Frontiers in Crop Improvement 1(2) : 101-108 (2013)

SEED SIZE : RELATION TO SEED QUALITY AND SEED YIELD—A REVIEW

L.K. Sharma, G.U. Kulkarni, M.A. Vaddoria, C.K. Mandavia and S.P. Singh[1]

Department of Genetics and Plant Breeding, Junagadh Agricultural University, Junagadh-362 001

[1]Agriculture Research Station, Kalai, Aligarh (C.S.A. Uni. of Agric. and Tech., Kanpur-2)

ABSTRACT

The seed size that is a characteristic of each plant species is of central importance for their regeneration because of its effect on dispersability and seedling establishment. The seed size of different crops is differ according to their nature, the seed size affecting seed size variation, second methods of seed size grading and third effect of seed size on plants in relation to seed quality and yield. There are different methods for seed size grading viz., test Sieves, test weight and specific gravity separator etc. Seed weight or specific gravity of seed is closed associated with viability, seedling vigour and growth subsequently seed yield.

Key words : *Seed size, seed quality, seed yield, test sieves, test weight.*

The seed size that is a characteristic of each plant species is of central importance for their regeneration because of its effect on dispersability and seedling establishment. The review has attempted firstly, to study the factor affecting seed size variation, second methods of seed size grading and third effect of seed size on plants in relation to seed quality and yield.

Factors affecting seed size variation

The greatest divergences in seed size among the flowering plants (the angiosperms) have been associated with the differentiation between (I) shorter and taller plants and (II) temperate and tropical plants (Moles, 2005). Seed size variation due to variation from plant to plant which results from genetic differences and its surrounding environment (Wood *et al.,* 1977). The various environmental factors (Table-1) known to cause seed size variation such as, mineral nutrition, pollination thoroughness and seed number, position of seeds produced in different parts of inflorescence, removal of plant parts, season, soil moisture, solar irradiance and day length and temperature (Baskin and Baskin, 2005).

Methods for seed size grading

By Test sieves : The extent of seed size variation is most frequently determined by grading sample on the test sieves in a standard reproducible manner (Brinkman,1972). The sieves used for grading vary among plant species. By sieving the seed lot on the basis of size, simply into categories such as, large, medium and heavy seed.

By Test weight: Seeds can be weighted individually and the results either grouped into class intervals. Clearly it is tedious and at present uneconomic to separate seeds by individual weights on a commercial scale. By weighting 100 seeds and than seed lot grouped into categories on the basis of 100 seed weight. It is economic and more preferable than individual seed weight.

By Specific gravity separator: This method makes use of a combination of weight and surface characteristics of the seed to be separated. This machine separates seeds of the same density but of different size and seeds of the same size but of different densities. Removal of badly damaged, deteriorated, insect damaged crop seed and stones from good seed lot. It is more suitable to direct application to suitable grading.

Seed weight or specific gravity of seed is closed associated with viability, seedling vigour and growth subsequently seed yield (Tesng and Lin, 1962).

Effects of seed size in relation to seed quality and yield

Cereals Crops

Wheat

Nijhawan *et al.,* (1989) reported that use of large, ungraded or small seeds for sowing 5 wheat cultivars

Table 1: Seed size variation due to environmental factor in which the plants growing.

Crops	Environmental Factor	Reference
Triticum aestivum	Light, Moisture	Brocklehurst *et al.,* (1978).
	Competition, irradiance	Martinez-Carrasco and Throne (1979)
	Temperature	Campbell *et al.,* (1981)
Zea mays	Position	Lambert *et al.,* (1967)
Sorghum bicolor	Predation, position	Hamilton *et al.,* (1982)
Hordeum vulgare	Position	Giles (1990)
Cicer arietinum	Position	Sheldrake and Saxena (1979)
Glycine max	Moisture	Ramseur *et al.,* (1984)
	Nutrition	Streeter (1978)
	Position	Heindl and Brun (1984)
	Predation	Smith and Bass (1972)
	Season	Egli *et al.,* (1978)
	Temperature	Egli and Wardlaw (1980)

give av. grain yields of 4.16, 4.01 and 3.81 t/ha, respectively. Cv. WH-147 give the highest yields of 5.03, 4.45 and 4.26 t by using large, ungraded and small seeds resp.

An experiment conducted by Kalakannavar et al., (1989) to study the effect of seed size and density (weight) grading. Seeds of wheat are groped into four classes between 3.18mm and 2.78mm, 2.78 to 2.38 mm, 2.38 to 1.98mm and 1.98 to 1.58mm with the help of slotted screens. Each class further divided into heavy and light density fractions with the help of aspirator. Incase of seed size, laboratory germination was differed significantly with respect to seed sizes and there was a decreasing trend in germination with the decrease in seed size. There is a gradual decrease in root length with decrease in seed sizes similarly other characters like dry weight of seedling, vigour index and field emergence % also differed significantly with seed size. Incase of seed density heavy seeds are found to perform better than light seeds, but differed significantly only dry weight of seedling and vigour index. Singh (1970) noticed that seed size had positive correlation with germination % and coleoptiles length in wheat.

Kalakannavar *et al.,* (1989) studied seeds of wheat are graded into 4 sizes of (a) 2.78-3.18, (b) 2.38-2.78, (c) 1.98-2.38 and (d) 1.58-1.98 mm. Seeds within each grade were divided into heavy and light density fractions. Percentage germination in seeds of (a) and (b) grades was similar and higher than in smaller seeds of (c) and (d) grades. Percentage germination was higher in the heavy seeds than in the light seeds. Root length and seedling DW decreased with a decrease in seed size. Heavy seeds were superior to light seeds in seedling DW and vigour index.

Bajra

Mangat and Satija (1991) the seeds of *Pennisetum typhoides* (*P. glaucum*) subdivided into large (L), medium (M) and small (S) seed size groups. Head yield was positively correlated with grain yield, with higher correlation coefficients in the M and S groups. In the L and M groups tiller number showed the highest correlation with grain yield. The results indicated that selection for seed size affects the interrelationships of yield and its component traits.

Khairwal and Tomer (1976) reported that seed weight was positively correlated with viability and germination percentage.

Ramanadane and Thirumeni (2001) reported that seed index (100 seed weight) ranged from 0.981 g (larger seeds) to 0.403 g (smaller seeds). Larger seeds exhibited its superiority over other grades in all the physiological traits except speed of germination where medium-sized seeds performed better than the others and concluded that seed size is a major component influencing seed vigour in small seeded crops like pearl millet and therefore, size grading of seeds is an essential operation before planting to obtain vigorous and uniform stand establishment in the field and to increase the yield of good quality seeds.

Four bajra (*Pennisetum americanum*) cultivars showed that large seeds (>1.70 mm) are superior to medium (1.00-1.70 mm) and small (<1.00 mm) seeds in field emergence, earhead length and wt and give grain yields of 87.06 g/plant compared with 80.40 and 74.15 g for medium and small seeds resp (Kawade *et al.,* 1988).

Mangat *et al.,* (1988) subdivided 26 Pennisetum typhoides (*P. americanum*) populations into large, medium and small-seed size groups revealed that seed size greatly affected the genetic variability of the populations. Discriminate analysis of paired comparisons revealed that large and small seeded populations performed better for various yield components than medium seed-size populations, suggesting correlated responses for important attributes.

Maize

Seeds of 5 maize cultivars are graded into 3 sizes keeping ungraded seed as the control. Germination at 25°C revealed that grading of seeds did not improve germination percentage or seedling vigour. Cultivar differences were observed for germination percentage. Germination ranged from 97% in cv. Ageti 76 to 78% in cv. Partap and Local. None of the 18 fungal species (belonging to 13 genera) recovered from the graded seeds exhibited specificity with respect to seed grade except Fusarium moniliforme, its incidence was greatest on shrivelled and deformed seeds (Randhawa *et al.,* 1990).

An experiment was conducted by Krishnaveni and Vanangamudi (1989) on Maize cv. COH 1. Seeds graded by using 0.296 inch (G1) and 0.281 inch (G2) round hole sieves; seed passing through the 0.281 inch sieve was also collected (G3). Result revealed that seed recovery was 53.4, 28.4 and 18.2% for G1, G2 and G3, resp., corresponding germination values were 98.0, 95.0 and 88.0% and seedling vigour index values were 19.85, 17.95 and 13.70. After accelerated aging, germination was 85.0, 83.0 and 73.0% in G1, G2 and G3 seed, resp., while vigour index was 16.90, 11.95 and 10.85.

Seeds of maize hybrids are size graded and grouped into large (7.5-11.0 mm), medium (7.0-7.5 mm) and small (6.75-7.00 mm) seeds. The field performance study revealed that non-significant differences in growth attributes, yield components and yield due to size grading in all the hybrids (Kurdikeri *et al.,* 1998).

Sorghum

Sasthri *et al.,* (2001) reported that seed size significantly affected seed recovery, 100 seed weight, germination and seedling vigour. The seed recovery ranged from 9.7 to 70.3%. The recovery of large sized seeds retained in BSS 10 x 10 was 18.1%, whereas the recovery of medium sized seeds retained in BSS 8 x 8 was 70.3%. The recovery of small sized seeds was the least which was 9.7%. The 100 seed weight decreased from 1.408 to 0.982 g with decrease in seed size and size grades. The large seeds retained in BSS 7 x 7 recorded the highest germination of 95%. It was followed by medium sized seeds retained in BSS 8 x 8 sieve. The seeds retained in BSS 10 x 10 sieve recorded the lowest germination.

Singh (1988) reported that the storage quality of large (3.5 mm) and medium (3.0 mm) seeds was better than that of small seeds (2.7 mm).

Senthilkumar and Dharmalingam (1980) reported that in sorghum greater increase in dry weight due to larger seed size and relatively high vigour associated with the large seed could be described to more mature embryo containing adequate nutrient reserves both contributing its physiological stamina or vigour factor residing in it (Heydecker, 1972 and Pollock and Ross, 1972).

An experiment conducted by Mahajan *et al.,* (1998) on sorghum seeds parents 296A and SPV106 are bold seeded while 2077A, 168, CS3541 and CS3541(R6) have a smaller seed size. The study revealed that the observed and calculated mean of the F1 in respect of grain yield differed significantly indication non-additive type gene action while the gene action for seed size appeared to be additive. The cross 296A x CS3541 exhibited significant heterosis but non-significant inbreeding depression.

Tiwari and Gontia (2001) reported that seed germination and seedling vigour for bold-sized seeds slightly higher than ungraded seeds. Compared with ungraded seeds, bold and medium sized seeds had higher percentages of seed yield per plant (16.50 and 16.04%, respectively) and harvest index (12.00 and 13.47%, respectively).

Oilseeds Crops

Soybean

An experiment conducted by Dawande and There (1993) on soybean cv. Moneta seeds are graded into small (5.5 g), medium (7.3 g), large (12.0 g) and ungraded (9.0 g) categories. Germination, plant height, pods/plant, grains/plant and grain yield were highest with large seed.

An experiment conducted by Kausal *et al.,* (2008) to study the optimum sieve size (2.8, 3.2, 3.6, 4.0 or 4.4 mm) for grading the seeds of soybean cultivars JS-335, MACS-13, MACS-124 and PK-472. Concluded that grading soybean cultivars based on a sieve size of 3.6 mm was more effective and economical than grading based on a sieve size of 4.0 mm (recommended). The proposed sieve size of 3.6 mm, the recovery of good seeds increased by 6.0-7.0%. Seeds recovered using the proposed sieve sizes were acceptable in terms of germination percentage and physical purity.

An experiment conducted by Khandagale *et al.*, (2007) to study the effects of seed size (large, >13.60 g; medium, 10.80-13.60 g; and small, <10.80 g) and storage period (30, 60, 90, 120, 150, 180, 210, 240 or 270 days after harvesting) on the germination of seeds of various soybean genotypes. MAUS 2, MAUS 1 and MAUS 59 had large seeds. MAUS-62-2, MAUS 32, MAUS 38 and MAUS 61-2 had medium seeds. MAUS 60, DS 1 and Monetta produced small seeds. Large seeds recorded higher mean seed germination (78.53%) than medium (76.09%) and small (63.51%). During storage, the deterioration in germination was greater in large seeds than in small and medium seeds. Seed germination decreased as the storage period increased (77.77 and 68.81% at 30 and 270 days after harvesting, respectively). Large seeds germinated earlier than small and medium seeds.

Vanangamudi (1988) used breeder seeds of soybean var. CO-1, Braga, DS 74-37, Hardee, Hill and DGM-24 are size grading using 15/64" (6.00 mm) and 14/64" (5.6 mm) sieves and seeds retained by the respective sieves are designed as large and small seeds. Result revealed that small seeds found to maintain its viability during storage recording 76.0 and 36.7 % germination 73.5 and 33.6 % recorded by large seeds respectively at 8 and 16 months of storage.

Verma and Gupta (1975) observed that a small seed was found to deteriorate slowly than large seeds and also large seeds have longer root and shoot length than small seeds because of initial capital in large seed as compared to lesser food reserve in small seeds.

Groundnut

Varman *et al.,* (1990) concluded that growth and yields determined for 8 groundnut cultivars with 100-seed weights between 20 and 47 g. dry matter production at 15 d after sowing and pod yield at 105 days after sowing were positively correlated with 100-seed weight; pod yield was highest in cv. VG 77 (8.81 g/plant), which had the largest seeds.

Kale *et al.*, (1988) reported that a positive and significant correlation between oil content per seed and 100-seed weight. In all of the cultivars their maximum percentage of oil was in medium sized seeds.

An experiment conducted by Ramadevi and Rama Rao (2005) on two cultivars (JL 24 and TPT 4) and five seed sizes (Bold, medium, small, shriveled and ungraded seed). Seeds are graded into five different sizes by manually and by its test weight. The test weight of bold seed was 54.8 g in JL 24 and 46.5 g in TPT 4, medium seed (41.6 g in JL 24 and 38.03 g in TPT 4), small seed (29.5 g in JL 24 and 28.7 g in TPT4), shriveled seed (22.05 g in JL 24 and 21.25 g in PT 4) and ungraded seed (34.2 g in JL 24 and 33.15 g in TPT 4). The result revealed that the field emergence was higher in bold and medium sized seed than ungraded seed in both genotypes. The high percent of field emergence recorded by bold seed compared to small and medium sized seed could be ascribed partly to large reserves present in seed and partly attributed to the role of small embryonic activation and enhanced growth rate (Khare *et al.,* 1996). Plants raised from larger seeds had more plant height, more number of primary, secondary branches and leaf area while it as lower in shriveled seed. The plants from bold seed recorded significantly higher total dry matter followed by medium seed while shriveled seed recorded lower values. The number of pods per plant was significantly higher in plants from bold seed with 15.10 followed by medium sized seed with 12.90. The lowest number of pods per plant was recorded in plants from shriveled seed with 6.9 followed by small sized seed with 9.3. The seed index of plants from bold seed was highest with 52.51 g followed by medium sized seed with 39.84 g. The plants from shriveled seed recorded lower seed index with 21.65 g followed by small sized seed with 29.12 g. The pod yield was more in the plants from bold seed followed by medium sized seed while plants from shrivelled seed recorded less pod yield

Islam *et al.*, (2007) reported that Leaf area index (LAI), dry matter (DM) production, yield and yield components and also seed quality of groundnut varied significantly due to variation of seed size. Planting of large seeds (>10 mm) produced significantly higher LAI, DM, mature pods/plant, 1000 seed weight, pod yield, harvest index and shelling percentage than those produced from small (5-7 mm) or bulk seeds (upgraded). Large seeds, on an average, gave 13.1%, 37.2% and 19.6% higher yield over medium, small and bulk seeds respectively. The percent of germination, length of seedling, dry matter content and vigour index were more when the crop was raised from large seeds in both the years.

An experiment conducted by Sahoo *et al.,* (1988) using bunch groundnut of four cultivar Dh 3-30, TMV-2 and S-206 retained by 7.42 mm and JL-24 retained by 8.59 mm sieve are termed as bold and seeds passed through these sieves are termed as small. The results showed that plants raised from bold seeds produced higher yields than small seeds. In case of oil content there should be significant difference observed. Bold seeds contained more oil than small seeds. There is non significant difference among seed quality parameters such as, germination; root and shoot length, dry weight of seedling and vigour index.

Misra and Gaur (1982) reported in TG-1 variety of groundnut that the medium seed (bet 7-9 mm) contained maximum oil than bigger (> 9mm) and Small (< 7 mm), while Reddy (1978) reported that large seeds have more oil content than small seeds in peanut.

Sunflower

Sunflower exhibits a wide variation in seed size and seed weight due to poor seed filling which affects uniformity of crops (Saleem *et al.,* 2003).

An experiment conducted by Krishnaveni Sivasubramanian, (2001) the seed size classified as large (G1; 4.0 mm (10/64 inches) retained), medium (G2; 3.6 mm (9/64 inches) retained), small (G3; 3.2 mm (8/64 inches) retained), and ungraded (G4; a mixture of seeds above the size of 8/64 inches). Result revealed that the germination and vigour index was higher for G1 achenes, and large and medium sized achenes had 8% greater germination than the small sized achenes. The ungraded achenes showed a similar trend to G2. The weight of filled achene per head, kernel/husk ratio, 100 seed weight and seed yield were more pronounced using G1. Considering the total recovery, G1 recorded the optimum of 80%. Though G3 recorded 95% seed recovery, it is inclusive of small sized seeds. G2 recorded the uniform size of seeds which can be used for grading the seeds. Results also revealed that G1 showed positive association between seed size, germination and crop performance.

An experiment conducted by Dharmalingam and Basu (1989) to study the influence of achene size on seed quality in sunflowers cv. EC. 68415. Revealed that the 100-achene wt, seed wt and pericarp wt showed a linear association with achene size. The 3 dimensional measurements showed that the length and breadth of achenes decreased concomitantly with the reduction in achene size. The germination potential of achenes did not differ significantly; however, field emergence was significantly higher for the large and medium size achenes than the small ones. Seed vigour evaluations confirmed the superiority of the large and medium size achenes over small and ungraded ones. Use of size 4 and 6 wire mesh sieves as scalping and grading screens, resp., not only improved seed quality but also consumer preference on account of the uniformity of seed size.

Saleem *et al.*, (2003) using three revalidated seed lots of Morden sunflower seeds having 70%, 68% and 69% germination are graded into four groups heavy seeds, medium seeds, medium seeds and light seeds using Delta type-51 (Denmark made) specific gravity separator. The recovery % on specific gravity seed revealed that 12.4% of the seed are heavy, 35.4% heavy medium and 44% medium and 8.3% light seed category. 89 % of the seeds are either heavy medium or medium seeds. Significant differences are found for all seed quality parameter among different specific gravity grade. The 100 seed weight ranged from 5.86 g to 7.16 g in different class of specific gravity grades. Similar observations are made by Prasad, *et al*., (1994) in sunflower seeds. Germination percentage was recorded maximum (73%) in heavy seeds and minimum (64%) in light seeds. Seedling length and seedling dry weight are highest (20.99cm and 0.177 g) in heavy seeds and minimum (16.04 cm and 0.146 g) in light seeds. vigour index are highest (1536) in heavy seeds and lowest (1084) in light seeds. while electrical conductivity of seed leachate was lowest (1480 dSm-) in heavy seeds and highest (1855 dSm-) in light seeds. When the seeds of different specific gravity grades are sown in field, the crop growth and yield parameters differed significantly. Maximum field emergence (68%) and plant population (65%) at a harvest are observed in heavy seeds and minimum (57% and 50%) in light seeds. head diameter and number of filled seeds are maximum (21.83cm and 742.34) in heavy seeds and minimum (16.72 cm and 522.72) in light seeds. Seed yield per ha also maximum (13.34 q/ha) in heavy seeds and minimum (5.98 q/ha) in light seeds.

Kaya and Day (2008) concluded that large seeds produced vigorous germination and seedling growth yet small seeds could also be used for successful sunflower production in salt affected areas.

Mustard

Dubey *et al.,* (1989) showed that in 3 Brassica juncea cultivars, large seeds were superior to small seeds in various germination and seedling vigour tests such as electrical conductivity of leachate, radical and plumule length, germination after 3 d, soaking in water (at 40°C for 4h), emergence on brick gravel and field emergence. Field emergence showed positive association with all the vigour tests except electrical conductivity of leachate and radical length.

Dubey *et al.,* (1989)reported that seeds of three varieties namely Varuna, Rohini and Vaibhav are graded as large and small by using 2.1 mm sieve for Varuna and Rohni and 1.5 mm sieve for Vaibhav. Among the seed grades, the large grade was superior for all the vigour test parameter compared to small.

Pulses Crops

Green gram and Black gram

Babu *et al.,* (1990) recorded in 15 cultivars of V. radiata, seed wt was positively correlated with percentage germination, seedling height and DW, root length and primary leaf length, breadth and area. In 15 V. mungo cultivars seed wt was positively correlated only with root length, primary leaf length and area and seedling DW.

An experiment conducted by Nijhawan *et al*., (1989) in mungbean cv. Pusa Baisakhi, sowing large seeds (retained on an 8/64-inch mesh sieve), medium seeds (retained on a 7/64-inch sieve), small seeds (passing a 7/64-inch sieve), graded (bold) seeds and bulk ungraded seeds gave seed yields of 1.45, 1.54, 1.07, 1.81 and 1.37 t/ha, resp. The number of pods/plant was highest with graded (bold) seeds.

Gram

An experiment conducted by Anuradha *et al.,* (2009) to study the influence of seed size on physiological and biochemical seed quality characters in Bengal gram cv. CO 4 using seeds retained on 19/64”, 18/64”, and 16/64”, round perforated metal sieves and with seeds passed through 16/64”, round perforated metal sieves along with control. The result revealed that larger size seeds retained on 19/64: round perforated metal sieves recorded the maximum germination (86%) and seedling vigour (3903). The protein content (22.25 %), á-amylase activity (29.4 mm) and dehydrogense activity (0.540) are also more in larger seeds followed by medium sized seeds, indicating that seed size had a positive association with seed quality parameters in chickpea.

Gurbanov and Berti (1970) suggested that the increase in germination in larger seeds might be dueto increased activity of redox-enzymes helping in breaking down the complex food material in to simple soluble sugars.

Eser *et al.,* (1991) reported that seeds of three varieties are graded by size into 3 groups and sown in a randomized block design for observations on yield and growth. Greatest values for seedling emergence/m^2, time to 50% flowering, plant height, plants/m^2, biological and grain yields and harvest index were obtained from large seeds, with the lowest values for these characters recorded for small seeds. The large seed group produced on average 31.4% greater economic yields than the small seed group.

Emenky and Khalaf (2008) reported that medium seeds of chickpea are superior in seedling emergence percentage, while large seeds manifested higher plant height, height of the lowest pod and number of primary branches

Nijhawan *et al.,* (1990) conducted a trial with 4 gram (Cicer arietinum) cultivars, sowing large (mean 100-seed wt 14.5 g), ungraded (12.3 g) or small seeds (8.4 g) give av. seed yields of 3.11, 3.07 and 2.78 t/ha, resp. There were significant yield differences between cultivars but not between seed grades.

Pigeon pea

Nath and Bhardwaj (1989) reported that the comparison of 2 pea cultivars differing in seed size showed that bold-seeded cv. EC 4108 produced higher levels of endogenous auxin and cytokinin-like substances and accumulated higher amounts of starch and proteins in the seed than small-seeded cv. IC 4604. It is suggested that capacity of the seed to grow and accumulate reserve materials is regulated by endogenous levels of auxin and cytokinin-like substances.

Arthur *et al.,* (1991) noticed that pea lines HA001, HA002, HA003 and HA004, differing in mean seed size (ranging from 78-473 mg) and composition. For the larger-seeded genotype HA004, percentage protein increased with increasing seed size, while for the small-seeded genotype (HA003) there was mid-range negative value. It is suggested that any assessment of percentage protein in pea genotypes must take account of seed size.

Verma *et al*., (2005) reported that hundred seed weight and seedling vigour index revealed significant differences among seed grades of all cultivars. Large seeds expressed high seedling vigour index than small seeds in all cultivars.

REFERENCES

1. Anuradha, R.; Balamurugan, P.; Srimathi, P. and Sumathi, S. (2009). *Legume Res., 32(2)*: 133-135.
2. Arthur, A. E.; Adams, H.; Strouts, K., Jones, D. A.; Wang, T.L. and Hedley, C. L. (1991). *Seed Science Research., 1(4)*: 203-208.
3. Babu, B. C.; Muralidharan, V.; Rani, M. S.; Nagarajan, M.; Rangasamy, S. R. and Perumal. R. K. (1990). *Journal of Agronomy and Crop Science., 164(3):* 213-216.
4. Baskin, C. C. and Baskin, J. M. (2005). Seeds Ecology, Biogeography and Evolution of Dormancy and Germination. *Academic Press*., Pp: 200-207.
5. Brocklehurst, P. A., Moss, J. P. and Williams, W. (1978). *Ann. Appl. Biol. 90:* 265-276.
6. Campbell, C. A., Davidson, H. R. and Winkleman, G. E. (1981). *Can. J. Plant Sci., 61:* 549-563.
7. Dawande, V. B. and There, D. N. (1993). *Journal of Soils and Crops., 3(2):* 144-145.
8. Dharmalingam, C. and Basu, R. N. (1989). Seed *Research., 17(2):* 128-134.
9. Dubey, A. K., Poonam Singh., Goyal, R. D. and Katiyar, R. P. (1989). *Seed Research., 17(2):* 204-207.
10. Dubey, A. K., Singh, P., Goyal, R. D. and Katiyar, R. P. (1989). *Seed Research., 17(2):* 208-210.
11. Egli, D. B. and Wardlaw, I. F. (1980). *Agron. J., 72:* 560-564.
12. Egli, D. B.; Leggett, J. E. and Wood, J. M. (1978). *Agron. J., 70:* 127-130.
13. Egli, P. B., Tekrony, D. M. and Wiralaga, R. A. (1990). *Journal of Seed Technology., 14:* 1-12.
14. Emenky, F. A. and Khalaf, A. S. (2008). *Research Journal of Seed Science., 1(1):* 11-18.
15. Eser, D.; Ukur, A. and Adak, M. S. (1991). *International Chickpea Newsletter., 25:* 13-15.
16. Giles, B. E. (1990). *Heredity., 64:* 239-250.
17. Gurbanov, Y. V. and Berti, Z. G. (1970). *Indian J. Pl. Physiol., 25(4):* 427-431.
18. Hamilton, R. I.; Subramanian, B., Reddy, M. N. and Rao, C. H. (1982). *Ann. Appl. Biol., 101:* 119-125.
19. Heindl, J. C. and Brun, W. A. (1984). *Crop Sci., 24:* 542-544.
20. Heydecker, W. (1972). Vigour in “viability of seeds: (ed. Roberts, E. H.), Chapman & Hall Ltd., II New letter lane, London. Pp: 209-251.
21. Islam, M. S.; Sultana, C. W.; Jahan, M. A.; Hossain, M. M. and Hasan, M. S. (2007). *International Journal of Sustainable Agricultural Technology., 3(6):* 28-31.
22. Kalakannavar, R.M.; Shashidhara, S. A. and Kulkarni, G. N. (1989). *Seed Research., 17(2):* 182-185.
23. Kale, D. M. Gadgil, J. D. and Murty, G. S. (1988). *Journal of Oilseeds Research., 5(2):* 170-175.
24. Kausal, R.T.; Jeughale, G.S.; Kakade, S.U. and Pavitrakar, N.R. (2008). International Journal of Agricultural *Sciences., 4(1):* 59-62.

25. Kawade, R. M.; Ugale, S. D. and Patil, R. B. (1988). *Seed Research., 16(2):* 222-225.
26. Kaya, M. D. and Day, S. (2008). *African Journal of Agricultural Research., 3(11):* 787-791.
27. Khairwal, J. S. and Tomer, R. P. S. (1976). Science and Culture., 47(5): 175-177.
28. Khandagale, G. B., Ladke, V. P. and Dahiphale, R. V. (2007). *Annals of Plant Physiology., 21(1):* 140-141.
29. Khare, D.; Rout, N.D.; Rao, S. and Lakshmi, J. P. (1996). *Seed Res. 23(1):* 75-79.
30. Krishnaveni, K. and Sivasubramanian, K. (2001). *Madras Agric. J. 88(1/3):* 133-134.
31. Krishnaveni, K. and Vanangamudi, K. (1989). *Madras Agric. Journal., 76(5):* 285-287.
32. Kurdikeri, M.B.; Ashwathaiah, B., Ashwathnarayana, S. C., Rajenderaprasad, S. and Deshpande, V. K. (1994). *Karnataka J. of Agri. Sci., 7(4):* 437-441.
33. Lambert, R. J.; Alexander, D. E. and Rodgers, R. C. (1967). *Crop Sci., 7:* 143-144.
34. Lokesh, K.; Reddy, D.M.V.; Krishnappa, N.; Chandrakanthappa Kammar and Swamy, S. N. (2000). *Current Research Bangalore., 29(7/8):* 122-126.
35. Mahajan, R.C.; Sudewad, S. M. and Jawale, L. N. (1998). *J. MAU., 23(3):* 310-311.
36. Mangat, B.K. and Satija, D.R. (1991). *Crop-Improvement., 18(1):* 27-31.
37. Mangat, B.K.; Satija, D.R. and Gupta. V.P. (1988). *Indian J. of Genetics and Plant Breeding., 48(1):* 91-94.
38. Martinez-Carrasco, R and Throne, G. N. (1979). *J. Exp. Bot. 30:* 669-779.
39. Misra, S. D. and Gaur, B. K. (1982). *Indian J. of plant Physio., 25(1):* 106-109.
40. Moles, A.T. (2005). *Science., 307:* 783a.
41. Nath, V. and Bhardwaj, S. N. (1989). *Indian Journal of Plant Physiology., 32(2):* 178-181.
42. Nijhawan, D. C.; Hooda, I. S.; Saxena, K. K. and Yadav, R. K. (1989). *Haryana J. of Agronomy., 5(2):* 163-165.
43. Nijhawan, D. C.; Hooda, I. S., Saxena, K. K. and Yadav. R. K. (1990). *Haryana Journal of Agronomy., 6(1) :* 83-86.
44. Nijhawan, D.C.; Verma, O. P.; Hooda, I. S. and Tyagi, R. C. (1989) *Haryana J. of Agronomy., 5(1):* 40-44.
45. Patel, Z.G.; Chandhari, P. R. and Kumar, V. C. (1994). *Gujarat Agricultural University Research Journal, 20(1):* 146-147.
46. Pollock, B. M. and Ross, E. E. (1972). Seeds and Seedling Vigour. In "Seed Biology (ed. Kozlowskil, T. J.). *Academic Press,* New York. Pp: 313-307.
47. Prasad, S. R.; Sathyanarayana Reddy, A.; Seenappa, K. and Venkata Reddy, T. N. (1994). *J. oil. Seed. Res., 11(1):* 196-200.
48. Ramadevi, J. and Rama Rao, G. (2005). *Madras Agric. J., 92 (7-9):* 584-588.
49. Ramanadane, T. and Thirumeni, S. (2001). *Madras Agric. J., 87(7/9):* 503-505.
50. Ramseur, E. L.; Quisenberry, V. L.; Wallace, S. U. and Palmer, J. H. (1984). *Agron. J., 76:* 442-446.
51. Randhawa, H.S.; Dey, S.K.; Kaur, J.; Sharma, H. L.; Hari Singh; Khehra, A. S. and Singh, H. (1990). *Annals of Biology, 90(6):* 49-52.
52. Reddy, S.K. (1978). *Thesis Abstract., 4(2):* 89-90.
53. Sahoo, A.K.; Kulkarni, G. N. and Vyakaranahal, B. S. (1988). *Seed Research, 16(2):* 136-142.
54. Saleem, S.I.; Naranyana Swamy, S.J.; Prasanna, K. P. R. and Rajendra Prasad. (2003). *Seed Research, 31(1):* 8-12.
55. Sasthri, G., Srimathi, P. and Malarkodi, K. (2001). Madras Agric. J., 88(1/3): 143-144.
56. Senthilkumar, K. A. and Dharmalingam, C. D. (1980). *Madras Agric. J., 67:* 453-461.
57. Sheldrake, A. R. and Saxena, N. P. (1979). *Ann. Bot., 43:* 459-466.
58. Singh, A. R. (1988). *Seed Research., 16(2):* 251-253.
59. Singh, B. P. (1970). *Madras Agric. J., 57(8):* 449-452.
60. Smith, R. H. and Bass, M. H. (1972). *J. Econ. Ent., 65:* 606-608.
61. Streeter, J.G. (1978). *Agron. J., 70:* 74-76.
62. Tesng, S. T. and Lin, C. I. (1962). *Proc. Int. Seed. Test. Assoc., 27 :* 459-475.
63. Tiwari, V. N. and Gontia, A. S. (2001). *Advances in Plant Sciences, 14(1):* 111-114.
64. Torres, M. and Martinez Honduvilla, C. J. (1990). *Agricoltura Mediterranea, 120(2):* 220-225.
65. Vanangamudi, K. (1988). *Seed Research, 16(1):* 75-80.
66. Varman, P. V.; Arjunan, A.; Manaharan, V.; Ramalingam; R. S. and Sivaram; M. R. (1990). *Madras Agricultural Journal, 77(5-6):* 260-261.
67. Verma, R. S. and Gupta, P. C. (1975). *Seed Research, 3(1):* 39-44.
68. Verma, S. K.; Bajpai, G. C.; Tewari, S. K. and Jogendra Singh (2005). *Legume Research, 28(2):* 143-145.
69. Vyas, R. P.; Kumar, R.; Prakash, V. and Katiyar, R. P. (1990). *Seed Research, 18(1):* 44-46.
70. Wood, D. W.; Longden, P. C. and Scott, R. K. (1977). *Seed Sci. and Technol., 5:* 337-352.

Received : February-2013; Revised : April-2013; Accepted : May-2013