Chapter 2

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Chapter 2

Review of Literature

Historical Background

India has the proud heritage of one of the most ancient civilizations of the world enriched by discoveries and developments in almost all branches of science. The economy those days (and even to-day) was based primarily on agriculture which necessitated a good understanding of the life of the plant and its response to the environment (Sen, 1988). How to grow crops and to domesticate animals were discovered independently in several widely separated centres from about 8000 or 9000 BC, first around Mesopotamia (Davidson et al, 1975).

The ancient scriptures include many references to amazing discoveries and observations. The Atharva Ved (2000 BC), the Brhadaranayaka Upanishad and the Brasayurved (1st Century BC) particularly, are most remarkable in this respect. In the Brhat Parasar Samhita and Brasayurved, Parasar refers to the cotyledons and endosperms of a seed as ‘Bijamatrka tu Bijassayam’, indicating their motherly function for nourishment of the embryo, the plumule, etc. The necessity of air, water and season (temperature, light, etc) and soil (for nutrition) for germination is clearly mentioned by Susrut in his Susrut Samhita. Parasar also states that cotyledons (and endosperms) nourish a seedling until its roots are developed and they dry up when the seedling can use the earth for its nourishment. In the Vaiseshika Upanishad (Sutra), it is said that plants exhibit the phenomena of living, working, sleeping (contraction of leaves), movement towards a favourable and repulsion from an unfavour-
able, stimulus, and death. Gunaratna, in the Saddarsanasamuccaya of Haribhadra, refers to three stages of plant life -- infancy (juvenile phase), youth (development) and age (senescence) (Sen, 1988).

Agriculture was well-developed in India even in the pre-Vedic times. Great cities like Mohenjodaro and Harappa, with its teeming populations, indicate the production of food on a big scale. Implements for irrigation and furrowed lands have also been discovered in the ruins of places of the Vedic period. There is a reference in the Taittiriya Samhita to the sowing of rice in summer and pulses in winter, indicating a probable knowledge of rotation of crops. Mixed cropping was also in vogue in some cases. There are also references to the selection and treatment of seeds, seasons of sowing and harvesting and manuring for improved production. Exposing seeds to dew at night and drying during day for about a week (alternate moisture and drying treatment) were considered useful for improvement of seed quality. It is now known that such treatments improve the viability of seeds. Broadcasting of seeds was also practiced (Sen, 1988).

In the early part of the Christian era, further advances were made. The Chinese pilgrim Hiuen Tsang (6th Century AD) refers to the agricultural and horticultural developments and to products in different regions. The Krishi Parasar written during this period is a text, devoted solely to agriculture and agricultural practices. Seventh century onwards, India was repeatedly attacked by invaders from Persia, Afghanistan and Central Asia and the rate of original scientific development, particularly in practical and experimental sciences, rapidly declined. European missionaries, traders and physicians, Portuguese, French, Dutch, Englishmen and others, who visited...
exploit] India from 15th Century onwards were interested in Indian plants of medicinal and commercial values, and some of them encouraged systematic investigations [in their own interest !!] (Sen, 1988).

Seeds – In Crop Production

1. Variety of Uses

Man has always made extensive use of seeds in nutrition. The main crops used are firstly, cereals, providing high bulk, starchy staple foods, and secondly, legumes or pulses. These two groups of plant still figure very largely in human nutrition, although in modern 'civilized' society it all too easy to forget this. Furthermore, hundreds of millions of people, mostly in the developing countries of Asia and Africa, in the world still rely very heavily on plants, and especially on plant seeds, as major components of their diet (Bryant, 1985). This is clear from the following figure.

Figure 2.1

Uses of plants and animals as food sources in typical diets of several different regions of the world.

(After Bryant, 1985)
In addition to the direct use of seeds or of milled seeds in nutrition, many different types of seed are used for more extensive processing to provide products for human and animal nutrition and also for industrial use. The range of seeds used in this way is too wide to provide an exhaustive list, but includes, for example, several oil-rich seeds used for the extraction of lipids to make cooking oils, or as lipid-rich additives for animal feed, or for industrial purposes. Protein-rich seeds may be processed to give purified plant protein, soybean and peas are often used for this purpose. The storage polysaccharides may also be extracted to make various packaged snack foods.

2. Nutritional and Commercial Value

The range of seeds used in human and animal nutrition, and for industrial purposes, is very wide, as is the range of specific uses. In the context of the use of seeds or processed seeds for food, nutritional quality is all important. Three aspects of nutritional quality are usually considered: (i) the carbohydrate:protein ratio, (ii) protein quality, and (iii) P:S ratio in fatty acids and PUFA content.

Cereals and millets constitute a major foodstuff in the diet of man and the predominant item in the diet of poor. Stable civilizations have arisen only when primitive hunting communities have learned how to raise successive cereal crops from cultivated land. Without the use of cereals man is reduced to an uncertain and unsettled nomadic life (Davidson et al, 1975). The chief staples used in this country are rice (Oryza sativa), wheat (Triticum aestivum), jowar (Sorghum vulgare), maize (Zea mays) and bajra (Pennisetum typhoides) are cultivated on a smaller scale (Rajalaxmi, 1981).
Maize (corn, makka or makai, Zea mays) was first cultivated and consumed by the Red Indians in North America. It was introduced in the other countries relatively recently. Today, it is one of the major crops in India and many people in Punjab, Rajasthan, and tribal people in Gujarat use it as a staple. Apart from the seed, food-grain and industrial uses (starch and oil extraction), maize is also used for the fodder production. Maize contains a higher proportion of carbohydrates than any other food plants, together with a considerable amount of protein, fat and vitamins (Rajalaxmi, 1981).

Legumes have been cultivated from early times. The Ramayana mentions many of the legumes used at present in India. Pigeon pea (redgram, arhar, tur or tuver, Cajanus cajan) was first cultivated in the Middle East and South-East Africa around 5000 BC. In addition to proteins, legume grains also provide calories, lipids, minerals and vitamins. Besides being important for human consumption, grain legumes could also form an additional constituent of the feed for poultry, pigs, livestock and inland fish production, where they could compliment the cereal diet with regard to the limiting amino acids (Abrol and Chatterjee, 1980).

Peanut (groundnut, mungphali or magphali, Arachis hypogaea) was first cultivated in Brazil prior to the Inca Empire. Oilseed crops have been the backbone of agricultural economy of India from time immemorial. Peanut seeds are major source of cooking oil in this country (Reddi and Reddy, 1980). The cake that is left after the oil has been extracted from peanut seeds is an excellent source of protein, it is used as the animal and poultry feed, as a fertilizer, and up to some extent as an enrichment to the human diet in a modified form. (The nutritional aspects of these three seed crops are shown in Table 2.1.)
Table 2.1: The comparative nutritional aspects of peanut, maize and pigeonpea.

<table>
<thead>
<tr>
<th>Nutrient*</th>
<th>Peanut</th>
<th>Maize</th>
<th>Pigeonpea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories (cal)</td>
<td>567.0</td>
<td>350.0</td>
<td>335.0</td>
</tr>
<tr>
<td>Carbohydrates (g)</td>
<td>26.1</td>
<td>66.2</td>
<td>57.6</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>25.3</td>
<td>11.1</td>
<td>22.3</td>
</tr>
<tr>
<td>Biological Value</td>
<td>55.0</td>
<td>59.0</td>
<td>57.0</td>
</tr>
<tr>
<td>Efficiency Ratio</td>
<td>NA</td>
<td>1.0</td>
<td>NA</td>
</tr>
<tr>
<td>Oil (g)</td>
<td>40.1</td>
<td>3.6</td>
<td>1.7</td>
</tr>
<tr>
<td>P:S ratio</td>
<td>1.63</td>
<td>2.92</td>
<td>NA</td>
</tr>
<tr>
<td>PUFA (%)</td>
<td>31.0</td>
<td>41.0</td>
<td>NA</td>
</tr>
<tr>
<td>C18:2</td>
<td>30.4</td>
<td>53.0</td>
<td>NA</td>
</tr>
<tr>
<td>C18:3</td>
<td>NA</td>
<td>1.0</td>
<td>NA</td>
</tr>
<tr>
<td>Saturated FA</td>
<td>19.0</td>
<td>14.0</td>
<td>NA</td>
</tr>
<tr>
<td>Minerals (g)</td>
<td>2.4</td>
<td>1.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Ca (g)</td>
<td>0.050</td>
<td>0.010</td>
<td>0.073</td>
</tr>
<tr>
<td>Mg (g)</td>
<td>NA</td>
<td>0.144</td>
<td>NA</td>
</tr>
<tr>
<td>Fe (g)</td>
<td>0.003</td>
<td>0.002</td>
<td>0.006</td>
</tr>
<tr>
<td>P (g)</td>
<td>0.350</td>
<td>0.348</td>
<td>0.304</td>
</tr>
<tr>
<td>Fibre (g)</td>
<td>3.100</td>
<td>2.700</td>
<td>1.500</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>3.000</td>
<td>14.900</td>
<td>13.400</td>
</tr>
<tr>
<td>Vit-A (10^3 iu)</td>
<td>0.083</td>
<td>1.502</td>
<td>NA</td>
</tr>
<tr>
<td>Vit-B₁ (mg)</td>
<td>0.900</td>
<td>0.420</td>
<td>0.450</td>
</tr>
<tr>
<td>Vit-B₂ (mg)</td>
<td>0.130</td>
<td>0.100</td>
<td>0.190</td>
</tr>
<tr>
<td>Folic Acid (mg)</td>
<td>0.020</td>
<td>0.020</td>
<td>0.183</td>
</tr>
<tr>
<td>Free</td>
<td>0.016</td>
<td>0.014</td>
<td>0.019</td>
</tr>
<tr>
<td>Bound</td>
<td>0.004</td>
<td>0.006</td>
<td>0.084</td>
</tr>
<tr>
<td>Nicotinic acid (mg)</td>
<td>19.900</td>
<td>1.800</td>
<td>2.900</td>
</tr>
<tr>
<td>Choline (mg)</td>
<td>224.0</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

* approximate values (per 100 g).

Source: *Nutritive Values of Indian Foods* (1971)  
C Gopalan, B V Rama Sastri, S C Balasubramaniam  
NIN, ICMR, Hyderabad
India - Background of Problems

Weather

India is a land of many climates and varieties of soils, the geographic location and the physical features largely determine the climate of the country. Being a country with extremely varied terrain and climate, almost worthy of a continent, there is every year some area where there are floods or drought. Although India has the second largest water potential in the world after USA, some parts are chronically dry and if rains fail beyond the usual period the resultant drought becomes a further hardship imposed upon the already suffering population. As is well known, most of our agriculture is on the mercy of 'God Rain', and the poverty and ignorance make the dependence still more strict. In fact, the spurt in food production in early 1980s has been mainly due to adequate and timely rains in most of the country (Shukla, 1982).

Before 1975, large areas of India experienced severe drought conditions for years in succession. The high temperature in summers, erratic rainfall, meager irrigational facilities and poverty combined to aggravate the situation. What one year of delayed rainfall can do to even an advanced country like UK was seen in 1976. Moisture stress in the form of intermittent, terminal, or prolonged drought is the most important and universal environmental factor that limits the yield of crops creating a scarcity of food. India is crossed by a vast zones of arid and semi-arid land that forms almost 40% of total land area.

Natural calamities, like floods, cyclones and earthquakes, and man-made calamities, like wars, all bring about the helplessness of general population against the immenseness of the
forces. In all these situations there is reduction of availability of food and seed grains and of cultivable area. Quite frequently this country experiences erratic rainfalls, monsoon depressions, breaks in monsoon, thunder-storms and hail, cyclonic storms, western disturbances, cold waves and frosts, high winds and squalls, etc (Koteswaram and Raman, 1980).

Population
Higher demands posed by uncontrollably increasing population curbs the overall economic and scientific development of the nation. It brings poverty, the mother of all unfortunates, and so the malnutrition. Today India’s greatest problem is what and how to feed the masses.

Technical
There is a nation wide shortage of food and seed grains. What can be frustrating than the fact that almost 10% of produce is lost in the field, thanks to rats and other pests. The rats in India outnumber men by 6:1. Often the amount consumed and spoiled by rats made all the difference between famine and adequacy. Another 10% or so is lost in the course of post-harvest handling, which includes losses occurring in the threshing yard, during transit and storage. An estimated 70% of the rest (ie, 55% of the original) is kept back by the agriculturist for self-utilization, deferred selling or, for the purpose of seed. By faulty storage systems the efforts put in by the scientists, agriculturists, and policy makers to boost food productivity through various measures are almost neutralized.

The storing facilities are usually primitive and inefficient, and make the grains prone to deteriorating factors like moisture, rodents, birds, insects, bacteria and fungi. All these factors result in a drastic cut down in the effective
availability of grains for utilization.

Seed Viability

Seeds, plant propagules comprised of latent embryos supplied with their own food reserves and protected by special covering layers, are relatively dry structures compared with other plant tissues and, in this condition they are resistant to the ravages of time and their environment. But resistant is a relative term and seeds do deteriorate: the type, the extent and the rapidity of the deterioration, and the factors which control it are important to agronomists, horticulturists, plant breeders, seedsmen, seed analysts, and those concerned with the conservation of genetic resources. In addition, the changes in seeds which lead to loss of viability (germination potentiality) may be relevant to the wider biological problems of senescence and ageing (Roberts, 1972a).

Factors Affecting Seed Viability

A life cycle of a seed, which disappears in soil when sown and comes up with a plant bearing many seeds, can be illustrated as follows:

Factors that can potentially influence the seed viability at each stage have been excellently discussed by Roberts (1972) in his edited volume 'Viability of Seeds.' These factors may be summarized as follows (See also Figure 2.3, p 24)

Seed sowing and seedling emergence (Pollock, 1972)
- state of the seed
  - vigour
  - biochemical makeup
  - extent of genetic anomalies
  - seed moisture
  - viability, and extent of deterioration
  - dormancy
  - mechanical damage (physical integrity)
  - levels of various hormones
  - seed exudation
- time of onset of seed growth
- method of planting (mechanical injuries to seeds)
- environmental and soil conditions
  - temperature
  - temperature-time combination
  - soil water potential:
    - matric and osmotic potentials
  - oxygen
  - light: quality, quantity and duration
  - soil
    - physical and chemical conditions
    - microflora and plant pathogen

Vegetative growth (Austin, 1972)
- light
- temperature
- water
  - irrigation, rainfall and soil moisture
- mineral nutrition and fertilizers
- other organisms
  - pathogens and, insect and rodent pests
- plant-to-plant interaction
- endogenous hormonal levels

Reproductive growth (Austin, 1972)
- all those affecting vegetative growth and
- time of flowering: synchronization
- time of pollination
- pollen tube growth

Seed development and maturation (Austin, 1972)
- circadian variation in seed moisture
- environmental
  - temperature
  - humidity, rainfall (preharvest)
  - light
- biochemical and physiological status of mother plant
  - quality and quantity of supply of
    - nutrients
- photoassimilates
- hormones etc
- extent of reserve deposition
- source:sink effect
- time, rate and degree of desiccation
- maturation
  - seed size and weight
  - temperature (thermal or freezing injuries)
  - humidity
  - photoperiod
- other organisms, including neighbour plants
- time of termination of maturation

**Harvesting, processing and packaging** (Moore, 1972)
- time of harvest
- type and severity of mechanical impact
- mode of
  - further processing
  - transportation and distribution

**Storage** (Roberts, 1972b, 1972c; Christensen, 1972)
- three major environmental agents
  - temperature
  - humidity
  - oxygen tension
- other environmental agents
  - radiation
  - organisms: micro- and macro-
- state of seed
  - viability
  - vigour
  - physical status: seed moisture, mechanical injuries
  - biochemical status: respiration and seed metabolism
  - genetic integrity
Theories to account for loss of seed viability

Extrinsic
- Ionizing radiations
- Pathogen attack
- Growth inhibitors
- Mycotoxins
- Phenolics
- Indoleacetic acid
- Abscisic acid
- Mutagens
- Products of fermentation

Intrinsic
- Accumulation of toxic metabolites
- Growth inhibitors
- Mutagens

Denaturation of nucleic acids
- DNA
- Long-lived mRNA

Denaturation of proteins
- Enzymes
- Structural proteins

Denaturation of lipoprotein membranes
- Mitochondria
- Plastids, lysosomes, dictyosomes,
- Cell membranes

Depletion of essential metabolites
- Respiratory loss of food reserves
- Loss of vitamins, hormones, etc

Fig 2.3 The Viability Theories
(After Roberts, 1972a)
Factors listed above can be fully or partially controllable or non-controllable at all. In this context, researchers have put in their efforts in studying these factors, alone or in combination with others, in relation to viability (Roberts, 1972a). Most of the work on seed viability has been centred around the deterioration of viability of seeds during storage in view of the importance of maintenance of genetic constitution and gene erosion of many invaluable and rare germplasms. Since it is very difficult to maintain the viability during storage in many parts of India due to prevailing high temperature and high humidity, this subject has remained a pragmatic issue for the Indian seed physiologists and other seedsmen.

Biochemical and Physiological Changes Associated with Seed Development and Maturation

Many comprehensive studies have been carried out on the physiological and biochemical changes associated with development and maturation or ripening of seeds of cereals (Chinoy, 1947; Saxena, 1969; Sircar, 1970; Mehta et al, 1973; Chatterjee et al, 1976; Mitra et al, 1976; Agrawal, 1977; Paul et al, 1977; Vijaikumar, 1979; Dua et al, 1983; Singh and Asthir, 1988), millets (Bhatia and Singh, 1979), grain legumes (Saxena, 1969; Sreeramulu and Rao, 1972; Bedford and Matthews, 1976; Sainis and Sane, 1976; Chatterjee et al, 1978; Rauf, 1978, 1980a, 1980b; Rauf and Banerji, 1978; Sharma, 1981; Bhambri and Malik, 1982; Nagraj and Kumar, 1984; Khatra et al, 1986; Singh, 1990). It is now established, from these and other studies, that seeds of most crop species are considered to be mature when they attain maximum dry weight (Delouche, 1980; Egli, 1981) and greatest vigour and viability (Delouche, 1980; TeKrony et al, 1984). The maturity when maximum seed dry weight oc-
curs is usually called the physiological maturity (Harrington, 1972; Thomas, 1972; Delouche, 1980; Powell et al, 1984; Brook- ing, 1990; Rasyad et al, 1990).

The literature indicates that the ultimate chemical composition during seed maturation is determined by the genetic factors and hence varies widely among species and their varieties and cultivars. Some modifications of composition may result from agronomic practices and also may be imposed by environmental conditions prevalent during seed development and maturation, but such changes are relatively minor. Major reserves may be deposited within the radicle/hypocotyl or within extra-embryonic tissues. Most mature seeds contain at least two or three reserves in appreciable quantities and to a large extent they are generally synthesized concomitantly during seed development.

Role of Hormones

While the growing seed is accumulating its major storage reserves, changes are also occurring in its content of other important chemical substances—the growth regulators or hormones, auxins, gibberellins, cytokinins and abscisic acid. These substances are believed to have important function(s) in the regulation of certain aspects of (i) seed growth and development, (ii) synthesis, accumulation and deposition of the storage reserves, (iii) fruit growth, and (iv) other physiological phenomena (Bewley and Black, 1985b). Also, the mechanisms whereby overall growth is regulated are considered to be mediated by the organic molecules present in low concentrations called plant growth regulators (PGRs).
Changes Associated with Ageing

Sequence of events which bring about the reduction or loss of germinability and vigour in seeds and the sites at which they occur still remain obscure (Abdul-Baki, 1969; Bewley and Black, 1985c; Saxena and Pakeeraiah, 1986; Maheshwari, 1987). These events usually result into a decline in the metabolic activities manifested by (i) the lowered germination, (ii) decreased seedling growth and reduced respiration, (iii) an increase in overall activities of certain enzymes such as phytase, protease, and phosphatase, (iv) a decrease in activities of other enzymes such as catalase, peroxidase, dehydrogenases, amylases, and glutamate dehydrogenase, and (v) an increase in membrane permeability which leads to a greater leakage of sugars, amino acids, and inorganic solutes from the seeds. Free radical damages and chromosomal losses are also well documented (Koostra and Harrington, 1969; Villiers, 1974; Basu, 1976; Saxena, 1979; Saxena and Pakeeraiah, 1986; Mehra, 1990; Malhotra, 1990).

A fair amount of work in the field of seed viability has centred around biochemical changes observed in ageing seeds, such as changes in activity, respiration and ATP content, protein and DNA synthesis, the chemical content of seeds, genetic changes in membrane permeability. Reports of the effect of ageing on enzyme activity are frequently contradictory. Certain enzymes lose activity with loss of viability of seeds, eg, dehydrogenases (Thorneberry and Smith, 1955). The loss of activity of this group of enzymes (as detected by reaction in situ with tetrazolium salt) is used as a measure of viability of seeds. There are reports of loss of peroxidase and catalase activity with loss of viability, the decline in peroxidase activity has been observed to bear good correlation with germination capacity. Several workers have reported enzymatic changes
during either natural loss of viability (Anderson, 1970; Pandey, 1987) or artificially induced loss of viability (Agrawal, 1981; Vimala, 1984). Loss of activity of some other enzymes seem to be a time-dependent degradation, which continues long after seeds death. Thus activity of nucleases has been detected biochemically in extracts of the 103 year old non-viable wheat (Osborne et al, 1974). In this group of degradative enzymes there occurs an increase in activity with loss of viability, eg, an increase in DNase has been demonstrated in non-viable rye embryos (Roberts and Osborne, 1973) and RNase has been shown to increase in those that have just become non-viable (Roberts, 1972c).

During the course of seed ageing complex consequences of impaired metabolism may result into extensive damage to the seed altering the interactions between embryonic and extra-embryonic tissues. Lesions in embryo cells, for instance, could ramify into reduced nutrient requirement, as well as decreased production of hormones and other chemical factors controlling the reserve breakdown (Bewley and Black, 1978; Halmer, 1985); thus, are likely to affect the mobilization process. The biochemical damages occurring in other seed tissues could negatively influence the growing embryo because of the nutrient shortage (Aspinall and Paleg, 1971) and even by the production of toxic or inhibiting substances (Corsi and Avanzi, 1969). Investigations have also suggested that changes in extra-embryonic tissues can also precipitate loss of germinability (Bhattacharya and Sen-Mandi, 1985; Petruzzelli and Taranto, 1989). Free radical damages and chromosomal aberrations are well documented by Villiers (1974), Saxena (1979), and Saxena and Pakeeraiyah (1986).
Ellerton and Perry (1983) reported reduced rate of seed deterioration during simulated preharvest deterioration. Woodward and Taylorson (1981) proposed that ageing led to a breakdown between glycolysis and Kreb's cycle leading to the prolonged accumulation of ethanol during the early stages of germination of low vigour seeds and increased respiratory quotient. The peroxidation of phospholipids is the mechanism by which many people believe that membrane deterioration takes place (Wilson and McDonald, 1986). Peroxidation occurs preferentially in the polyunsaturated fatty acids of the phospholipids leading to the production of free radicals and a decline in polyunsaturated fatty acids. Priestley et al (1980, 1985) found little changes in the free radical content in the soybean cotyledons, but no difference could occur in the axes after a long term storage. Indirect evidence for the role of free radicals in ageing has come from studies of naturally occurring antioxidants or tocopherols and the effect of antioxidant seed treatments.

Accelerated Ageing

The technique of accelerated, artificial or simulated ageing was initially developed as a test to estimate the longevity of seed in warehouse storage; subsequent studies verified the accuracy of this test in predicting the life-span of a number of different species under a range of storage conditions (Delouche, 1985; Delouche and Helmer, 1987; Delouche et al, 1967; Rushing, 1969; Delouche and Baskin, 1973). Helmer (1962) suggested that it might have an additional utility as a test for predicting seed performance, under various conditions, other than storability, for example, Baskin (1970) indicated the use of this test to predict the stand establishment of peanuts.
Other studies have shown that this 'vigour test' functions equally well in forecasting stand establishment of cotton (Bishnoi and Delouche, 1975), pea (Caldwell, 1960), bean (Roos and Manalo, 1971), and soybean (Byrd and Delouche, 1971; TeKrony and Egli, 1977).

Murata et al (1979) observed that the rate of decline in germination increased as the stressing conditions, temperature and moisture, were intensified. Egli et al (1978) considered the technique of accelerated ageing 'an excellent predictor of seed viability.' Measurements of germination after a period of accelerated ageing (Baskin, 1981) or after controlled deterioration (Mathews and Powell, 1981) are accepted by the International Seed Testing Association (ISTA) as standard methods for the assessment of seed vigour.

Powell and Harman (1985), however, believe that accelerated ageing performed under different array of conditions can give contrasting results, and may not correspond with those of natural ageing (Priestley and Leopold, 1983). Furthermore, different species may respond differently to any one set of ageing conditions (Perl et al, 1987). Nevertheless, many workers have confirmed that the results of physiological and biochemical changes are comparable with those of natural ageing; albeit with differing magnitudes (Chhabra, 1984; Saxena et al, 1985; Dal, 1984; Hussaini et al, 1988).

Presoaking Seed Treatments

The presoaking or the presowing seed pretreatment has been suggested as one of the effective ways to manipulate physiological and biochemical processes (Saxena and Pakeeraiah, 1986). The beneficial effects of pretreatment are not induced to the same
degree in all seed as different seeds behave distinctly with respect to their moisture content and the duration of soaking period (Basu, 1976; Saxena, 1979). The presoaking treatments with the plant growth regulators (PGRs) and various chemicals to the seeds to stop/reduce/reverse the loss of viability during the storage are equally controversial as how such pretreatment elicit molecular changes to counteract deterioration phenomenon occurring during the storage (Savino et al, 1979). Basu (1976) and Basu and Dasgupta (1974) have shown that even the primitive treatment like hydration-dehydration could effectively extend the longevity of stored aged seeds. The important consideration in this context would be the biochemical and physiological responses of the different parts of seed to the hydration-dehydration treatment.

Vigour and Yield

Seed vigour can potentially affect yield in a number of ways (Heydecker, 1977; TeKrony and Egli, 1991), however there are two distinct ways in which poor seed vigour could affect crop yield: (i) It could reduce potential field emergence so that, if the subsequent performance of the individual plants were unaffected, seedling yield could be reduced through the establishment of a sub-optimal plant-population density, and (ii) Because the individual plants which do emerge subsequently perform less well than those from a better-quality seed lot. If this is the case, then compensation through increasing sowing rate may not be possible and emphasis should be on prevention, rather than cure, through sound techniques of production, storage and quality control (Roberts et al, 1989).

For the prevention of low production and poor quality of crop, uses of PGRs to manipulate the seed vigour is a common
The introduction of chemical growth regulators has added a new dimension to the possibility of modifying the plant growth (Mehrotra et al, 1983). Application of wide variety of PGRs have been extensively used in order to ascertain their beneficial effects upon the growth and the yield (Basu and Rudrapal, 1982; Caldwell et al, 1988).

Various natural and synthetic plant growth substances can be used to manipulate plant growth and yield in many different ways, like application to stem (injection), leaf (spray or spreading), soil (drench), and seed (presowing soaking treatment), before the plants are exposed to stressing environment. PGRs combined with presowing soaking treatment could provide an unique opportunity to the growers wanting more yield and to give their crop a good 'start.' Exogenously applied PGRs probably fulfill the required level of endogenous phytohormones, which has been lost during an ageing (Pakeeraiah, 1985).

Presoaking seed treatment (priming, hardening or hydration-dehydration) is not a new technique. According to McGill (1988), seed hydration may alter the ability of the seed to germinate at sub-optimal soil moisture conditions, and thereby overcome some of the obstacles in stand establishment. This is in line with the other findings of (Cal and Obendorf, 1972; Bennett and Waters, 1987) in corn. Gray and Steckel (1976) and Szafirowska et al (1981), also, reported that the seed hydration resulted in earlier emergence, earlier maturity, increased yield, and improved quality of many vegetable crops. Dasgupta et al (1976), Punjabi et al (1982) and Mandal and Basu (1984) have supported our findings in cereals, who observed the beneficial effects of pretreatment on the growth and yield in different cultivars of wheat and barley. The growth regulators
are known to enhance the dry matter accumulation through pre-sowing applications (Kumar and Tayal, 1982; Moore, 1989).

Different aspects of seed development and seed storage have been thoroughly scrutinized from several angles by the seed physiologists and seed technologists mainly due to relevant theoretical and practical demands. Whatever information that is available on the (i) effect of degree of seed maturation on the storage potential, (ii) on the physiological and biochemical changes in the seeds (harvested at various maturity levels) during storage, and (iii) use of externally PGRs or hormones and seed treatments in such cases, is quite limited and does not cover all these aspects, hence, these are the areas that require due recognition from seed physiologists. Research in this direction is imperative in order to acquire detailed knowledge and to exploit it pragmatically.