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THE EFFECT OF HYDRO PRIMING ON WHEAT SEED GERMINATION RATE

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LIST OF ABBREVIATIONS

CSA-Central Statistical Agency

FAO-Food Agricultural Organization

RCBD- Randomized Complete Block design

DAP- Die ammonium Phosphate

ANOVA- Analysis of Variance

LSD- Lateen Square Design

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ABSTRACT

Cereals contribute to 50% of total caloric intake and 95% of the total food requirement globally. Increasing climate change and population has increased the food demand and endangered the productivity of food crops due to various biotic and abiotic stresses and within these conditions' world is trying to push itself towards increasing the grain yield per unit of land. Several methods of seed priming are practiced to rejuvenate the seeds and remove the environmental stress. Hydro priming, a method of seed priming, has prominent advantage of stresses resistance, better crop stand, and emergence. In order to cope with the future challenges of crop productivity knowledge on the beneficial effects of hydro priming is important. Hydro priming induces DNA repair processes and Antioxidant responses associated as pre-germinative metabolism that leads to early and better seedling growth. Seed priming is an important problem in developing countries which seeds stored in inappropriate condition. Delayed germination, reduced normal seedling percentage and changed antioxidant enzymes activity are some indications of aged seeds. Priming is a technique applied before planting and can improve seed characteristics especially under abiotic stress conditions. The main objective of the study was to evaluate aging effect on seed quality and to study the interaction between seed aging and seed priming. The experiment was conducted in a factorial experiment based on completely randomized design with three replicates. Results showed that seed aging reduced germination percentage, germination index, seedling length, normal seedling percentage, seedling dry weight, and activity and increased the germination mean time and electrical conductivity of seeds. The highest germination percentage, germination index, seedling length, normal seedling percentage, seedling dry weight, and the minimum germination mean time of seeds were attained from hydro-priming treatment under non primed condition. Hydro-priming improved aged seeds quality and increased enzymes activity. Therefore, priming is a technique can be applied to improve aged seeds germination and seedling characteristics. Seed Hydro priming may be the best solution to the germination related problems especially in crops grown in unfavorable conditions and enhanced activation of the plant defense mechanism describes this process. Defining the exact treatment duration, water volume, and temperature of water during Hydro priming can revolutionize the farming system with better results.

Key words: Wheat; Accelerated aging; Hydro-priming; Germination.

1. INTRODUCTION

1.1 Background and Justification

Cereals are annual grasses having thin, long stalks cultivated worldwide for their edible grain (Sarwar, 2013). Cereals belong to family Poaceae containing mainly seven principle crops grown worldwide namely rice, wheat, maize, sorghum, barley, oats and rye (Deepa et al., 2013). Cereals contribute to almost 50% of total caloric intake with 700 million hectares cropping area (Dunwell, 2014). The major cereals fulfill about 95% of the total food requirement (Zargar et al., 2017; Asgari et al., 2017). Population is increasing worldwide i.e. 10 million by 2050, which has increased the demand of food and commodities, but along with it increasing global warming, heat stress, drought, salinity, and other abiotic stresses have come up the way resulting in the endangered productivity of these crops (Maiti and Satya, 2014). Limited agricultural land and the reproductive capacity of the field crops is all that we have for ensuring food security (Sher et al., 2019). However, within the conditions of increasing climate change world is pushing itself towards increasing the grain yield per unit of land (Singer et al., 2019).

The biotic and abiotic stresses are eradicating by the farmers from old ages by promising seed priming technique that gave trailblazing media that grounds close monitoring (Sivasubramaniam et al., 2011). Seed priming has a prominent advantage of inducing resistance like drought stress, heat stress, salinity, etc. in many field crops including cereals. The results from the works on seed priming have indicated well importance of priming for a better crop strand and emergence (Nawaz et al., 2013). There are many methods of seed priming that rejuvenate the seeds and remove the environmental stress including Hydro priming that includes the prehydration of the seeds and activates the early germination events (Lutts et al., 2016).

Priming treatments like Hydro priming has been effective in seed vigor enhancement to achieve rapid and uniform seed germination of different field crops including cereals (Tian et al., 2014). A rapid and uniform emergence and root growth leads to the successful establishment of the seedling (Lutts et. al., 2016). It can be successfully used to fulfill the present needs of uniform germination and stand establishment (Nawaz et al., 2013). It reduces the gap between seed sowing and emergence of seedling thus synchronizing emergence (Parera and Cantliffe, 2010). This will enable the crop to escape the stresses by shortening the maturity days, have vigorous growth and higher yield (Subedi and Canada, 2014). Hydro priming can successfully utilize in areas with environmental stresses like high heat and drought because in such conditions hydro priming increases the water uptake efficiency and seed hydration (Waqas et al., 2010). Enhanced activation of the plant defense mechanism describes this process (Hussain et al., 2019). This review covers the effect of seed hydro priming on morphological and biochemical changes on major cereals. It highlights major achievements of hydro priming in the cereals till date. It also explains the stress tolerance mechanism that will help to cope with the increasing climatic change in the world. Furthermore, the future prospects and limitations associated with hydro priming that can be successfully utilized in future are also discussed.

1.2 Objective of the study

The main objective of the study is designed to evaluate the effect of hydro priming on wheat seed germination.

2. REVIEW OF THE RELATED LITERATURE

2.1 Effect of Hydro priming in Wheat

Wheat is considered as the second most important stable food crop after rice grown by about 40% of the world population providing 20% of daily protein and food calories (Giraldo et al., 2019). Sowing time of wheat is one of the most important factors affecting its total yield. Hydro priming of seeds before sowing found to improve the stand establishment, growth and yield of late sown wheat in Rice-Wheat system (Kant et al., 2006). Hydro priming helps to advance the wheat sowing by 10 days that positively affect the yield. It was found that Hydro priming of wheat seeds promoted early emergence, total germination count, increased number of tillers, grain weight, biological as well as economical yield of late sown wheat under different moisture conditions (Ali et al., 2013). The water productivity of wheat is 1500 liters of water per kg of wheat (FAO, 2012). Hydro priming of wheat helped in increasing the water use efficiency under water stressed conditions with higher germination percentage and homogeneity of seedling emergence helping to reduce the water consumption at huge quantity for same quantity of wheat thus decreasing the cost of irrigation (Meena et al., 2014). Sowing of wheat on 22nd of November with 16 hours hydro-primed seeds resulted highest germination, growth, yield parameters as well as highest economic return (Sitanshu et al., 2017). Hydro priming of wheat seeds also helped to improve the aged wheat seeds quality, induced increment in enzyme activity, improved germination and seedling characteristics (Ghasemi et al., 2015).

2.2 Seed Priming

Seed Priming is a pre-sowing treatment that allows the imbibition of seeds under controlled conditions preventing the radicle emergence and loss of desiccation tolerance in order to induce antioxidant responses as well as DNA repair process associated with pre-germinated metabolism (Ventura et al., 2012). During the initial phases of seed germination, seeds face various stresses leading to oxidative damage of nucleic acids, lipids and proteins (Kranner et al., 2010). Within these conditions seed repair is a need for conservation of seed vigor and efficient germination. Rehydration in seed priming induces major cellular processes in seeds like DE novo synthesis of proteins and nucleic acids, activation of antioxidants, adenosine triphosphate (ATP) production, accumulation of phospholipids and sterols and regulation of DNA repair mechanism which is an important constituent of pre-germinative metabolism induced at start of imbibition (Paparella et al., 2015). Higher activities of different enzyme like proteases, α and β-amylase and iso-citrate lyase involved in the mobilization of stored reserves in seed playing a vital role in breakdown of macromolecules for embryo growth are seen in primed seeds exerting a positive influence on better and early growth of seedlings (Sisodia et al., 2018).

Under normal and stressful conditions, seedlings emerged from primed seeds have been reported with enhanced activities of CAT(Catalase), SOD (Superoxide dismutase) and POD (Peroxidase) that imparts stress tolerance leading to strengthen the defense line of the crop (Zheng et al., 2016). The antioxidant machinery system plays a vital role during seed storage, germination and development by scavenging the excessive ROS (Reactive Oxygen Species) to non-injurious level persuaded by various stresses (Mansour et al., 2019). ROS are the source of oxidative damage of membrane lipids, proteins, nucleic acids as well as enzymes inactivation that eventually leads to the death of cell which is counteracted by the seed defense system and DNA repair (Forti et al., 2020). The biochemical events triggered by water uptake during seed imbibition are associated with ROS accumulation and transformation (Bailly et al., 2008).

Poor soil and high soil temperature will be posed within the alarming climate change in future and seed quality will be a need to be influenced by seed priming (Sivasubramaniam et al., 2011). Hydro priming relies on only soaking of seeds in pure water followed by re-drying to original moisture content prior to sowing making it a low cost and environmentally friendly technique (Rhaman et al., 2020). Uncontrolled water uptake by the seeds during hydro priming is the main limiting factor of hydro priming which results unequal degree of hydration leading to asynchronous metabolic activation within the seeds (Mc Donald, 2000). Drum priming as a variant of Hydro priming can be successfully used as an alternative to conventional Hydro priming which allows the seeds imbibition in controlled manner and results simultaneous hydration. Drum priming includes gentle rotation of seeds in a drum and gradual hydration by addition of water in vapor form (Yu et al., 2012).

On-farm priming may also be used especially for resource poor farmer in marginal environment (Harris et al., 2005). Conventional hydro priming has shown better germination, growth and yield performances in different crop researches. Seed Hydro priming may be the best solution to the germination related problems especially in crops grown in unfavorable conditions (Nawaz et al., 2013). However, it is very important to define the accurate treatment duration, temperature and water volume used in hydro priming in order to ensure desired level of seed priming hydration and better results (Lutts et al., 2016). The packing techniques for primed seeds storage is need to be made that will revolutionize farming in moisture starved areas where farmers are technologically and traditionally poor (Sivasubramaniam et al., 2011).

2.3 Seed priming importance

Seed priming is a technique that improves germination and crop establishment of several types of crop (Aziza et al., 2004). New scientific knowledge of seed physiology and seed biochemistry, combined with new technology, can enhance seed quality. Seed priming is one of the seed enhancement techniques that may allow scientists to develop more innovative efficient procedures for making improvements in crop production. The technique's performance depends on the crop variety, crop imbibition behavior, priming method, and imbibition time. Seed priming has been widely used to enhance the germination response of agricultural crop species (Bradford 1986) and is the most important physiological seed enhancement method. Seed priming is a hydration treatment that allows controlled imbibition to induce pre-germinative metabolism ("activation"), but radicle emergence is prevented. The hydration treatment is stopped before desiccation tolerance is lost.

An important problem is to stop the priming process at the right moment. This time depends on the species and the seed batch. The seeds can be re-dried for storage, distribution, and planting. The speed and synchronicity of germination of primed seeds are enhanced and can be interpreted as though priming increases seed vigor. Priming permits a wider temperature range for germination, releases dormancy and achieves faster emergence of uniform seedlings.

A practical drawback of primed seeds is often a decrease in storability and the need for cool storage temperatures. The rate of water absorption in the initial 24 hours of imbibition may be one of the factors that control seedling vigor. Seeds that were allowed to imbibe slowly in 25% polyethylene glycol 6000 had increased shoot weight (Ehsanullah and Smith, 2002). Priming is a non-expensive and value added practice that greatly improve yield. This might be due to some biochemical and physiological changes brought about by seed soaking (Khan et al., 2002). The improved germination of primed seeds may therefore, be attributed to counteraction of free radicals and re-synthesis of membrane bound enzymes as in unprimed seeds (Srinivasan and Saxena, 2001).

2.4 The Effect of Seed hydro priming

Seed aging is an important problem in developing countries where seeds are stored in places usually without appropriate humidity and temperature. Temperature and seed moisture content are two main factors influencing seed viability in storage. Delayed germination, slow growth, reduced normal seedling number and changed antioxidant enzymes activity are some indications of aged seeds (Walters, 1998). Oxidative damages are responsible for deterioration in aged seeds. Free radical oxidations and protein enzymatic dehydrogenation and aldehyde oxidation might reasonably contribute to seed quality reduction (Ghassemi-Golezani *et al*., 2010). Reductions in the activity of enzymes such as superoxide dismutase, catalase, peroxidase and glutathione reductase in aged seeds have been suggested by most of researches. Reduced enzyme activity in aged seed decreases the respiratory capacity, which in turn lowers both the energy (ATP) and assimilates supply of the germinating seed. Therefore, several changes in the enzyme macromolecular structure may contribute to lowered germination efficiency.

Vigorous seeds can increase crop yield in two ways: firstly, optimum density made by higher seedling percentage even under abiotic stress conditions and secondly, increased growth and higher emergence rate (Ghasemi-Golezani *et al*., 2010). Many seed priming and post priming treatments have been used to improve the performance of invigorate and damaged seeds of many crops (Basra *et al*., 2003; Farooq *et al*., 2006). Priming is a technique applied before planting and can improve germination characteristics especially under abiotic stress conditions like drought, cold, salinity and high temperature stresses (Sedghi *et al*., 2010). Also most of researches reported that priming improved the quality of aged seeds by increasing enzymes activity such as antioxidant enzymes and amylases (Ansari *et al*., 2013).

3. MATERIALS AND METHODS

3.1 Description of the study area

This study was conducted at Wolkite University in plant science department Laboratory which is located on 170 Km from Addis Ababa to west on the road of Jima. Freshly harvested seeds of wheat were obtained from Wolkite University, department of plant science. During the accelerated aging, seeds were subjected to 100% relative humidity. The seeds were pretreated with 10°C water for 6, 12 and 18 h.

3.2 Experimental design

The experiment was performed in a complete block design with four replications (4 priming levels x 4 replicates): Factor of levels of priming: non-primed wheat seed, hydro-priming for 0, 6, 12, and 18 hours). Priming was performed at room temperature (25℃). Twenty g of seeds was placed in 500ml of hydro priming solutions. An aeration pump was used during the experiment to provide oxygen from the ambient atmosphere into the chamber.

Twelve Petri dishes were washed with detergent using hot water as protective measure against pathogens and the experiment was laid out in completely block design (CBD) with three replications. Wheat seeds were also cleaned manually after physical purity is checked. Twenty seeds of wheat were sown in each Petri dish containing a filter paper. The Petri dishes were kept at room temperature (30oC±4) throughout the study and both treated and control Petri dishes were kept moist continuously by adding distilled water whenever needed.

3.3 Measurements methods

The germinated seeds (2 mm radicle elongation) were counted daily to calculate germination rate. At the end of the germination period, germination percentage and normal seedling percentage, germination mean time were determined.

3.3.1 Germination

Then the germination tests were evaluated for 8 days, according to the rules of the International Seed Testing Association (ISTA, 1985). The percentage germination was determined using the 'between papers' method, according to the standard germination test (ISTA, 2011). Three replicates of 60 seeds of wheat were placed between layers of germination paper. The seeds were then incubated in a germination chamber at 20℃ for 3 days.

The number of normal seedlings developed from a replicate of 60 seeds represented the germination percentage, and the results were the average of the 3 replicates of 60 seeds.

3.3.2 Mean emergence time (MET):

Three replicates of 180 seeds were placed between layers of paper. The number of germinated seeds was counted every day and the mean emergence time (MET) was calculated using the following formula (Demir et al., 2008):

$MET = \sum nD / \sum n$

Where

n is the number of seeds newly germinated on day D from the beginning of the germination test and $\sum n =$ Total number of seeds germinated.

3.4. Statistical analysis

We performed analysis of variance, and when the results were significant, used a least significant difference (LSD) test to detect differences between pairs of treatments, with significance at $P < 0.05$. Statistical analysis was carried out using version 25 of the SPSS software. Mean comparisons were performed using an ANOVA.

4. RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1. Seed germination

Wheat seed germination was significantly different from that of unprimed seeds for all hydro priming seeds (significantly higher).

Germination was highest for a hydro priming time of 18 hours, which was significantly different to all other hydro priming times except 12 hours (Table 1).

1. Results of first day measures of wheat seed germination

Table 1: Results of first day measures of wheat seed germination after priming

Means

Report

Germination_percentage_in_day_one

TREATMENT	Mean	N	Std. Deviation
TREATMENT 1	10.00a	3	5.00000
TREATMENT 2	25.00b	3	5.00000
TREATMENT 3	46.67c	3	5.77350
TREATMENT 4	53.33c	3	2.88675
Total	33.7500	12	18.47910

LSD: 1.43

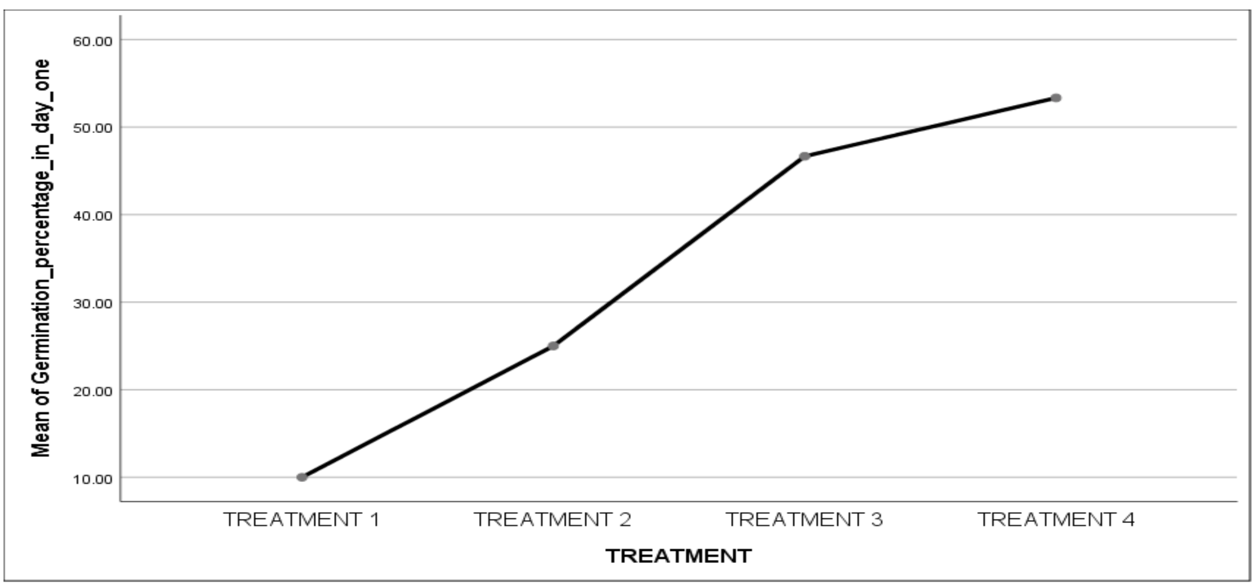


Figure 1: Results of first day measures of wheat seed germination after priming

2. Results of first day measures of wheat seed germination

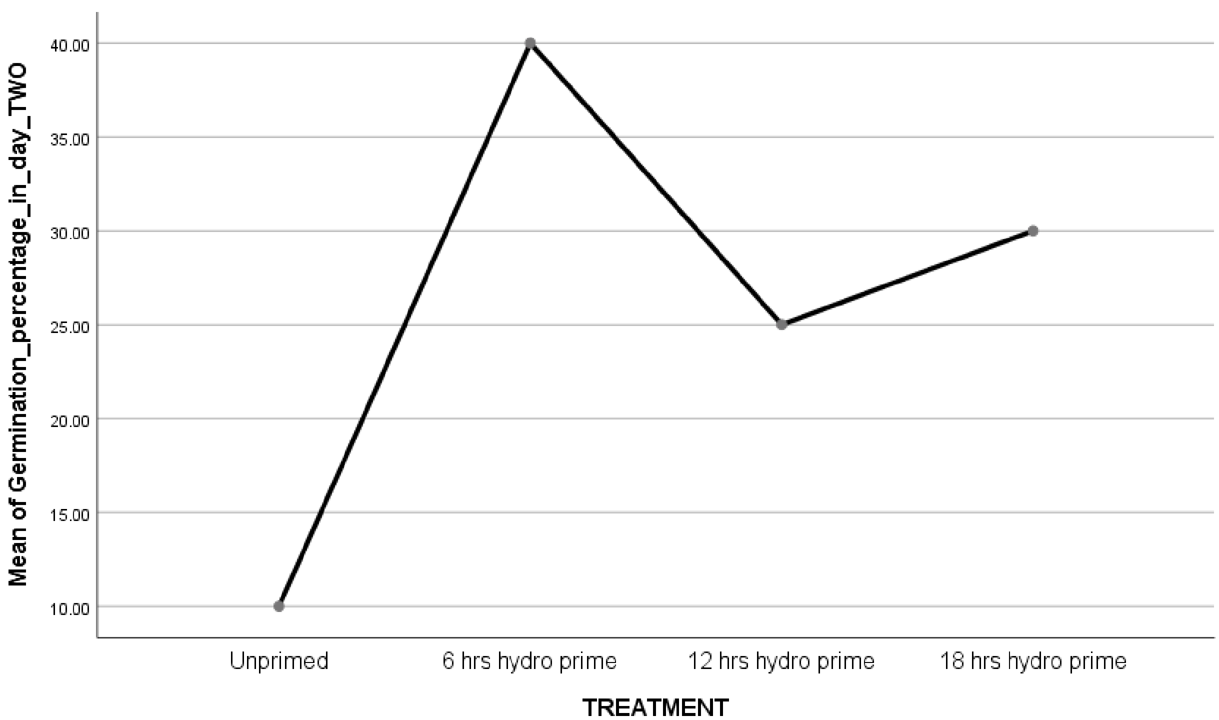
Table 2: Results of first day measures of wheat seed germination after priming

Report

Germination_percentage_in_day_TWO

TREATMENT	Mean	N	Std. Deviation
Unprimed	10.00a	3	5.00000
6 hrs hydro prime	40.00b	3	5.00000
12 hrs hydro prime	25.00c	3	8.66025
18 hrs hydro prime	30.00c	3	10.00000
Total	26.2500	12	12.99038

LSD: 1.224



Figuer 2: Results of second day measures of wheat seed germination after priming

3. Results of third day measures of wheat seed germination

Table 3: Results of third day measures of wheat seed germination in non-primed seed and after priming as influenced by priming treatment

Report

Germination_percentage_in_day_THREE

TREATMENT	Mean	N	Std. Deviation
Unprimed seed	21.67a	3	10.40833
6hrs hydro primed	18.33ab	3	5.77350
12hrs hydro primed	15.00b	3	8.66025
18hrs hydro primed	13.333cb	3	2.88675
Total	17.0833	12	7.21688

LSD: 1.224

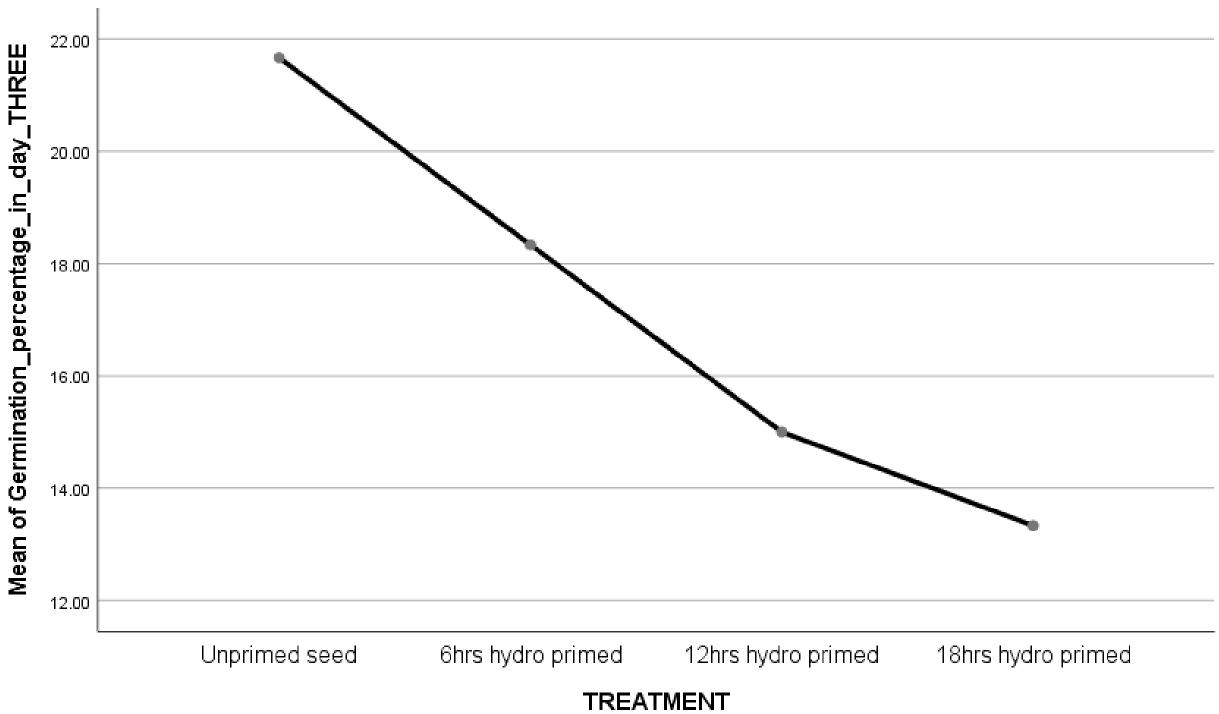


Figure 3: Results of third day measures of wheat seed germination after priming

4. Results of fourth day measures of wheat seed germination

Table 4: Results of fourth day measures of wheat seed germination in non-primed seed and after priming as influenced by priming treatment

Report

Germination_percentage_in_day_FOUR

TREATMENT	Mean	N	Std. Deviation
Unprime seed	20.00a	3	5.00000
6hrs hydro primed seed	6.6667b	3	2.88675
12hrs hydro primed seed	6.6667b	3	2.88675
18hrs hydro primed seed	3.3333c	3	2.88675
Total	9.1667	12	7.33402

LSD: 0.529

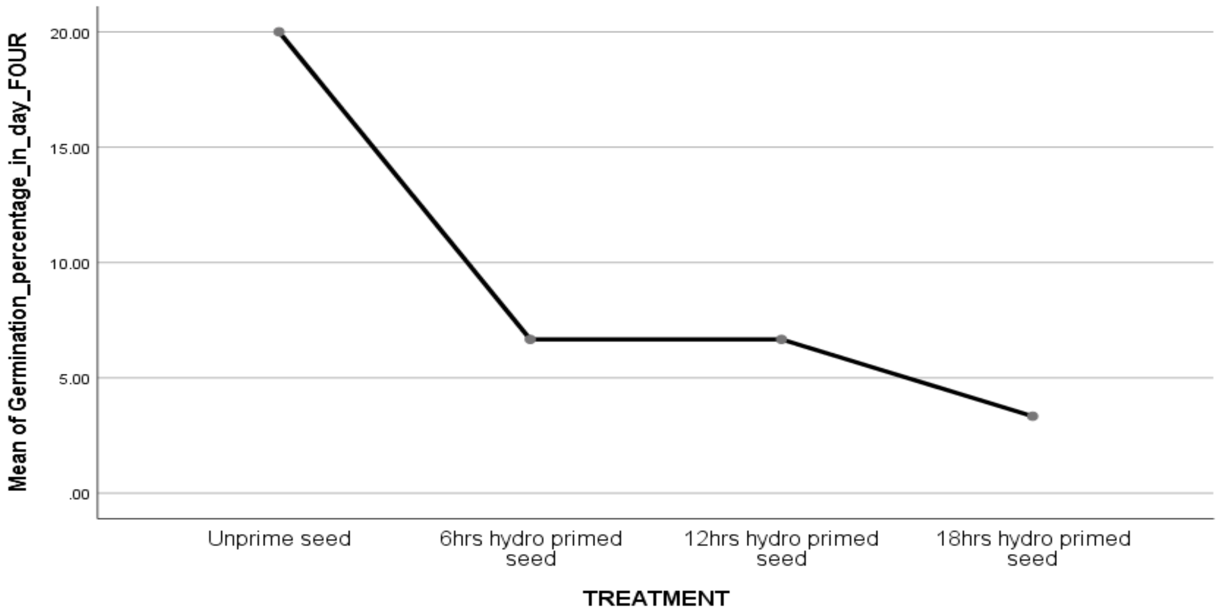


Figure 4: Results of forth day measures of wheat seed germination after priming

5. Total germination of un primed and hydro primed seeds of wheat

Table 5: Results of total wheat seed percentage

Report

Total_Germination_percentage

TREATMENT	Mean	N	Std. Deviation
Unprimed seed	19.44a	3	4.19281
6hrs Hydro primed seed	29.996b	3	2.88675
12hrs Hydro primed seed	31.11c	3	.96417
18hrs Hydro primed seed	33.33d	3	5.00000
Total	28.4708	12	6.37424

LSD: 0.539

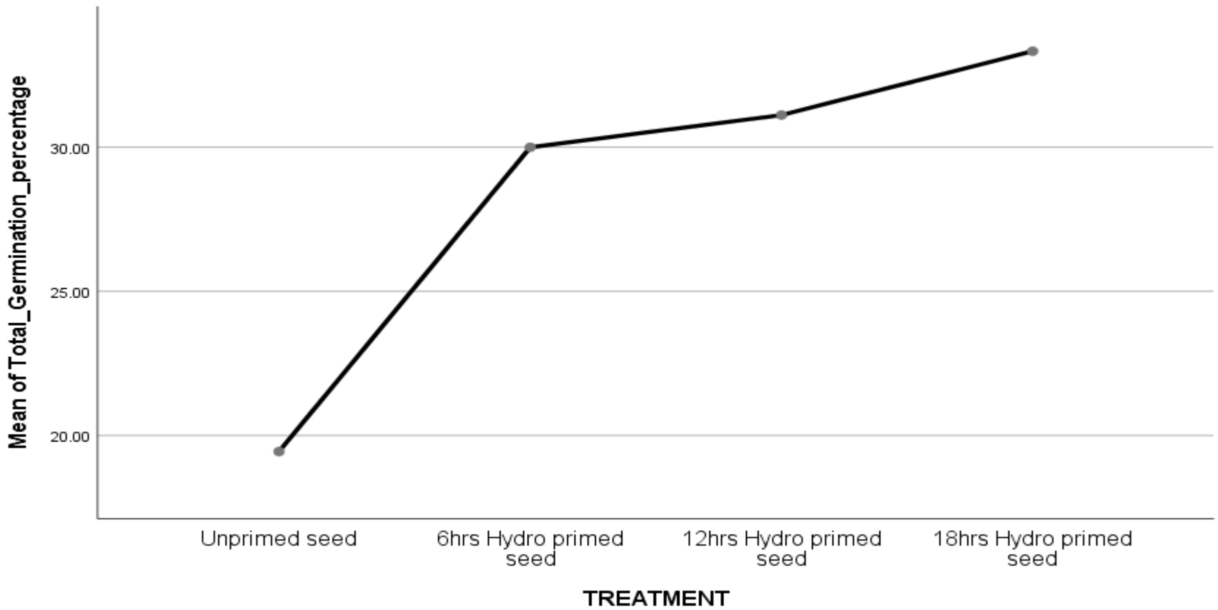


Figure 5: Results of total wheat seed percentage

4.1.2. Seed germination index (GI)

Wheat seed germination index (GI) was increased significantly by all priming treatments except non hydro priming.

The highest GI values resulted from hydro priming by 18hrs. Additionally, GI tended to increase as hydro time increased (Table 1).

4.1.3. Mean emergence time (MET)

Table 6: Results of for measures of MET Wheat seed

Report

MET_DAY

TREATMENT	Mean	N	Std. Deviation
Unprimed seed	1.7047a	3	.28742
6hrs Hydro primed seed	1.36b	3	.12490
12hrs Hydro primed seed	1.2667c	3	.02887
18hrs Hydro primed seed	1.221d	3	.22491
Total	1.3881	12	.25766

LSD: 0.029

Untreated Wheat seeds had a MET of 1.7047 days. After seed priming, MET decreased significantly in all hydro priming seeds (Table 1). Hydro-priming for 18hrs significantly lower MET than all other hydro-priming seeds. With respect to hydro time, the lowest METs were achieved for 12 and 18 hours, which were significantly lower than all shorter hydro times.

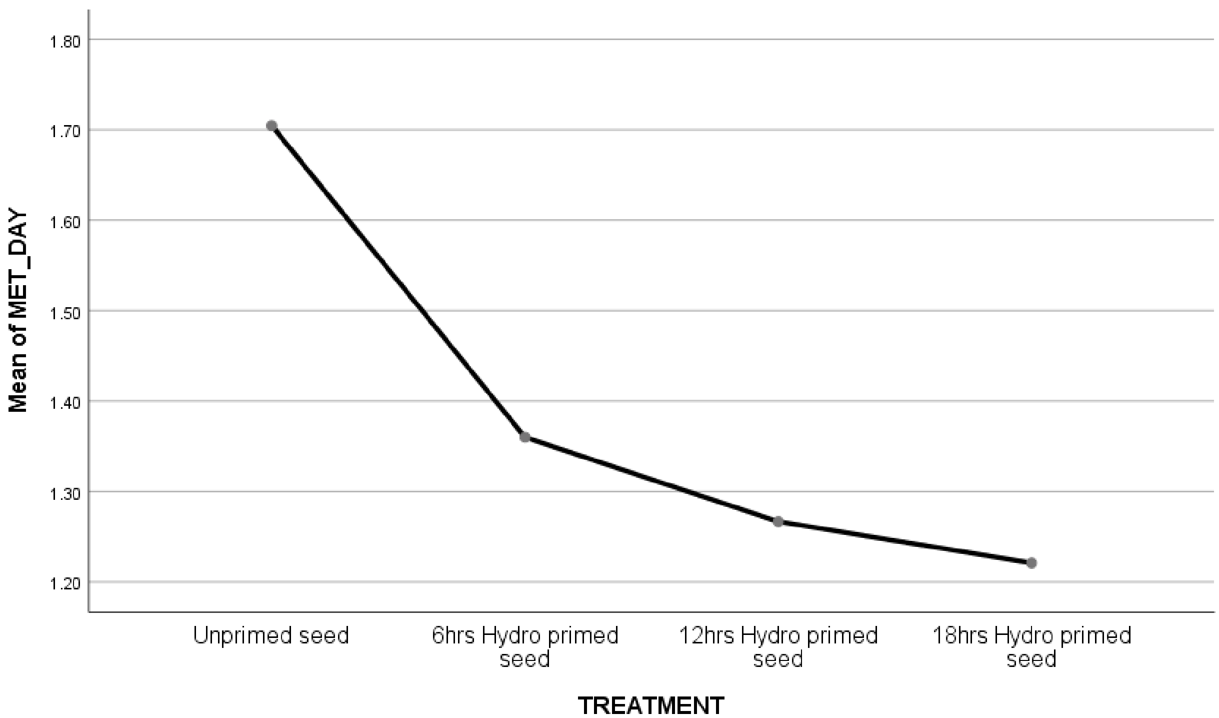


Figure 6: Results of for measures of MET Wheat seed

4.2 DISCUSSION

There was a significant at ($P < 0.05$) of seed hydro priming for the germination percentage and germination mean time (*Table 5 and 6*).

Germination percentage of wheat seeds increased as the hydro priming time of treatment period progressed. In favor of this finding, Ansari *et al*. (2013) and Seiadat *et al*. (2012) reported that priming improves germination characteristics in many crops. Decreased germination in aged seeds can be due to the reduction of α- amylase activity and carbohydrate contents (Bailly *et al.*, 2002), or denaturation of proteins (Nautiyal *et al*., 1985).

Increased period of hydro priming (6 to 18 hrs) significantly decreased germination mean time. Germination mean time of unprimed seeds was the highest and the primed seed for 18 hr had the lowest germination mean time. Therefore, priming had accelerated germination of seeds.

Therefore, our findings showed that priming improved seeds germination and seedling characteristics in studied cultivars. Also Basra *et al*. (2003) and Farooq *et al*. (2006) suggested that priming had positive effect on germination characteristics.

5. CONCLUSION

Hydro priming is a best approach towards seed enhancement for the increasing the overall germination and yield of cereal crops at normal as well as stressful conditions. Being a simple and zero cost technology, it can be recommended at the farmers' level practice through different extension activities around the globe. Furthermore, researches can also be conducted in large scale with Hydro priming to ensure its positive effects and determine the treatment durations. Within this changing climate, Hydro priming can be a priority for future seed man.

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APPENDIX

Appendix **1:** Results of first day measures of wheat seed germination in non-primed seed and after priming as influenced by priming treatment

ANOVA

Germination_percentage_in_day_one

			Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	(Combined)		3572.917	3	1190.972	51.970	.000
	Linear Term	Contrast	3450.417	1	3450.417	150.564	.000
		Deviation	122.500	2	61.250	2.673	.129
Within Groups			183.333	8	22.917		
Total			3756.250	11			

Multiple Comparisons of Germination_percentage_in_day_one

	(I) TREATMENT	(J) TREATMENT	Mean Difference (I-J)	Std. Error
LSD	TREATMENT 1	TREATMENT 2	-15.00000*	3.90868
		TREATMENT 3	-36.66667*	3.90868
		TREATMENT 4	-43.33333*	3.90868
	TREATMENT 2	TREATMENT 1	15.00000*	3.90868
		TREATMENT 3	-21.66667*	3.90868
		TREATMENT 4	-28.33333*	3.90868
	TREATMENT 3	TREATMENT 1	36.66667*	3.90868
		TREATMENT 2	21.66667*	3.90868
		TREATMENT 4	-6.66667	3.90868
	TREATMENT 4	TREATMENT 1	43.33333*	3.90868
		TREATMENT 2	28.33333*	3.90868
		TREATMENT 3	6.66667	3.90868

Appendix **2: Results of second day measures of wheat seed germination in non-primed seed and after priming as influenced by priming treatment**

ANOVA

Germination_percentage_in_day_TWO

			Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	(Combined)		1406.250	3	468.750	8.333	.008
	Linear Term	Contrast	303.750	1	303.750	5.400	.049

Deviation	1102.500	2	551.250	9.800	.007
Within Groups	450.000	8	56.250		
Total	1856.250	11			

Multiple Comparisons

Dependent Variable: Germination_percentage_in_day_TWO

	(I) TREATMENT	(J) TREATMENT	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
LSD	Unprimed	6 hrs hydro prime	-30.00000*	6.12372	.001	-44.1213	-15.8787
		12 hrs hydro prime	-15.00000*	6.12372	.040	-29.1213	-.8787
		18 hrs hydro prime	-20.00000*	6.12372	.011	-34.1213	-5.8787
	6 hrs hydro prime	Unprimed	30.00000*	6.12372	.001	15.8787	44.1213
		12 hrs hydro prime	15.00000*	6.12372	.040	.8787	29.1213
		18 hrs hydro prime	10.00000	6.12372	.141	-4.1213	24.1213
	12 hrs hydro prime	Unprimed	15.00000*	6.12372	.040	.8787	29.1213
		6 hrs hydro prime	-15.00000*	6.12372	.040	-29.1213	-.8787
		18 hrs hydro prime	-5.00000	6.12372	.438	-19.1213	9.1213
	18 hrs hydro prime	Unprimed	20.00000*	6.12372	.011	5.8787	34.1213
		6 hrs hydro prime	-10.00000	6.12372	.141	-24.1213	4.1213
		12 hrs hydro prime	5.00000	6.12372	.438	-9.1213	19.1213

*. The mean difference is significant at the 0.05 level.

Appendix 3: Results of third day measures of wheat seed germination in non-primed seed and after priming as influenced by priming treatment

ANOVA

Germination_percentage_in_day_THREE

			Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)		122.917	3	40.972	.728	.563
	Linear Term	Contrast	120.417	1	120.417	2.141	.182
		Deviation	2.500	2	1.250	.022	.978
Within Groups			450.000	8	56.250		
Total			572.917	11			

Multiple Comparisons

Dependent Variable: Germination_percentage_in_day_THREE

	(I) TREATMENT	(J) TREATMENT	Mean	Std. Error	Sig.	95% Confidence Interval

			Difference (I-J)			Lower Bound	Upper Bound
LSD	Unprimed seed	6hrs hydro primed	3.33333	6.12372	.601	-10.7880	17.4547
		12hrs hydro primed	6.66667	6.12372	.308	-7.4547	20.7880
		18hrs hydro primed	8.33333	6.12372	.211	-5.7880	22.4547
	6hrs hydro primed	Unprimed seed	-3.33333	6.12372	.601	-17.4547	10.7880
		12hrs hydro primed	3.33333	6.12372	.601	-10.7880	17.4547
		18hrs hydro primed	5.00000	6.12372	.438	-9.1213	19.1213
	12hrs hydro primed	Unprimed seed	-6.66667	6.12372	.308	-20.7880	7.4547
		6hrs hydro primed	-3.33333	6.12372	.601	-17.4547	10.7880
		18hrs hydro primed	1.66667	6.12372	.792	-12.4547	15.7880
	18hrs hydro primed	Unprimed seed	-8.33333	6.12372	.211	-22.4547	5.7880
		6hrs hydro primed	-5.00000	6.12372	.438	-19.1213	9.1213
		12hrs hydro primed	-1.66667	6.12372	.792	-15.7880	12.4547

Appendix 4: Results of fourth day measures of wheat seed germination in non-primed seed and after priming as influenced by priming treatment

ANOVA

Germination_percentage_in_day_FOUR

			Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)		491.667	3	163.889	13.111	.002
	Linear Term	Contrast	375.000	1	375.000	30.000	.001
		Deviation	116.667	2	58.333	4.667	.045
Within Groups			100.000	8	12.500		
Total			591.667	11			

Multiple Comparisons

Dependent Variable: Germination_percentage_in_day_FOUR

	(I) TREATMENT	(J) TREATMENT	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	Unprime seed	6hrs hydro primed seed	13.33333*	2.88675	.002	6.6765	19.9902
		12hrs hydro primed seed	13.33333*	2.88675	.002	6.6765	19.9902
		18hrs hydro primed seed	16.66667*	2.88675	.000	10.0098	23.3235
	6hrs hydro primed seed	Unprime seed	-13.33333*	2.88675	.002	-19.9902	-6.6765
		12hrs hydro primed seed	.00000	2.88675	1.000	-6.6569	6.6569
		18hrs hydro primed seed	3.33333	2.88675	.282	-3.3235	9.9902

	(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
	12hrs hydro primed seed	Unprime seed	-13.33333*	2.88675	.002	-19.9902	-6.6765
		6hrs hydro primed seed	.00000	2.88675	1.000	-6.6569	6.6569
		18hrs hydro primed seed	3.33333	2.88675	.282	-3.3235	9.9902
	18hrs hydro primed seed	Unprime seed	-16.66667*	2.88675	.000	-23.3235	-10.0098
		6hrs hydro primed seed	-3.33333	2.88675	.282	-9.9902	3.3235
		12hrs hydro primed seed	-3.33333	2.88675	.282	-9.9902	3.3235

*. The mean difference is significant at the 0.05 level.

Appendix 5: Results of total wheat seed percentage

ANOVA

Total_Germination_percentage

			Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	(Combined)		343.255	3	114.418	8.828	.006
	Linear Term	Contrast	274.476	1	274.476	21.178	.002
		Deviation	68.778	2	34.389	2.653	.131
Within Groups			103.685	8	12.961		
Total			446.940	11			

Multiple Comparisons

Dependent Variable: Total_Germination_percentage

	(I) TREATMENT	(J) TREATMENT	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	Unprimed seed	6hrs Hydro primed seed	-10.55333*	2.93946	.007	-17.3317	-3.7749
		12hrs Hydro primed seed	-11.67000*	2.93946	.004	-18.4484	-4.8916
		18hrs Hydro primed seed	-13.88667*	2.93946	.001	-20.6651	-7.1083
	6hrs Hydro primed seed	Unprimed seed	10.55333*	2.93946	.007	3.7749	17.3317
		12hrs Hydro primed seed	-1.11667	2.93946	.714	-7.8951	5.6617
		18hrs Hydro primed seed	-3.33333	2.93946	.290	-10.1117	3.4451
	12hrs Hydro primed seed	Unprimed seed	11.67000*	2.93946	.004	4.8916	18.4484
		6hrs Hydro primed seed	1.11667	2.93946	.714	-5.6617	7.8951
		18hrs Hydro primed seed	-2.21667	2.93946	.472	-8.9951	4.5617
	18hrs Hydro primed seed	Unprimed seed	13.88667*	2.93946	.001	7.1083	20.6651
		6hrs Hydro primed seed	3.33333	2.93946	.290	-3.4451	10.1117
		12hrs Hydro primed seed	2.21667	2.93946	.472	-4.5617	8.9951

*. The mean difference is significant at the 0.05 level.

Appendix 6. Results of for measures of MET Wheat seed

ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
MET_DAY * TREATMENT	Between Groups	(Combined)	.431	3	.144	3.841	.057
		Linearity	.358	1	.358	9.564	.015
		Deviation from Linearity	.073	2	.037	.979	.416
	Within Groups		.299	8	.037		
	Total		.730	11			

Multiple Comparisons

Dependent Variable: MET_DAY

	(I) TREATMENT	(J) TREATMENT	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	Unprimed seed	6hrs Hydro primed seed	.34467	.15792	.061	-.0195	.7088
		12hrs Hydro primed seed	.43800*	.15792	.024	.0738	.8022
		18hrs Hydro primed seed	.48367*	.15792	.016	.1195	.8478
	6hrs Hydro primed seed	Unprimed seed	-.34467	.15792	.061	-.7088	.0195
		12hrs Hydro primed seed	.09333	.15792	.571	-.2708	.4575
		18hrs Hydro primed seed	.13900	.15792	.404	-.2252	.5032
	12hrs Hydro primed seed	Unprimed seed	-.43800*	.15792	.024	-.8022	-.0738
		6hrs Hydro primed seed	-.09333	.15792	.571	-.4575	.2708
		18hrs Hydro primed seed	.04567	.15792	.780	-.3185	.4098
	18hrs Hydro primed seed	Unprimed seed	-.48367*	.15792	.016	-.8478	-.1195
		6hrs Hydro primed seed	-.13900	.15792	.404	-.5032	.2252
		12hrs Hydro primed seed	-.04567	.15792	.780	-.4098	.3185

*. The mean difference is significant at the 0.05 level.