed pretreatments in wheat cultivars on traits of chlorophyll content and absorbed nitrogen under green house conditions

### 3.4 Morpho-physiological traits

Under field conditions, all of pretreatments at four cultivars gave bigger grain yield than control and among them CCC treatment gave the highest yield, 591 g/m$^2$. Responses of cultivars varied with the type of pretreatments. Therefore, the grain yields of cultivar Shariar were 635, 625 and 613 g/m$^2$ for hydropriming, CCC and MN, respectively. Cultivar Zarrin treated with IAA and CCC had 628 and 620 g/m$^2$ grain yield, respectively. Pretreatment with CCC gave the grain yield for cultivars Sardary and Azar 590 and 520 g/m$^2$, respectively (Fig. 3-A). The increase of grain yield with pretreatments was due to the expansion of leaves, which resulted in higher photosynthesis, assimilation and ultimately higher production of total dry matter. Accumulated priming materials in plants were effective during seed set and grain filling (Haris *et al.*, 1999 and 2004). Many researchers reported the increase of grain yield in wheat cultivars due to pretreatments, as 37% in (Misra and Dwibedi 1980), and 15% (Haris *et al.*, 1999 and 2004). Success in seed priming depends on type of cultivar, osmotic potential of solution, time of priming, temperature environment, seed vigor, the rate of seed re-drying and the conditions during primed seed storage (Parera and Cantliffe 1994).

The highest number of grains per spike, 66 grains, was counted for cultivars Shariar and Zarrin, and the lowest values was determined in cultivars Azar and Sardary, with 36 and 30 grains respectively (Fig. 3-B). Irrespective of cultivar, pretreatments with IAA, CCC, DW and MN had 54, 53, 52 and 51 grains per spike, respectively. Pretreatments with CCC for 1000-Kernel weight of 45 g and treatments by CCC, DW and MN which gave 372, 371 and 366 spikes per square meter were the highest values of these parameters (Fig. 3-C and D). The range of variations for number of spikes per square meter was between 277 and 392, related to cultivars Sardary and Zarrin, respectively.

The highets total dry matter was measured for pretreatments DW, IAA and CCC, with values of 1198, 1185.3 and 1196.6 g/m$^2$, respectively (Fig. 3-E). The increased number of spikes per square meter at all pretreatments is a reason for higher total dry matter production. The smallest plant height was obtained for IAA and CCC pretreatments (Fig. 3-F).

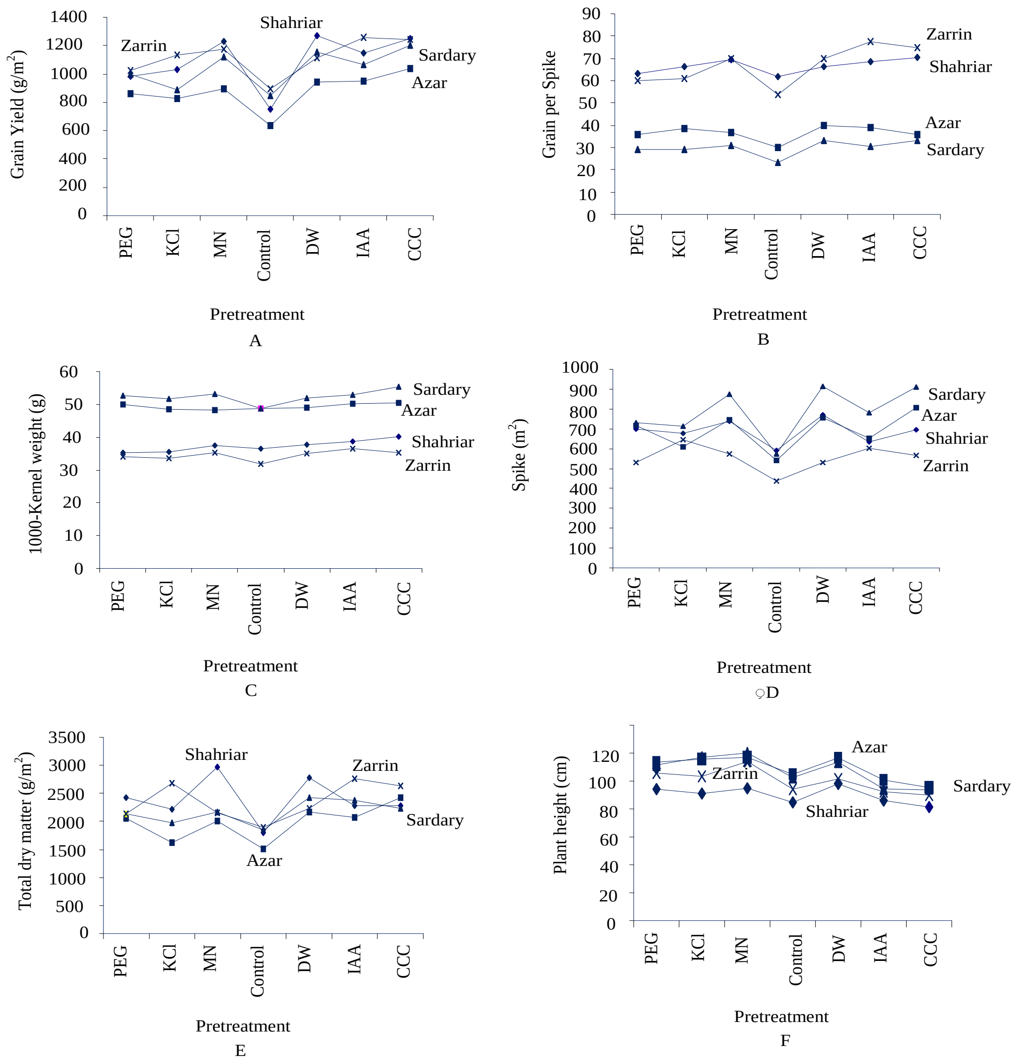


**Figure. 3.** The effects of different seed pretreatments in wheat cultivars on morpho-physiological traits under field conditions.

### 3.5 Inducing of tolerance to drought stress

The highest variation in grain yield under drought stress compared to well watered plants were measured in cultivar Shahriar (39 %), primed with IAA, cultivar Azar (23 %), primed with CCC, cultivar Sardary (32%) primed with PEG and cultivar Zarrin (45%) primed with CCC. In contrast, pretreatment with potassium chloride in all four cultivars had the lowest variations in grain yield (Table 3). Potassium ion induced tolerance to drought stress under drought treatment (Khajeh-hosseini *et al.*, 2003). Depending on the cultivar responses of grain yield components to pretreatments were different. The percentage of variation in grain yield components within primed seeds with potassium chloride at four cultivars showed that under drought stress 1000-kernel weight had the lowest value. In contrast, except cultivar Sardary, maximum percentage variation was seen for number of spikes per square meter (Fig. 4). Saha *et al.*, (1990) reported that performance of grain yield at primed seeds of soybean had differed and depended on cultivar type. The increase of grain yield at primed seeds in wheat, barley, rice, sorghum, chickpea and millet were stated by different researchers (Harris *et al.*, 2001; 2004; Misra and Dwibedi 1980; Paul and Choudhury 1991).

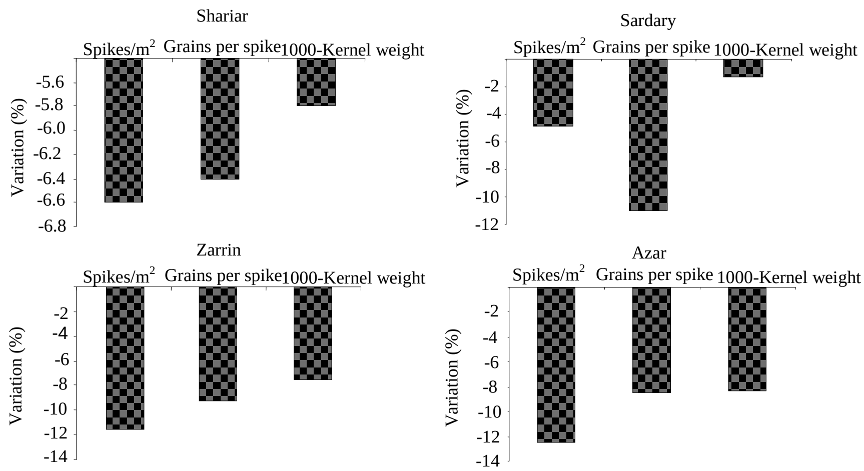


**Figure. 4.** Variations percentage of grain yield components of primed seed with using of potassium chloride in wheat cultivars under drought stress in comparison with well watered.

All pretreatments in our experiment had lower variation of total dry matter under drought stress compared to well-watered treatments (Table 3). Among them potassium chloride had the lowest value, which could be related to the fact that potassium induces higher tolerance to drought stress. Pretreatments resulted in high total dry matter production through effects on growth period. Primed seeds had after sowing faster germination, rapid establishment, and uniform growth.

Such a plant expands root system at shorter time compared to the control and by uptaking more water and nutrients produces photosynthetic organs rapidly and reaches earlier autotrophic stage (Duman 2006). Relative water content of wheat flag leaf primed with potassium chloride has minimal variation (Table 3).

**Table 3.** Variations percentage for traits of grain yield, total dry matter and relative water content in primed seeds of wheat cultivars under drought stress with comparison well watered.

| | Grain yield (g/m$^2$) | | | | | | |
|---|---|---|---|---|---|---|---|
| Cultivar | PEG 10% | KCl 2.5% | MN 4% | Control | DW | IAA 20ppm | CCC 1000ppm |
| Shariar | -17.6 | -7.1 | -25.1 | -36.1 | -33.0 | -39.0 | -32.0 |
| Azar | -22.5 | -1.9 | -7.4 | -15.6 | -9.1 | -16.6 | -23.9 |
| Sardary | -32.4 | -2.3 | -8.8 | -27.7 | -16.5 | -16.7 | -17.1 |
| Zarrin | -27.3 | -4.3 | -37.7 | -33.4 | -32.9 | -40.8 | -45.4 |
| | Total dry matter (g/m$^2$) | | | | | | |
| Shariar | -14.2 | -12.3 | -11.0 | -18.1 | -14.3 | -15.5 | -13.3 |
| Azar | -12.7 | -10.1 | -13.8 | -17.4 | -17.2 | -12.4 | -14.0 |
| Sardary | -13.9 | -9.8 | -10.3 | -15.8 | -10.7 | -11.7 | -12.2 |
| Zarrin | -15.7 | -10.4 | -18.1 | -20.2 | -11.0 | -13.6 | -12.3 |
| | Relative water content (%) | | | | | | |
| Shariar | -28.0 | -9.1 | -24.9 | -37.1 | -19.6 | -22.7 | -11.7 |
| Azar | -25.4 | -10.5 | -17.3 | -25.6 | -14.6 | -18.9 | -12.3 |
| Sardary | -19.5 | -9.6 | -16.2 | -27.1 | -11.0 | -17.9 | -13.6 |
| Zarrin | -37.0 | -8.0 | -34.0 | -35.0 | -21.8 | -34.5 | -9.7 |

Variation (%)=[(Mean cultivar under stress-Mean cultivar under well watered)/Mean cultivar under well watered]×100

### 3.6 Correlation coefficients traits

Traits of wheat such as number of spikes per square meter, number of grains per spike, total dry matter has with grain yield positive but significantly different correlation (Table 4). With increasing value of these traits, grain yield increases as well. Number of spikes per square meter and number of grains per spike at potassium chloride pretreatment had the highest percentage of variation. Therefore, these traits could be used as an indirect criterion for the selection for high grain yield. Chimenti and Hall (1994) observed positive correlation between leaf area and grain yield in sunflower under drought stress, and used it as an indirect selection in screening tolerant genotypes under drought stress.

**Table 4.** Correlation coefficients of wheat cultivars traits of primed seed using of different pretreatments.

| Trait | Grain yield ($g/m^2$) | Spikes/$m^2$ | Grains per spike | 1000-Kernel weight (g) | Total dry matter ($g/m^2$) |
|---|---|---|---|---|---|
| Spikes/$m^2$ | 0.91** | | | | |
| Grains per spike | 0.92** | 0.83* | | | |
| 1000-Kernel weight (g) | 0.54 | 0.74 | 0.59 | | |
| Total dry matter ($g/m^2$) | 0.79* | 0.79* | 0.76* | 0.29 | |
| Relative water content | 0.50 | 0.66 | 0.29 | 0.33 | 0.55 |

* and **: Significant differences at $p \leq 0.05$ and 0.01 probability levels, respectively.

## 4 CONCLUSION

Responses of wheat cultivars were different to pretreatments. Seed priming with IAA and CCC for 30 minutes had positive effects on seedling regarding nitrogen absorption and grain yield traits. It also increased the components of grain yield more than other pretreatments for 18 hours. In opposite, urea pretreatment had negative effect on seedling related traits compared to control. Therefore, we excluded urea pretreatment in green house and field experiments. The biggest percentages of variation for grain yield under drought stress compared to well-watered treatment were found for cultivars Shariar, Azar, Sardary and Zarrin with IAA 39%, CCC 23%, PEG 32% and CCC 45%, respectively. In contrast, potassium chloride pretreatment showed at all four cultivars the minimum variations for grain yield, total dry matter and relative water content, probably due to induction of higher drought tolerance This pretreatment, except in cultivar Sardary, had the strongest effect on trait number of spikes per square meter. The trend of variations for plumule length at laboratory experiment was similar with plant height at field conditions. In the case of CCC pretreatment, the pretreatment decreased internodial lenght and subsequently plant height, but in other pretreatments it was increased. Seed priming improved grain yield up to 40 percent. Increase of 25% in absorbed nitrogen causes better vegetative growth and total dry matter compared to control. Pretreatments increased seed vigor and rapid growth at seedling stage under field conditions what had direct effect on grain yield. In addition, improving the germination percentage and uniformity emergence, pretreatment results in suitable density with increased tiller number and grains per spike. Under drought stress conditions, it is recommended that seeds be primed with potassium chloride. It is suggested that proteomic techniques should be used to identify molecular mechanisms under drought stress for primed seeds.

## 5 ACKNOWLEDGEMENTS

The financial support for this research was provided by Management and Programming Organization.

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