Indian Journal of Agricultural Sciences **87** (11): 1482–6, November 2017/Article
https://doi.org/10.56093/ijas.v87i11.75716

Design and development of seed priming prototype for hydropriming of okra (*Abelmoschus esculentus*) and pea (*Pisum sativum*) seeds

MANOJ KUMAR MAHAWAR[1], J P SINHA[2] and KIRTI JALGAONKAR[3]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012

Received: 07 February 2017; Accepted:11 July 2017

ABSTRACT

Seed priming is being manually performed to enhance the germination related quality attributes. The objective of this study was to develop an effective mechanical priming system capable of improving the germination associated properties of okra (*Abelmoschus esculentus*) and pea (*Pisum sativum* L.) seeds. Based on the recommended design and prior optimization of operational parameters for hydropriming of both seed lots, a functional prototype was developed. Controlled conditions of selected process parameters, viz. soaking duration, process temperature, rotation speed and air flow rate were maintained during the experimental run. Three different levels each of germination percentage (80, 65, 50) for okra and (80, 70, 60) for pea, soaking duration (4, 5, 6 h) for okra and (45, 60, 75 min) for pea, process temperature (20, 25, 30°C), rotation speed (320, 340, 360 rpm), air flow rate (2.192, 2.740, 3.288 m^3/min) for okra and (0.411, 0.548, 0.685 m^3/min) for pea seeds were the operational parameters. Developed prototype was evaluated for its performance for hydropriming based on process responses, viz. moisture content after hydropriming (MC), final germination percentage (FGP), seedling length (SL), seedling dry weight (SDW), vigour indices (VI-I and VI-II) and electrical conductivity (EC). It was found to be effective in recuperating the quality attributes of both the seeds. Overall results supported the hypothesis that mechanical hydropriming using the developed prototype was observed to be effective as well as economical for okra and pea seeds.

Key words: Air flow rate, Hydropriming, Seed priming prototype, Soaking

Improvement in seed germination is an active area of research and efforts are being made to enhance seed germination in various economically important plants as evident by earlier reports (Kaur *et al.* 2009, Suleman *et al.* 2011). Seed priming is a pre-sowing strategy for influencing the seed development at a later stage by modulating pre-germination metabolic activity prior to radicle emergence (Taylor and Harman 1990). Harris (1996) proposed this low cost, low risk intervention and termed it as 'on-farm seed priming' that would be appropriate for all farmers, irrespective of their socio-economic status. Considering water availability and labour costs, direct seeding is an appropriate alternative to traditional transplanting. However, poor germination, uneven crop stand, and high weed infestation are the main constraints to its adoption (Balasubramanian and Hill 2002).

Seed priming is not a new technology and has been a recommended practice for several crops. This technology being low cost and less labour intensive provides better crop growth and yield. It has proved to be a successful strategy to improve the germination percentage and uniformity of emergence in grass, vegetable and field crops (Kaya *et al.* 2006).

The mechanism of seed priming is to initiate the repairing system for membrane and the metabolic preparation for germination through controlling water absorption rate of seed (Mittal and Dubey 1995). Seed priming techniques have been used to accelerate synchronized germination, improved seedling establishment, stimulate vegetative growth and yield in many crops like sunflower (Singh and Rao 1993), chickpea (Kaur *et al.* 2002), cotton (Casenave and Toselli 2007), wheat (Iqbal and Ashraf 2007), garden pea (Maroufi and Farahani 2011) and okra (Sharma *et al.* 2014). There exist several methods of priming where the mechanism to restrict and supply of both air and priming medium to the seeds differs, these are: halopriming, osmopriming, solid-matrix priming, biopriming and hydropriming. In this particular study, evaluation of only hydropriming technique was undertaken on okra and pea seeds. Hydropriming includes soaking of seeds in water before sowing which may or may not be followed by air drying of the seeds. Subsequently, findings of reported studies substantiated that hydropriming of vegetable seeds is carried out in the laboratories using manual practices. Such kind of manual priming operation doesn't involve precise control of process

[1]Former Ph D Scholar (e mail: manojmahawar362@gmail.com), [2]Principal Scientist (e mail: jpsinha@gmail.com), Division of Agricultural Engineering, [3]Former Ph D Scholar (e mail:jalgaonkar.kirti@gmail.com), Division of Food Science and Post-Harvest Technology.

affecting parameters which further reduces the overall efficacy of the process. And hence, a need was felt to mechanize this priming process particularly for vegetable seeds with the proper control of process affecting variables. Therefore, the present study was focused to develop a small scale/batch prototype and evaluate its performance for hydropriming of okra (*Abelmoschus esculentus*) and pea (*Pisum sativum*) seeds.

MATERIALS AND METHODS

One lot each of okra seed (cv. Pusa A4) and pea seed (cv. *Arkel*) was procured from National Seeds Corporation, New Delhi, India. Another lot of pea seed was procured from ICAR-IARI regional station, Karnal (Haryana), India. The seed lots were tested for their corresponding germination percentage and moisture content. In order to have a comparison of mechanized hydropriming using developed prototype, three seed lots of both the crops were selected in such a way that among them, one each will be of minimum germination, one each of above and one each of below minimum germination of okra and pea seeds, respectively. The minimum germination percentage for okra and pea seeds is 65 and 75%, respectively (Indian Minimum Seed Certification Standards 2013). To achieve this variation in seed lots, the procured seeds were subjected to variable duration of accelerated aging (40°C, 100% RH) in order to obtain desired lots of each crop with variation in germination and moisture content. The total duration of aging was 10 days for okra and 2 days for pea seeds. Samples were withdrawn after 5^{th}, 8^{th} and 10^{th} day in case of okra, and on 2^{nd} day in case of pea seeds, respectively and tested for germination as well as moisture content.The seed lots selected for experiments with 80% germination (11.33% d.b. moisture), 65% germination (13.97% d.b. moisture) and 50% germination (16.89% d.b. moisture) for okra and 80% germination (14.94% d.b. moisture), 70% germination (25.47% d.b. moisture) and 60% germination (28.04% d.b. moisture) for pea seeds, respectively. The selected independent variables along with their actual levels are depicted in Table 1 (okra) and Table 2 (pea), respectively.

The estimation of physical and engineering properties is considered to be of prime importance before conceptualizing the design of any relevant processing equipment.Therefore, geometric, gravimetric, frictional and germination related properties of the selected seed lots of both the crops were evaluated (the detailed information has been reported by the authors in separate studies) and were considered while designing this particular prototype. Some basic design considerations like simplicity of design for fabrication, usage of corrosive resistive material, manufacturing cost and ease of operation for multiple seeds with minimal modification were also considered among the design criteria's for fabrication. Different components of the prototype were finalized with their respective functional requirements.The design criteria of prototype which were prioritized are listed as follows: (i) Priming chamber was considered to be the core part of the developed machine. It was fabricated using stainless steel and it should accommodate adequate amount of seeds for priming. (ii) Hollow space has been provided for the continuous circulation of water all along the priming chamber for maintaining uniform process temperature. (iii) A sieve with variable mesh size to be kept inside the priming chamber for placing over the seeds. Sieves with aperture size simulated with axial dimensions of okra and pea seeds must be employed. (iv) Hollow pipe with equidistant openings (0.5 mm diameter) were fixed all along the periphery of priming chamber for supplying adequate aeration to the seeds. (v) Accessories, viz. air pump, submersible pump, digital timer, immersion heater and motor must be properly connected.

Table 1 Actual levels of independent variables for okra seeds

Variables	Actual level		
Germination percentage,% (X_1)	50	65	80
Priming duration, h (X_2)	4	5	6
Temperature, °C (X_3)	20	25	30
Rotation speed, rpm (X_4)	320	340	360
Air flow rate, m^3/min (X_5)	2.192	2.740	3.288

Table 2 Actual levels of independent variables for pea seeds

Variables	Actual level		
Germination percentage,% (X_1)	60	70	80
Priming duration, min (X_2)	45	60	75
Temperature, °C (X_3)	20	25	30
Rotation speed, rpm (X_4)	320	340	360
Air flow rate, m^3/min (X_5)	0.411	0.548	0.685

Size of the priming chamber was standardized to (37×37×33) cm. A circular section of 30 cm diameter and 30 cm depth was carved out from the chamber. Sieves of diameter 28.5 cm needs to be placed inside the chamber at a depth of 17.5 cm for placing over the seeds. For okra, stainless steel sieve (10 mesh with 2 mm opening) and for pea seeds, poly acrylic sieve (4 mesh) was employed. For pea seeds, poly acrylic material was selected because stainless steel sieve was causing significant damage to the thinner seed coat of pea seeds. The chamber was connected with rubber hose pipes for continuous water circulation using water pump. Motor was attached to the assembly for providing rotation to water as well as seeds kept for hydropriming. During the process, adequate air supply was given to the seeds with an air pump (DC 12-13.5V, 14A, $pressure_{max}$: 10 kg/cm^2, displacement: 35 lpm).

Accessories, viz. submersible pump (165-250 V, 50Hz, H_{max}-1.6m, output- 1200 lph), immersion heater (1500W, 230V, 50Hz), digital timer (0-60 min), thermostat (0 to 80°C) and motor (220 V, 50 Hz, 40 W) were also required to accomplish the operational requirements of seed priming prototype. All the accessories were connected accordingly with their corresponding power sources.

Based on preliminary studies performed, individual machine components were finalized and fabricated to their respective design specifications. The machine components were then integrated appropriately to obtain a consolidated structure. Fig 1 shows the schematic line diagram of the developed prototype. The prime function of this prototype was to improve the vigour and viability of aged seeds with the precise control over the set conditions of hydropriming. During hydropriming, adequate amount of seeds were allowed to immerse in sufficient quantity of water (all seeds must fully dipped in water with appropriate aeration). After hydropriming, the seeds were removed and kept at ambient conditions with light/dark period of 12/12 hours and relative humidity 50 ± 5% till the surface moisture is removed. The dried seeds were further kept for evaluation of germination associated characteristics using standard procedures.

Response surface methodology (Box-behnken design) with 46 experimental run each for okra and pea seeds was adopted to examine the performance evaluation of the prototype. The dependent parameters selected were: moisture content after hydropriming (MC), final germination percentage (FGP), seedling length (SL), seedling dry weight (SDW), vigour indices (VI-I and VI-II) and electrical conductivity (EC). Respective methodologies used for the determination of the process responses are given in Table 3.

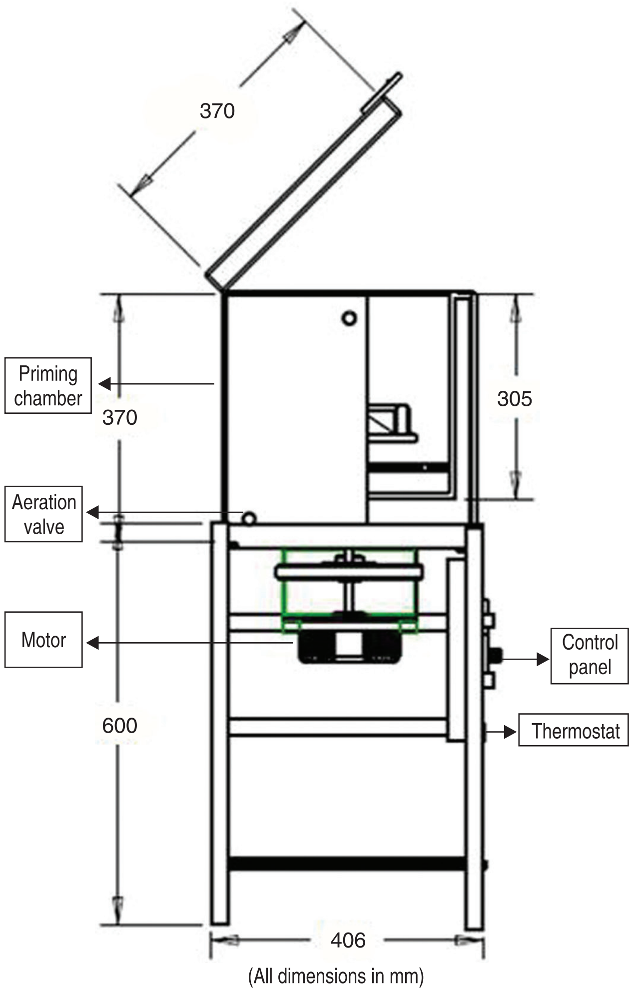

Fig 1 Isometric view of developed seed priming equipment

Table 3 Methodologies for determination of process responses with respective units

Observations	Method	Unit
Moisture content (MC)	105°C for 24 h	% (d.b)
Final germination (FGP)	(ISTA, 1993)	%
Seedling length(SL)	Average length of 10 seedlings	cm
Seedling dry weight(SDW)	Afzal *et al.* (2005)	mg
Vigour index I(FGP × SL)	Abdul-Baki and Anderson (1973)	-
Vigour index II(FGP × SDW)	Abdul-Baki and Anderson (1973)	-
Electrical conductivity(EC)	(ISTA, 1993)	mS/cm

MC:Corresponds to the moisture values after hydropriming, FGP: Corresponds to the germination of seeds after hydropriming, SL: Average length of the seedlings after hydropriming, SDW: Average seedling dry weight after hydropriming

RESULTS AND DISCUSSION

Moisture content after hydropriming (MC)

Moisture content of seeds has an important role in determining its vigour and viability. After the completion of hydropriming process, moisture content of the seeds was increased in range of 32.45 to 86.72% d.b. for okra seeds and 30.32 to 51.78% d.b. for pea seeds, respectively. The moisture absorption capability of low vigorous seeds (seeds subjected to aging) was found more as compared to fresh seed lots. It must be due to the reason that in case of aged seed lots, the membrane becomes more permeable and thereby allowing for easy absorption of moisture during hydropriming.

Final germination percentage (FGP)

FGP of hydroprimed okra seeds was significantly influenced by initial germination of seeds and soaking duration. Since, the seed coat of okra seeds is relatively harder, the moisture migration was slow and prolonged to a longer duration which in turn improves the quality parameters. However in case of pea seeds, the thin seed coat was damaged at higher soaking duration and higher rotation speed which abruptly resulted in increasing number of dead and abnormal seeds. The proportional increase in FGP with initial germination was observed but rate of increase of germination was faster in low vigourous seeds when compared with seeds which are more vigourous. This may be attributed to their positive response towards hydropriming rather than those of high vigour seeds. The increase in germination related attributes after hydropriming were in conformity for finger millet (Kumar *et al.* 2002), onion (Caseiro *et al.* 2004) and okra (Sharma *et al.* 2014).

Seedling length (SL)

SL of hydroprimed seeds ranged from 23.16 to 38.83 cm for okra seeds and 15.83 to 26.71 cm for pea seeds, respectively. Initial germination and soaking duration were found to be significantly affecting SL of okra seeds. This increase might have resulted owing to absorption of more water due to increase in the elasticity of cell wall and development of a stronger and efficient shoot and root system (Subbian *et al.* 2000).

SL of pea seeds was greatly influenced by initial germination and rotation speed, while the effect of process temperature was found to be less significant. The pertaining reason should be reduction in number of normal and healthy seeds after exposure to longer priming duration and higher rotation speed. The damage of thin seed coat of pea seeds supposed to be the major reason for reduction in seed quality parameters.

Seedling dry weight (SDW)

SDW per 10 seedlings ranged from 158.65 to 204.06 mg for okra seeds and 223.54 to 348.56 mg for pea seeds, respectively. The initial germination and soaking duration had profound effect on SDW of okra seeds. However, for pea seeds, rotation speed had significant effect, while soaking duration and initial germination were also observed to be the basis for this variation in SDW values. SDW values were found significantly reduced with the increased period of accelerated aging in case of both the crops. This result was in accordance for wheat seeds (Ghasemi *et al.* 2014).

Vigour indices (VI-I and VI-II)

The hydroprimed seeds of okra exhibited VI-I from 1273.8 to 3106.4 and for pea seeds, it was ranged from 902.31 to 2083.38. VI-II for post hydroprimed okra seeds ranged from 8697.78 to 16409.9 and 12071.2 to 27440 for pea seeds, respectively. This increase was due to the positive effect of hydropriming on low vigourous seeds of both the crops. Mahmoodi *et al.* (2011) also reported the improvement in vigour indices of maize seeds after hydropriming.

Electrical conductivity (EC)

EC of okra seeds ranged from 0.022 to 0.0475 mS/cm and 0.172 to 0.346 mS/cm for pea seeds, respectively. The seeds subjected to aging have been reported to leak more solutes when placed in water than vigorous seeds. One of the explanations for this variation is attributed to the reorganisation of cellular membrane during priming which reduces the solute leakage. Similar trend was reported in hydroprimed seeds of french bean (Pandey 1989), eggplant and radish (Rudrapal and Naukamura 1988) and wheat (Basra *et al.* 2005).

Economic assessment

Economic evaluation is considered to be an important factor along with the technical assessment. Adoption of any successful technology which is not economically viable is not justified. And hence after the completion of experimental run, the developed prototype was subjected to cost analysis to predict the overall expenditure incurred in the process. Following assumptions and calculations were considered to calculate the operating cost of machine:

i. Average annual use 250 h
ii. Life of equipment 10 years
iii. Salvage value (% of initial cost) 10%
iv. Electricity rate/unit ₹ 3.5/kwh
v. Repair and maintenance (% of initial cost) 2%
vi. One labour is required to operate the machine ₹ 250/6h (day)
vii. Capacity of priming chamber Okra= 5 kg, Pea= 3 kg

Using the standard cost analysis method, the total cost of operation of seed priming prototype was observed to be ₹ 55/h. However, the operating cost was ₹ 66/kg for okra and ₹ 17/kg for pea seeds, respectively. The payback period of the machine was calculated to be approximately 6 months. The saving in man hours and in terms of cost was found to be quite substantial and it justified the use of seed priming prototype over the manual method of hydropriming.

Optimization of process parameters

The process affecting parameters were subjected to optimization by assigning goals (i.e. maximization, minimization, in range) for the process variables as well as responses. All the independent parameters were kept in range, moisture content after hydropriming was kept in range, final germination, seedling length, seedling dry weight, vigour indices were kept maximized and electrical conductivity was minimized for both the crops.These constraints resulted in the optimum solution with maximum desirability. Optimal solution for okra was initial germination 73%, soaking duration 6h, temperature 23°C, rotation speed 330 rpm and air flow rate 2.50 m^3/min. Whereas, in case of pea seeds, the optimal solution was initial germination 75%, soaking duration 55 min, temperature 20°C, rotation speed 320 rpm and air flow rate 0.50 m^3/min (Mahawar *et al.* 2016).

From the present study, it can be concluded that the developed priming prototype was successful in boosting the germination related attributes of aged okra and pea seeds up to a certain limit. Experimental data showed that the consequence of hydropriming process was more prominent in less vigourous seeds as compared to high vigourous seeds. The developed prototype was also effective from performance as well as economical point of view and demonstrated considerable potential for commercialization. The main advantages of this design over previous methods of priming are: (i) The time lag of usual priming methods can be reduced to a certain extent. (ii) Continuous monitoring and precise control over the process affecting parameters which remains the major drawback of existing priming practices. (iii) The developed system is easy to fabricate with the production cost of a single unit is approximately

₹ 12000. (iv) Economic indicators and performing mechanical priming on small scale made the overall process financially feasible.

The developed prototype can further be utilized for on-farming purpose if used judiciously. However, the possibility of adopting other priming methods using this prototype needs to be explored. Also, different vegetable seeds with variable germination can also be used as a substrate for further investigation with necessary modification in the design.

ACKNOWLEDGEMENT

The first author is grateful to financial support provided by University Grants Commission (UGC) in the form of Rajiv Gandhi Fellowship. Gratitude is extended towards National Seed Corporation, New Delhi for supplying good quality seeds.

REFERENCES

Abdul-Baki A and Anderson J D. 1973. Vigor determination in soybean seed by multiple criteria. *Crop Science* **13**: 630–3.

Afzal I, Basra S M A and Iqbal A. 2005. The effects of seed soaking with plant growth regulators on seedling vigour of wheat under salinity stress. *Journal of Stress Physiology and Biochemistry* **1**: 6–14.

Balasubramanian V and Hill J E. 2002. Direct seeding of rice in Asia: emerging issues and strategic research needs for 21st century. (*In*) *Direct Seeding: Research Strategies and Opportunities*, pp 15-39. Pandey S M, Wade M L, Tuong T P, Lopes K and Hardy B (Eds). International Research Institute, Manila, Philippines.

Basra S M A, Afzal I, Rashid R A and Farooq M. 2005. Pre-sowing seed treatments to improve germination and seedling growth in wheat (*Triticum aestivum* L.). *Biology Series Search Pad* **17**(1): 155–64.

Casenave E C and Toselli M E. 2007. Hydropriming as a pre-treatment for cotton germination under thermal and water stress conditions. *Seed Science and Technology* **35**: 88–98.

Ghasemi E, Ghahfarokhi M G, Darvishi B and Kazafi Z H. 2014. The effect of hydro-priming on germination characteristics, seedling growth and antioxidant activity of accelerated aging wheat seeds. *Agronomical Research in Moldavia* **4**(160): 41–8.

Iqbal M and Ashrat M. 2007. Seed treatment with auxins modulates growth and ion partitioning in salt stressed wheat plants. *Journal of Integrated Plant Biology* **49**: 1003–15.

Kaur R, Arora S and Thukral A K. 2009. Enhancing seed germination of Chlorophytyum borivilianum Sant. Et fernard. With pgrs, steroid hormones and zinc. *Research Journal of Seed Science and Technology* **2**: 32–9.

Kaur S, Gupta A K and Kaur N. 2002. Effect of osmo and hydropriming of chickpea seeds on the performance of crop in the field. *International Chickpea Pigeonpea Newsletter* **9**: 15–7.

Kaya M D, Okc U G, Atak M C, Ikili Y and Kolsarici O. 2006. Seed treatments to overcome salt and drought stress during germination in sunflower (*Helianthus annuus* L.). *European Journal of Agronomy* **24**: 291–5.

Kumar A, Gangwar J S, Prasad S C and Harris D. 2002. On-farm seed priming increases yield of direct–sown finger millet in India. *International Sorghum Millets News letter* **43**: 90–2.

Mahawar M K, Samuel D V K, Sinha JP and Jalgaonkar K. 2016. Optimization of pea (*Pisum sativum*) seeds hydropriming by application of response surface methodology. *Acta Physiologiae Plantarum* **38**: 212.

Mahmoodi T M, Ghassemi-golezani K, Habibi D, Paknezhad F and Ardekani M R. 2011. Effect of hydro-priming duration on seedling vigour and fieldestablishment of maize (*Zea mays* L.). *Research on Crops* **12**(2): 341–5.

Maroufi K and Farahani H A. 2011. Effects of hydropriming on germination percentage in garden pea (*Phaseolus vulgaris* L.). *Advances in Environmental Biology* **5**(8): 222–3.

Mittal R and Dubey R S. 1995. Influence of sodium chloride salinity on polyphenol oxidase, indole 3-acetic acid oxidase and catalase activities in rice seedlings differing in salt tolerance. *Tropical Science* **35**: 141–9.

Pandey D K. 1989. Priming induced alleviation of the effects of natural ageing derived selective leakage of constituents in french bean seeds. *Seed Science and Technology* **17**: 391–7.

Rudrapal D and Naukamura S. 1988. The effect of hydration-dehydration pre treatments on egg plant and radish seed viability and vigour. *Seed Science and Technology***16**: 123–30.

Sharma A D, Rathore S V S, Srinivasana K and Tyagi R K. 2014. Comparison of various seed priming methods for seed germination, seedling vigour and fruit yield in okra (*Abelmoschus esculentus* L. Moench). *Scientia Horticulture* **165**: 75–81.

Singh B G and Rao G. 1993. Effect of chemical soaking of sunflower (*Helianthus annuus* L.) seed on vigour index. *Indian Journal of Agricultural Science* **63**: 232–3.

Subbian P, Annadu R K and Palaniappan S P. 2000. *Agriculture Facts and Figures*. Kalyani Publisher, Ludhiana.

Suleman M K, Bhatt N R, Jacob S and Thomas R R. 2011. Germination studies in *Ochradenus baccatus decile, Peganum harmala* L. and *Gynandris sisrinchium Parl*. *Research Journal of Seed Science* **4**: 58–63.

Taylor A G and Harman G E. 1990. Concepts and technologies of selected seed treatments. Annual Reviews of Phytopathology **28**: 321–39.