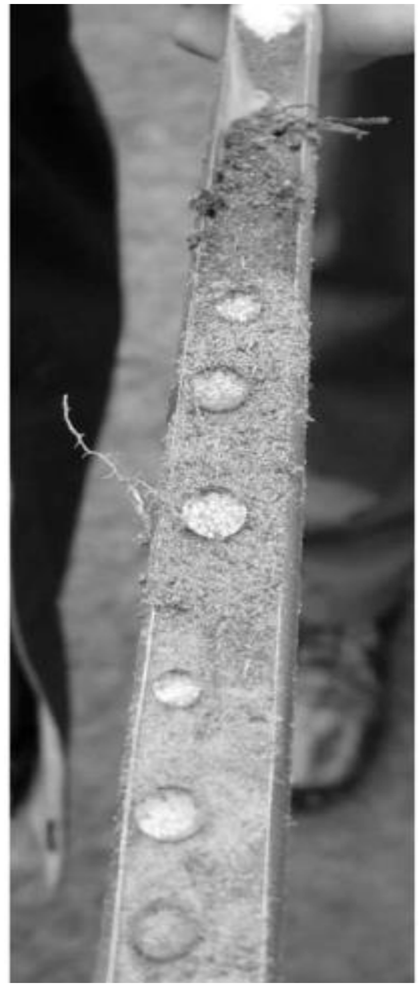
Non-wetting sands – A Literature Review

South Australian No-Till Farmers Association, 2020.

Non-wetting sands

Water repellent soils occupy more than 5 million hectares of western and southern Australia (Jessica, et.al) and are often referred to by farmers as 'hydrophobic', 'oily', or 'non-wetting soils (M. M. Roper et al). Non-wetting sands develop when there is an accumulation of hydrophobic organic substances in a susceptible soil. Water repellency generally occurs in the surface layers of sandy soils where hydrophobic materials of the plant occur as particulate organic matter and as waxy coatings on sand particles (Ma'shum et al. 1988; Franco et al. 1995). Water repellant soils are commonly caused by fungi producing water repellent residues (Jessica, et.al); waxy substances in plants are not effectively broken down by their passage through the sheep and sheep camps also tend to be more water-repellant because of the accumulation of organic matter (Blackwell 1996). Soils with a small surface area like sand are more prone to water repellency as it takes less hydrophobic material to coat individual particles, compared to silt or clay (Jessica, et al).

Difficulties in farming arise due to the hydrophobic condition of the soil. Because large volumes of soil remain dry, plants are unable to access nutrients contained therein, resulting in poor early nutrient-use efficiency in soils (Blackwell et al. 1994b). Causing delayed germination of crop and pasture plants, poor stand establishment, and increased risks from wind and water erosion (Bond 1964; King 1981; Tate et al. 1989). Water repellent soils wet up unevenly resulting in poor seed germination, resulting in patchy and delayed emergence, poor crop establishment and reduced grain yield (Blackwell *et at.* 1994a).



Soil core sampler containing a 25 cm long water repellent sandy column

Two methods can be performed to determine the severity of the soil water repellency. First is called Water-drop penetration times (WDPT), it measures the time taken for a droplet to penetrate the soil (Jessica *et al*). This involves placing droplets of distilled water onto the surface of a soil placing droplets of distilled water onto the surface of a soil sample and recording the time for the complete infiltration. The procedure determines the presence of soil water repellency and how long it persists in the contact area of a water droplet (Bisdom et al., 1993). The second method is the molarity of ethanol drop (MED), the MED solution is needed to penetrate the soil in under 10 seconds (Jessica *et al).* Wettable soils have a MED of zero. Scales of repellency are: low, MED >0-1.0; moderate, MED 1.2-2.2; severe, MED 2.4-3.0; and very severe, MED >3 (King 1981).

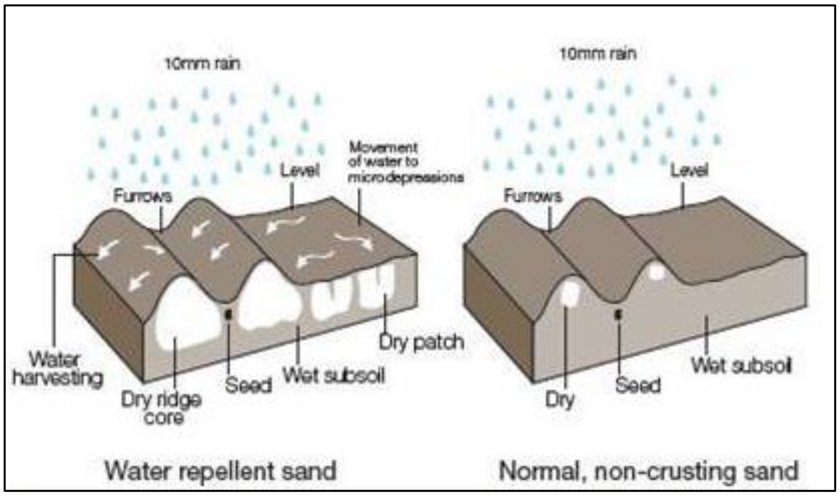


Figure 1: Water harvesting from ridges of dry, water repellent sand, compared with a level and non-repellent sand.

A wide range of management strategies has been developed to offset the impacts of water repellency on agricultural production in dryland systems (M. M. Roper *et al)*. Mitigation, Amelioration and avoidance options. Mitigation strategies minimize or reduce the effects of water repellency on agricultural production without markedly altering the repellency status of the soil. Amelioration strategies change the properties of surface soils and the benefits are usually longer-term (M. M. Roper *et* al).

An amelioration study by Stephen Davies combated the soil water repellence over the medium to long term by changing the soil texture through addition of clay-rich amendments or by physical displacements.

For the avoidance options are alternative land use options, typically utilizing perennial species, that once established are less impacted by the soil water repellence (Stephen Davies).

Mitigation tools:

Water harvesting or *furrow sowing* has been used to manage water repellent soils because it allows water harvesting from the ridges into the furrow and allows placement of the seed deeper in the soil, either in the lower topsoil or shallow subsoil, which is often more wettable (Feng et al, 2001). Furrow sowing has been shown to improve plant emergence compared with conventional, level sowing or 'flat planting' (Crabtree and Gilkes 1999; Crabtree and Henderson 1999; Blackwell 2000).

Figure 2: Poor wetting up and crop establishment in knife points sown furrows in water repellent sand

In Davies et al. literature, the authors described furrow as the most commonly used seeding approach for water repellent and non-repellent soils. Topsoil can be thrown by seeding points or pushed, by discs and press wheels, to form a furrow. No-till and zero-till methods make smaller furrows and retain more soil cover than cultivation. Full cut cultivation can pose very high erosion risks on water repellent sands.

Water repellent soil on the ridges is very effective at shedding rainfall into the furrow. Wider furrows will harvest more water due to the broader ridges, forming a greater catchment however, the furrow does not need to be deep. Deep furrows can increase the risk of furrow infill and seed being buried too deep (Davies et al).

Soil wetting agents contain surfactants that reduce the surface tension of water at the soil surface and improve water entry into repellent soil (Dekker et al. 2005; Barton and Colmer 2011; Lehrsch et al. 2011). In an example, Barton and Colmer (2011) demonstrated that application of either granular or liquid surfactant before the commencement of irrigation reduced the severity of soil water repellency by 30-60%. The use of surfactants has been shown to be particularly beneficial during drought, resulting in much greater uniformity of soil water content than in untreated soils (Soldat et al. 2010). Research by (Blackwell et al. 1994c) states that surfactants have been applied to reduce the impacts of repellency on sand-based, turf-grass systems.

No-tillage and stubble retention have been adopted by growers to improve the timeliness of operations and reduce costs, but other benefits include reduced erosion (Flower et al. 2008). Water infiltration into water-repellent sands has been shown to improve under no-tillage and stubble retention, increasing soil-water contents by 2-4% v/v compared with annual cultivation and stubble removal, and this resulted in improvements in grain yield of to 50% in some years (Roper et al. 2013a).

Figure 3: Furrows in severely repellent sandy soil, sown with winged points

Figure: Clay spreading using a multi-spreader

Figure: Clay delving

Claying is a widely used additive for reducing hydrophobicity in sandy soils. Publish studies from Australia reported a twofold increase in crop yields and long-term beneficial effects through clay amendment (Cann,2000; Mckissock et al 2002). Clay usually applied in dry form on the topsoil and subsequently incorporated to a depth of 5-10 cm. Application of clay to water-repellent sand increases the surface area of the soil and masks the waxy surfaces of the repellent sand particles (Ward and Oades 1993). After application, wetting and drying cycles help clay to disperse and increase its effectiveness.

Clay spreading involves excavating clay from the subsoil in a pit to a deep sandy area and spreading using a scraper onto the soil surface (M. M. Roper et al). Application of heavy, clay-rich subsoil at rates of ≥200tha–1 is difficult to incorporate and more costly to apply given the high volumes that need to be excavated and spread. Clay delving is another technique for claying, this can be used in Sodosols and Chromosols where the top of the clay layer is within 50-60 cm of the soil surface (Davenport et al. 2011). Delving implement penetrates the soil and breaks into the clay layer, lifting clods of clay to the surface.

No evidence was found in the literature where seed priming had been trialed specifically to aid germination in non-wetting sands; albeit, seed priming has been used in other circumstances to improve germination.

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Seed priming solutions for Wheat, Canola and Barley

Seed priming enhances the germination rate and uptake of nutrients and also controls seed-borne pathogens by influencing the pre-germination metabolic activities (Taylor and Harman 1990). Seed priming has been demonstrated to improve germination and emergence in seeds of many crops, especially under stress condition (G.R. Mohammadi and F. Amiri). Seed priming improved the germination and vigour of wheat crop that leads to 17% increase in grain yield than non-primed seed (Farooq et al. 2008).

Quick and uniform field emergence is essential to achieve high yield in crops.

(i). The beneficial effect of priming has been demonstrated for many crops such as wheat, soybean, maize and sunflower;

(ii). Seed priming has been successfully used to improve germination and seedling emergence of many crops, particularly vegetables and small grasses;

(iii). Seed priming has been found to be a double technology for enhancement and achieve better yields in many crop species;

(iv). Seed priming initiates metabolic processes necessary for germination;

(v). Seed priming improves emergence, stand establishment, tillering, grain, straw yields and harvest index (Sarlach, Rashpal. 2013).

Wheat

The cultivation of wheat has been a primary activity in South Australian agriculture since European settlement. According to the study and experiments of Sarlach, Rashpal (2013), it may be concluded that 12 hours of seed priming is useful to enhance uniform seedling emergence and to enhance yield in wheat. Seed priming improved the germination and vigour of wheat crop that leads to 17% increase in grain yield than non-primed seed (Farooq et al. 2008).

In a research study by Michael P. Fuller et al, seed priming treatments are simply applied practices that can reduce the effects of salinity with small inputs of capital and energy. Seed priming or invigoration treatments are being used to improve the rate and speed of germination under stressed conditions or with substandard seed lots. (Michael P. Fuller et al, 2012). In literature by (Afzal et al. 2005) a method using salt priming increased salinity tolerance of wheat in terms of improves metabolite reserves, seedling vigour, and K+ and Ca2+ contents along with decrease Na+ contents. According to (Hussain et al. 2013), seed priming with CaCI2 improves seedling emergence, seedling establishment, plant height, tillers number, grain number, grain weight and yield under drought stress in wheat. In another study, (Farooq et al. 2006b) showed that seed priming with KCI or CaCI2 improved the seedling growth, stand establishment as well as yield performance in direct-seeded rice.

Canola

A research study of Mohammadi, Amiri (2010) states that Canola seeds are commonly planted in seedbeds having unfavourable moisture if the rain will not be able to fall during planting time. Drought stress is important in priming canola, according to (Mohammadi, Amiri, 2010) depending on the levels of stress it can be in good yield or the opposite. (Prisco et al, 1970) pointed out that this stress adversely affects the growth and development of the crop. During this stress condition, there is a decrease in water uptake both during imbibition and seedling establishment. An experiment was conducted to evaluate the effect of seed priming on canola, it was carried out at Seed Research

Laboratory of Faculty of Agriculture of Razi University, Kermanshah Iran. The experiment was based on three factors (a) priming method (control, KNO3, and distilled water), (b) drought stress levels (0.0, -0.3, -0.6, -0.9, -1.2, and -1.5 MPa), and (c) canola cultivars (Okapi and Talayeh).

Distilled water: Canola seeds were immersed in distilled water at 25°C for 18 hours under dark conditions. KNO3 treatment: the seeds were immersed in 500 ppm KNO3 solution at 25°C for 2 hours under dark conditions (Singh and Rao, 1993). The seeds under study showed different responses to the increased drought stress level (Table 2)

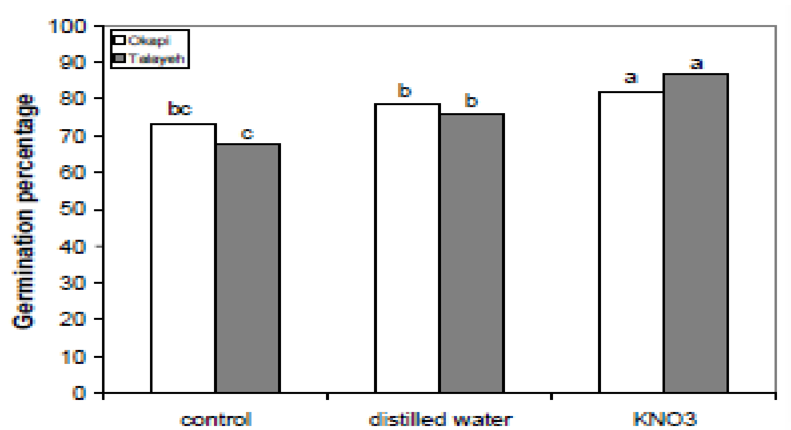

Fig.1: The effect of different seed priming treatments on germination percentage of two canola cultivars.

Table 2. Means comparison of the drought stress level × cultivar interaction for the traits under study.

Drought stress level (MPa)	Germination percentage		Mean germination rate		Radicle length (cm)		Plumule length (cm)		Seedling dry weight (mg)	
	Talayeh	Okapi	Talayeh	Okapi	Talayeh	Okapi	Talayeh	Okapi	Talayeh	Okapi
0	95.8 ab	100 a	0.63 a	0.68 a	2.15 b	2.62 a	2.22 c	2.99 a	70.44 bc	89.11 a
-0.3	89.7 b	89.9 ab	0.61 a	0.61 a	2.12 b	2.40 a	1.92 d	2.64 b	61.33 cd	80.67 b
-0.6	48.2 c	88.7 b	0.46 bc	0.51 bc	2.00 b	2.13 b	0.84 e	0.87 e	43.55 de	73.00 bc
-0.9	43.5 c	77.9 b	0.37 d	0.45 c	1.07 c	1.16 c	0.46 f	0.86 e	31.00 e	66.56 c
-1.2	29.4 d	66.4 bc	0.24 e	0.26 e	0.80 d	0.84 d	0.00 e	0.29 f	22.22 f	51.00 d
-1.5	26.9 d	43.4 c	0.10 f	0.14 f	0.70 d	0.81 d	0.00 e	0.00 e	11.00 g	41.44 de
LSD (0.05)	10.09		0.07279		0.1655		0.285		8.004	

The same letters at each column indicate an insignificant difference at the 0.05 level of probability. LSD, least significant difference

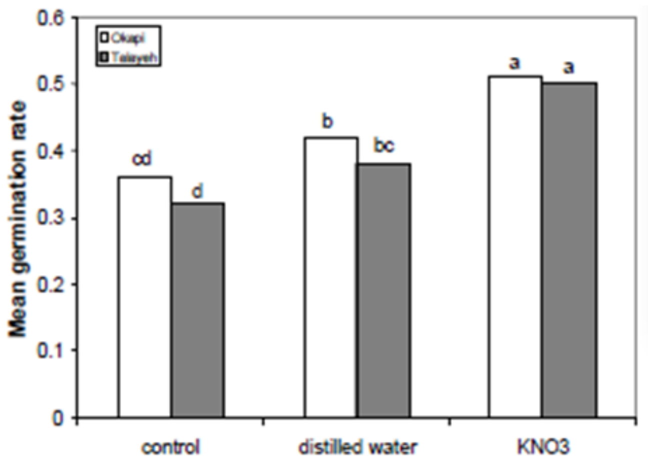

Fig2.: The effect of different seed priming treatments on mean germination rate of two canola cultivars

Therefore, the study results showed that both KNO3 and distilled water treatments improved Canola seed performance. However, for the most traits under study, seeds primed with KNO3 showed better performance than those primed with distilled water (Mohammadi, Amiri.2010). The study also showed that priming canola seed goes well with KNO3 under high levels of drought stress, the improvements were more notable at the higher levels of drought stress (Mohammadi, Amari. 2010).

In another study, seed osmo-priming with NaCl enhanced seedling emergence, seed germination, and plant growth in canola and chickpea (Farhoudi and Sharifzadeh 2006; Sarwar et al. 2006). In a study by (Shahzad et al.2003), canola seeds responded to different priming treatments and seed yield was increased due to priming. Osmo-conditioning performed better than hydropriming. Freshly osmo-primed seeds for 8 h proved better than the other treatments. Primed seeds maintained their increased vigour by six months of low-temperature storage. The beneficial effects of priming were maintained after six months of storage at a low temperature. (Akers et al. 1987) reported that the priming effect was not lost during eight months of storage. Hydro-primed seeds stored at 15 to 20 C had better quality in comparison to those stored at 25 C for two days had better germination efficacy than those with other treatments (Farajollahi, Eisvand 2017).

Barley

Barley is used commercially for animal feed, malt production, and human consumption. Although only 13% of the barley produced worldwide is processed into malt, it is well known as the premier malting and brewing grain (Steven, 2011). Barley seeds used in the brewing industry must have high germination capacity, purity of variety, uniformity in grain size, and have low protein content (Junhaeng et al). Authors performed different priming techniques and experiment on barley. In the said experiment, (Junhaeng et al) performed a complete factorial randomized design with four replications 4 priming levels (a) non-primed barley seed, (b)hydropriming, (c) osmo-priming with PEG, (d) hydropriming with KNO3; 6 hydro-time levels (6,8,10,12,14, or 16 hours); 4 replicates (a) viability, (b) germination, (c) germination index, (d) mean emergence time. Priming was performed at room temperature (25C). Twenty g of seeds were placed in 500 ml of priming solutions. After the end of each hydro-time, the barley seeds were dried in a fan-forced oven at 32C for 48-72 hours as required to reach the initial seed moisture content (Junhaeng et al).

As a result, the authors reported that the initial barley seed moisture content was 10.6%. After the seed priming treatment and re-drying, a significant difference in seed moisture content was detected between the priming techniques and hydro-time, but the differences were very small and overall show that seeds were returned to a moisture content close to that of the non-primed seeds. It is then concluded that hydropriming, hydropriming plus KNO3 and osmo-priming by PEG4000 could speed up seed germination. Seed priming enhanced barley seed quality in terms of malt quality especially speed of germination. Another result shows that priming can shorten the malting process for 64.81%. Barley seed germination was not significantly different from that of unprimed seeds for all priming solutions except for PEG4000 solution at water potential of −0.75 MPa (significantly higher) and osmo-priming byPEG4000 at −0.50 MPa (significantly lower).

Germination was highest for a hydro-time of 12 hours, which was significantly different to all other times except 8 hours (Table 1).

In a literature study by Rouhollah Amini, an experiment was conducted to evaluate the effects of priming with polyethylene glycol (PEG) on drought stress tolerance of barley. Drought stress could be detrimental or even lethal to the germinating seeds, especially if it occurred when the seeds were hydrated beyond critical moisture content (Chen et al. 2010).

Table 1: Results of four measures of barley seed quality in non-primed seed and after priming as influenced by (A) Priming treatment and (B) Hydro-time.

Treatment	Seed quality			
	Viability (%)	Germination (%)	GI	MET (day)
Priming methods (A)				
non-prime seed	85 c	88 b	28 e	1.89 a
hydro-priming	93 b	89 b	29 e	1.70 b
hydro-priming plus KNO_3 at 2.5 mg/mL	97 ab	94 a	44 a	1.15 ef
hydro-priming plus KNO_3 at 5 mg/mL	96 ab	95 a	44 a	1.13 f
hydro-priming plus KNO_3 at 10 mg/mL	96 ab	95 a	44 a	1.15 ef
hydro-priming plus KNO_3 at 20 mg/mL	93 b	95 a	41 b	1.28 d
osmo-priming by PEG4000 at −0.50 MPa	94 ab	83 c	33 d	1.42 c
osmo-priming by PEG4000 at −0.75 MPa	95 ab	92 a	41 b	1.22 de
osmo-priming by PEG4000 at −1.50 MPa	99 a	88 b	38 c	1.29 d
$LSD_{0.05}$	*	*	*	*
Hydrotime (hours) (B)				
6	96 a	91 ab	36 b	1.44 a
8	95 a	90 b	35 b	1.45 a
10	95 a	90 b	35 b	1.43 a
12	96 a	93 a	40 a	1.31 b
14	93 ab	90 b	40 a	1.26 b
16	89 b	92 ab	41 a	1.25 b
CV (%)	8.54	4.81	8.77	8.28

** GI: Germination Index; MET: Mean Emergence Time*
Means followed by the same letter within each column were not significantly different

The factorial experiment has four replications: priming with polyethylene glycol (PEG), osmotic potential levels (0, -7, -10 and -14 MPa), levels of drought stress (0, -3, -6 and -9 MPa). The seeds were placed at temperature 15°C in a dark growth chamber for 7 days with different osmotic potentials, and then washed with sterilized distilled water and dried superficially. The seeds then placed at temperature 20°C with different drought stress levels for the germination test.

Based on the results of germination and seedling growth of barley, the study showed that priming with PEG may possibly increase barley seed tolerance to reduced water uptake caused by drought stress. Also, it is possible that priming initiates certain protective mechanisms against drought stress. The results of this study indicated a significant improvement in germination and early growth of barley to priming treatment. Soaking of the barley seeds in PEG solutions resulted in improving germination rate and percentage under drought stress and also the normal conditions (Amini,2013).

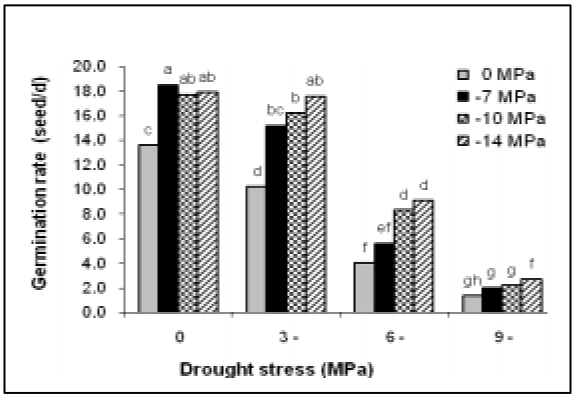

Figure 1: the effect of priming and drought stress on germination rate of barley seeds

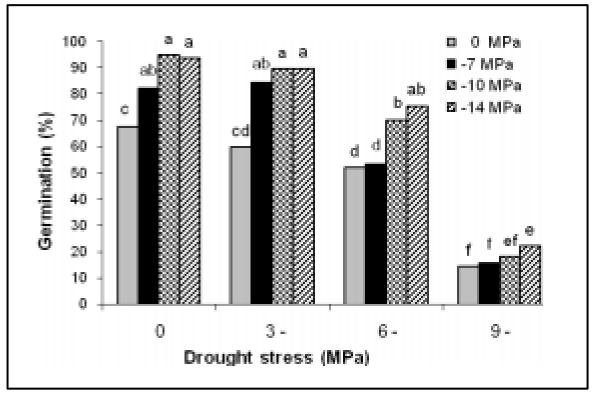

Figure 2: The effect of priming and drought stress on germination percentage of barley seeds

Increasing the drought stress potential decreased the germination rate of all non-primed and primed seeds, significantly. At all drought stress potentials, the priming increased the germination rate of the barley seeds (Amini, 2013).

The seed priming and drought stress had significant effect on germination percentage of barley seed but the interaction effect of these factors was not significant. At all drought stress potentials, increasing the priming osmotic potential increased the germination percentage of the barley seeds (Amini,2013).

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Methods for handling and seeding primed seeds

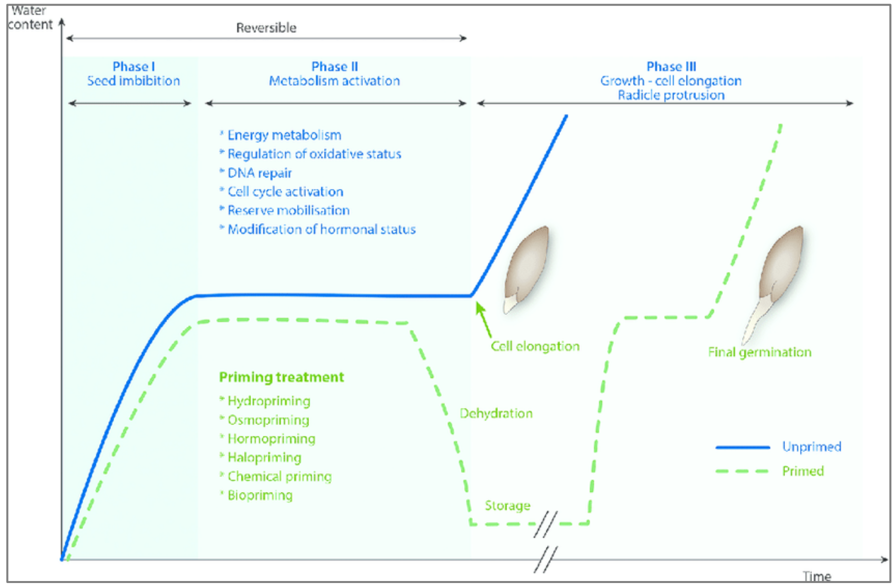

Figure: Seed hydration curves and germinating phases in unprimed and primed seeds.

Seed priming is done to increase the speed and uniformity of germination particularly under stresses. It begins when a seed is soaked with water to hydrate. The purpose of seed priming is to minimize the period of emergence and to protect seed from environmental stresses during the critical phase of a seedling establishment to synchronize emergence which leads to the uniform establishment and improved yield (Sisodia et al).

Primed seeds pass through the 3 phases of seed germination. **Phase I**: rapid water imbibition, this is the process where the seeds are soaked in water for a certain period just to allow the seeds to hydrate and absorb the water. **Phase II**: activation of metabolic activities, soaked seeds are drained and lightly dried. Since the seeds absorbed the water there will be an increase in metabolic and enzyme activation. This phase makes the seed ready to sprout. **Phase III**: radicle protrusion, all the biochemical reaction gets activated and the seed grows a future root. According to (Bray 1995) priming allows a seed to hydrate up to a seed moisture content involving the entire phase I and before the end of phase II. Hydration treatment and re-drying increased germination efficiency and seedling emergence in many species of Brassica (Jet et al. 1996). 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 vigour (Junhaeng et al).

Better results in crop performance and seed germination differ from various seed priming techniques. Good results also depend on the good dynamics between the seed priming techniques and other factors like on plant species/genotypes, seed morphological and physiological parameters (Murungu et at. 2004).

(a) Hydro-priming: is a technique for enhancing germination without the emergence of the radicle and plumule which involves soaking of seeds (McDonald 1999). It is the simplest method of seed priming the seeds are soaked in pure water and re-dry to original moisture content. This method is low-cost and environment-friendly since hydro-priming uses pure water and does not use additional chemical substances. In a study by (Jisha bet at. 2013), he agreed that hydropriming is an inexpensive and simple method to improve abiotic stress tolerance of plants. The soaked seeds are brought to their original weight through proper drying under shade (Jisha et al. 2013). The water is freely available to seeds, its uptake only being governed by the affinity of the seed tissue for water (Taylor et al. 1998). Hydropriming initiates physiochemical alterations in seeds prior to germination (Basra et at. 2003). Plants produced from hydroprimed seeds had greater water uptake which is positively associated with seedling growth (Yagmur and Kaydan 2008). The disadvantage of this method is uncontrolled water uptake by seeds (Taylor AG, et al). Another disadvantage according to (McDonald 2000) is that seed is not equally hydrated, which results in a non-uniform activation of the physiological processes necessary to synchronize and improve germination. A variant of hydropriming is called drum priming, which is patented by Rowse (1991). The invention relates to the priming of seed so that the faster and more uniform germination will occur after planting in the field or greenhouse and to methods of treating seed (Rowse, 1991). Drum priming is a technique wherein seed are gently rotating in drum and gradually hydrated by addition of water in vapour form. Drum priming allows seed imbibition in a controlled manner and could be an alternative to conventional hydropriming (Wojtla et al, 2016). Another variant of hydropriming is called on-farm priming, consist of seed soaking in water followed by surface drying and subsequent sowing. The duration of treatment obligatorily cannot be longer than “safe limit” (maximum time of priming without risk of seed or seedling damage by premature germination) Joshi et al, (1999).

(b) Osmo-priming or osmo-conditioning is the term used to describe the soaking of seeds in aerated, low water potential solutions (M. Farooq). This method of priming uses osmotic solution with low water potential instead of pure water. Osmo-priming is accomplished using chemicals that lower osmotic potential in the seed environment. Polyethylene glycol (PEG) is commonly used osmotic priming material because it is readily available and has no physiological reaction with seeds (Arnab, et al). Other different compounds that can be used in osmo-priming method included polyethylene glycol (PEG), mannitol, sorbitol, glycerol, and inorganic salts such as NaCl, KCl, KNO3, K3PO4, KH2PO4, MgSO4, and CaCl2 (Yacoubi R, et al). In osmo-priming, degree and rate of imbibition are restricted through the exposure of seeds to low external water potential. Osmo-priming is analogous to lengthy initial imbibition of seeds that induces metabolic activities

even before germination (Chen and Arora 2011). A greater germination percentage was noted in plants raised from seed soaked in water for 12 hours or osmo-primed with PEG for 24 hours under cold soil environment. In a greenhouse trial, osmo-priming with (CaC12 and CaCi2 + NaCI) improves seedling vigour index and seedling and stand establishment in flooded soil (Ruan et al 2000). (Sedghi et al 2010) recommended that seed priming with NaCI to get better yield under environmental constraints. Du and Tuong (2002) concluded that when rice is seeded in very dry soil, priming further increased plant density. When in drought-prone areas, seed priming reduced the need for a high seeding rate.

(c) Halo-priming: This is a simple and cheap agro-technique and therefore found suitable to be recommended to the farmers owing to better synchrony of emergence and crop stand under various conditions of the environment. Halo priming uses different inorganic salt solutions (NaCI, KNO3, CaCI2, CaSO4) which facilitate the process of seed germination and subsequent seedling emergence even under adverse environmental conditions (Sedghi et al. 2010). Improved stress tolerance of primes plants is thought to arise from the activation of cellular defence response due to halopriming (Beckers and Conrath 2007).

(d) Solid Matrix-priming: This is similar to osmotic priming that allows the seed to attain a threshold moisture content and pre germinative metabolic activity but preventing radicle emergence. The process of SMP includes the admixture of a predetermined amount of solid matrix material and a predetermined amount of water and the mixture allowed to stand preferably in a container which allows entry of air but reduces evaporative losses, resulting insufficient amount of moisture level in seeds. Matrices can be readily used in tree seed nursery operations (A. Sisodia et at). This method includes hydrated solid matrices soaked with osmotic solutions (McDonald 2000) such as hydrated sand

(e) Biopriming: is a process of a biological seed treatment that refers to a combination of seed hydration. It is an ecological approach using either bacteria or selected fungal antagonist against the soil and seed-borne pathogens (Sivasubramaniam et al. 2011; Afzal et al. 2016; Rakshit). This technique involves the addition of beneficial rhizosphere microorganisms in the priming process (Sharma et al. 2015; Meena et al. 2016,2017).

(f) Nutri-priming: or nutrient priming means soaking of seeds in the nutrient solution of specific concentration, instead of pure water, for a certain period of time prior to sowing (Shivay et al. 2016).

(g) Thermo-priming:

a priming method where seed treatments carried out at various intervals of time before sowing. Seeds germinate better under alternating temperature conditions compared to a constant daily temperature (Felippe 1980; Shin et al. 2006; Markovskaya et al. 2007).

In an experiment by Sarlach, Rashpal (2013), once the seed was primed, it will be removed in priming media and will be rinsed thoroughly with distilled water. The seeds will be hand dried lightly using blotting paper and will be ready for germination which will take 8 days before seedling fresh weight is measured. In another experiment at the Department of Plant Breeding and Genetics, Punjab Agricultural University, primed seeds were also sown in a sandy loam soil at the area. The primed seeds were treated with thiram against the seed-borne diseases. (Sarlach, Rashpal. 2013).

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The crop outcomes of primed seeds

Seed priming is a successful practice to improve crop establishment under the adverse environment. Priming has positive effects including acceleration of seedlings emergence, the establishment of better and rapid seedlings, more rapid canopy closing, better competitive ability with weeds and better root development Priming is more effective under stressful conditions (Eivsand et al. 2010). Seed priming of different crops can alleviate the adverse effects caused by stress (drought and salt) and enhance crop yield. Seed priming mainly involves uptake of water to initiate the early events if germination but not sufficient to permit radicle protrusion, followed by drying (McDonald 1999). Lastly, priming has been commercially used to eliminate or greatly reduce the amount of seed-borne fungi and bacteria (Gupta et al).

In priming, seeds are re-dried near to their original weight, to permit routine handling and safe storage if necessary (Farooq et al. 2006a, d). Drying seeds slowly after priming may induce the synthesis of LEA (late embryogenesis abundant) proteins, while incubating seeds at high temperatures may induce heat shock proteins, both of which may provide protective mechanisms that are beneficial to seed longevity (Gurusinghe et al., 2002).

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Arnab Gupta1,2, Malavika Dadlani2, Arun Kumar MB2, Manami Roy1, M Naseem1, V K Choudhary1, R K Maiti1, SEED SCIENCE & TECHNOLOGY Seed Priming: The Aftermath

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