Seed priming technique

Abstract

Seed priming is a technique by which seeds are partially hydrated to a point where germination processes begin but radical emergence does not occur. Priming can be found effective both for legumes and grain crops. A pot experiment was conducted under green house conditions at Pir Mehr Ali shah, Arid Agriculture University, Rawalpindi during summer of 2007. The seeds were invigorated by traditional soaking (hydropriming), osmo-conditioning (soaking of seeds in aerated, low-water-potential solutions) using, potassium di-hydrogen phosphate KH2PO4, Mannitol, Polyethylene glycol (PEG), sodium molybdate (Na2MO4. 2H2O) and hormonal priming by using salicylic acid (SA). The ranges of osmotic potential for all the priming treatments were -0. 5 to -1. 2 M Pa. All the invigoration treatments significantly affected plant vigor, biomass, root, shoot length and nodulation. Osmopriming using P @ 0. 60% applied in the form of KH2PO4 significantly improved seed vigour in terms of mean emergence time (5. 52 to 4. 51 days), final germination percentage (74 to 89%) root and shoot length and nodulation (0 to 4 nodules seedling-1) followed by mannitol priming (Mannitol @ 2%). Overall all the seed priming techniques significantly improved the vigour of mungbean seedlings as compare to control. The use of polyethylene glycol is expensive and gave similar results as for dry seeding so it should be replaced by hydropriming in further experiments. It is recommended that nutrient-priming and osmopriming can be used as effective tool for invigoration of mungbean seeds, for better growth and seedling establishment.

Key words: Osmo-priming, hydropriming, vigna radiata, seedling vigour, nodulation

INTRODUCTION

Seed priming is a practice by which seeds are partially hydrated to a point where germination processes begin but radical emergence does not occur (Harris et al., 2000). Seed priming can be found effective for legumes i. e., yields of Mungbean and Chickpea were increased substantially by priming seeds for 8 h before sowing (Harris et al., 1999; Musa et al., 2001; Rashid et al., 2004).

Mungbean (Vigna radiata (L.) Wilczek) is grown on over 200, 000 ha with production of more than 100, 000 t under rainfed and irrigated conditions in Pakistan. Yields for the rainfed area are generally low and variable due to sparse, erratic rainfall and marginal soils. Mungbean production in Punjab Province is dependent mainly on surface irrigation but it is also grown under rain fed conditions. In the Southern region of Pakistan rainfall is scanty and mungbean is grown with surface irrigation only. Poor crop establishment is a major restraint for mungbean production (Naseem et. al., 1997; Rahmianna et al., 2000) and high yields can be associated with early vigor (Kumar et al., 1989).

Improved seed invigoration techniques are being used to reduce the germination time, to get synchronized germination, improve germination rate, and improve seedling stand in many horticultural (Bradford et al. 1990; Rudrapal and Nakamura 1998) and field crops like wheat, maize (Aquilla and Tritto 1991; Basra et al. 2002) and more recently rice (Farooq et al. 2004).

These invigoration techniques include hydropriming, osmoconditioning (Basra et al. 2005), osmohardening (Farooq et al. 2006) and hardening (Farooq et al. 2004). These treatments can also be employed for earlier and better nursery stand establishment (Lee et al. 1998).

This study was initiated to explore the effects of aerated hydration, hormonal priming (salicylic acid), nutrient priming (Phosphorous and molybdenum loading) and osmo-conditioning on mungbean (vigna radiata) seed vigour under green house conditions.

MATERIALS AND METHODS

Seed material

Seeds of mungbean cultivar Chakwal Mung-97 (CH-MUNG 97) were obtained from Barani Agricultural Research Institute (BARI), Chakwal. The seeds were sterilized by using 30% hypochlorite for five minutes and then washed three times with distilled water.

Seed Treatments

The following seed priming treatments were applied

Nutrient priming

The seeds were soaked in aerated solution of phosphorous (P @ 0. 60 & 1. 20 %) and molybdate (Mo @ 0. 02 & 0. 04 %). The sources for phosphorous and molybdenum were potassium dihydrogen phosphate (KH_2PO_4) and sodium molybdate ($Na_2MoO_4 . 2H_2O$), respectively.

Osmopriming

The seeds were soaked in aerated solutions of mannitol (mannitol @ 2 % & 4 %) and polyethylene glycole (Polyethylene glycol @ 5% & 10%).

Hormonal priming

The seeds were soaked in aerated solution of salicylic acid (SA @ 10 & 20 ppm)

Post treatment operations

After seed treatments the seeds were given surface washing three times by distilled water. Aeration was also applied by pump. Air dried soil was placed in 10-cm tall plastic pots with 6-cm diameter. The soil used in the pot experiment was sandy loam having pH of 7. 9. Soil was made friable by scratching the surface with a two cm wide table fork to a depth of 1-cm of moist soil. The seeds were also inoculated before sowing. Ten numbers of seeds were planted in each pot and thinned to six plants per pot. Similar amount of water applied in regular intervals to all pots under study. The plants were harvested 21 days after sowing (DAS), and seedlings root/shoot length were taken. The seedlings were dried at 75 oC for 48 hours and the dry matter was finally determined. The complete randomized design (CRD) was used in pot experiment. Analysis of variance (ANOVA) was used to compare treatment means.

RESULTS

The data showed that different seed priming treatments had significant (p <0. 05) effect on mean emergence time (MET). The mean emergence time decreased with the application of seed priming treatments. Maximum mean emergence time (5. 52 days) observed in T1 (control) where dry untreated seeds were sown. Minimum (4. 51 days) MET was observed in T5 (P @ 0. 06 % applied in the form of KH2PO4). All the treatments resulted in lower MET as compare to control (5. 52 days). The data also revealed similar trend with respect to fifty percent (E50) seeds to emerge as of MET. The lowest E50 was observed in T5 (P @ 0. 60 %).

There was significant (p <0. 05) effect of different seed priming techniques on dry weight of 21 days old seedlings (Fig 1). The maximum fresh and dry weight was obtained in T5. All the priming treatments increased the fresh and dry weight of the seedlings except T2 and T12. As far as final germination is concerned maximum germination was achieved in T5 (P @ 0. 60%). The lowest germination percentage was observed in T11 and T12 where polyethylene glycol was applied at the rate of five (5) and ten (10) percent (Table 1).

There was significant (p <0. 05) effect of different seed priming techniques on nodule formation and number of 21 days old seedlings (Fig 1). All the priming techniques significantly increased the nodulation of seedlings as compare to control except T10 and T12. Maximum nodule number was observed in T5 (P @ 0. 60%) followed by T3 (Mo @ 0. 02%). The data also depicts that T9 and T11 are at par and T1, T10 and T12 gave similar results.

The data depicts that seed priming had significant impact on the root as well as shoot length, 21 days after sowing (DAS). All the priming treatments significantly increased the root as well as shoot length of seedlings. The data revealed that T5 (P @ 0. 60%) and T9 (mannitol @ 2 %) gave the best results. The lowest root length (4. 56 cm) was observed in control. T4 (Mo @ 0. 04%) showed lower root length than T2 and T3 (Mo @ 0. 02 %) and higher from control. Treatment T6 (P @ 1. 2%) showed lower root length than T5 (P @ 0. 06%) and at par with T1 and T4. Hormonal priming using salicylic acid

(SA @ 20 ppm) also showed lower root length than T7 (SA @ 10 ppm) and at par with T4 and T6. The data also showed that T10 (mannitol @ 4%) is lower than T9 (mannitol @ 2%) and at par with T7. The data also depicts that T12 (PEG @ 10%) showed lower root length as compare to T11 (PEG @ 5 %) which showed also higher root length than all other treatments except T2 and T9 (Figure 1).

Maximum shoot length observed in the T5 (P @ 0. 06 %) followed by T9 (mannitol @ 2%). The data also depicts the shortest shoot length was observed in the control. The data also revealed that T4 resulted in lower shoot length than T3 and T2. It is also evident that T6 is lower than T5 and at par with T3 and T2 (Figure 1). T8 showed higher shoot length than T7 and at par with T2, T3 and T6. Treatments T9 and T10 and T11, T12 also showed similar results.

Discussion

Earlier and more uniform germination and emergence was observed in primed seeds as indicated by lower MET and E50, higher germination percent and root and shoot dry weight (tables 1). Lesser MET and E50 specify the earlier and rapid germination. These findings support the prior work on canola (Brassica compestris) (Zheng et al., 1994), wheat (Triticum aestivum) (Nayyar et al., 1995) and rice (Oryza sativa) (Lee and Kim 2000; Basra et al., 2003) who described improved germination rate and percentage in seeds subjected to hydropriming and seed hardening for 24 h.

This study revealed that osmo, nutrient and hormonal priming could invigorate mungbean seeds. One of the reasons for decreased MET is that during pre-sowing seed treatments the dormancy of the seed is broken and the seed bio-chemical processes commences, which lead to faster germination and emergence (Farooq et al., 2006). Seed priming ensured the proper hydration, which resulted in enhanced activity of a-amylase that hydrolyzed the macro starch molecules in to smaller and simple sugars. The availability of instant food to the germinating seed gave a vigorous start as indicated by lower E50 and MET in treated seeds (Farooq et al., 2006) during priming de novo synthesis of a-amylase is also documented (Lee and Kim, 2000). Early emergence as indicated by lower E50 and MET in treated seeds may be due to the faster production of germination metabolites (Saha et al. 1990; Lee & Kim 2000; Basra et al. 2005) and better genetic repair, i. e. earlier and faster synthesis of DNA, RNA and proteins (Bray et al. 1989). Gray and Steckel (1983) also concluded that priming increased embryo length, which resulted in early initiation of germination in carrot seeds.

The increased shoot and root length in primed plants can be due to metabolic repair of damage during treatment and that change in germination events i. e., changes in enzyme concentration and formation and reduction of lag time between imbibition and radicle emergence (Bradford et al., 1990). Treated seeds had stronger embryos that were able to more easily emerge from seeds (Harris et al., 2005). These results are also in line with the findings of Sekiya et al. (2009) who reported enhanced root and shoot length of seedlings obtained from P enriched seeds. To contribute to plant growth and development seed priming has been widely reported technique (Harris et al., 2005). Ajouri et al. (2004) reported a stimulation of P and Zn uptake, as well as an improved germination and seedling growth in barley after soaking seeds in water and in solutions containing 5-500 mM P.

It has been also reported invigorated seeds had higher vigour levels (Ruan et al. 2002), which resulted in earlier start of emergence as high vigour seed lots performed better than low vigour ones (Hampton and Tekrony 1995). Yamauchi and Winn (1996) also reported positive correlation between seed vigour and field performance in rice.

Earlier, Zheng et al. (2002) reported earlier and uniform emergence in rice seeds osmoprimed with KCl and CaCl2 and mixed salts under flooded conditions. Hydropriming improved the early and vigorous crop establishment in maize (Nagar et al. 1998) and Helichrysum bracteatum L. (Grzesik & Nowak 1998). However, other studies resulted in poor emergence from hydroprimed Kentucky bluegrass seeds under field conditions (Pill & Necker 2001). However Nascimento and West (1999) reported early germination of primed seeds but not recorded any improvement in the growth of seedlings in muskmelon seeds under laboratory conditions. Confounding results, where priming did not show any beneficial results, also reported by different research workers (Mwale et al., 2003; Giri and Schillinger, 2003).

The increase of nodulation, seedling vigor and tolerance to stresses may depend on various factors occurring during priming treatment. One hypothesis is that benefits of priming can be due to metabolic repair of damage during treatment and that change in germination events i. e., changes in enzyme concentration and formation and reduces lag time between imbibition and radicle emergence (Bradford et al., 1990). One of the possible reasons for early nodule formation may be due to enhanced activity of a-amylase and sucrose synthase in primed seeds which may facilitate plant growth and vigor (Lee and Kim, 2000).

From the present study it may be concluded that seed priming may enhance the seedling vigour of mungbean. Nutrient priming using phosphorous and osmopriming with mannitol were the most efficient priming treatments in this study. In further research work biochemical basis for the enhanced phenology of mungbean may be evaluated.

REFERENCES

- Aquilla D. A., V. Tritto. 1991. Germination and biochemical activities in wheat seeds following delayed harvesting, ageing and osmotic priming. Seed Sci. Tech. 19: 73 – 82.
- Anonymous. 2009. Agriculture statistics of Pakistan. Ministry of Food, Agriculture and Livestock. Economic wing, Islamabad. Pp. 46-47.
- Association of Official Seed Analysis (AOSA). 1998. Rules for testing seeds. J. Seed Tec. 12: 1-112.
- Association of Official Seed Analysis (AOSA). 1983. Seed Vigor Testing Handbook. Contribution No. 32 to the Handbook on Seed Testing.
- Barber, S. A. 1995. Soil nutrient bioavailability, 2nd edn. Willey, New York
- Basra, S. M. A., M. Farooq, K. Hafeez and N. Ahmad. 2004. Osmohardening: A new technique for rice seed invigoration. Int. Rice Res. Notes. 29: 80 – 81.

- Basra SMA, Farooq M, Tabassum R. 2005. Physiological and biochemical aspects of seed vigor enhancement treatments in fine rice (Oryza sativa L.). Seed Sci. Tech. 33: 623 – 628.
- Basra S. M. A., M. N. Zia, T. Mehmood, I. Afzal, A. Khaliq. 2002. Comparison of different invigoration techniques in wheat (Triticum aestivum L.) seeds. Pak. J Arid Agric. 5: 11 – 16.
- Basra, S. M A., Farooq, M. and Tabassum, R. 2005. Physiological and biochemical aspects of seed vigor enhancement treatments in fine rice (Oryza sativa L.). Seed Sci. Tech. 33: 623-628.
- Basra, S. M. A., Farooq, M. and Khaliq, A. 2003. Comparative study of pre-sowing seed enhancement treatments in fine rice (Oryza sativa L.). Pak. J. Life Soc. Sci. 1: 5-9.
- Basra, S. M. A., Farooq, M., Hafeez, K and Ahmed, N. 2004. Osmohardening: A new technique for rice seed invigoration. Inter. Rice Res. Notes. 27: 74-75.
- Basra, S. M. A., Farooq, M., Tabassum, R. and Ahmed, N. 2005. Physiological and biochemical aspects of seed vigor enhancement treatments in fine rice (Oryza sativa L.). Seed Sci. Tech. 33: 623-628.
- Basra, S. M. A., M. Farooq and A. Khaliq. 2003. Comparative study of pre-sowing seed enhancement treatments in indica rice (Oryza sativa L.). Pakistan J. Life Soc. Sci. 1: 5-9.
- Basra, S. M. A., Zia, M. N., Mehmood, T., Afzal, I. and Khaliq, A. 2002. Comparision of different invigoration techniques in wheat (Triticum aestivum L.) seeds. Pak. J. Arid Agri. 5: 11-16.
- Bose, B. and Mishra, T. 1992. Response of wheat seed to pre-sowing seed treatments with Mg (NO3). Annals. Agri. Res. 13: 132-136.

- Bradford KJ, Steiner JJ, Trawatha SE. 1990. Seed priming influence on germination and emergence of pepper seed lots. Crop Sci. 30: 718 – 721.
- Bradford, K. J., 1990. A water relations analysis of the seed germination rates. Plant Physiol. 94: 840-849.
- Bray C. M., P. A. Davison, M. Ashraf, R. M. Taylor, Biochemical changes during osmopriming of leek seeds, Ann. Bot. Lond. 63: 185-193.
- Bray, C. M., Davison, P. A., Ashraf, M., Taylor, R. M. 1989. Biochemical changes during osmopriming of leek seeds. Annals Bot. 36: 185-193.
- Chojnowski M., F. Corbineau, D. Côme, Physiological and biochemical changes induced in sunflower seeds by osmopriming and subsequent drying, storage and aging, Seed Sci. Res. 7: 323-331.
- Coolbear, P., Francis, A., Grierson, D. 1984. The effect of low temperature pre-sowing treatment under the germination performance and membrane integrity of artificially aged tomato seeds. J. Exp. Bot. 35: 1609-1617.
- Rudrapal, D., S. Nakamura, The effect of hydration-dehydration pretreatments on eggplant and radish seed viability and vigour. Seed Sci. Tech. 16: 123-130.
- Dahal, P., Bradford, K. J., 1990. Effects of priming and endosperm integrity on seed germination
- Das, J. C., and A. K. Choudhury. 1996. Effect of seed hardening, potassium fertilizer, and paraquat as anti-transpirant on rainfed wheat (Triticum aestivum L.). Indian J. Agron. 41: 397-400.

- Duman, I. 2006. Effects of seed priming with PEG or K3PO4 on Germination and Seedling Growth in Lettuce. Pak. J. Bio. Sci. 9 (5): 923-928
- Ellis, R. A. and E. H. Roberts. 1981. The quantification of ageing and survival in orthodox seeds. Seed Sci. and Technol. 9: 373-409
- Farooq M, Basra SMA, Cheema MA, Afzal I. 2006. Integration of pre-sowing soaking, chilling and heatingtreatments for vigor enhancement in rice (Oryza sativa L.). Seed Sci. Tech. 34: 499 – 506.
- Farooq M, Basra SMA, Hafeez K, Ahmad N. 2005. Thermal hardening: A new seed vigor enhancement tool in rice. J. Integ. PlantBio. 47: 87 – 193.
- Farooq M, Basra SMA, Hafeez K, Warriach EA. 2004. The influence of high and low temperature treatments on the seed germination and seedling vigor of coarse and fine rice. Int. RiceRes. Notes. 29: 69 – 71.
- Farooq M, Basra SMA, Hafeez K. 2006. Seed invigoration by osmohardening in fine and coarse rice. Seed Sci. Tech. 34: 181 – 187.
- Farooq M, Basra SMA, Karim HA, Afzal I. 2004. Optimization of seed hardening techniques for rice seed invigoration. Emir. J. Agric. Sci. 16: 48 – 57.
- Farooq, M., Basra, S. M. A., Hafeez, K and Ahmad, N. 2005. Thermal hardening: a new seed vigor enhancement tool in rice. Ac. Bot. Sin. 47: 187-193.
- Farooq, M., Basra, S. M. A., Hafeez, K and Warriach, E. A. 2004. The influence of high and low temperature treatments on the seed germination and seedling vigor of coarse and fine rice. Inter. Rice Res. 29: 69-71.

- Farooq, M., Basra, S. M. A., Tabassum, R. and Ahmed, N. 2006. Evaluation of seed vigour enhancement techniques on physiological and biochemical basis in coarse rice (Oryza sativa L.)Seed Sci. Tech. 34: 741-750.
- Farooq, M., S. M. A. Basra and R. Tabassum. 2006. Enhancing the performance of direct seeded fine rice by seed priming. Plant Prod. Sci. 4: 446-456.
- Fu, J. R., X. H. Lu, R. Z. Chen, B. Z. Zhang, Z. S. Liu, Z. S. Li, et al., Osmoconditioning of peanut (Arachis hypogen L.) seeds with PEG to improve vigour and some biochemical activities. Seed Sci. Tech. 16: 197-212.
- Giri, G. S and W. F. Schillinger, 2003. Seed priming winter wheat for germination, emergence and yield. Crop Sci., 43: 2135-2141
- Grandi, T. M., G. J. Marinho, D. A. Lopes, and A. P. Araujo, 1999. Effect of seed phosphorous concentration on nodulation and growth of three common bean cultivars. J. Plant Nut. 22: 1599-1611.
- Grzesik M, Nowak J. 1998. Effects of matriconditioning and hydropriming on Helichrysum bracteatum L. seed germination, seedling emergence and stress tolerance. Seed Sci Technol 26: 363 – 376.
- Hampton, J. G. and D. M. Tekrony. 1995. Handbook of ISTA vigour test methods. 3rd ed. Zurich: ISTA. 10. Jeng TL, Sung JM. 1994. Hydration effect on lipid peroxidation and peroxide-scavenging enzyme activity of artificially aged peanut seeds. Seed Sci Techn. 22: 531 – 539

- Harris, D. 1996. The effects of manure, genotype, seed priming, depth and date of sowing on the emergence and early growth of Sorghum bicolor (L.) Moench in semi-arid Botswana.
- Harris, D. 2002. ‘ On-farm’ seed priming for better crops in marginal areas of developing Soil Tillage Res. 40: 73-88.
- Harris, D., Joshi, A., Khan, P. A., Gothkar, P. and Sodhi, P. S. 1999. On-farm seed priming in semi-arid agriculture: development and evaluation in maize, rice and chickpea in India using participatory methods. Experi. Agri. 35: 15-29.
- Harris, D., Raghuwanshi, B. S., Gangwar, J. S., Singh, S. C., Joshi, K. D., Rashid, A. and Hollington, P. A. 2001. Participatory evaluation by farmers of ‘ on-farm’ seed priming in wheat in India, Nepal and Pakistan. Experi. Agri. 37: 403-415.
- Harris, D., Rashid, A., Hollington, P. A., Jasi, L. and Riches, C. 2002. Prospects of improving maize yields with ‘ on-farm’ seed priming. ‘ Sustainable Maize Production Systems for Nepal’: Proceedings of a Maize Symposium 2001, 180-185, (Eds Rajbhandari, N. P., Ransom, J. K., Adikhari, K. and Palmer, A. F. E.) Kathmandu, Nepal. Kathmandu:
- Harris, D., Tripathi, R. S. and Joshi, A. 2000. On-farm seed priming to improve cropestablishment and yield in direct-seeded rice. In IRRI: International Workshop on Dry-seeded Rice Technology, Bangkok, 25-28 January 2000. The International Rice Institute, Manila, The Philippines, 164 pp.
- Harris, D., Tripathi, R. S. and Joshi, A. 2002. ‘ On-farm’ seed priming to improve crop establishment and yield in dry direct-seeded rice.

Proceedings of the International Workshop on Direct Seeding in Asian Rice Systems: Strategic Research Issues and Opportunities, January

- Hisashi, K. N and A. M. Francisco. 2005. Effects of 6-methoxy-2-benzoxazolinone on the germination and a-amylase activity in lettuce seeds. J. Plant Physiol. 162: 1304-1307.
- Islam, A. K. M. A., N. Anuar and Z. Yaakob, 2009. Effect of genotypes and pre-sowing treatments on seed germination behavior of jatropha. Asian J. Plant Sci. 8: 433-439.
- Kaur, S. A. K. Gupta and N. Kaur. 2005. Seed Priming Increases Crop Yield Possibly by Modulating Enzymes of Sucrose Metabolism in Chickpea. J. Agronomy & Crop Science 191, 81-87
- Kumar, R., Tyagi, C. S. and Ram, C. 1989. Association of laboratory seed parameters with field performance in mungbean. Seeds Farms. 15: 33-36.
- Lee SY, Lee JH, Hong SB, Yun SH. 1998. Effect of humidification and hardening treatment on seed germination of rice. Kore. J. CropSci. 43: 157 – 160.
- Lee, S. S. and Kim, J. H. 1999. Morphological change, sugar content, a-amylase activity of rice seeds under various priming conditions. Kore. J. CropSci. 44: 138-142.
- Lee, S. S. and Kim, J. H. 2000. Total sugars, a-amylase activity and germination after priming of normal and aged rice seeds. Kore. J. CropSci. 45: 108-111.
- Lee, S. S., Kim, J. H. Hong, S. B. and Yun, S. H. 1998. Effect pf humidification and hardening treatment on seed germination of rice. Kore. J. CropSci. 43: 157-160.

- McDonald M. B. 1999. Seed priming, in: M. Black, J. D. Bewley (Eds.), Seed Technology and its Biological Basis, Sheffield Academic Press, Sheffield, UK. 287-325.
- McDonald, M. B. 2000. Seed priming. In: Seed Technology and Its Biological Basis (eds. M. Black and J. D. Bewley), Sheffield Acad. Press, Sheffield, England. pp. 287-326.
- Musa, A. M., D. Harris, C. Johansen and J. Kumar. 2001. Short duration chickpea to replace fellow after AMAN rice: The role of on-farm seed priming in the high barind tract of Bangladesh. Expl Agric. 37: 509-521.
- M. Black and J. D. Bewley (eds.) Sheffield Acad. Press, Sheffield, England.
- McDonald M. B. 1999. Seed priming, in: M. Black, J. D. Bewley (Eds.), Seed Technology and its Biological Basis, Sheffield Academic Press, Sheffield, UK. 287-325.
- Mwale, S. S., Hamusimbi and K. Mwansa, 2003. Germination, emergence and growth of sunflower (Helianthus annus L.) in response to osmotic seed priming. Seed Sci. Technol., 31 : 199-206.
- Nagar R. P., M. Dadlani and S. P. Sharma. 1998. Effect of hydropriming on field emergence and crop growth of maize genotypes. Seed Sci Res 26: 1 – 5.
- Nayyar, H., D. P. Walia and B. L. Kaishta. 1995. Performance of bread wheat (Triticum aestivum L.) seeds primed with growth regulators and inorganic salts. Indian Journal of Agricultural Sciences, 65: 112-116,
- Nascimento, W. M. ansd S. H. West, 1999. Muskmelon transplant production in response to seed priming. Hort. Tech. 9: 53-55.

- Naseem, S. B., Khan, A. H., Islam, M., Mollah, U. and Ali, M. A. 1997. Effect of seeding methods and varying surface soil moisture on the stand establishment of mungbean (Vigna radiata L.). Bang. J. Scienti. Indus. Res. 32: 295-301.
- Nerson, H. and Govers, A. 1986. Salt priming of muskmelon seeds for low temperature germination. Scien. Hort. 28: 85-91.
- Peoples, M. B., D. F. Herridge and J. K. Ladha. 1995. Biological nitrogen fixation. An efficient source of nitrogen for sustainable agricultural production. Plant and Soil. 174: 3-28.
- Pill, W. G. and A. D. Necker. 2001. The effects of seed treatments on germination and establishment of Kentucky bluegrass (Poa pratensis L.). Seed Sci Technol 29: 65 – 72.
- Pill, W. G. 1995. Low water potential and pre-sowing germination treatments to improve seed quality. In: A. S. Basra (ed.). Seed quality. Food Products Press, Binghampton, N. Y. , p. 319-359
- Ruan, S., Xue Q and Tylkowska R. 2002. Effects of seed priming on germination and health of rice (Oryza sativa L.) seeds. Seed Sci Technol 30: 451 – 458.
- Rahmianna, A. A., T. Adisarwanto, G. Kirchhof and H. B. So. 2000. Crop establishment of legumes in rain fed lowland rice-based cropping system. Soil Tillage Res. 56: 67-82.
- Rashid, A., Harris, D., P. Hollington and Ali, S. 2004. On-farm seed priming reduces yield losses of mungbean (Vigna indiata) associated with mungbean yellow mosaic virus in NWFP of Pakistan. Crop protect. 23: 1119-1124.

- Rudrapal D, Nakamura S. 1998. The effect of hydration dehydration pre-treatment on eggplant and radish seed viability and vigor. Seed Sci. Tech. 26: 123 – 130.
- Rudrapal, D., S. Nakamura. 1988. The effect of hydration-dehydration pretreatments on eggplant and radish seed viability and vigour, Seed Sci. Technol. 16 123-130.
- Saha R, Mandal AK, Basu RN. 1990. Physiology of seed invigoration treatments in soybean (Glycine max L.). Seed. Seed Technology and its Biological Basis, Sheffield Academic Press, Sheffield, UK, 1999, pp. 287-325.
- Sekiya, N. and K. Yano. 2009. Seed P-enrichment as an effective P supply to wheat. Plant and Soil. 327: 347-354
- Steiner, J. J. 1990. Seedling rate of development index: indicator of vigor and seedling growth response Crop science. 30: 1264-1271
- Yamauchi and Winn T. 1996. Rice seed vigor and seedling establishment in anaerobic soil. Crop Sci 36: 680 – 686.
- Yoon, B. Y. H., H. J. Lang and B. G. Cobb. 1997. Priming with salt solutions improves germination of pansy seed at high temperatures. Hort. Sci. 32: 248-250.
- Zheng G. H., Wilen R. W., Slinkard A. E., Gusta L. V. 2002. Enhancement of canola seed germination and seedling emergence at low temperature by priming. Crop Sci. 34: 1589-1593.
- Zheng G. H., R. W. Wilen, A. E. Slinkard and L. V. Gusta. 1994. Enhancement of canola seed germination and seedling emergence at low temperature by priming. Crop Science, 34: 1589-1593.