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A Critical Overview of Chickpea Seed Technological Research

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The pulses are the most important constituents of vegetarian diet because they contain higher percentage of protein and oil as compared to the cereals. These are the rich source of energy; minerals and vitamins, hence occupy an important place in human dietary needs. The chickpea grain contains high quality protein and lysine ranging from 18-23 per cent [1]. The amino acid composition of pulse protein is such that if mixed with diet of cereals it has a biological value far greater than that of either component alone [2]. Thereby assume great significance with reference to protein nutrition of the population around the globe as they contribute about 27 per cent of the total dietary protein. The Indians are perhaps fortunate that the cultivation and consumption of pulses has, from times immemorial, been a part of our life. But there has always been a wide gap between demand and supply of the pulses. The per capita availability of pulses [3] has declined from 71 g day/person (1955-56) to less than 35 g day/person (2002-03), which is far less than the optimum requirement per capita/day estimated to be 104 g.

There are two types of chickpeas viz., *desi* and *kabuli* grown in the world [4]. The *desi* type seeds are used in both forms green as well as dry. The green seeds are used as *'CHHOLE'* for vegetable purpose and *'HOLA'* a roasted form. The dry seeds are puffed and called *'CHANA'*. The flour is made from cotyledons of seeds, after removal of seed coat is called *'BESAN'* and is used for preparation of many kinds of snacks; *'NAMKINS'*, *'PAKORA'*, *'CURHI'* and sweets in northern India. The green tender tops of young branches are also used as vegetable (*SAAG*), after 'nipping'. In Middle East countries the foods prepared are known as *'HOMMOS'*, *'BITEHINEL'*, *'FALAFEL'*, *'TISQID'*. Recently due to change in food habits of urban people in India a steady demand for Kabuli types is increasing for preparing *'CHHOLE'* and eating it with *RICE, PURIS, CHAPATIS, KULCHE AND BHATURE*.

Pulses play another important role in agricultural production due to their association with *Rhizobia* in their root nodules to fix atmospheric nitrogen which in turn is very useful in crop rotation [5]. The pulses are able to do relatively well even under poor soil fertility conditions. These have been occupying 6-8 m ha of area in various years, but the unhappy situation is that such a vast area has produced only 11- 12 million metric tonnes of grains contributing about 70 per cent of total world chickpea production [6]. Chickpea or Bengal gram (*Cicer arietinum* L.) is the third important winter season pulse grain legume crop of India. In spite of release of a number of high yielding varieties in India in last five decades or so, there stands instability in total chickpea production from one year to another [3]. The chickpea production increased from 3.7 mt in 1949-50 to 6.2 mt in 1951-60 from an area of 8.8 mha. The area and production has decreased consistently in the last five decades as compared to 1951-60 (Table 1). However, there is consistent increase in average yields in the last five decades. The yield levels have changed from 515 kg/ha to 817 kg/ha, which is nearly 55 per cent increase over 1951-60 whereas, it is 13 per cent increase over the last decade. It has taken place due to development of new high yielding varieties with greater potential. However, the potential of these varieties has not been realised and instability in yields still exists. The average yield (8 qt/ha) of chickpea in India is still half of the other Asian

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Table 1. All India area, production and average yield of chickpea in last five decades.

Year	Area (m ha)	Per cent decrease	Production (m t)	Per cent decrease	Average yield (kg/ha)	Per cent increase
1951-60	8.8	-	6.2	-	515	-
1961-70	8.5	-3.40	5.1	-17.74	602	+16.9
1971-80	7.6	-13.63	4.9	-20.96	634	+23.1
1981-90	7.0	-20.45	4.7	-24.19	671	+30.0
1991-98	6.8	-22.72	5.2	-16.12	762	+48.0
1999-03	5.8	-34.00	4.7	-24.19	817	+55.0

Source: Agricultural statistics at a glance, Ministry of Agriculture, Govt. of India.

countries, which is the crux of the researchable issues.

The factors for decrease in area and production are that crop is grown on marginal lands, irresponsive to increased doses of fertilizers and irrigations and it's photo-thermo sensitive in nature [7]. There are various factors; abiotic and biotic stresses, which aggravate the situation. The adoption of other inputs relating to improved production technology for pulses has been low due to their lower profitability under irrigated conditions, where as a greater response has been noticed from competing crops like wheat mustard, toria, potato, pea and cotton. Due to its adaptation to dry areas chickpea is not only poorly managed but also has left little scope for crop production technological variations [8]. Lack of information about improved technology, lower adoption of rhizobium culture, high variability in yield levels, inherent low yielding potential of existing varieties, lack of yield stability, susceptibility of varieties to an array of diseases and insect-pests and non-availability of quality seed in required quantity at reasonable price and right time are some of the other causes of concern to the researchers in India. Hence, high priority has to be accorded for increasing pulse production through supply of quality seed to the farmers [9]. The quality seed refers to its high vigour and viability under all odds and the ability of seed to develop into a healthy seedling and ultimately a healthy plant-giving rise to production up to it's full. Poor plant stand due to poor quality seeds, variable soil moisture, depth of sowing, soil temperature, diseases and insect-pests infestations are established reasons for unstable yield levels in chickpea in almost all parts of the world.

Due to constant decrease in production, the per capita net availability of chickpea in India has decreased to 63.3 per cent over 1951-60 levels (Figure 1).

World chickpea production has ranged from 7-9 million tonnes in recent years, and is approximately four times higher than lentil. However, world trade is similar to lentil because India produces and consumes approximately 4–6 million tonnes of chickpea each year. The import for *kabuli* type chickpea has tremendously increased in the country along with *desi* 'gram dal', involving nearly 466 crore of rupees in 1997-98 even though India has the privilege of having largest acreage under pulses in the world. Therefore, there is a need to upgrade the total production of chickpea either by increasing the area or by increasing average yield of chickpea in the country. The major exporting countries are Turkey, Canada, Australia, Syria, and Mexico. The major chickpea importing countries are India, Bangladesh, Spain, Pakistan and Algeria [10].

Distribution:

The crop is considered to have originated in South-eastern Turkey [11]. Van der Maesen [12] believed that the species originated in the southern Caucasus and northern Persia (Figure 2). However, Ladizinsky [11] reported the center of origin to be southeastern Turkey. Van der Maesen [13] recognized the southeastern part of Turkey adjoining Syria as the possible center of origin of chickpea based on the presence of the closely related annual species, *C. reticulatum* Ladizinsky and *C. echinospermum* P.H. Davis. Wild *C. reticulatum* is interfertile with the cultivated pulse and morphologically closely resembles cultivated *C. arietinum*. It is regarded as the wild progenitor of chickpea [11]. Chickpea is grown in South Asia (India, Pakistan, Bangladesh, Srilanka, Nepal and Myanmar), West Asia (Iraq, Turkey, Syria, Cyprus), Europe (Italy, Spain), North

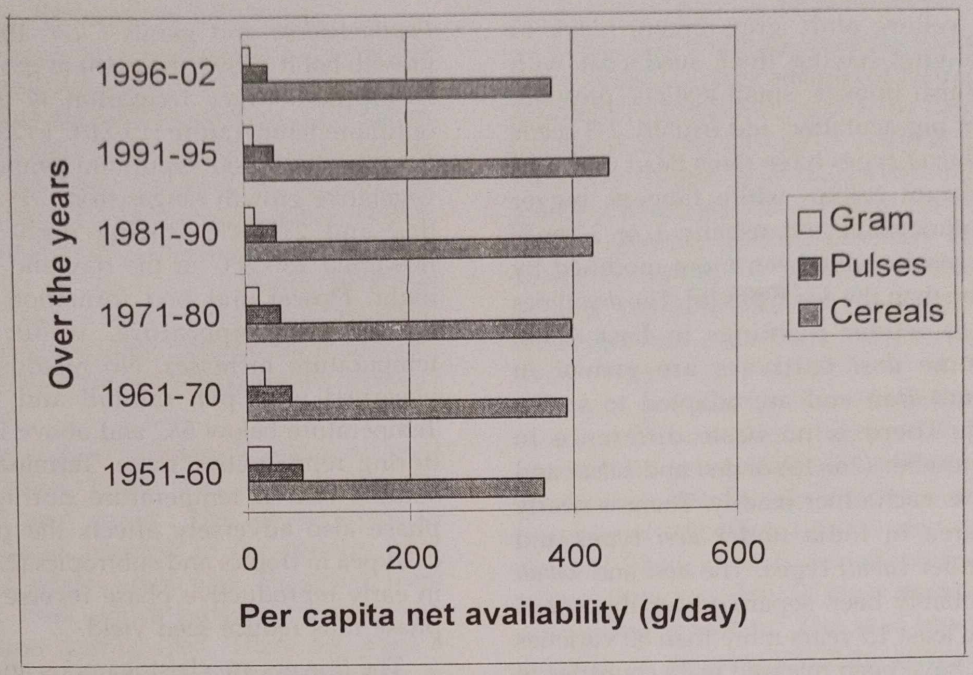

Figure 1. Per capita net availability (g/day) of cereals, pulses and gram over the years in India. Source: Agricultural Statistics at a glance Ministry of Agriculture, Govt. of India

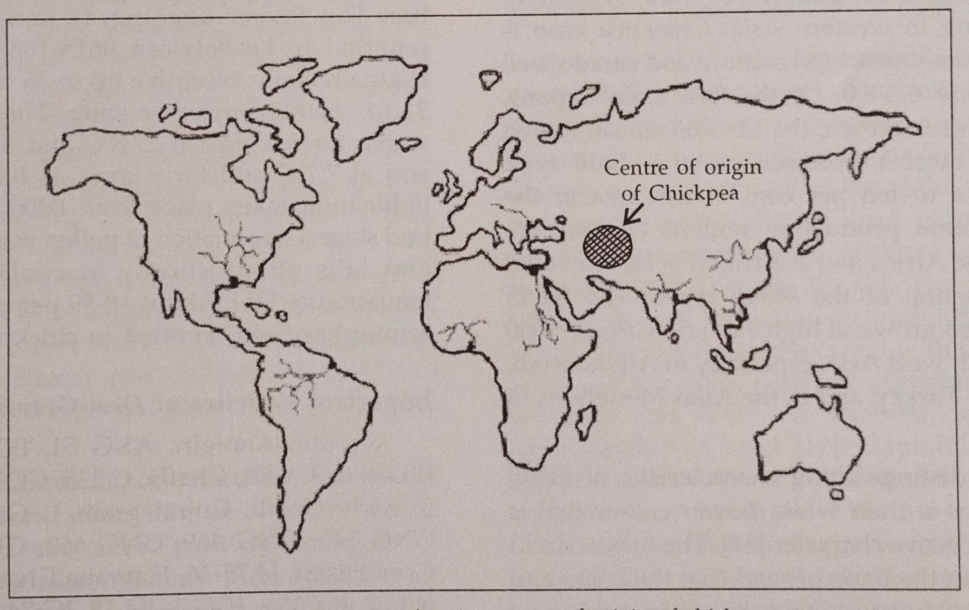

Figure 2. world map showing centre of origin of chickpea.

Africa (Tunisia, Egypt, Algeria, Morocco), East Africa (Ethiopia, Kenya, Sudan), America, Mexico and C.I.S. In India Madhya Pradesh, Chhatisgarh, Rajasthan, Uttar Pradesh and Maharashtra are major growing areas. It is also grown in A.P., Assam, Bihar, Gujrat, Haryana, H.P., Karnataka, Nagaland, Orrisa, Punjab, Tamilnadu and West Bengal.

Types of Chickpea:

The chickpea has been divided in two groups [14]: (i) Macrospora- referred as *kabuli* and (ii) Microspora- referred as *desi* by Indian breeders. The *desi* types are characterized by small, irregularly shaped seeds of various colours (light brown, brown,

dark brown, yellow pink, grey, green, black or variegated colours) having thick seed coat with purplish or bluish flowers, small leaflets, presence of anthocyanin pigmentation and usually 2-3 seeds per pod. The *kabuli* types have rams head or round seed shape, cream colour, white flowers, bigger leaflets, no anthocyanin and usually 1 or 2 seeds per pod. The *kabulis* have been more modified by human selection than the *desi* types [6]. The *desi* types are adapted to winter plantings in East Asian countries. Some *desi* cultivars are grown in Afghanistan and Iran and are adapted to spring planting [15]. There is no basic difference in chromosome number (2n=16) of *desi* and *kabuli* and both types cross each other readily. There is nearly 85 per cent area in India under *desi* types and 15 per cent under *kabuli* types. The *desi* and *kabuli* have most probably been separated for thousands of years. In the least 15 years more than 80 varieties of *kabuli* types have been released in 22 countries of the world [16]. The *desi* types are comparatively small seeded and are adapted to winter (October-November) sowing in eastern Asia and the large seeded *kabuli* types are adapted to summer (March-April) planting in western Asia. Chickpea crop is particularly sensitive to soil salinity and can do well in pH range of 6.5-8.0. Of the five main regions, where chickpea is grown, the Mediterranean region and Latin America produce mostly *kabuli* type chickpea. Five to ten per cent of the area in the other three main production regions (Indian sub continent, East Africa and Australia) is also devoted to the production of the *kabuli* types. The *kabuli* chickpea is also grown at high elevation area (>1000 m elevation) in west Asia, especially in Afghanistan, Iran, Iraq and Turkey, and in the Atlas Mountains of North Africa.

The most distinguishing characteristic of *kabuli* from *desi* types is their white flower colour that is monogenic recessive character [17]. The *kabulis* could be identified on the basis of seed coat thickness and colour (cream/white) and because of lot of introgression of *kabuli* germplasm into *desi* germplasm and vice versa [18; 19; 20], an array of genotypes in *kabulis* with varying degree of seed coat thickness and colour are found.

Breeding System and Flowering Morphology:

Chickpea is predominantly a self- pollinated crop with only 1.58-1.92 per cent natural cross- pollination [21; 22]. It belongs to family *Leguminosae*, sub-family *Papilionoideae* and genus *Cicer*. Its indeterminate growth habit allows the plant to grown vegetatively if supplementary irrigation is given or if the optimum temperature (15-21°C to 23-29°C) prolongs for a longer period. Optimum temperature for early vegetative growth ranges from 29°-32°C during the day and 21°-24°C during night. Whereas, for flowering 26°-29°C in the day and 18°-21°C in the night. Flower and pod formation in chickpea is related to temperature, it decreases as the temperature increases. No relationship has been observed with pH, rainfall and wind velocity. Temperature below 5°C and above 29°C is harmful during reproductive stage. Terminal drought and sudden rise in temperature during reproductive phase also adversely affects the productivity of chickpea in tropics and subtropics [23]. Winter rains in early reproductive phase reverse the vegetative phase thus reduce seed yield.

The flowers are cleistogamous and protandrous. The anthers burst one to two days before the bud opens. Flowers start opening between 0900-1000 hrs. However, anthesis may take place on the previous day of flower opening between 0900-1000 to 1430 hrs. The flower opening at Ranchi (India) was reported to be between 0615-1638 hrs. [24]. The stigma remains receptive up to 36 hrs, commencing 24 hrs before flower opening. The pollen remains viable for 8.30 hrs at 27.8°C and 95 per cent R.H. and at 7.7°C and for 9 days at 100 per cent R.H. Pollination takes place from 0800 to 1200 hrs. in bud stage. Germination of pollen was highest at 25°C and falls off drastically at cooler and warmer temperature [25]. About 18-59 per cent natural pod setting has been reported in chickpea [26].

Important Varieties of *Desi* Gram:

Avrodhi, Annigiri, AKG 51, BGD 72, BG 209, Bharti (ICCV10), Chaffa, C 235, CO3, CO4, DCP 92-3, Early Gulab, Gujrat gram 1, Gaurav, GNG 16, GNG 146, GNG 469, GNG 663, GL 764,GF 89-36, Gora Hisari, H 75-36, Haryana Chana No. 1, H-208, ICC 2, ICCV 4, JGG 1, JG 18, JG 74, JG 315, JG 322, JAKI 9218, Kiran (RSG 2), KWR 108, KDG 1168 (Alok), Karnal chana 1, L 550, Mahamaya 2, Pant G 186, Phule G 12, Pusa 240, Pusa 256, Pusa 261, Pusa 329, Pusa 362, Pusa 372, Pusa 391, Pusa 408, Pusa 413, PBG 1, PBG 3, RSG 44, Sadabahar, Sadbhawna, T3, T9, Ujjain 24, Uday, Viwash (Phule G5), Vijai, Vishal and WCG 2 (Surya).

Important Varieties of *Kabuli* Gram:

JG 5, L 551, Pusa 267, Pusa 1003 and Pusa 1053.

Seed Technology Research in Chickpea:

Work on chickpea improvement in India started in 1930s at Imperial Agricultural Research Institute, Pusa, Bihar. At that time the major emphasis was on selection of pure lines from the land races. Earlier the cultivars/lines were evaluated on the basis of their yielding ability and later emphasis was laid on collection of germplasm, studying of hybrid vigour and combining of desirable traits through hybridization. Finally breeding for improved plant type, increased harvest index and control of diseases and insect pests through resistant cultivars received greater attention.

Before dawn of seed industry in India, all seed was farmer saved. There was little difference between seed and grain. The importance of improved seed was realized in the country after 18000 tones of wheat seed was imported from Mexico during 1966, which brought revolution in wheat production during 1968. There has been a rapid advancement in seed technology research in various crops in India and abroad from simple germination test of seed to seedling vigour tests [27], seed viability [28], seed health [29], seed production and seed certification, maintenance of genetic purity, seed processing, seed treatment, packaging [30], storage [31] and of course in the field of seed marketing. In hybrids, the seed production technology has solved the problem of non-synchronization of male and female parents by using supplementary pollination, recommending appropriate planting ratio of male and female parental lines to get maximum hybrid seed, the pollen viability and stigma receptivity for maximum seed setting and knowledge of diagnostic characters for maintaining purity of the crop. Seed invigoration and seed treatment has helped to improve germination percentage and plant stand in the field [32].

However, in most of the research programs in chickpea, concentration has been on breeding programs and the seed production and its technology have received only little attention. A better seed production technology is vital to produce high quality seed in order to ensure reliable crop establishment and realizing the real genetic potential varieties. After green revolution in India, a strong requirement of sufficient high quality seed was felt to keep the existing levels of production as well as to upgrade the present levels. The farmers' demand and attitude regarding seed needs are also changing. They insist now on improved and genetically pure cultivars and demand high quality seeds, which are higher in germination, vigour and emergence.

Germination and its Improvement:

Germination test has been legally accepted as an index of seed quality, in spite of facing some serious problems of standardizing in some crops and varying results in classification of normal and abnormal seedlings. Seeds of chickpea belong to orthodox group in which the mean viability period is extended with a decrease in seed moisture [26; 33]. Under insect free ambient conditions of storage, seeds can be kept viable for at least 3-4 years. ISTA [34] has recommended a constant temperature of 20°C or daily temperature amplitude of 20°C-30°C for optimum germination test of chickpea. Minimum standard requires that a high quality chickpea seed should have germination above 85 per cent. Standard germination test in *kabuli* types is affected due to presence of mycoflora on thin seed coat. *Desi* types do not show much fungal infection during germination test due to their thick seed coat and anatomical structure. The *desi* types were found superior in germination than *kabuli* types and the germination and field emergence were significantly low in large *kabuli* seed group as compared to small and medium seed groups [35]. *Desi* types with coloured testa gives higher germination, field emergence and yield than that of *kabuli* types [23; 36].

Seed mycoflora have appreciable effects on seed germinability and quality, ultimately affecting crop productivity. Besides pathogenic organisms (borne externally or internally) saprophytic organisms directly or indirectly affect the ability of pathogens to cause infection during seed germination [37]. Mycoflora associated with chickpea seeds have also been reported [17; 38; 39; 40]. The storage fungi caused drastic reduction in viability of chickpea seeds [41]. The fungi associated with chickpea seeds are *Ascochyta rabiei, Fusarium oxysporum, Rhizoctonia bataticola* and *Alternaria alternata*, which affected germinability of seed [17]. Captafol and Bavistin showed maximum control of seed-borne pathogens followed by Hadron. The bio-control agent *Trichoderma harzianum* also gave significant reduction of seedborne pathogens over the untreated control [42]. All seed treatment (chickpea meal agar Benlate, Brassicol, Benlate + Brassicol, Benlate + Dithane M-45) significantly improved germination over control [43] and significantly reduced recovery of *Alternaria spp.*, except in case of the Benlate treatment. In similar studies in cowpea the chemicals Ridomil, Blitox-50 and Tetracycline were found at par in the control of bacterial leaf blight disease in the field and were significantly superior over unsprayed control. However, seed yield and 1000-seed weight were not influenced by the chemical sprays [44].

Germination in wild *Cicer spp.* could be increased by treatment of seed with gibberellic acid [45]. Benlate, Vitavax and Bavistin could improve laboratory germination over control by 26.7 per cent, 53.3 per cent, 60.0 per cent and 73.3 per cent respectively [46]. The halogenation treatment was found superior to germination, seedling growth, dry matter production, and vigour index in all the pulse seeds studied. There was also significant reduction in bruchid infestation in halogenated seed as compared to the control [47].

Seed inoculation:

Seed inoculation improves yield only for crops grown for the first time or after rice, where *Rhizobium* populations are naturally low or absent. In virgin sandy soils or for the first planting in heavier soils, inoculation is said to increase yield by 10-62% [48].

Seed and Seedling Vigour:

Seed and seedling vigour is one of the most important seed quality factors in the efficient production of crops, under today's economic pressures. Seed vigour as an indicator of quality is relatively new as compared to germination and purity. It is a complex character and a number of tests/parameters have been developed to evaluate seed vigour in crop plants [27; 28; 30; 49]. A good seed vigour tests should provide good reproducibility of results, easy interpretation and good identification of field performance potential. The fact that seed lots may have the same germination yet, may be quite different in the way they perform under stress in the laboratory and in the field, are well understood now. Seed vigour supplements the standard germination test for its quality [50].

In chickpea, seedling vigour has been stated to be improved by using fungicides (Benlate, Brassicol, and Dithane M-45) either alone or in combination [43]. No conspicuous differences in the viability and germination percentage of *desi* and *kabuli* types were reported [51]. However, the accelerated ageing test showed that the viability of seeds as well as the percentage of normal seedlings was much lower in *kabuli* than in the *desi* types. The results thus indicate that the *desi* types have higher vigour than the *kabuli* types. This provides advantage to the *desi* types over the *kabuli* types not only in maintaining higher viability over a prolonged storage period but also in the field emergence under adverse environmental conditions. In chickpea, *desi* lines with coloured testa showed higher percentage of emergence than the salmon-coloured *kabuli* lines [23; 36]. The laboratory and field vigour parameters, viz.; seed density and speed of emergence gave good prediction for seedling establishment in the field [52]. The *desi* types had advantage of higher standard germination and viability than *kabulis* due to their thick seed coat structure that is less prone to mycofloral infection during storage and emergence in field [53]. Thin seed coat in *kabulis* opens the avenues for imbibitional and pathogenic injuries. Physiological cracking of seed coat in *kabulis* reduces quality of seeds during storage too [54].

Plant Stand Establishment:

It is an established fact that quality seeds alone increase the productivity by the extent of 15-20 per cent [9]. Plant stand may be a major constraint in realization of genetic potential of existing varieties in major chickpea growing areas [55]. The factors for inadequate plant stand may be many, ranging from low germination and low vigour seeds to the effect of seed size, inappropriate agronomic practices adopted, inadequate soil moisture, poor health of seeds and higher temperature at sowing period. The optimum plant stand for chickpea was recommended as 33 plants/m^2 and it has been observed that the field emergence in *desi* types is better than *kabuli* types [51]. Field emergence in *kabuli* types could be increased up to 17.8 per cent by seed dressing with Thiram (3g/kg) just before sowing [56]. The results of standard laboratory germination tests are identical for *desi* and *kabuli*. However, *kabulis* show a lot of mycofloral infection during germination test, if the seeds are not dressed with a fungicide before testing. The field emergence differences under adverse soil physical conditions might be attributed to differences in seed vigour, mycofloral infection on seeds or soil borne infections. The emergence of cream coloured chickpea was erratic and reduced because of a seed rot and pre-emergence damping off caused by *Pythium ultimum* and *Fusarium solani*, through no conspicuous differences in the viability and germination percentage of *desi* and *kabuli* were observed [57].

Accelerated ageing test showed that the viability of seeds as well as the percentage of normal seedlings was much lower in *kabuli* than in *desi* types. The results thus indicate that the *desi* types have higher vigour than the *kabuli* types. This provides advantage to the *desi* types over the *kabuli* types not only in maintaining higher viability over a prolonged storage period but also in the field emergence under

adverse environmental conditions. The plant stand of chickpea were poor because of limited moisture in soil and is the major cause of large yield gap between farmer's field and experimental stations [58]. Improved stands can be obtained by placing seed at soil depths with adequate moisture and by selecting genotypes, which emerge better at sub-optimal bed conditions (23-24 per cent soil moisture).

Treating seeds with a fungicide in chickpea seems essential because there is hardly any area in the country where the wilt free seed of chickpea can be produced. The role of fungicides in relation to seed viability, vigour, field emergence, plant stand and disease survival in the soil as well as during storage needs to be strengthened. Treating seeds could improve field emergence in *desi* and *kabuli* types up to 2.5 per cent and 17.8 per cent, respectively with Thiram (3g/kg) just before sowing [56]. The application of fungicides significantly increases emergence in some brown and black coloured accessions that were highly resistant to seed rot [57].

Seed Size and Seed Coat Thickness:

The seed size indicates the amount of reserve food to give the plant a vigorous start from a bold seed. *Kabuli* type chickpeas (Mediterranean and Middle Eastern origin) generally have the largest seeds, and grow well under irrigated conditions. *Desi* chickpeas (Indian distribution) have smaller seeds, and yield better in Indian subcontinent, Ethiopia and often elsewhere. Crosses between *Kabuli* and *Desi* have produced strains with medium-size seeds and fair yields [59]. In the *kabuli* types, variation for 100 seed weight is wide enough and a range of 8.2- 65.5 g/ 100 seeds in a study of 300 *Kabulis* was reported [60]. A study of 108 accessions reported a range of 25-59 g/ 100 seed weight in *kabuli* chickpea. The *desi* types had 11.4-28.9g/100 seed weight in seven accessions/cultivars [35]. Previously small seed sized cultivars were developed in the country, according to their uses. However, recently the consumer preference has shifted to large seed size (>25g/100-seeds). Large seeded types fetch higher price both in domestic and foreign markets. In USA and Spain the consumer preference was for large seeded type *kabulis*, therefore, probably the concept might have originated from there. The seed size has no significant effect on germination percentage, vigour index, plant stand and yield per plant in *desi* types cultivars like; Vikas, Vishwas, Chafa, N-31 and N-59 [61]. *Desi* and *kabuli* seeds differ mainly in their seed coat and crude fiber contents. The thickness of seed coat of *desi* types are approximately thrice than those of *kabulis* [62]. The differences in yields between small, medium and large size groups were highly significant. The yield levels of small and medium seed size groups of *kabulis* were comparable to *desi* types. However, large *kabuli* seeded types showed low yield levels. Germination and field emergence were significantly low in large *kabuli* seed group as compared to small and medium seed groups. *Kabuli* large seed group was also inferior in root-shoot length and vigour index, and also showed rapid deterioration in viability when stored under ambient conditions. It has also been reported that large seed size in *kabuli* gram had more physiological seed coat cracking [54]. These cracked seed coat types had poor seed quality. The smaller seeds have more surfaces to volume ratio; therefore, emerge better under sub-optimum seedbed moisture conditions [63]. The anatomical structure of *kabuli* seeds reveals that the outermost layer (epidermis) of a uniseriate palisade layer is without thickening of cell wall. In *desi* seeds it is a multiseriate palisade layer, which later becomes thick-walled scleroids, heavily stainable with toluiodine blue, indicating the presence of phenolic compounds contributing to seed coat colour. Like epidermal cells the walls of sub epidermal cells do not thicken in *kabuli* seeds, even though their size is considerably reduced. In *desi* seeds these cells become thick walled as the seed matures. The palisade layers of seed coat are generally associated with permeability and germinability of seeds. Seed coat thickness in *desi* and *kabuli* chickpeas varies a lot. Seed coat of *desi* types was 2.72 times and 3.25 times thicker than *kabulis* with normal testae and *kabulis* with cracked testae respectively [56]. Similarly, It was stated that seed coat in *desi* types was 14.2 per cent and in *kabulis* 4.9 per cent of the total seed mass [64]. Seed coat percentage was positively correlated with seed coat thickness and was negatively associated with 100-seed weight. The proportion of seed coat was lower in large seeded than in small seeded type. Hence, it is a general view that bold seeds give higher yields than small seeds. Therefore, seeds are processed and graded before they are marketed.

Cultivar Purity:

There has not been much work on characterization and varietal identification in chickpea. Genetic purity of cultivars is most important component of seed quality. A number of released varieties in chickpea have a narrow genetic base, thus making varietal identification a difficult task for quality control. As the numbers of cultivars

expand, the relevance for cultivar purity increases as a measure of seed quality [65]. Uniform standards for crop purity and germination are available for various crops in the Indian Minimum Seed Certification Standards (IMSCS)[66]. However, standardized procedures are not available to seed analysts for determining cultivar purity. As a general rule, no cultivar can be identified or rejected purely by examining only seed or morphological characters in the field. Therefore, for keeping the purity of cultivars, stable visual diagnostic characteristics of seed, seedling and adult plant morphology are essential to know. Descriptors for chickpea have been prepared [67] to facilitate characterization. An integrated approach of morphological, biochemical and image analysis of seeds for varietal identification and characterization may be of immense importance in keeping highest standards of cultivar purity.

Nucleus and Breeder Seed Production:

Royal commission on Agriculture submitted a report as early as 1928 to increase the facilities for supply of breeder seed and maintenance of varietal purity in all crop plants. Method of seed production in a crop depends upon the breeding system of the crop, presence or absence of pollen vector, habit of plant and its reproductive method. Chickpea is a predominantly self-pollinated crop with fairly low amount of natural cross-pollination (<2 per cent) [21; 22]. The quality of seeds in a crop depends upon the heritability of its morphological characters of seeds. It is therefore of utmost importance that the initial quality of seed should be of highest standard [68].

Harvesting and Threshing:

Moisture content of harvested crop affects the seed quality and hence it determines with which moisture content the crop should be threshed. Harvesting at high moisture content increases the chances of mycofloral infection on seed while harvesting at low moisture content increases mechanical damage to seed. It was observed that in 'Vikas' and 'Bishwas' chickpea varieties the physiological maturity of the seeds is attained after 56 days of anthesis when the seeds attain 12-17 per cent moisture content and give germination percentage of 82-100 [69]. The threshing of chickpea at peripheral speeds of 384 m/min and 333 m/min at 18 mm concave clearance and obtained more threshing efficiency, but there was rapid fall in per cent germination with the increase in cylinder speed [70]. The peripheral speed of the threshing mechanism was the most predominant variable influencing the germination of chickpea seed. Higher peripheral speed resulted in lower germination. The concave clearance of 15 mm had favorable effect on germination and eight to nine per cent seed moisture content appeared to be optimum for threshing chickpea [71]. Among different threshing methods, manual threshing may not be economical even though it ensures least physical damage and better storability [72]. Likewise threshing with tractor treading will also not be an ideal method of threshing which causes more damage resulting shorter duration of storage life. However, threshing by bullocks treading is a compromise and feasible method of threshing, where better seed quality is maintained for longer period by storing the seeds in sealed polyethylene bags.

Seed Certification:

There was no systematic seed certification programme for chickpea seed production in the country up to 1980s. The seed certification on scientific lines for the production of high quality seeds was suggested for better seed quality [33]. It has also been reported that no chickpea seed certification programme existed in any country at that time [73]. Seedborne diseases of chickpea are of economic importance and seed certification is necessary to ensure production of seed with acceptable levels of disease. Seed certification scheme must include field inspection for seedborne diseases. Field inspection for chickpea wilt may be done twice in the growing season. The wilt fungus is soil borne as well as seedborne and an early wilting of plants occurs on infestation. Therefore, the first inspection should be done within 40 days after planting. Second inspection at flowering/pod setting stage would ensure the roguing of infected plants. Roguing will greatly reduce seedborne inoculums in harvested seed lots. Seed harvested from healthy plants, from the field where wilt had been observed, should not be rejected.

Field inspections for foliar diseases like *Ascochyta* blight, *Botrytis* grey mould, *Alternaria* blight and *Colletotrichum* blight may be organised at the flowering and full pod stages of the crop. Additional field visits will be needed after spells of rain. Generally, 5-8 sprays of a suitable fungicide can control foliar diseases effectively during the growing season. Foliar application of Chlorothalonil (Bravo 500; Daconil) is effective in controlling Ascochyta blight of chickpea. Chickpea is a low input crop and farmers do not use pesticides/ fungicides routinely.

However, protective fungicides should be used for the production of quality seed. Rust, powdery mildew and stunt are not seedborne. Seed production of chickpea can be adversely affected if stunt occurs early in the season. The decision to use seed from chickpea fields having these diseases will depend upon severity of these diseases, as the low incidence has to be ignored.

Minimum Seed Certification Standard of chickpea:

Factor	Seed class	
	Foundation	Certified
Pure seed (Minimum)	98 per cent	98 per cent
Inert matter (Maximum)	2 per cent	2 per cent
Other crop seeds (Maximum)	None	5/kg
O.D.V. (Maximum)	5/kg	10/kg
Total weed seeds (Maximum)	None	None
Objectionable weed seeds (Minimum)	-	-
Germination (Minimum) including hard seeds	85 per cent	85 per cent
Moisture (Maximum)		
Ordinary container	9 per cent	9 per cent
Vapour proof container	9 per cent	8 per cent

Carryover Seed:

The breeder must carry over enough seed to safeguard against the loss of a variety if, there is a complete failure during the foundation seed multiplication stage. In addition, the breeder should further safe guard variety by arranging to have a portion of the seed originally released, stored under ideal conditions. The breeder should produce sufficient quantity of seed so that it can meet the requirement of 2-3 productions of foundation seed. The production of breeder seed is a very expensive process, with the associated risks of contamination by repeated multiplication and loss due to adverse growing conditions. These risks can be reduced and the continuity of the seed programme better assured by carry over breeder seed. Such carry over seed must be stored under optimum conditions in order to maintain its vigour and viability.

Storage:

Extent of damage to seeds affects the yield of crop. Seeds of chickpea and pea with lesser number of holes were found to yield higher than those with greater number of holes [74]. Charjan [75] observed that infested seeds were invariably inferior to normal seeds in terms of 100-seed weight, viability and vigour irrespective of number of holes they contained and maximum percentage incidence of fungal flora was found on multi-holed seeds compared with other damaged and normal seeds.

Sharma and Singh [76] reported that oils of coconut, sesame, rapeseed and cottonseed effectively protected the chickpea seeds from *Callosobruchus chinensis* for 12 months without impairing seed quality traits and seedling vigour. Das [77] attained success in completely inhibiting oviposition by *C. chinensis* female by treating seeds with neem, sesame and coconut oils and the viability of treated seed remained unaffected. Solar heat exposure for 24 hours was quite effective, giving complete egg mortality of pulse beetle in all the coloured polyethylene bags, except green and colorless (white) transparent ones, however, the germination in black colored polyethylene bags was significantly reduced as compared to transparent ones [78]. It was revealed that the germination decreased with increase in levels of *Callosobruchus maculatus* (Fab.) infestation in chickpea during storage under ambient conditions [79]. Singh [80] recorded decline in germination and vigour in response to fumigation at high seed moisture content and high temperature in chickpea and green gram. Phosphine was found more deleterious to seed quality than methyl bromide in chickpea. These results suggest that great care is necessary in the choice of fumigants in combination with the storage environment before fumigating the seeds.

Storage fungi such as *Aspergillus flavus*, *A. niger*, *A. sydowi*, *A. wentii*, *Fusarium moniliforme*, *F. pallidoroseum* and *Penicillium oxalicum* cause drastic reduction in viability of chickpea seeds. Viability was reduced at room temperature and 98 per cent to zero in the seeds artificially infected with *A. flavus*, *A. niger* and *Penicillium oxalicum* after 9-12 months of storage [81]. In general there is sizable decrease in germinability, with the increase in storage period. Seeds stored in polythene bags show minimum deterioration in viability as compared to seeds stored in cloth bags, earthen pots, gunny bags or paper bags [41]. They stated that polythene bag provided much protection to gram seeds in preventing the development of fungal colonies both quantitative and species wise. It was also noted that *Rhizopus arrhizus*, *Aspergillus niger* and *Aspergillus flavus* were the most commonly occurring fungi, irrespective of period and container of storage. The reasons for unexpected fluctuation in the occurrence or non-occurrence of a number of fungi at different intervals

may largely be attributed to the untoward fluctuation in the atmospheric RH and temperature during the period of storage that favour the growth and development of fungi. The loss in germination due to increase in storage period was reported which, accelerated with increase in RH [82]. The seed treatment with Thiram considerably reduced the loss of germination however; treatment above 0.30 per cent did not result in additive effects [83]. The requirement of RH and temperature favourable for the growth and development of different fungi may be varying which results in appearance of a fungus at one instant and non-appearance at the other. There is a drastic increase in the number of infected seed with increase in the number of mycoflora from the initial stage of storage, which affects the nutritive value of the grains. Reddy [84] recorded a loss in thiamine and niacin content of chickpea grains in storage.

Constraints:

Ascochyta blight, Fusarium wilt, pod borer etc are the major constraints in stabilizing the yield levels in chickpea. The result is that the nation is not able to produce more than 7 million tones from an area of 6-7 million hectares. There has been negative growth trend in productive potentials of the crop in the last decades. Following constraints in chickpea production are felt in India.

a) **Crop instability**: During past 15 years more than 55 high yielding varieties of chickpea have been released at both state as well as central level. However, the total production stagnated at 7 mt. The instability in production still persists in spite of best efforts. The gap between research station and farmer's yield is yet large. The productive potential of the existing varieties is not being fully realized. The crop is grown on accumulated monsoon water in marginal lands and faces moisture stress through out its life cycle. Inadequate plant stand or non-uniform plant population is a problem due to abiotic stress. There are many other factors of low and unstable yields: the crop is indeterminate in growth habit; fluctuations in environmental conditions (temperature, photoperiod, winter rains) affect vegetative/ reproductive phase of the plant; lower temperatures and supplementary irrigation (natural or artificial) prolong vegetative phase, producing excessive vegetative growth; lower seed set; flower drop and reduced reproductive phase resulting in less number of pods per plant and yield. The crop is susceptible to many soil/seedborne mycofloral infections. Fusarium wilt and Ascochyta blight are serious diseases, which can cause 20-100 per cent loss. In west Asia and North African countries, low temperature causing freezing injury or death or delayed onset of podding reduces yield tremendously [85].

b) **Pathogens**: More than 41 diseases have been reported attacking chickpea in different parts of the world. Out of them 33 are fungal, 1 bacterial and 7 viral diseases of chickpea have been reported. Some of them are of immense economic importance. Fusarium wilt is most important in India but its incidence is unpredictable and it is very difficult to control soil borne diseases. The fungus can survive in the soil even in the absence of the host for at least six years [86]. Besides Fusarium wilt (*Fusarium oxysporum* f.sp. *ciceri*), dry root rot (*Rhizoctonia bataticola*), black root rot (*Fusarium solani*), collar rot (*Sclerotium rolfsii*), root rot (*R. solani*) and stem rot (*Sclerotium selerotiorum*) are some other disease that have drawn attention of the scientists. Among the leaf diseases, Ascochyta blight is considered most important. Other leaf diseases like Botrytis grey mould, Colletotrichum and Alternaria blights have also been reported to be serious in some years. Of the several diseases recorded on chickpea very few are reported as seedborne. The seedborne nature of *Ascochyta rabiei* [87] and *Fusarium oxysporum* f. sp. *ciceri* has been described [73].

Ascochyta blight and Botrytis grey mould caused heavy loss to chickpea in northern India and Pakistan during 1979-1982. Alternaria blight also occurred in some parts. These diseases have the potential of devastating the crop, particularly when the humidity and temperatures are high. There is some evidence that the sudden outbreak of these diseases in the commercial fields was partly due to infected seeds. There were at least 5 chickpea pathogens carried by infected seeds in 70 chickpea samples collected [73]. These were of Fusarium wilt, Ascochyta blight, Botrytis grey mould, Colletotrichum blight and Alternaria blight. Fusarium wilt pathogen of seed chickpea was controlled by use of a mixture of Benomyl and Thiram [73; 86]; Ascochyta blight by use of Thiram [88] and by Benomyl [89] and Botrytis grey mould by 25 per cent Bavistin + TMTD 50 per cent [90]. There is information available in the literature on the fungicidal seed treatment for the control of Colletotrichum and Alternaria blight.

c) **Pests**: Pod borer (*Helicoverpa armigera*) alone is a major and constant problem and has the potential of causing 60-80 per cent loss. At least 54 insect-

pests attack this crop all over the world, causing biotic stress [91].

d) **Competition**: The cultivation of chickpea is not as safe as wheat, mustard or peas; therefore, the farmers give less preference to it. Lack of price support or other incentives by Government are also inadequate.

e) **Lack of quality seed**: Non-availability of quality seed to the farmers is another problem for low yields. In spite of highest breeder seed production of gram amongst pulses the total yield in the country remains below 4.5 mt during the year 2002-03. The seed replacement rate in chickpea is 2-3 per cent only. The farmers use their own saved seed due to high seed rate in self-pollinated crops and due to low yield levels the seed multiplication ratio is below 36 per cent [92].

f) **Lack of variability**: Early maturing varieties are not sufficient in number.

g) **Consumer preference**: Alternative consumer utility is meagre for chickpea and the consumer prefers *Kabuli* types more as they serve an alternative to pulses.

h) **Post harvest losses**: Post harvest losses due to shattering of pods are very high.

i) **Seed Quality**: The two of the factors considered in seed quality are appearance and germinability. Shriveled, green, discolored, broken or infected seeds cause reduction in market value. A high germination level is important for seed to be used for planting in unfavorable weather conditions.

There have been limited efforts in seed technological researches in India as well as abroad. It has been experienced that the use of quality seed alone increases productivity of the crop to the extent of 15-20 per cent [9]. In chickpea these gains up to 70-80 per cent have been observed in national demonstrations conducted at farmers field. The quality of seeds is generally estimated by its purity (both physical and genetic), germination (viability), moisture, vigour and seed health attributes. Standard germination test is universally accepted as an index of seed quality and is popular as it is simple and cheap but germination test conducted at optimum conditions, may fail to predict field performance, particularly under adverse field conditions [93]. Though, association of standard germination test results with field emergence has been reported in some crops, under favourable field conditions [49]. Since, germination test does not reflect field performance potential of a seed lot under diverse environmental conditions, the seed vigour as a quality parameter has gained significance.

Future Thrust:

The present low productivity of pulses can be increased with the cultivation of high yielding, disease resistant varieties, rational use of NPKS and micronutrients and proper weed and water management techniques [94]. The results of the various researches have showed that 10-15 per cent yield increases can be obtained with *Rhizobium* seed inoculation when grown for the first time in the soil [95]. Inter/mixed cropping of pulses provide insurance and yield certainty under rainfed conditions. The contribution of timely weed control and balanced use of fertilizers varies from 25 to 40 per cent. Near potential crop yields can be obtained when there is no water stress, by the increased efficiency of all applied inputs. The National workshop on Development of Action Plan for Increasing Production of Pulses and Oilseeds held at IARI in eighties had also identified non-avai1ability of quality seed as a major constraint to increasing production of pulses. Now, the strategy for increasing the production of pulses should be a multi-pronged coordinated effort in which research, extension and input supply agencies collaborates with the farmers in an extensive scale particularly improved quality seeds. Since the price of quality seed is generally higher than the ordinary seed, which contributes maximum to the total inputs, required for chickpea production. As most of the pulses require very high seed rate because of the higher values for 1000-seed weight (TEST WT.) thus becoming unaffordable for the poor farmers. So, the alternative rests with the option to provide seed to the farmer after all value additions at a reasonable price to enhance the productivity and production.

The population in India is increasing at alarming rate, therefore, the total land holding is shrinking day by day (0.14ha/head as per 2001 census) and the total area under cultivation (113.13m ha) is decreasing due to urbanization [3]. There is stabilization of yield levels in self-pollinated conventional varieties as well as in cross-pollinated hybrids of major cereals. The pulses have not been able to make a quantum jump as in cereal crops. There had often been negative trends in pulses due to their higher susceptibility to biotic and abiotic stresses. Efforts made in boosting pulse production in the country have not been very fruitful. However, the increased production of pulses could be achieved if quality seed of varieties is easily available to the

farmer along with the information technology for its cultivation. Importance of biotechnology for developing transgenics for drought, insect-pest resistance, greater nitrogen fixation can be of great use in improving productive potential of chickpea. Incorporation of Bt gene in chickpea is underway. The future research thrusts in chickpea may be:

1. Technology for stabilizing the yield levels.
2. Identification of disease free areas for higher yields.
3. Minimizing the losses during harvesting, threshing and storage and mechanization of harvesting and threshing methods.
4. Measures to control wilt and pod borer.
5. Development of early, photo-insensitive cultivars of determinate growth habits and semi erect plant types.
6. Characterization of varieties using morphological, biochemical, molecular marker techniques and computerized machine vision parameters.
7. Reduction of flower/ pod drop.
8. Increasing the area under cultivation.
9. Response to supplementary inputs (Fertilizers and irrigations).
10. Use of *Rhizobium* cultures.
11. Studies of the use of *Mycorrhiza* in association with *Rhizobia* to enhance phosphate utilization.
12. Technology for proper plant stand under soil moisture stress.

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