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Seed quality enhancements in vegetables: An approach towards climatic stress mitigation

Throughout the life cycle, crops are exposed to a wide range of abiotic stresses such as cold, heat, drought, flooding, salinity, heavy metals, which impose a negative impact on plant growth and productivity. Seed being a small delicate living entity is more vulnerable to these stresses. Moreover, seed being a starting point of plant life, faces these stresses at first and foremost during germination. Faster and uniform germination of seed as well as establishment of vigorous crop is very much important, which in turn depends on seed germination and vigour per se. Hence, seed enhancement through different invigoration techniques could be an effective approach to strengthen the seed.

SEED enhancements deal with post–harvest treatments that improve germination and seedling growth that facilitate the delivery of seeds and other materials required at the time of sowing. Moreover, seed enhancement helps in improving the performance of seeds to maximize the potential yield and quality of crops under the stressed conditions. These treatments are performed on the seeds after harvest, but prior to sowing or before the storage. These 'value added' techniques are performed on a given seed lot to fulfil the objectives given here.

- Improvement in seed quality
- Improvement in reliability of plant establishment
- Increase in uniformity of plant stand
- Reduction in seeding rates and thinning costs
- Facilitate precision planting, e.g. Pelleting.
- Overcome dormancy or stressful (biotic and abiotic) conditions

The seed enhancement includes seed processing, priming, pre-germination, seed coating and pelleting, seed fortification and infusion.

Seed processing

Seed lots received from the fields often have high moisture content and contain trash, inert material, weed seeds, etc. Seed processing upgrades the seed quality by removing foreign material, undesirable seed, other crop seed, diseased and weed seeds, uniform size grading and seed treatment with chemical protectants during processing improves planting value and protects the crop from pest and diseases in the field and during storage.

Seed processing ensures the following

- Uniform planting rates due to proper sizing and by removing seed appendages which hinder planting.
- Improve seed crop marketing by improving seed quality.
- Prevents spread of weeds by removing weed seeds.
- Improves crop quality by removing other crop seeds from pure seeds.
- Seed treatment with chemical protectants during processing protects the crop from pest and diseases in the field and during storage.
- Reduce seed loss by removing high moisture, foreign material and drying the seed.

Benefits of seed treatment:

- Protection against seed-borne and soil-borne pathogens.
- Protection of emerging seedlings from damage by herbicides.

Drying	→	Conditioning and precleaning	→	Cleaning	→	Upgrading	→	Seed treatment
Seeds possess high moisture at time of harvest, therefore requires drying before processing		Scalping, debearding. hulling, shelling or any other operation to allow seed flow readily through cleaners and elevators		Removing impurities and debris (inert material, weed seed, other crop and broken seed) from seed. It can be done manually or mechanically.		After cleaning specific size grading to remove undersized, other crop and weed seeds is done to upgrade the processed seed		Applying chemicals (fungicides, insecticides, and growth regulators) or bioagents or botanicals

Steps in Seed processing

Table 1. Types/methods of seed priming

Type of priming	Methodology	Uses and remarks
Hydropriming	Soaking of seed in water for a specific period of time	Often used in arid regions to improve seed performance in dry soils
Osmopriming	Soaking in high osmotic potential solutions {(PEG 4000 or 6000), Mannitol}	Mostly used in drought-prone regions to improve seed performance in adverse conditions
Halopriming	Soaking in salt solution (mono /dihydro salts of K, Na, Mg nitrate, phosphate)	It permits the controlled entry of water into seed. It can be used against salinity stress
Matrix priming	Mixing seeds with organic or inorganic carrier and water (sand, arabic, vermiculite)	It permits the controlled entry of water into seed
Bio priming	Exposing seed to beneficial microorganisms (bacteria and fungi)	Improves uptake of nutrients, resistance to diseases and pests, and overall health of crops
Nano priming	Soaking seed with nano materials (metallic, biogenic metallic, polymeric nanoparticles, carbon nano tubes)	Improves uptake of nutrients, helps in mitigation of abiotic tresses (heavy metals, salinity, drought), resistance to diseases, and improves overall performance of seed

- Physical treatments to control deep-seated pathogens including viruses.
- Stimulation of germination and/or enhancement of growth during seedling stage by application of nutrients.
- Speedy establishment of beneficial micro-organisms on the roots for fixing nitrogen, enhancing nutrient uptake or stimulating growth by microbes.

Seed priming

Seed priming process involves soaking of seed in water/ osmotic solution that allows them to imbibe water, go through initial stages of germination, but does not permit the radicle protrusion through seed coat. Seed germination follows a triphasic pattern, which starts from uptake of water during imbibition and is followed by ATP production, mobilization of reserves, initiation of RNA and DNA synthesis, protein synthesis and in the last phase cell expansion and radicle emergence. The goal of priming is to prepare seed for planting and improve the likelihood of successful germination, leading to improved crop yields and reduced crop losses.

Among various seed priming methods, nano-priming is relatively new and has several advantages over traditional seed priming methods. The small size of the particles allows for rapid penetration of the seed coat, leading to improved seed germination and viability.

Seed priming has numerous benefits, including improved germination rate, improved crop yields, reduced crop losses, and improved quality of crops. Additionally, seed priming can reduce the need for chemical inputs, such as pesticides and fertilizers, making it an environmentally friendly and sustainable technique.

Seed invigoration

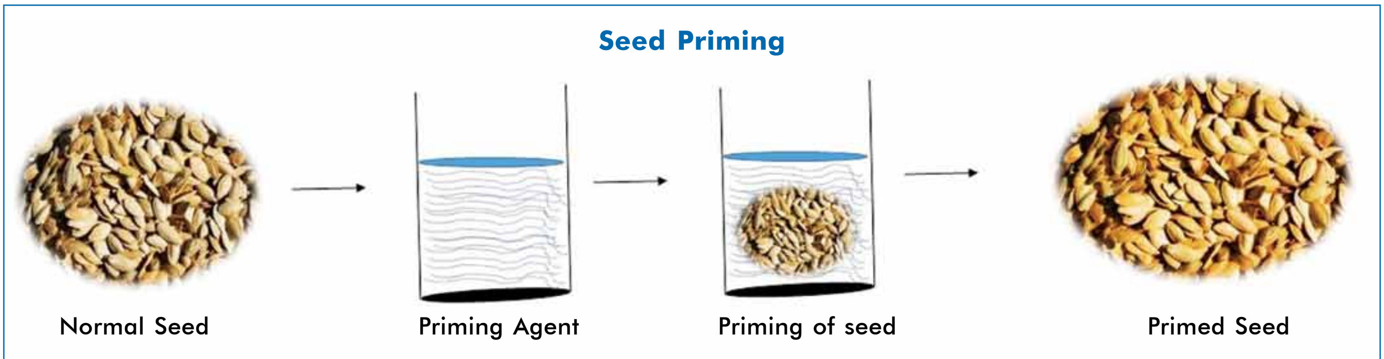
An improvement in seed performance by any post-harvest treatment which involve controlled hydration of seed in high osmotic solution resulting in improved germinability, greater storability and better field performance.

Pre-germinated seeds

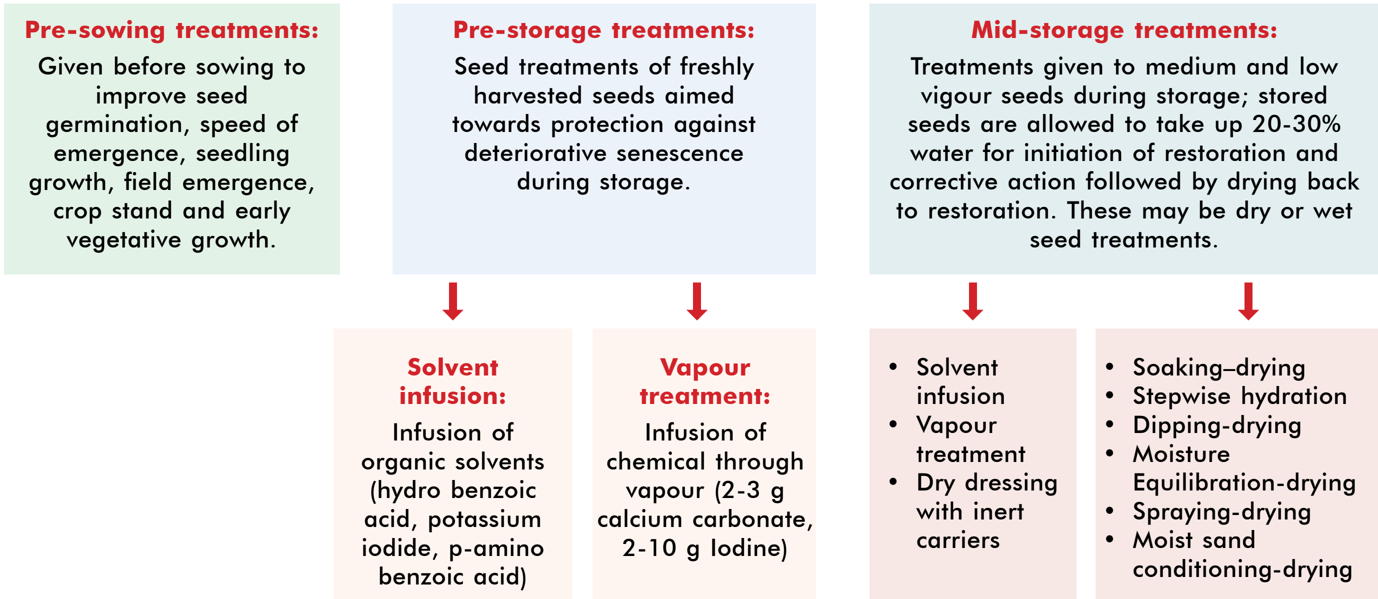
Seeds are pre-germinated and sown in a protective fluid carrier/gel, i.e. creating a stable 'packaged' environment. Nutrients, fungicides and insecticides may be incorporated into the carrier gel. This gives the advantage over uncontrollable factors in the field environment which affect seed germination. Generally used for turf grass, vegetables, flower seeds.

Seed coating

Seed coating is a process that involves applying or addition of a material or protective layer to seed, to improve their physical properties and protect against damage during storage and planting. The term 'coated seed' has been defined as a seed that has been 'pelleted', 'tableted' or 'taped'. The goal of seed coating is to improve the handling, placement, storage, and planting characteristics of seeds can be greatly enhanced by altering the shape of seeds or placing the chemicals on seed coat



Methodology of seed priming



Classification of Seed invigoration

which regulate and improve germination. Additionally, seed coating can reduce the need for chemical inputs, making it an environmentally friendly and sustainable technique. Some types of coating are given below.

Physical coating: This method involves applying a physical layer, such as a clay or polymer coating, to seed samples to improve their handling and storage characteristics. Physical coatings can also help to protect against damage from pests and diseases. E.g. Slurry coating, Film coating and Temperature-sensitive polymers (Intellicoat). In case of slurry coating, a wettable powder is suspended in water to make slurry and a known quantity of slurry and the seeds are dumped in mixing chamber where they are blended. The treatment fluid is directly applied to the seeds in the form of mist in a mist-o-matic seed treater.

Chemical coating: This method involves applying a chemical substance, such as a pesticide or fertilizer, to seed samples to improve their performance and increase crop yields. Chemical coatings can also help to reduce the need for additional inputs during the growing season, making it a more sustainable option. E.g. Captan, Apron, Vitavax, etc.

Bio-coating: This method involves applying beneficial microorganisms, such as bacteria and fungi to seed samples to improve their performance and increase their viability. Bio-coatings can improve the uptake of nutrients, increase resistance to diseases and pests, and improve the overall health of crops. E.g. Micro-organisms (*Rhizobium, Trichoderma*).

Film coating: Film coating is the application of a thin, durable and water permeable coat which can be used to contain small amount of pesticides and other products securely, so that they may have maximum effect at the time of sowing. Film coatings do not significantly obscure the shape and weight of the seed. The seed shape is not changed and increase in seed weight is by 1-10%. In film coating, the chemicals mostly fungicides (insecticides and other protectants can also be used) along with a polymer are applied or sprayed on the seeds though a specialized machine. The polymer dries rapidly, so that the seeds receive a complete and uniform, dry polymeric coating. Moreover, colours can be added to the polymers to code different varieties or seed lots. The colouration gives not only the seed an attractive and glossy appearance, but also has the practical use of allowing differentiation between varieties and between different types of treatment. Film coating products contain polymers, dyes and surfactants and form a fine, air- and water-permeable film that improves the distribution and retention of crop protection agents on the seed surface. The coating products contribute to significant reduction in the amount of dust released during the application of the crop protection agents to the seed and during handling and use of the treated seed on the farm.

There are two types of polymers used: Hydrophilic polymer, which absorbs water uniformly and facilitate early emergence; Hydrophobic polymer, which repels water and cause delayed germination.

Besides, some novel applications have also been developed using the film coating method. For example, artificial polymers (Intelimers) exhibiting temperature-sensitive permeability to water (Landec Corporation, Menlo Park, California) have been developed, which are permeable to water at warm temperatures, but not at cool temperatures. Modifying the composition of the polymer can set the temperature at which the permeability changes. Seeds coated with these polymers will not imbibe water if the temperature is below the set point of the polymer, potentially protecting the seed from imbibitional chilling injury. The coatings are also being used to delay germination after sowing, such as for timing the emergence of male parent lines at different times for hybrid seed production. Moreover, starch-based biopolymer is also being used in film coating to slow water uptake and alleviate chilling injury.

Seed pelleting

Seed pelleting is a process that involves forming seed samples into small and round or globular pellets of

Table 2. Different types of material for seed pelleting

Type	Material	Feature
Dyes	*Botanicals dyes:* Jamun fruit extract, *Beta vulgaris* tuber extract, *Curcuma longa* rhizome powder, *Hibiscus rosa sinensis* flower extract *Synthetic dyes:* Turquoise blue, Congo red, Sky blue, Jade green	• Should not be toxic and hazardous
Polymers	Pink polykote, Green polykote, Red polykote	• Should be biodegradable
Adhesive material	Gum arabica, methylcellulose, gelatin, casein salts, Plastic rexins, polyvinyl acetate, methyl ethyl cellulose, Polyurethane polyvinyl alcohol, dextran and polyethylene oxide.	• Should possess the required degree of water solubility for easy emergence • Should have affinity for both seed coat and the filler material • Should have appropriate viscosity • Should have required strength and plasticity to prevent breakage
Filler material	Lime, gypsum, dolomite, rock phosphate, clay minerals like montmorillonite, vermiculite. Besides blood, peat, poultry manure, moss and mucilage	• Must be porous to allow movement of air to the seed • Must weaken/break down easily when it comes in contact with soil moisture to prevent any physical impedance • Should not be toxic to the seed • Economical for commercial use

uniform size, typically using a mixture of inert material, binders and other materials to facilitate precision planting, improve the handling, storage, and planting characteristics of seed.

The inert material creates a natural water holding media and provides small amount of nutrients to young seedlings. Seed pelleting also serves as a mechanism of applying needed material in such a way that they affect the seed or soil at the seed soil interface. Seed pelleting may obscure the original shape and size of the seed. The pellet contains chemicals, fungicides, polymers, dyes, filler material and adhesive. The seeds of many crop species are either small or irregularly shaped, making it difficult to singulate them for planting. Seed pelleting addresses both of these problems by coating seeds with clay or other materials to give them a uniform shape and size and increasing their size and density to allow more precise placement in the soil. Additionally, seed pelleting can help to protect seed samples from damage during storage and handling, leading to improved seed viability and performance.

Seed fortification

It is impregnation of required substances for invigorating the seed, where the seeds are soaked either in water or dilute solutions of bioactive chemicals such as micronutrients, growth regulators, vitamins and seed protectants. Seeds are soaked in solutions of equal volume for a duration of 6-24 hours depending upon the crop, to raise the moisture content of the seed to 20-25% just enough for endogenous impregnation of the chemicals by exogenous application. The choice of chemicals, concentration and duration of soaking vary with the species and determine the success of the treatment.

Seed infusion

This technique involves direct incorporation of bioactive chemicals into seeds by using organic solvents. It has been known that ethyl alcohol and acetone can make the hard coats of some seeds permeable. Dry seeds are immersed for 1-4 hours in solvents such as ethyl alcohol, acetone or dichloromethane containing desired solutes. Following infusion, the seeds are removed from the organic solution and the solvent is evaporated by air or vaccum dessication for 1-2 hours. The treated seeds can be stored for extended periods or sown directly into the soil, with the additional benefit of bioactive compound.

Organic solvent infusion provides many advantages over conventional seed treatments, such as:

- This technique allows the incorporation of non-water-soluble compounds directly into the seeds as they are highly soluble in organic solvents.
- Several compounds can be added simultaneously

to the seed to provide a range of seed response from release of dormancy to protection against soil microorganisms.

- Seeds can be safely treated in organic solvents for long periods of time without altering viability- a common problem associated with aqueous solutions of seed protectants.
- Compared to conventional methods, only small amount of bioactive chemicals is needed for organic solvent infusion, which minimizes the problem of residue toxicity.
- As the chemicals are infused into the seed, they offer little or no danger during handling.

Seed tapes and mats

Seed tapes: These are narrow bands of material, such as paper or other degradable material, with seeds spaced randomly, in groups or in a single row or in pattern. Seed tapes are an easy way to plant a row of seeds with precision spacing. This technique is useful for valuable and expensive seeds. It provides uniform spacing for seeding and avoids the thinning of seedlings. These seed tapes are easy to use and seeds are fastened to some sort of thin biodegradable paper by an adhesive that itself is biodegradable. This allows for the plant roots to grow through the paper as the adhesive dissolves around the seed so as not to obstruct growth. These tapes are well suited for small seeds of vegetables (carrots, beets, lettuce) and flowers.

Seed mats: These are broad sheets of material, such as paper or other degradable material, with seeds placed in rows, groups or at random throughout the sheets. Pre-seeded mats come with attractive flower seed mixes often chosen around a theme and are a good if you don't mind your choice of flowers being somewhat limited. A unique combination of annual, biennial and perennial plants ensures instant colour and a long-term garden. The seed mat aids initial growth by acting as a mulch mat to allow the seedling a head-start over other competing plants and also helps to retain vital moisture while the seeds germinate. The seed is distributed evenly throughout the mat allowing correct spacing for germination. After seeds have germinated, some seedlings may be thinned out and transplanted to other areas of the garden. The seed mat consists of two sheets of special paper and the seeds are placed in-between at exact distances. For seed mats, only quality seed pre-tested in laboratory should be used. The space between the single seed grains is adapted to seed species and quality, thus guaranteeing the optimal number of plants in each cultivating pot or bed.

SUMMARY

Seeds bear the impact of any stress at first during seed germination. Therefore, strengthening of seed through different seed enhancement techniques is of paramount importance. A number of seed enhancement techniques such as priming, coating, pelleting, etc. are used to enhance the performance and vigour of seed. Besides, coating, pelleting, seed tape and mat also ensure the precision sowing of valuable seeds. In conclusion, these enhancement treatments are used to maintain and upgrade the quality of seed.

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Infestation of lesser grain borer on roasted makhana seeds under storage

The internal stored grain insect (lesser grain borer), *Rhizopertha dominica* (Coleoptera: Bostrichidae) was found infesting on the roasted makhana seeds of 3 standard size grades, i.e. 7 mm, 9 mm and 11 mm. It was recorded that insects preferred to feed on 11 mm size seeds, followed by 9 mm and 7 mm, respectively. Both grub and adult stages were able to cause substantial damage. The adult laid the eggs on the seeds by entering inside the kernels through the apical natural opening. The average temperature and relative humidity for *R. dominica* development was maintained as 32.5 ± 1°C and 70 ± 5°C, respectively. It took 35–50 days for completing its life cycle, which included four stages: egg, larva, pupa and adult. Females laid about 200–500 eggs in their lifetime, singly. Incubation period lasted for 5±0.3–9±0.4 days, while larval and pupal period took 30±5 and 8±2 days, respectively. Mean longevity of adult male and female was 26 and 17 weeks, respectively. The damage potential was assessed using the artificial infestation (purposive samples) with different numbers of tested insect. The study indicated that significant loss of roasted makhana seeds during 15 days of storage with 40±1.24% losses, caused by 10 adults per 100g seeds. The total quantitative losses observed for 6 months storage period was 64±1.16% in the samples with 10 adults per 100g of roasted makhana seeds. The initial losses were very high and became slow after 20 days. Presently available method of fumigation by aluminium phosphide was practised and found feasible for the insect control.

Internal makhana feeding

Lesser grain borer (adult and grub)

Source: ICAR Annual Report 2022-23