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Full Length Research Paper

The Role of Seed Priming for Better Productivity of Crops in Ethiopia: Implications for Changing Environment

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Success of crop production depends on existence of optimum condition starting from germination to maturity of crops. However, optimized condition is not usually possible for different reasons. Currently, salinity and drought stresses are among the major crop productivity liming factors in the worlds including Ethiopia. To alleviate problems of salinity and drought on crop production, seeds priming is considered as the cheapest and most effective measure. This paper discusses the concepts of seed priming, techniques of priming, research efforts made so far in Ethiopia to evaluate the role of seed priming in alleviation of these stresses and the implications of the findings for future research.

Key words: Invigoration, seedling emergence, shoot length, vigor index.

INTRODUCTION

Drought stress, as on the abiotic, significantly reduces productivity of crops in dryland areas of the worlds (Lipiec et al., 2013) by affecting all aspects crop physiology (Munns and Tester, 2008**)** through inhibiting seed germination, early establishment and seedling growth by creating low osmotic potential and preventing water uptake (Kaya *et al*., 2006). Dryland farming is widely practiced in Ethiopia and accounts for over two-thirds of all agricultural land (MoA, 2011). Unfortunately, droughts have frequently plagued Ethiopia and are a major climatic hazard that impacts the long-term sustainability of this rapidly growing African nation (Mersha and Laerhoven, 2018). The semi-arid and dry sub-humid agro-ecological zones of the country, which account for nearly 47% of the country's 113 million ha, are marginal environments for crop production and are highly vulnerable to droughts and a significant proportion of population continues to rely on food aid and safety net programs (Mekonen, 2007). Increasing soil salinity is among the major causes of low agricultural productivity in these areas (Qureshi et al.,2018). It is abiotic stress severely affecting crop yield through increasing soil osmotic potential which results in constrained water and solvent uptake via roots (Daszkowska-Golec 2011), disturbing plant osmotic balances (Das and Roychoudhury 2014) and inducing huge oxidative stress ($Na+$ and $Cl-$ toxicity) thereby inhibition of physiological processes like photosynthesis, growth, respiration and flowering (Roychoudhury and Chakraborty, 2013). Ethiopia stands first in Africa in the extent of salt affected soils due to human-induced and natural causes (Qureshi *et al.,* 2019) many researchers have reported that currently 11 million ha of land is exposed to salinity (Frew, 2012; Ashenafi and Bobe, 2016).

Targeting best seed germination, rapid and uniform seedling emergence are among the most important agronomic practices in stages of crop plants under adverse conditions (Paparella et al., 2015) in order to achieve better yield through optimizing plant stand (Gelmond, 1978). One of the cheapest and effective approaches to overcome abiotic stresses effects is seed priming (Farooq *et al*. 2006).

Concepts and benefits of seed priming

Priming is defined as defined as a procedure that hydrates the seed in a specific environment. Subsequently, the seed is dried to bring out its initial moisture content, so that the germination processes can begin, but restrict radicle emergence (Giri and Schillinger, 2003). It involves prior exposure to elicitors which brings a cellular state that hinders the harmful effects of abiotic stress, and plants raised after priming are more tolerant of abiotic stress. Priming induces resistance upon pathogen attack and confers enhanced disease protection to the plant (Van Hulten et al. 2006). Seed priming involves soaking of seed in water or other solvents for a certain period that leads to changes in metabolic profile of the seed (Hussain et al. 2016)

Primed seeds usually exhibit increased germination rate, greater germination uniformity, and sometimes greater total germination percentage (Kaya et al. 2006**)** grow more vigorously, and perform better in adverse conditions (Desai et al. 1997). Gregg and Billups (2010) summarized benefits of seed priming as extending temperature range over which seed can germinate, increasing germination percentage of seeds at any soil temperature and reducing days to seedling emergence by 50% and elimination or reduction of the presence of certain seed-borne fungi and bacteria. This paper attempts to discuss the different techniques of seed priming and their role in improving crop productivity in Ethiopia under adverse conditions.

Traditional methods of seed priming

There are a number of priming agents and/or methods which increases germination and growth especially under environmental constraints (Jisha et al. 2013). However, the degree of efficacy of different priming agents varies with plant species and diverse environmental conditions (Iqbal and Ashraf 2005). Different authors have reported availability and importance of various seed priming techniques (Jisha et al. 2013; Paparella et al. 2015; Mukherjee, 2019) and the classification of the priming techniques varies with the chemical nature of the priming agent (Ibrahim, 2016). Each of this seed priming technique has been discussed in detail below.

Hydropriming

Hydropriming is a nontoxic, economical, and simple technique that improved plant growth and production under environmental constraints in terms of improved seedling establishment and osmotic adjustment (Kaur *et al*., 2002). In hydropriming, seeds are soaked in distilled water at room temperature, and seed imbibition determines length of hydropriming (Kaya *et al*., 2006). It is evident from the literature that soaked seeds must be properly dried because inadequate drying is harmful (Thomas *et al*., 2000). Soaked seeds are brought to their original weight through proper drying under shade (Jisha *et al*., 2013). Hydropiming initiates physiochemical alterations in seeds prior to germination (Basra *et al*., 2003). In addition, protoplast in hydroprimed seeds has greater permeability to nutrients and water, lesser viscosity, and greater resistance to dehydration (Jisha *et al*., 2013). Plants produced from hydroprimed seeds had greater water uptake which is positively associated with seedling growth (Yagmur and Kaydan 2008). It is a very simple, low-cost technology as simple water is used in this priming technique. Hydropriming is followed by surface drying or redrying of seeds to their original weight. Many studies have reported that hydropriming may improve the stand establishment, seedling vigor, and productivity of field crops under optimal and suboptimal conditions (Roy and Srivastava, 1999; Mohammad *et al*. 2008; Nawaz et al. 2016; Ansari and Zadeh 2012).

Halopriming

Halo-priming refers to soaking seeds in a solution of inorganic salts, i.e. NaCl, KNO_3, $CaCl_2$ and $CaSO_4$ (Choudhary *et al.,* 2019) of variable concentration. Various studies have also reported that halopriming improved the stand establishment, seedling growth, and productivity of diverse crop species under optimal and suboptimal conditions (Khan *et al*., 2009; Iqbal et al., 2006; Kadiri and Hussaini 1999 and Sedghi et al., 2010).

Osmopriming

Soaking of seeds for a certain period of time in a solution of sugar, PEG, etc. followed by air drying before sowing (Choudhary et al., 2019). In this case, the seed is soaked in solutions with low water potential (Jisha et al. 2013). Osmopriming enables researchers to study alteration in seeds from physiologically inactive dry state to physiologically active hydrated state (Chen and Arora, 2011). $MgSO_4$, KH_2PO_4, K_3PO_4, KCl, KNO_3, mannitol, NaCl, $CaCl_2$ and other chemicals used to create solutions with low water potential (Jisha et al. 2013). Osmopriming is the standard priming techniques, different osmotic can be used in seed priming and these have got different characteristics and levels of efficacy (Taylor *et al*., 1998. Many studies have reported that osmopriming improves the stand establishment and seedling/crop growth under optimal and suboptimal conditions. For example, osmopriming (20% PEG-8000) of ryegrass and sorghum seeds improved the germination rate of both crops under suboptimal conditions (Hur 1991). Many other authors have also showed improved seedling emergence, seedling vigor, stay green, and leaf growth as compared to unprimed seeds (Pradhan *et al*. 2015; Theerakulpisut *et al*., 2017; Safiatou, 2012 and Sadeghi *et al*., 2011).

Solid Matrix Priming

Matrix priming, also known as the solid matric conditioning, is accomplished with the controlled and limited hydration, as in hydropriming and osmopriming. However, the matrix priming utilizes the solid medium (matrix which delivers water and nutrients to seed prior to emergence of radical including vermiculite and diatomaceous and water-absorbent polymer) for seed priming purpose (Taylor and Harman, 1990). These solid matrix materials have low bulk density and low osmotic potential and high water-holding capacity. Khan (1992) recommended the use of matrix priming due to the good water-holding capacity of the solid matrix and its ease of removal from the seed. The matrix priming has the ability to provide a good amount of oxygen to the seed during the process of hydration. It is reported to improve germination metabolism (Grzesik and Nowak, 1998), protein level and fruit quality (Ilyas *et al*., 2002) and germination percentage (Kubik *et al*., 1988) in various crops.

Hormonal priming

The use of plant hormones and other plant growth regulators as seed pre-sowing treatment can improve plant growth under stressful conditions (Jisha et al. 2013). There are a number of reports in the literature where seed soaking in GA3 (gibberellic acid) has been shown to improve germination (Khan *et al*. 2002; Jisha *et al*., 2013). Seed priming with hormones to improve the crop performance under stressful environments has also attained greater attention in recent past (Sneideris *et al*. 2015). The hormonal priming generally consists of priming of seeds with different chemicals including hydrochloric acid, hypochlorite and other natural substances. In a study, the seed priming with ascorbic acid and salicylic acid (500 ppm each) improved the seedling growth and seedling dry weight under saline and non-saline conditions (Afzal et al., 2006) and also increases the level of soluble sugars in the rice grains. Increased contents of soluble sugars were recorded in cytokinin (Deshpande *et al.,* 2003), gibberellic acid, and to a greater extent in indole acetic acid-treated rice seeds (Kim *et al*., 2006).

Factors governing success of seed priming

Priming must be practicable and affordable by farmers for its adaptability (Mukherjee, 2019). Seed priming is influenced by the complex interaction of factors including plant species, water potentiality of the priming agent, duration of priming, temperature, seed vigor and dehydration and storage conditions of the primed seeds (McDonald, 2000; Mukherjee, 2019). The success of priming depends on optimized duration of priming, availability of adequate aeration, availability of minimum temperature to minimize radical protrusion and method of priming which must be non-toxic, chemically pure, amenable for maintaining correct osmotic potential, free from pathogen invasion, economically and easily available (Varier *et al*., 2010). Corbineau and Come (2006) also opined that among the factors affecting seed priming, oxygen, temperature, and water potential of priming medium are the most important ones.

Effect of seed priming on phenological, growth, yield and yield related parameters of crop in Ethiopia

Seed germination

Priming with Gibberellic Acid (GA3) reduces deleterious effects of salinity and significantly improve seedling growth performance of maize, pea and *Lathyrus sativus* by increasing percentage of seed germination and reducing mean germination time under laboratory conditions (Berhanu *et al.,* 2018). Jima *et al*., (2015) also reported that priming onion seeds with KNO_3 at the relatively lower concentration of 1% for a relatively shorter duration of (12 hours) remarkably increased standard germination and germination percentage rate under laboratory condition. Results of field experiment also shows significant improvement in germination of soybeans seeds accounting for 92.67% and 89.85% due to priming with water and KH_2PO_4, respectively, (Meseret, 2020).

However, priming the crop with KH_2PO_4 (Potassium dihydrophosphate) and GA3 did not show any statistical variation on germination percentage. The same author also explained that speed of germination is dependent on interaction of varieties, priming type and duration of priming. Accordingly, the highest Speed of Germination was recorded when Wello variety was primed with water for 6hr (42.89) whereas the lowest speed of Germination was observed on Gishema variety primed with KH_2PO_4 for 0hr (33.99). Primed variety showed an increased in speed of germination over the control. The probable reason for early emergence of the primed seed may be due to the completion of pre-germination metabolic activities making the seed ready for radicle protrusion. Maximum values of standard germination (100%) result in common bean due to priming with distilled water and lower concentrations of NaCl (0.1M and 0.2M) in controlled conditions (Roba and Jima, 2016). Maximum and statistically similar values of germination percentages were also observed in sesame due to priming of seeds with tap water for 12 h (91.5%) and $CaCl_2$ (2%) solution (88.75%) whereas control treatment (unprimed) shows 78.75% under laboratory condition (Yalew *et al.,* 2019). Sowing primed rice seeds was found to be advantageous in shortening duration of seedling emergence, heading, and maturity (Tilahun *et al*., 2013).

Seeding growth

Priming of with GA3 shows a stimulatory effect on seedling vigor index, shoot and root length, shoot, and

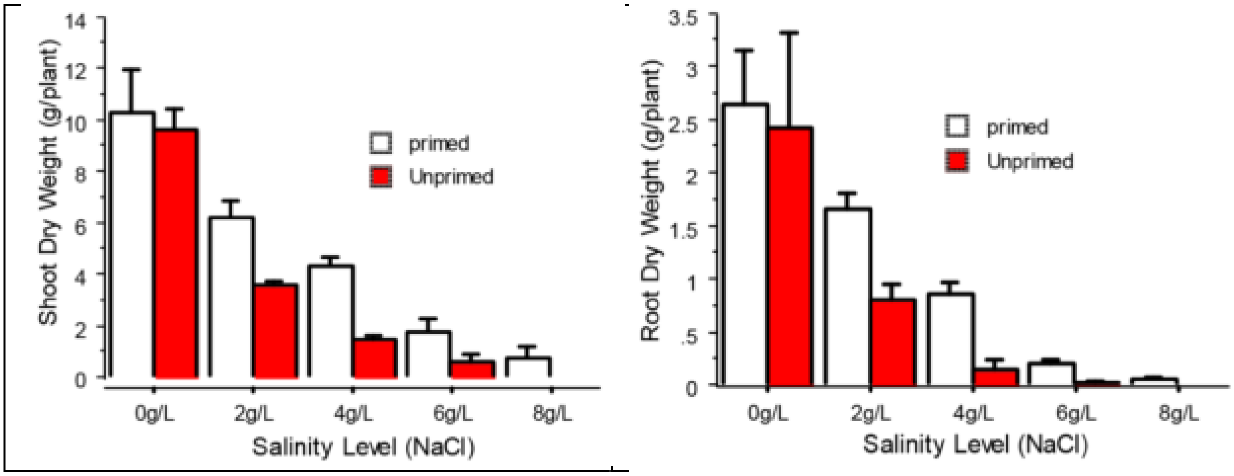

Figure 1. Effect of different salinity levels on shoot and root dry weights of primed and unprimed seeds of maize in five weeks of growth time (mean ± stand. Dev.) (Berhanu and Gebremedhn, 2013).

Table 1. Effect of concentration of Sodium Chloride (NaCl) on Shoot length, Seedling height and Vigor index-I of Common bean (Roba and Jima, 2016)

Treatments (NaCl concentration)	Shoot Length (cm)	Seedling height(cm)	Vigor Index I
0.0M(H_20)	29.23ab	55.37ab	5536.7ab
0.1M	32.36a	56.77a	5676.7a
0.2M	29.26ab	53.30abc	5330.0ab
0.3M	27.86bc	51.87abc	5097.8b
0.4M	25.03c	47.50c	4511.3c
Un-Primed seed(control)	26.50bc	50.47bc	4451.3c
LSD	3.96	5.86	551.74
CV	7.84	6.26	6.08
Significant Level	*	*	**

Means within the same column followed by different letter are significantly different at P ≤ 0.05.

root fresh and dry weights of maize *Zea mays* L., *Pisumsativum*Var. *abyssinicum* A. Braun and *Lathyrussativus* L.J. in saline condition 6 dS/m (Berhanu and Melkamu, 2018). Vigor index shows the viability and ability of seeds to emerge and survive in difficult conditions (stress) and the authors indicated that maximum seedling vigor index was observed at 0 dS/m (40.467 for primed and 28.970 for unprimed) and minimum seedling vigor index was at 12 dS/m (2.589 for primed and almost zero value for unprimed treatment. Hydropriming (tap water) increase sesame root length by 17% compared with control treatment under laboratory condition. Priming sesame seeds with tap water and $CaCl_2$ (2%) solution increases sesame seedling vigor index by 25% and 34%, respectively, compared with unprimed treatment (Yalew *et al*., 2019). According to result from field experiment in soybean, seedling root length significantly differed due to priming types. Moreover, seedling dry weight significantly varies from 166.67mg to 250gm per plant in due to interaction effect of variety, priming type and priming duration. Maximum and statistically similar values result were observed when Belessa95 variety primed with water for 12hr (250gm), and Gishema variety primed with water for 6hr (250gm) and Wello variety primed with KH_2PO_4 for 0hr (246.67mg) (Meseret, 2020). Primed varieties also showed an increase seedling vigor index 1 and 2 over the control.

Priming of onion seeds with lower concentration of potassium nitrate (1%) for 12hrs improves seedling dry weight and vigour index II by 60% and 80%, respectively, compared with unprimed treatment in nursery seed bed. This osmotic primining also shows better improvement in seedling growth performance of onion compared with hydro-priming (Jima *et al*., 2015). Berhanu and Gebremedhn (2013) also observed highly significant reduction in shoot and root dry weights of maize seedling under pot experiment which was conducted in an open field in unprimed seeds compared to primed ones (Figure 1). Roba and Jima (2016) also reported that shoot length, seedling height and vigor index I common bean can be enhanced by priming with lower concentration levels of sodium chloride under green house (Table 1).

Table 2. Effect of priming treatments on phenological and growth parameters of chickpea (Abebe, 2016),

Treatments	Days to 50% emergence	Days to 50% flowering	Days to maturity	plant height	Stand count at emergence	stand count at harvest
Control	8.6 1[a]	46.89[a]	114.89[a]	39.16[b]	55.06[b]	50.83[b]
Water	7.25[b]	44.44[b]	112.83[b]	41.96[a]	60.72[a]	57.11[a]
KH_2PO_4 (0.5%)	7.11[b]	46.11[a]	111 78[b]	39.65[b]	53.72[b]	50.50[b]
LSD	0.3748	1.619	1.084	1.139	4.408	4.579
F-test	**	*	**	**	**	**
CV (%)	7.234	5.216	1.414	4.176	11.52	12.758

Table 3. Effect of hydro and osmopriming on yield and yield components of chickpea (Abebe, 2016).

Treatments	Seed yield (kg ha^{-1})	Harvest Index (%)	Number of seeds $plant^{-1}$
Control	2212.6[b]	54.89[b]	58.87[b]
Water	2541.8[a]	61.60[a]	60.58[b]
KH_2PO_4 (0.5%)	2285.0[b]	54.90[b]	75.38[a]
LSD	242.72	3.74	9.53
F-test	*	**	**
CV(%)	15.27	6.84	22.43

Phenological and growth parameters

Osmopriming (0.5% KH_2PO_4 were applied for 8 hrs) found to decrease days to 50% emergence by 17% as compared with unprimed treatment while, hydro priming for the same duration reduced days to 50% flowering by 16% in chickpea (Abebe, 2016). Results from field experiment shows that seedling emergence index is dependent on variety, duration and time of priming in soybean (Meseret, 2020). Water treatments took significantly lesser days for 50% flowering by 2.5 days compared to unprimed seed which may be due to better early and faster emergence whereas effect of osmpriming did not show any difference with control treatment in chickpea. On the other hand, both hydro and osmo invigoration seed treatments took significantly lesser days to physiological maturity compared to control (Abebe, 2016). Hydropriming also shows best performance in plant height, stand count at emergence and at harvest (Table 2). Abebe *et al*., (2017) concluded that seed priming with water and cow urine substantially shorten days to seedling emergence, days to heading and days to maturity in bread wheat, but significantly increases total number tillers and leaf area index (LAI) from field experiment. Hydro-primed rice seeds were associated with higher LAI (Tilahun *et al*., 2013).

Effect of priming on yield and yield related traits of crops

Hydropriming of seeds for 8hrs significantly improved seed yield and harvest index of six chickpea varieties compared with osmopriming (0.5% KH_2PO_4) and control treatments (Table 3) under field condition. However, seed yield obtained from osmopriming and control treatments were (unprimed seeds) were not different statistically (Abebe, 2016). * and ** denotes non-significant at $p<0.05$, significant at $p<0.05$ and $p<0.01$ respectively. Values sharing the same letters in each column are not different statistically and those having different letters in the column are significantly different from each other.

Field trial conducted by Abebe *et al*., (2017) shows 15% and 11% increment in grain yield of bread wheat due to priming with water and cow urine compared with unprimed treatment. Moreover, the authors concluded that 37% and 19% reduction in incidence of bread wheat fusarium head scab due to priming seeds with water and cow urine compared with unprimed treatment. Economically, hydro priming results in maximum net benefit (35122 Ethiopian Birr ha^{-1}) over the control and cow urine treatments and the best marginal rate of return (8954%) (Abebe *et al*., 2017). Field experiment conducted to evaluate effect of priming onion seeds with different concentrations of potassium nitrate salt (0% /distilled water/, 1%, 2%, 3%, no-priming) and duration of exposures of seeds (12 hrs, 24 hrs, 48 hrs and 72 hrs) to the chemicals gave the highest marketable bulb yields due to priming the onion seeds with distilled water for 72 hrs, and with KNO_3 salt at the concentrations of 1% for 12 hrs and at the concentration of 2% for 24 and 72 hrs, respectively (Jima *et al*., 2015).

On contrary, results of two year experiment on hydro priming of maize (for 14hrs), sorghum and pearl millet (for 8hrs) shows less productivity of the crops compared with dry sowing and the benefit of priming is manifested when priming is integrated with other technologies such as tied ridging and micro-dosing of fertilizer (Amare *et al.,* 2020).

Number of unproductive tillers and unfilled spikeletes get much reduced with hydro-priming of rain-fed lowland rice production at Fogera plain which is regularly experiencing terminal moisture stress resulting in 50% yield advantage (Tilahun *et al*., 2013). The authors indicated that hydro-primed rice seed for 24 hours and re-drying it for 24 hours at the farmers planting time resulted in the highest grain yield of the crop by encouraging completion of the crop phenological growth stages earlier and escaping of the negative effects of terminal moisture stress.

CONCLUSION

Most findings from abroad and in the country showed positive and significant roles of priming crop seeds in improving productivity of studied crops in moisture stressed and saline environments including reduction of incidence of biotic stresses. This can make seed priming one of the best alternative agronomic options for sustainable productivity of crops under changing environment. Based on the available literatures, hydropriming seems the cheapest and most effective method of seed priming for better crop productivity. However, most the studies conducted in the country (Ethiopia) are limited to controlled environment (laboratory), using limited number of priming agents and priming durations only for few numbers of crops. Hence, comprehensive field studies are required to properly evaluate effectiveness of seed priming considering all available priming agents, different priming durations and concentrations through integration with other agronomic practices for various varieties of major crops under different environments. Economic advantages of the priming should also be considered in order to make complete conclusions and recommendations.

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