SEEDLING ESTABLISHMENT AND YIELD OF MAIZE UNDER DIFFERENT SEED PRIMING PERIODS AND AVAILABLE SOIL MOISTURE

*MUHAMMAD IMTIAZ SUDOZAI[1], SHAMSUDDIN TUNIO[1], QAMARUDDIN[2] CHACHAR[1] and INAYATULLAH RAJPAR[3]

1 *Department of Agronomy, Sindh Agriculture University, Tandojam - Pakistan.*
2 *Department of Plant Physiology, Sindh Agriculture University, Tandojam - Pakistan.*
3 *Department of Soil Science, Sindh Agriculture University Tandojam - Pakistan.*
Corresponding author: imtiaz.sudozai@gmail.com

ABSTRACT

Hydropriming of seeds responded very well to improve germination and emergence of many Agronomic crops. Among different strategies to cope with germinability issues, hydropriming is an easy, low cost, and low risk technique. Seed priming is as pre-sowing treatment in water or in an osmotic solution that allows seed to imbibe water to initiate the first stages of germination, but prevents radicle protrusion through the seed coat. Rapid and uniform field emergence is an essential prerequisite to reach the yield potential, quality, and ultimately profit in annual crops. Establishment of an adequate stand is also important for grain yield of crops and is uncertain in most of the tropical areas because available soil moisture at planting is often marginal for plant growth. Water stress during seed germination is among the most widespread abiotic stresses limiting seedling emergence, which ultimately reduces crop productivity. To achieve the objective of the study, field experiment was conducted at Students Farm, Sindh Agriculture University Tandojam, Pakistan. The experiment was laid out under Randomized Complete Block Design (Factorial) with three replications, to evaluate the effect of hydropriming periods (0 (control) 6, 12, 18, and 24 h) and available soil moisture levels (60-65, 55-60 and 50-55%) on maize (Zea mays L.) seedling growth and yield traits. Results showed maximum seedling growth traits viz. shoot length, root length, shoot dry weight plant^{-1}, root dry weight plant^{-1}, leaves seedling^{-1}, crop growth rate and leaf area plant^{-1}, and maximum yield traits viz. cobs plant^{-1}, grains cob^{-1}, seed index and seed yield when maize seed was sown for 18 h hydropriming. Similarly, In case of available soil moisture treatments maximum shoot length, root length, shoot dry weight, root dry weight, leaves seedling^{-1} crop growth rate, leaf area plant^{-1}, cobs plant^{-1}, grains cob^{-1}, seed index and seed yield were observed when maize seeds were sown in 60-65 and 55-60% available soil moisture, respectively. It is concluded that hydropriming is an efficient technique for enhanced seed emergence and seedling establishment under optimal and sub-optimal available soil moisture conditions. This study recommends 18h hydropriming before sowing maize when sown in 55-65% available soil moisture to achieve maximum emergence, establishment of vigorous rooting system and uniform plant stands which are necessary for growth and yield of maize.

Keywords: **Hydropriming, available soil moisture, maize, growth, yield**

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INTRODUCTION

Poor seedling emergence and establishment is one of the major abiotic constraint encountered by resource-poor farmers. Increasing the rate of crop emergence could increase crop stand establishment, efficient use of resources such as water and light to produce good yields. Many researchers found poor stand establishment (about 40%) with increased labor costs and exhaustion of seed supplies (Chiduza, 1993; Chiduza *et al*., 1995; Van Oosterhout, 1996). Improvement in seed germination is an active area of research and efforts are being made to improve seed germination in various economically important crops (Suleman *et al.*, 2011). Among the other factors, seed priming techniques could be used to accelerate seed germination, improve seedling establishment, stimulate vegetative growth and crop yield in many field crops like wheat (Ghiyasi *et al.,* 2008;), chickpea (Kaur *et al.,* 2002), cotton (Casenave &Toselli, 2007), lentil (Ghassemi-Golezani *et al.*, 2008), sunflower (Kaya *et al*., 2006), and maize (Foti *et al.,* 2008). In hydropriming seeds are soaked in water for usually overnight, followed by drying and planting the seeds in the same day. Due to imbibition seeds take short time to germinate, however, non-primed seeds take longer time with relation to soil moisture for imbibition. Therefore, it is suggested that seed germination might be increased by hydropriming technique (Hartman *et al*., 2002).

It is evident that hydroprimed seeds exhibit activation of cellular defense responses, due to which they can better tolerate subsequent biotic or abiotic stresses in the field (Beckers and Conrath, 2007). Seed priming enhances speed and uniformity of germination (Khalil *et al*., 2010), extend many biochemical modification which are basically needed for starting germination process viz. dormancy breaking, hydrolysis, enzyme creation and seed imbibition (Asgedom and Becker, 2001).

The available soil moisture affects emerging seeds, growth and yield of many crops and depends on readily available soil moisture of root zone. Use of limited soil moisture cause reduction in seed germination, seedling establishment and further growth. The adverse effects of low available soil moisture condition on seed emergence and related traits had also been well documented by Dhanda *et al*. (2004), Sadeghian and Yavari (2004), Gill *et al*. (2002), Mohammad *et al*. (2002) and Andoh and Kobata (2000). Other workers including Ambawatia (1995), Rakesh *et al*. (1999) and Khan *et al*. (2002) also reported that germination and growth of seedlings were significantly affected with change in available soil moisture conditions.

The decline rate of seed emergence was found to be obvious, varying with crop species and cultivars. In this scenario, hydropriming encounters available soil moisture dryness to endow plants with greater tolerance to subsequent stress exposure (Patanea *et al.,* 2009).

In the field, uniform stand establishment and vigorous early growth are still a pre-requisite for successful cropping system even under adverse available soil moisture conditions. Healthy plants with well developed root systems can withstand adverse conditions than those seedlings interrupted at an early stage. Among the seed priming treatments, hydro priming is in the control of farmer (without chemicals) and could be employed to accelerate germination, seedling growth and yield of many field crops under normal and water stress conditions. The little work has been done to fully understand agronomic and physiological changes occurring due to hydropriming periods and available soil water. In this research, the protocol was simple, cheap and does not require any chemical and sophisticated equipment. Hydropriming has practical and applied importance and could be recommended to farmers to achieve higher germination, uniform emergence and yield under field water stress conditions. This research, therefore, was taken in hand to assess the impact of hydropriming periods on the emergence, seedling establishment and yield of maize and to observe the effect of available soil moisture on maize crop emergence, establishment and yield and to evaluate the interactive effect of hydropriming periods and available soil moisture on crop emergence and related yield traits.

MATERIALS AND METHODS

Experimental Design and Treatments

A two factor field study was designed under randomized complete block at Students Farm, Sindh Agriculture University Tandojam (25^{o}25’60’N 68^{o}31’60E), Pakistan. In factor A, five hydropriming periods (no priming, 06, 12, 18 and 24 h priming) and in factor B, three available soil moisture (60-65, 55-60 and 50-55%) levels were applied to evaluate germination, seedling growth behavior and yield of maize. The experimental soil was clay loam, non-saline and low in organic matter (0.55-0.58%), available phosphorus (3.00-3.50 mg kg^{-1}) but high in exchangeable potassium (165 mg kg^{-1}). Hydroprimed and non-primed seed of maize were drilled with single coulter hand driven drill at 70 x 30 cm row and plant spacing respectively during February 15, 2009-10. The NP at 120-60 kg ha^{-1} in the form of urea, and single super phosphate, respectively were applied. Whole phosphorus (P) and half nitrogen (N) were applied during planting; the remaining N was split applied during 2nd and 3rd irrigations. Weed management practices for reducing weed-crop competition, were done through hand weeding. The irrigations were applied as per available soil moisture treatments.

Hydropriming

The seeds of crops were primed in a container having canal water for the periods indicated in factor A. Before sowing, hydroprimed seeds were dried by spreading the seeds in the shade for two hours. Hydroprimed seeds were handled for drilling in the same way as non-primed seed.

Available Soil Moisture

It involves determination of current water content of soil. Gravimetric measurement of soil water content described by Pikul (2003) was used. Moisture content (%) on dry weight basis was computed by:

$$\Theta_w = \frac{(Ww-Wd)}{Wd} \times 100$$

Where,

Θ_w = Moisture content on dry weight basis
Ww = Wet weight of soil (g)
Wd = Oven dry weight of soil (g)

Emergence (%) was recorded 7 days after sowing (DAS), shoot and root length and their fresh and dry weights were recorded at 7, 15 & 22 DAS, number of leaves per seedling was noted at 15 and 22 DAS, while crop growth rate and leaf area was measured at 15 DAS.

Method of Determination

Soil

***Soil texture**:* by Bouyoucos Hydrometer method (Kanwar and Chopra, 1967).
***Electric conductivity (EC)**:* by digital electric conductivity meter (HI-8333).
***Soil reaction (pH)**:* by digital pH meter, model SP-34 Suntex.
***Organic matter (%)**:* by Walkely-Black method (Jackson, 1958).
***Total nitrogen (%)**:* by Kjedahl method as described in soil chemical analysis by Jackson, (1958), method.
***Available phosphorus and potassium (mg kg^{-1})**:* by AB-DTPA method. (Soltanpour, 1991)

Emergence (%)

Emergence percentage was determined through quadrate method by throwing randomly thrice in each plot.

Shoot Length (cm)

Five plants from each treatment were randomly selected to measure shoot length and calculate average shoot length at subsequent intervals.

Root Length (cm)

Five plants from each treatment were randomly selected to measure root length and calculate average root length at subsequent intervals.

Shoot Dry Weight (g)

Shoot dry weight was taken with the help of an electric balance after drying each replication at 70°C in the oven to get the constant weight (Afzal *et al.*, 2004).

Root Dry Weight (g)

Root dry weight was taken with the help of an electric balance after drying each replication at 70°C in the oven to get the constant weight (Afzal *et al.,* 2004).

Leaves Seedling^{-1}

By counting the leaves of 5 randomly selected seedlings from each treatment and then average number of leaves seedling^{-1} were calculated.

Leaf Area (cm^2)

Five saplings from each treatment were randomly selected for leaf area during seedling stage. The leaves were separated and leaf area was measured manually by using the formula described by Hunt (1978):
LA= Leaf length x Leaf width x CF (0.75)

Crop Growth Rate (g m^2 day^{-1})

Crop growth rate (CGR) was worked out during seedling stage through the standard procedures described by Hunt (1978) as under:

$CGR = (W_2 – W_1) / (T_{2-}T_1)$

Where, W_1 and W_2 = initial and final dry weights respectively same as with times T_1 and T_2.

Cobs $Plant^{-1}$

At maturity cobs $plant^{-1}$ from 10 randomly selected plants were counted and then average cobs $plant^{-1}$ were calculated.

Grains Cob^{-1}

At maturity grains cob^{-1} from 10 randomly selected plants were counted and then average grains cob^{-1} were calculated.

Seed Index (g)

1000 grains from each treatment were weighed on an electric balance after sun drying.

Grain Yield kg ha^{-1}

At maturity harvest of m^{-2} threshed, weighed and computed for ha^{-1}.

Statistical Analysis

The data was statistically analyzed for analysis of variance to assess the significant differences among variables. While the individual mean differences for seed priming and available soil moisture, as well as interactive effects were analyzed using least significant difference test at 0.05% probability as per statistical methods developed by Gomez and Gomez (1984). The statistical analyses were performed by using Mstat-C Computer Software for Statistics.

RESULTS AND DISCUSSION

Statistical analysis of variances for maize (*Zea mays* L.) emergence and seedling growth traits as affected by hydropriming periods, available soil moisture and their interactive effect were significant at 5% probability level.

Effect of hydropriming on Growth Traits of Maize Seedlings (after7 days)

Statistical analysis of variance for maize seedling traits after 7 days of seed sowing recorded maximum emergence (81.40%), shoot length (12.73 cm), root length (11.06 cm), shoot dry weight $plant^{-1}$ (0.15 g) and root dry weight $plant^{-1}$ (0.04 g) when maize seed was kept for 18 h hydropriming, followed by, 12 h which recorded 75.39 emergence, 11.36 cm shoot length, 9.60 cm root length, 0.06 g shoot dry weight $plant^{-1}$ and 0.03 g root dry weight $plant^{-1}$ (Table 1).

It was noted that further decrease or increase in hydropriming periods viz. 6 and 24 h; significantly had lower seed emergence (69.38 and 71.15%), shoot length (10.46 and 10.60 cm), root length (7.64 and 8.37 cm), shoot dry weight $plant^{-1}$ (0.06 g) and root dry weight $plant^{-1}$ (0.02 g) respectively (Table 1).

Table 1. ***Maize seedling growth traits as affected by hydropriming periods***

Maize plant traits	SE	LSD (5%	Hydropriming periods (h)				
			No priming	6	12	18	24
7 days after sowing							
Emergence (%)	1.009	2.922	66.26 d	69.38 c	75.39 b	81.40 a	71.15 c
Shoot length (cm)	0.144	0.419	8.47 d	10.46 c	11.36 b	12.73 a	10.60 c
Root length (cm)	0.122	0.353	6.83 d	7.64 c	9.60 b	11.06 a	8.37 c
Shoot dry weight (g)	0.0008	0.002	0.05 d	0.06 c	0.08 b	0.15 a	0.06 c
Root dry weight (g)	0.0005	0.001	0.01 d	0.02 c	0.03 b	0.04 a	0.02 c
15 days after sowing							
Shoot length (cm)	0.410	1.189	17.82 d	22.02 c	26.40 b	30.73 a	22.68 c
Root length (cm)	0.139	0.405	7.69 d	8.96 c	10.78 b	11.77 a	9.16 c
Shoot dry weight (g)	0.01	0.030	0.23 d	0.32 c	0.43 b	0.55 a	0.38 c
Root dry weight (g)	0.001	0.003	0.11 d	0.13 c	0.16 b	0.21 a	0.15 c
Leaves seedling^{-1}	0.073	0.211	3.49 c	3.69 c	4.45 b	5.19 a	4.08 c
22 days after sowing							
Shoot length (cm)	0.678	1.965	25.51 d	30.14 c	37.57 b	41.31 a	35.17 c
Root length (cm)	0.162	0.470	9.05 d	10.86 c	12.47 b	15.90 a	11.81 c
Shoot dry weight (g)	0.010	0.030	0.50 d	0.65 c	1.44 b	1.96 a	1.23 c
Root dry weight (g)	0.002	0.007	0.14 d	0.19 c	0.25 b	0.32 a	0.21 c
Leaves seedling^{-1}	0.064	0.188	4.10 d	4.46 c	5.01 b	5.32 a	4.86 c

Values followed by same letters in each row do not differ significantly at 0.05 probability level.

Effect of hydropriming on Growth Traits of Maize Seedlings (after 15 days)

The higher shoot length (30.73 cm), root length (11.77 cm), shoot dry weight plant^{-1} (0.55 g), root dry weight plant^{-1} (0.21 g) and leaves^{-1} seedling (5.19) were observed when maize seed was retained for 18 h hydropriming, followed by, 12 h. However, 6 and 24 h seed hydropriming periods significantly decreased shoot length (22.02 and 22.68 cm), root length (8.96 and 9.16 cm), shoot dry weight plant^{-1} (0.32 and 0.38 g), root dry weight plant^{-1} (0.13 and 0.15 g) and leaves^{-1} seedling (3.49 and 4.08).

Effect of hydropriming on Growth Traits of Maize Seedlings (after22 days)

After 22 days, maize seed put for 18 h hydropriming recorded maximum shoot length (41.31 cm), root length (15.90 cm), shoot dry weight plant^{-1} (1.96 g), root dry weight plant^{-1} (0.32 g) and leaves^{-1} seedling (5.32), followed by 12 h.

In this study, it was observed that further decrease or increase in hydropriming periods viz. 6 and 24 h had significantly minimum shoot length (30.14 and 35.17 cm), root length (10.86 and 11.81 cm), shoot dry weight plant^{-1} (0.65 and 1.23 g), root dry weight plant^{-1} (0.19 and 0.21 g) and leaves^{-1} seedling (4.46 and 4.86). The minimum seedling growth traits were noted in the plots where seed was sown without hydropriming (Table 1).

Effect of hydropriming on Physiological Traits of Maize

The maximum crop growth rate (0.96 g m^2 day^{-1}) and leaf area plant^{-1} (55.98 cm^2) were observed when maize seed was hydroprimed for 18 h. The second lowest values of crop growth rate (0.70 g m^2 day^{-1}) and leaf area plant $^{-1}$ (45.69 cm^2) were found when seed was hydroprimed for 12 h. However, 6 and 24 h seed hydropriming had significantly minimum crop growth rate (0.22 and 0.58 g m^2 day^{-1}) and leaf area plant^{-1} (36.05 and 40.91 cm^2) (Table 2).

Table 2. ***Maize seedling physiological traits (after 15 days) as affected by hydropriming periods***

Maize plant traits	SE	LSD (5%)	Hydropriming periods (h)				
			No priming	6	12	18	24
Crop growth rate (g m^2 day^{-1})	0.01	0.03	0.16 e	0.22 d	0.70 b	0.96 a	0.58 c
Leaf area (cm^2)	0.66	1.91	29.18 e	36.05 d	45.69 b	55.98 a	40.91 c

Values followed by same letters in each row do not differ significantly at 0.05 probability level.

Effect of hydropriming on Yield Components of Maize

The results revealed higher number of cobs plant^{-1} (1.28), grains cob^{-1} (359.44), seed index (254.22 g) and seed yield (3421.88 kg ha^{-1}) when maize seed was hydroprimed for 18 h. However, 12 h hydropriming recorded cobs plant^{-1} 1.17, grains cob^{-1} 316.66, seed index 234.77 g and seed yield 3002.00 kg ha^{-1} (Table 3).

Further, decrease or increase in hydropriming periods viz. 6 and 24 h respectively had significantly minimum cobs plant^{-1} (1.07 and 1.11), grains cob^{-1} (286.66 and 302.00), seed index (223.22 and 224.88 g) and seed yield (2694.11 and 2836.77 kg ha^{-1}). The minimum maize yield components viz. cobs plant^{-1} (1.03), grains cob^{-1} (244.66), seed index (209.88) g and seed yield (2306.66 kg ha^{-1}) were witnessed in the plots where seed was sown without hydropriming (Table 3).

Table 3. ***Maize yield components as affected by hydropriming periods***

Maize plant traits	SE	LSD (5%	Hydropriming periods (h)				
			No priming	6	12	18	24
Cobs plant^{-1}	0.011	0.04	1.03 d	1.07 c	1.17 b	1.28 a	1.11 c
Grains cob^{-1}	5.37	15.57	244.66 d	286.66 c	316.66 b	359.44 a	302.00 c
Seed index	3.19	9.26	209.88 d	223.22 c	234.77 b	254.22 a	224.88 c
Seed yield (kg ha^{-1})	41.17	119.3	2306.66 e	2694.11 d	3002.00 b	3421.88 a	2836.77c

Values followed by same letters in each row do not differ significantly at 0.05 probability level.

Effect of Available Soil Moisture on Growth Traits of Maize Seedlings

Seeds sown in 60-65 and 55-60% available soil moisture displayed higher emergence (77.36 and 78.34%), shoot length (12.64 and 12.67 cm), root length (9.34 and 9.42 cm), shoot dry weight (0.08 and 0.09 g) and root dry weight (0.03 g) respectively after 7 days of planting. Further decrease in available soil moisture (50-55%) significantly reduced emergence (62.45 %), length (6.86 cm), root length (7.34 cm), shoot dry weight (0.05 g) and root dry weight (0.02 g) (Table 4).

Table 4. ***Maize seedling growth traits as affected by available soil moisture***

7 days after sowing Maize plant traits	SE	LSD (5%)	Available soil moisture (%)		
			60-65	55-60	50-55
Emergence (%)	0.718	2.26	77.36 a	78.34 a	62.45 b
Shoot length (cm)	0.112	0.32	12.64 a	12.67 a	6.86 b
Root length (cm)	0.094	0.27	9.34 a	9.42 a	7.34 b
Shoot dry weight (g)	0.0006	0.0012	0.08 a	0.09 a	0.05 b
Root dry weight (g)	0.0004	0.0012	0.03 a	0.03 a	0.02 b
15 days after sowing					
Shoot length (cm)	0.317	0.920	26.44 a	26.79 a	18.57 b
Root length (cm)	0.108	0.313	10.32 a	10.42 a	8.28 b
Shoot dry weight(g)	0.008	0.023	0.45 a	0.46 a	0.25 b
Root dry weight (g)	0.0009	0.002	0.16 a	0.17 a	0.12 b
Leaves seedling $^{-1}$	0.056	0.163	4.33 a	4.41 a	3.87 b
22 days after sowing					
Shoot length (cm)	0.525	1.522	37.78 a	37.91 a	25.97 b
Root length (cm)	0.125	0.364	13.12 a	13.23 a	9.84 b
Shoot dry weight(g)	0.008	0.023	1.44 a	1.51 a	0.61 b
Root dry weight (g)	0.002	0.005	0.26 a	0.27 a	0.17 b
Leaves seedling $^{-1}$	0.050	0.145	5.04 a	5.09 a	4.18 b

Values followed by same letters in each row do not differ significantly at 0.05 probability level.

After 15 days of seed sowing, higher shoot length (26.44 and 26.79 cm), root length (10.32 and 10.42 cm), shoot dry weight (0.45 and 0.46 g), root dry weight (0.16 and 0.17 g) and leaves seedling^{-1} (4.33 and 4.41) respectively were found in 60-65 and 55-60% in available soil moisture respectively. Both the (60-65 and 55-60%) showed non-significant differences in the maize seedling growth traits after 15 days. However, further decrease in available soil moisture (50-55%) significantly reduced shoot length (18.57 cm), root length (8.28 cm), shoot dry weight (0.25 g), root dry weight (0.12 g) and leaves seedling^{-1} (3.87) (Table 4).

After 22 days of seed sowing in 60-65 and 55-60% available soil moisture recorded higher shoot length (37.78 and 37.91 cm), root length (13.12 and 13.23 cm), shoot dry weight (1.43 and 1.51 g), root dry weight (0.25 and 0.27 g) and leaves seedling^{-1} (5.04 and 5.09) respectively. Further reduction in available soil moisture (50-55%) significantly recorded lower values of shoot length (25.97 cm), root length (9.84 cm), shoot dry weight (0.61 g), root dry weight (0.17 g) and leaves seedling^{-1} (4.18) (Table 4).

Effect of Available Soil Moisture on physiological Traits of Maize

The results of the experiment revealed higher crop growth rate (0.65 and 0.67 g m^2 day^{-1}) and leaf area plant^{-1} (46.88 and 46.95 cm^2) respectively when maize seeds were sown in 60-65 and 55-60% available soil moisture. These both available soil moistures recorded non-significant differences in the values of seedling physiological traits of maize. However, minimum crop growth rate (0.25 g m^2 day^{-1}) and leaf area plant^{-1} (30.78 cm^2) were noted in the plots where maize seed received 50-55% available soil moisture (Table 5).

Table 5. ***Maize seedling physiological traits (after 15 days) as affected by available soil moisture***

Maize plant traits	SE	LSD (5%)	Available soil moisture (%)		
			60-65	55-60	50-55
Crop growth rate (g m^2 day^{-1})	0.008	0.023	0.65 a	0.67 a	0.25 b
Leaf area (cm^2)	0.511	1.482	46.88 a	46.95 a	30.78 b

Values followed by same letters in each row do not differ significantly at 0.05 probability level.

Effect of Available Soil Moisture on Yield Components of Maize

The results of the study revealed that yield components of maize showed better response for cobs plant^{-1} (1.24 and 1.26), grains cob^{-1} (336.20 and 337.80), seed index (242.59 and 243.63 g) and seed yield (3200 and 3201 kg ha^{-1}) respectively when seeds were drilled in 60-65 and 55-60% available soil moisture. Further decrease in available soil moisture (50-55%) significantly reduced cobs plant^{-1} (0.92), grains cob^{-1} (232.40), seed index (202.00 g) and seed yield (2154 kg ha^{-1}) (Table 6).

Table 6. ***Maize yield components as affected by available soil moisture***

Maize plant traits	SE	LSD (5%)	Available soil moisture (%)		
			60-65	55-60	50-55
Cobs plant^{-1}	0.011	0.033	1.24 a	1.26 a	0.92 b
Grains cob^{-1}	4.16	12.06	336.20 a	337.80 a	232.40 b
Seed index	2.47	7.17	242.59 a	243.63 a	202.00 b
Seed yield (kg ha^{-1})	31.89	92.38	3200 a	3201 a	2154 b

Values followed by same letters in each row do not differ significantly at 0.05 probability level.

Interactive Effect of hydropriming x Available Soil Moisture on Growth Traits of Maize Seedlings

The statistical analysis of variance for maize seedling growth traits (after 7, 15 and 22 days) under the interactive effect of hydropriming x available soil moisture showed significant differences for emergence, shoot length, root length, shoot dry weight, root dry weight and leaves seedling^{-1} (Table 7).

After 7 days of sowing, higher maize seedling emergence (86.87 and 87.07%), shoot length (14.80 and 14.91 cm), root length (11.80 and 11.90 cm), shoot dry weight (0.193 and 0.194 g) and root dry weight (0.045 and 0.047 g) were found when maize seed was hydroprimed for 18 h in water and planted in available soil moisture of 60-65 and 55-60% respectively. Further decrease or increase in seed hydropriming periods (6, 12, 24 h and no priming) and lower available soil moisture (50-55%) significantly resulted in lower values of maize seedling growth traits (Table 7).

Table 7. ***Maize seedling growth traits (after 7 days) under the interactive effect of hydropriming periods x available soil moisture***

Available soil moisture x hydropriming periods		Emergence (%)	Shoot length (cm)	Root length (cm)	Shoot dry wt. (g)	Root dry wt.(g)
60-65%	No priming	70.56 e	9.80 c	7.40 e	0.059 d	0.020 e
	6 h	74.06 de	12.60 b	8.20 d	0.066 c	0.029 c
	12 h	80.07 bc	13.40 b	10.30 b	0.096 b	0.037 b
	18 h	86.87 a	14.80 a	11.80 a	0.193 a	0.045 a
	24 h	76.06 bcde	12.70 b	9.03 c	0.067 c	0.031 c
55-60%	No priming	71.18 e	9.82 c	7.30 e	0.058 de	0.022 e
	6 h	75.06 cde	12.60 b	8.40 d	0.067 c	0.030 c
	12 h	81.07 b	13.40 b	10.40 b	0.097 b	0.038 b
	18 h	87.07 a	14.91 a	11.90 a	0.194 a	0.047 a
	24 h	77.36 bcd	12.70 b	9.10 c	0.067 c	0.032 c
50-55%	No priming	57.05 g	5.80 f	5.80 f	0.036 g	0.013 g
	6 h	59.05 g	6.20 f	6.33 f	0.042 f	0.013 g
	12 h	65.05 f	7.30 e	8.10 d	0.054 e	0.025 d
	18 h	71.06 e	8.60 d	9.50 c	0.069 c	0.029 c
	24 h	60.05 fg	6.40 f	7.0 e	0.043 f	0.016 f
SE		1.74	0.25	0.21	0.0014	0.001
LSD (5%)		**5.06**	**0.72**	**0.61**	**0.004**	**0.002**

Values followed by same letters in each column do not differ significantly at 0.05 probability level.

Observation recorded on maize seedling traits after 15 and 22 days showed similar trend of recording higher values of shoot length, root length, shoot dry weight, root dry weight and leaves seedling^{-1} when seed was hydroprimed for 18 h and planted in available soil moisture of 60-65 and 55-60%. The values of these traits decreased 6, 12, 24 h and no hydropriming x 50-55% available soil moisture (Table 8 and 9).

The clear trend in the results was observed in interaction of available soil moisture % levels and 18 h hydropriming period with decline in 50-55% ASM for various maize seedling growth traits after 7, 15 and 22 days.

Table 8. ***Maize seedling growth traits (after 15 days) under the interactive effect of hydropriming periods x available soil moisture***

Available soil moisture x hydropriming periods		Shoot length (cm)	Root length (cm)	Shoot dry weight (g)	Root dry weight (g)	Leaves seedling^{-1}
60-65%	No priming	19.42 ef	8.36 e	0.25 ef	0.12 g	3.63 fg
	6 h	24.32 cd	9.38 d	0.37 c	0.14 e	3.84 ef
	12 h	29.44 b	11.41 b	0.48 b	0.17 bc	4.60 bc
	18 h	33.79 a	12.50 a	0.67	0.24 a	5.40 a
	24 h	25.21 c	9.90c d	0.452 b	0.16 d	4.20 e
55-60%	No priming	19.44 ef	8.35e	0.25 f	0.12f g	3.63 fg
	6 h	24.33 cd	9.86c d	0.38 c	0.14 e	3.84 ef
	12 h	29.46 b	11.50 b	0.48 b	0.17 b	4.54 bcd
	18 h	35.49 a	12.38 a	0.67 a	0.25 a	5.43 a
	24 h	25.23 c	10.00 cd	0.45 2b	0.17 cd	4.24 cd
50-55%	No priming	14.60 g	6.35 g	0.18 g	0.10 h	3.20 h
	6 h	17.41 f	7.63 ef	0.21 fg	0.11 h	3.40 gh
	12 h	20.31 e	9.43 d	0.31 d	0.13 f	4.20 de
	18 h	22.91 d	10.41 c	0.29 de	0.14 e	4.73 b
	24 h	17.61 f	7.59 f	0.24f g	0.12 g	3.80 ef
SE		0.71	0.24	0.018	0.002	0.12
LSD (5%)		**2.05**	**0.70**	**0.052**	**0.006**	**0.36**

Values followed by same letters in each column do not differ significantly at 0.05 probability level.

Table 9. ***Maize seedling growth traits (after 22 days) under the interactive effect of hydropriming periods x available soil moisture***

Available soil moisture x hydropriming periods		Shoot length (cm)	Root length (cm)	Shoot dry weight (g)	Root dry weight (g)	Leaves seedling^{-1}
60-65%	No priming	27.45 de	9.63 ef	0.56 f	0.16 f	4.20 de
	6 h	33.35 c	11.79 d	0.75 e	0.22 d	4.60 c
	12 h	42.08 b	13.54 b	1.77 b	0.29 b	5.40 b
	18 h	46.58 a	17.89 a	2.53 a	0.37 a	5.80 a
	24 h	40.20 b	12.73 bc	1.54 c	0.24 c	5.20 b
55-60%	No priming	27.44 de	9.63 ef	0.56 f	0.16 f	4.10 de
	6 h	33.35 c	11.80 d	0.75 e	0.22 d	4.66 c
	12 h	42.09 b	13.53 b	1.77 b	0.29 b	5.42 b
	18 h	46.59 a	17.90 a	2.53 a	0.37 a	5.77 a
	24 h	40.20 b	12.73 bc	1.55	0.24 c	5.22 b
50-55%	No priming	21.65 f	7.90 g	0.38 h	0.11 h	4.00 e
	6 h	23.73 f	8.98f	0.45 g	0.13 8g	4.12 de
	12 h	28.55 de	10.33e	0.77 e	0.19 e	4.20 de
	18 h	30.76 cd	11.90 cd	0.83 d	0.23 cd	4.40 cd
	24 h	25.11 ef	10.08 e	0.62f	0.15 f	4.16 de
SE		1.17	0.28	0.018	0.004	0.11
LSD (5%)		**3.40**	**0.81**	**0.052**	**0.012**	**0.32**

Values followed by same letters in each column do not differ significantly at 0.05 probability level.

Interactive Effect of hydropriming x Available Soil Moisture on physiological Traits of Maize

The higher crop growth rate (1.26 and 1.27 g m^2 day^{-1}) and leaf area plant^{-1} (63.81 and 63.82 cm^2) were observed when seed was hydroprimed for 18 h and planted in available soil moisture of 60-65 and 55-60% respectively. However, increasing (24 h) or decreasing seed hydropriming periods (6 and 12 h) and no priming with reduced (50-55%) available soil moisture resulted lower values of crop growth rate (0.13) and leaf area plant^{-1} (24.31) in maize seedlings (Table 10).

Table 10. ***Maize seedling physiological traits (after 15 days) under the interactive effect of hydropriming periods x available soil moisture***

Available soil moisture x hydropriming periods		Crop growth rate (g m^2 day^{-1})	Leaf area (cm^2)
60-65%	No priming	0.14 g	31.64 e
	6 h	0.25 e	40.28 d
	12 h	0.87 b	52.60 b
	18 h	1.26 a	63.81 a
	24 h	0.74 c	46.53 c
55-60%	No priming	0.21 ef	31.60 e
	6 h	0.25 e	40.30 d
	12 h	0.87 b	52.47 b
	18 h	1.27 a	63.82 a
	24 h	0.74 c	46.51 c
50-55%	No priming	0.13 g	24.31 g
	6 h	0.16f g	27.58f g
	12 h	0.35 d	31.99 e
	18 h	0.36 d	40.32 d
	24 h	0.25 e	29.68 ef
SE		0.018	1.14
LSD (5%)		**0.052**	**3.31**

Values followed by same letters in each column do not differ significantly at 0.05 probability level.

Interactive Effect of hydropriming x Available Soil Moisture on Yield Components of Maize

Seed hydroprimed for 18 h and planted in available soil moisture of 60-65 and 55-60% significantly enhanced cobs plant^{-1} (1. 43 and 1.44), grain cob^{-1} (399.00 and 401.33), seed index (243.6 and 242.6 g) and seed yield (3897.00 and 3897.33 kg ha^{-1}) respectively. The minimum values of all the yield components viz cobs plant^{-1} (0.85), grains cob^{-1} (183.00), seed index (187.33 g) and seed yield (1824.00 kg ha^{-1}) were found when hydroprimed seed (6, 12, and 24 h) and un-primed seed was sown in 50-55% available soil moisture (Table11).

Table 11. ***Maize yield components under the interactive effect of hydropriming periods x available soil moisture***

Available soil moisture x hydropriming periods		Cobs plant^{-1}	Grains cob^{-1}	Seed index (g)	Seed yield (kg ha^{-1})
60-65%	No priming	1.13 c	277.00 d	222.33 cde	2548.00d
	6 h	1.16 c	318.00 c	236.33 bcd	3002.33 c
	12 h	1.28 b	351.00 b	247.00 b	3373.00 b
	18 h	1.43 a	399.00 a	273.00 a	3897.00 a
	24 h	1.20 c	336.00 bc	239.33 bc	3179.66 bc
55-60%	No priming	1.12 c	274.00 d	220.00 de	2544.66 d
	6 h	1.17 c	319.00 c	237.33 bcd	3005.33 c
	12 h	1.30 b	353.00 b	249.00 b	3376.00 b
	18 h	1.44 a	401.33 a	270.33 a	3897.33 a
	24 h	1.20 c	338.00 bc	236.33 bcd	3183.66 bc
50-55%	No priming	0.85 f	183.00 f	187.33 g	1824.00 f
	6 h	0.89 ef	223.00 e	196.00 fg	2074.66 e
	12 h	0.94 de	246.00 e	208.33 ef	2257.00 e
	18 h	0.99 d	278.00 d	219.33 de	2471.33 d
	24 h	0.93 de	232.00 e	199.00 g	2147.00 e
SE		0.025	9.30	5.54	71.31
LSD (5%)		**0.074**	**26.96**	**16.05**	**206.6**

Values followed by same letters in each column do not differ significantly at 0.05 probability level.

Despite numerous advantages of production technologies, crop yield per unit area is still low in Pakistan. Poor germination and low seed viability are among the serious problems for crop production. The use of high quality seeds is essential to establish a suitable population in the field, which ultimately gives better economic results. The use of crop seeds of medium and low physiological quality is a common practice under tropical and sub-tropical production conditions which leads inadequate plant population in the field. The adverse consequences of poor crop establishment were not still confined which caused wastage of resources due to sub-optimal plant population densities or heterogeneous distribution of plants within fields. Surviving plants in a poorly established stand seldom get off to a good start.

Lack of available soil moisture during seed sowing reduce emergence. In this regard, hydropriming practice could enhance seed germination and seedling stand establishment. The priming technique due to its simplicity might be acceptable to the farmers as accepted to farmer in other semi arid region to a wide range of crops, for example maize (*Zea mays* L.), (Harris *et al*., 2007), wheat (*Triticum aestivum*, L.) (Harris *et al*., 2001), mung bean (*Vigna radiata* L.) (Rashid *et al*., 2004), Chickpea (*Cicer aritinum*, L.) (Musa *et al*., 2001) and millet (*Penisetum typhoideum*) (Kumar *et al*., 2002). Present study also shows that greater water severely affected germination, and related traits. Compared to unprimed (control), the hydropriming treatments showed comparatively better performance under water stress conditions.

In this study, maize seeds were hydroprimed in water for 6, 12, 18, 24 h and no priming. Among hydropriming periods, 18 h hydropriming resulted maximum emergence, shoot length, root length, shoot dry weight plant^{-1} and root dry weight plant^{-1} and leaves seedling^{-1} crop growth rate and leaf area plant^{-1}, after 7, 15 and 22 days. Similar trend was observed in number of cobs plant^{-1}, grains cob^{-1}, seed index and seed yield of maize.

Usually, seeds contain 8-12 % moisture and these seeds are in resting condition with no metabolic activity or said to be dormant. This type of seeds need hydration condition in relation to adequate temperature and oxygen. There are three phases of seed germination viz. initial rapid period, plateau phase (change due to water content); and radicle appearance followed by seedling growth. Seed germination rely on first two phases where seed imbibitions (Bradford, 1990). It has been observed that seed germination and seedling establishment are critical stages in plant. In normal conditions only dormancy and seasonal fluctuations has significant influence on germination. For higher yields, seedling and crop stand determines plant population and uniformity in the filed. If the seed material is very expensive, it is prime requirement that seed must germinate quickly and uniformly, and should efficiency to tolerate adverse germination conditions (Zhiyuan & Kent, 1999).

The increase in the values of shoot length, root length, shoot dry weight plant^{-1}, root dry weight plant^{-1} and leaves seedling^{-1}, crop growth rate and leaf area plant^{-1}, cobs plant^{-1}, grains cob^{-1}, seed index and seed yield might be due to the fact that the seeds soaked in water had rapid translocation of nutrients after hydrolysis of the cotyledonary reserves to growing seedling. Seed soaking overnight with tap water resulted in early emergence and deeper roots in corn (Harris *et al.,* 1999). Seed pre-soaking in water for few hours followed by drying appreciably increase vigour and viability of seed (Rudrapal and Basu, 1982) and improved germination percentage and field emergence.

Poor crop stand is one of the major abiotic constraints encountered by resource-poor farmers in marginal areas in India (Harris *et al.,* 1999). It is simple, low-cost, low-risk intervention; on-farm seed priming can make a positive impact on farmers livelihoods by increasing the rate of crop emergence, thus increasing rates of crop development, reducing crop duration and raising yields especially maize (Murungu *et al.,* 2004).

The seeds of maize sown in 60-65 and 55-60% available soil moisture displayed higher seed emergence, shoot length, root length, shoot dry weight plant^{-1}, root dry weight plant^{-1} and leaves seedling^{-1}. With regard to physiological and agronomic traits, the greater seedling growth rate, leaf area plant^{-1}, cobs plant^{-1}, grains cob^{-1}, seed index and seed yield were also observed when maize seeds were sown in 60-65 and 55-60% available soil moisture. Maize seedling growth traits had non-significant differences in both available soil moisture levels i-e 60-65 and 55-60% respectively.

In Pakistan, farmers are realizing lower yields due to scarcity of irrigation water and erratic distribution of rainfall, whereas, under normal growing conditions, farmers obtain good maize yields.

Understanding the moisture condition of the field is essential for crop establishment. Establishing adequate stands at optimum time is important for grain yield of crops and is uncertain in most of the tropical areas because available soil moisture at planting is often marginal for seed growth. In Pakistan about 1/5 of the wheat crop is grown under rainfed conditions every year and stand establishment is one of the major problems in these areas. In this study, it was observed that for seeds to germinate them have to attain specific moisture content and seeds of all crops germinate in a shorter time at high available soil moisture than comparatively at low available soil moisture. Among the abiotic stresses, drought is one of the most important constraints for maize production and productivity (Edmeades *et al.,* 2000, Azeez *et al.,* 2005), and large yield losses can occur when maize is exposed to drought conditions during critical stages of crop growth (Saini & Westgate, 2000; Chimenti *et al.,* 2006).

In this study, increased water stress showed negative impact on shoot length, root length, shoot dry weight plant^{-1}, root dry weight plant^{-1} and leaves seedling^{-1}, crop growth rate and leaf area plant^{-1}, cobs plant^{-1}, grains cob^{-1}, seed index and seed yield of maize. There are reports that studies conducted on available soil moisture at India, Thailand and Turkey showed that maize is very much sensitive to increased available soil moisture stress (Dass *et al.,* 2001; Cakir, 2004; Moser *et al.,* 2006). Similarly, the other growth parameters of maize such as roots and shoots were inhibited by 60-65 and 50-55% available soil moisture. The root and shoot parameters were also severely affected by the available soil moisture stress. However, Nayyar (2003) reported that root growth was relatively less affected due to stress than shoot growth.

The reduction in maize grain yield was pronounced due to deficit available soil moisture. The reduction in grain yield was also reported by (Moser *et al.,* 2006). Drought occurred during the vegetative period grain yield was numerically reduced by 6-22% (Pandey *et al.,* 2000). The greatest yield reduction was associated with stresses that were most intense during the 25 days period after flowering (Edmeades *et al.,* 2003). During flowering stage, single day of drought can potentially decrease yield upto a significant level (Tuberosa *et al.,* 2007).

In this study, yield components of maize were significantly affected by drought occurrence. Water stress condition significantly reduced the number of cobs per plant, seed index and grain numbers. Previous researchers also found reduction in yield components of maize in water stress conditions (Kamara *et al.,* 2003, Ribaut *et al.*, 2004; Chimenti *et al.,* 2006).

CONCLUSIONS AND RECOMMENDATIONS

The study on hydropriming is very important, especially for the development of pre-germination techniques aimed at improving seed emergence, seedling establishment, plant growth and yield. Hydropriming was much effective for 18 h in maize. These hydropriming hours were found optimum. Inadequate available soil moisture reduced seed emergence, seedling establishment, and yield components of maize. However, optimum available soil moisture (60-65 and 55-60%) supported hydroprimed seeds for enhancement of seedling and related traits. Thus, the seeds should be hydroprimed and sown in 55-65% available soil moisture which will certainly increase 35% maize yield.

This study recommends that Prior to sowing, maize seeds should be hydroprimed for 18 hours, and must be sown at 55-65% available soil moisture to obtain better seedling emergence, establishment and yield.

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