# EFFECTS OF PACKAGING MATERIALS AND STORAGE ENVIRONMENTS ON THE STORABILITY OF GROUNDNUT SEEDS

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF AGRICULTURE SCIENCE WITH HONOUR

CROP PRODUCTION PROGRAMME
FACULTY OF SUSTAINABLE AGRICULTURE
UNIVERSITI MALAYSIA SABAH
2017

*PUMS 99:1*

**UNIVERSITI MALAYSIA SABAH**

**BORANG PENGESAHAN TESIS**

JUDUL: KESAN BAHAN PEMBUNGKUSAN DAN PERSEKITARAN PENYIMPANAN PADA TEMPOH SIMPANAN KACANG TANAH

IJAZAH: IJAZAH SARJANA MUDA SAINS PERTANIAN DENGAN KEPUJIAN (PENGELUARAN TANAMAN)

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# ACKNOWLEDGEMENT

First and foremost, I would like to express my deepest appreciation to my supervisor Professor Dr Mohammad Bin Mohd Lassim, who has the passion and patience in guiding me to the completion of this thesis. Without his guidance and advices this thesis would not have been possible.

I would also like to thank Puan Nurul Syakina, the laboratory assistant for willing to lend out a hand to help me whenever I faced problems on the insufficiency of laboratory equipment, instruments and also chemicals required for carrying out my experiment. Other than that, she was also kind to help us even at non-working days especially Saturday in order for me to proceed my experiment smoothly.

Last but not least, I also wanted to thank Professor Madya Datuk Haji Mohd Dandan @ Ame Haji Alidin for his willingness to give permission for me to access the Seed Technology Lab for carrying out my experiment smoothly in a more controlled environment for germination test.

# ABSTRACT

A lab experiment was conducted at the Faculty of Sustainable Agriculture, in Universiti Malaysia Sabah, Sandakan. The objective of this study was to determine an acceptable storage environment and suitable packaging material for maintaining the viability and vigour of groundnut seeds. The experimental design was Completely Randomized Design (CRD) made up of three storage environment mainly cold room, refrigerator and ambient with groundnut seeds packaged differently into cloth and plastic packaging equally for four replications and treatment were expressed in 3 x 2 factorial design. Seed quality evaluation mainly germination test, seed moisture determination and standard germination vigour test was carried out every two weeks upon storage for 98 days. Results were analysed using SAS version 9.4 with two way ANOVA and significance among treatment means were analysed using Least Significant Difference (LSD) test at confidence level of 5%. Plastic packaging and cold room storage showed the best storage condition for groundnut seeds in terms of viability and seed moisture content throughout 98 days of storage period. However, viability at the end of storage was low at 49% and this indicates that groundnut seed has poor storability even when stored under low temperature with moisture proved packaging. Therefore, groundnut seeds should not be stored for longer periods due to high oil composition that makes it difficult to store.

**KESAN BAHAN PEMBUNGKUSAN DAN PERSEKITARAN PENYIMPANAN PADA TEMPOH SIMPANAN KACANG TANAH**

## ABSTRAK

Satu kajian makmal telah dijalankan di dalam Fakulti Pertanian Lestari, Universiti Malaysia Sabah, Sandakan. Kajian ini dijalankan bertujuan untuk mengkaji kesan bahan pembungkusan dan persekitaran penyimpanan terhadap tempoh simpanan biji benih kacang tanah varieti Margenta. Objektif kajian ini adalah untuk menentukan persekitaran penyimpanan dan bahan pembungkusan yang sesuai untuk mengekalkan percambahan dan daya maju biji benih kacang tanah. Reka bentuk eksperimen adalah Completely Randomized Design (CRD) yang merangkumi tiga persekitaran penyimpanan iaitu bilik sejuk, peti sejuk dan ambien manakala kacang tanah dibungkus secara berbeza ke dalam kain dan plastik pembungkusan dalam kuantiti yang sama bagi setiap pembungkusan dengan empat replikasi dan rawatan ini disusun secara 3 x 2 reka bentuk factorial. Penilaian kualiti biji benih terutamanya ujian percambahan, kelembapan biji benih dan ujian percambahan standard untuk daya maju biji benih dijalankan pada setiap dua minggu selepas penyimpanan dijalankan. Keputusan dianalisis dengan menggunakan SAS versi 9.4. dan perbezaan significant antara min rawatan dianalisis dengan menggunakan Kajian Least Significant Difference (LSD) pada tahap significant sebanyak lima peratus. Pembungkusan plastik dan simpanan dalam bilik sejuk menunjukkan keadaan penyimpanan terbaik bagi biji benih kacang tanah dari segi percambahan, indeks daya maju dan kelembapan biji benih sepanjang tempoh 98 hari penyimpanan. Walau bagaimanapun, peratus percambahan pada hari terakhir penyimpanan adalah serendah 49% dan ini menunjukkan bahawa biji benih kacang tanah mempunyai penyimpanan yang kurang baik mahupun disimpan di bawah persekitaran suhu rendah dengan bahan pembungkusan yang tahan kelembapan. Oleh itu, biji benih kacang tanah tidak boleh disimpan dalam tempoh yang lama kerana ia mengandungi komposisi minyak yang tinggi menyebabkan ia susah untuk disimpan.

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| | |
|---|---|
| cv. | Cultivated Variety |
| °C | Degree Celsius |
| °F | Degree Fahrenheit |
| ha | Hectare |
| mg | Milligrams |
| *P* | Probability |
| ANOVA | Analysis of Variance |
| AOSA | Association of Seed Analysts |
| B.C. | Before Christ |
| CRD | Completely Randomized Design |
| DAS | Days after storage |
| ISTA | International Seed Testing Association |
| LSD | Least Significant Differences |
| MARDI | Malaysian Agricultural Research and Development Institute |
| SAS | Statistical Analysis System |
| SMC | Seed Moisture Content |
| S.V.I | Seed Vigour Index |

# LIST OF FORMULAE

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

Groundnuts or peanuts (*Arachis hypogaea* L.) was a popular food source throughout the world. In Malaysia, groundnuts were prefereably consumed as peanut butter and confectionary snack. It was regarded as the sixth most important oilseed crop in the world due to its high oil composition of 48-50% and 26-28% protein content (Ndjeunga *et al.*, 2006).Other than that, it was also a rich source of dietary fibre and vitamins.

Groundnut was cultivated on 26.4 million hectare worldwide with a total production of 37.1 million metric tonne and an average productivity of 1.4 metric tonne per hectare (FAO, 2003). Around 70 percent of the world's groundnut production came from India and China which were major producers of groundnut. As a sum, they represent over two-thirds of the global groundnut output.

Seed was the basic propagating material used for the cultivation of crops. Therefore, storage of seed was necessarily important for farmers to maintain the quality of seeds until the right planting season. Thus, ensuring the maximum productivity of the crops after planting. Seed longevity was referred as the period of time the seeds remain highly viable and vigour. However, it could be greatly affected by the seed moisture content and the environmental storage condition mainly temperature and relative humidity (Trivedi, 2011).

Seed storage life was generally unaffected by subfreezing temperature provided that seed moisture content remains below 14% to prevent the formation of ice crystals which might cause cracking of seed's cellular structure. Excellent seed germination was observed in seeds dried to five percent moisture content and stored at subfreezing temperature for twenty years. However, the process of seeds cycled in and out of the freezer frequently without redrying might led to reduction in germination.

Nevertheless, the seed moisture content shows greater effect than storage temperature on seed longevity. When moisture content of seed exceeds 13%, seed storage fungi and increased heating via respiration will probably reduce shelf life within a short period of storage (Harrington, 1972). At 20% seed moisture content, the rapid process of respiration and activity of microbes leads to the faster rate of deterioration of the seed. Once reaching 30% moisture content, most of the non-dormant seeds germinate (Bewley and Black, 1985).



Furthermore, it can be seen that the effects of temperature and relative humidity are highly interdependent in their effect on stored seed. Since seed moisture is of most important concern, so the rule stipulates that in any case the temperature should not contribute more than half (Harrington, 1960). Hence, majority of crop seeds lose its viability quickly when storage humidity approaches 80% at temperatures of 77 °F to 86 °F (Copeland, 1976).

Seed storability refers to the ability of storage condition to maintain the seed quality in terms of viability and vigour for a period of time. For long term storage, the seed moisture content should exceed 8% and the storage humidity must be maintained below 35%. As we know, seeds are hygroscopic, any further increase in relative humidity storage environment beyond 35% will cause the low moisture seed to absorb moisture to become high moisture seed. Thus, the seed will become become fit for medium or short term storage.

Hence, to lengthen the duration of storage, seed moisture should be kept low and stored in preferable low relative humidity and temperature environment or package the seed in a tight impermeable packaging material in order to achieve longer storage life (Trivedi, 2011).

## 1.2 Justification

This research was carried out to determine the acceptable storage conditions involving temperature and relative humidity with suitable packaging materials on the storability of groundnut (*Arachis hypogaea* cv. Margenta). The high oil content of groundnut makes it difficult to be stored for long term period before planting. This crop was not very popular for planting in the country as food crop because rice is the main staple food to the community. Groundnut was eaten as snacks and junk food where it can be imported.

Vigour and viability test was used to determine the initial seed quality before storage. The aim of this test is to ensure preferable seed quality is achieved before storage treatment so that alteration of the seed quality within storage could be observed. For quick test on the viability of seed samples, tetrazolium chloride test should be considered as it saves time and materials compared to standard germination test. However, for high reliability standard germination test were selected.

Shelled groundnut storage may influence its shelf life. Mostly, farmers would prefer unshelled groundnut for storage rather than shelled due to double protection of the packaging materials and the shell itself. Packaging materials used would eventually have a larger impact on the longevity of seed with the subsequent fluctuations of the environment.

## 1.3 Objectives

The objective of this study is to determine the acceptable storage environment and types of packaging materials in maintaining the quality of groundnut seeds.

## 1.4 Hypotheses

Null hypothesis 1 ($H0_1$): Storage environment has no effect on the storability of groundnut seeds.

Null hypothesis 2 ($H0_2$): Packaging materials has no effect on the storability of groundnut seeds.

Alternative hypothesis 1 ($Ha_1$): Storage environment affect the storability of groundnut seeds.

Alternative hypothesis 2 ($Ha_2$): Packaging materials affect the storability of groundnut seeds.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Botanical Description of Groundnut

Groundnut is an annual herbaceous plant classified under the Fabaceae family, sub-family Papilionaceae, tribe Aeschynomeneae and sub-tribe Stylosanthinae. The genus *Arachis* is morphologically well-defined and distinguished from other genera by having a peg and geocarpic reproductive growth. There are more than 70 wild species from genus *Arachis* but only *A. hypogaea* is domesticated and cultivated worldwide. The genus can be further divided into nine sections called *Arachis, Caulorrhizae, Erectoides, Extranervosae, Heteranthae, Procumbentes, Rhizomatosae, Trierectoides* and *Triseminalae* (Gibbons *et al.*, 1972).

Groundnut is a self-pollinating, annual, herbaceous legume growing upright and has an indeterminate growth habit. Due to its atypical flower characteristics, natural cross pollination occurs at rates of less than one to six percent (Duke, 1981; Coffelt, 1989). It consist of three major stems, the main stem develops from the terminal bud on the epicotyl while the two lateral stems which is equivalent in length grows from the auxiliary buds. The taproot has an arrangement of four series lateral roots with abundant branching with numerous number of nodules (Moss and Ramanatha, 1995).

*A. hypogaea* has procumbent stems and can grow to about 0.5 metres tall. The leaves are alternate and compound with four ovate to oblong leaflets. The tubular, five-parted flowers are yellow and self-pollinated. After pollination, the flower stalks elongate to around 6 cm long and push the developing pods into the ground, so during harvesting the fruit (seeds) must be dug up from the soil. It is an indehiscent legume whereby its pod does not split open easily. The inflorescence is either simple or compound with the pods having located around the central axis of the plant (Isleib *et al.,* 1994).

Groundnut plant begins to flower within 30 to 40 days after planting and attained maximum flowering within six to ten weeks of planting. After fertilization completes, the tip of ovary bearing from the ovules grows out from the floral bracts, bearing the dried petals, calyx lobes and hypanthia. Thus, creating a unique floral structure called the carpophore which is commonly known as peg or gynophore (Ramanatha, 1988).

The pods of groundnuts is characterised by an elongated sphere with different reticulation on the surface. Commonly, there were one to five seeds within a pod (Gregory *et al.*, 1973; Ramanatha Rao, 1988; Stalker, 1997). However, there were considerable variability exists in the morphological traits in groundnut, mainly the seed size, seed colour, number of seeds per pod, pod length and pod breadth (Ramanatha and Murty, 1994; Retamal *et al.*, 1990; Stalker and Simpson, 1995).

## 2.2 Origin and Distribution of Groundnut

Groundnut (*Arachis hypogaea* L.) is originated in the New World. It was an ancient crop that was cultivated extensively in both Mesoamerica and South America at around 1000 B.C. The term *Arachis* is derived from the Greek word "arachos", meaning a weed, and "*hypogaea*", meaning underground chamber and botanically known as a weed with fruits grown below the soil surface (Hammons, 1973).

Groundnut is a common term used in most countries of Asia, Africa, Europe and Australia, whereas in North and South America it is preferably known as peanut. The terminology of groundnut refers to the pods containing seeds that mature below the soil, whereas the connotation of peanut is because this crop belongs to the leguminous family which includes other crops such as peas and beans (Gibbons *et al.,* 1972).

Nowadays, groundnut becomes a vital source of oil, food and forage crop generally distributed in the tropics, subtropics and temperate regions. However, the actual origin of the main cultivar, *Arachis hypogaea* L., is still under the subject of scientific inquiry. Nevertheless, according to Hammons (1973) the most convincing data indicating the origins of *A. hypogaea* was in the gardens of primitive, come from the digs on the coast of Peru, dated from 3750 to 3900 years before present (BP). On the other hand, there is also archaeological evidence of their existence in Mexico, dated 1300 to 220 BP (Hammons, 1982).

After the European contact, groundnut were dispersed throughout the world. They were distributed to the Western Pacific, China, Southeast Asia and Madagascar presumably in the sixteenth and seventeenth centuries with the discovery of voyages of the Spanish, Portuguese, British and Dutch. Today, groundnut crop is cultivated in 108 countries on about 22.2 million hectares, where 13.69 million hectares of groundnut were cultivated in Asia mainly India (8 million ha) and China (3.84 million ha). India, China and the United States are the leading producers of groundnut and contributes about 70% of the world's groundnuts production (FAO, 2007).

## 2.3 Morphological Characteristics of Groundnut Seeds

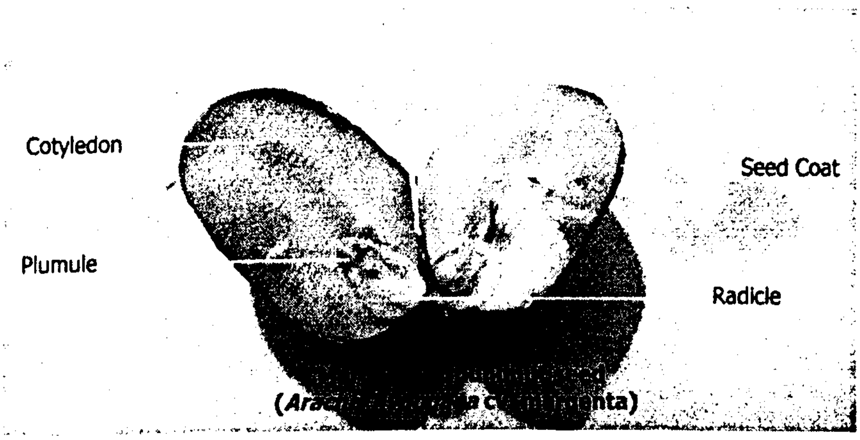


Figure 2.1 Longitudinal section of Margenta groundnut seed

A matured but dormant groundnut seed comprises of embryo made up of two cotyledons, the upper stem axis and young leaf primordial (epicotyl), the lower stem axis (hypocotyl) and primary root (Figure 2.1). The radicle itself was jointly made up from the hypocotyl and primary root. The hypocotyl functions to push the seed towards the surface of soil as germination proceeds. Thus, all of these structures are vital in the growth and development into a normal groundnut embryo (Gregory *et al.*, 1951).

The seeds of *A. hypogaea* tends to differ in terms of size, shape and colour. Its testa or seed coat is thin and papery. Generally, the seed coat consist of three unicellular layers that is the epidermis (schlerenchyma), the middle parenchyma and the inner parenchyma. The presence of these layers indicates that integuments of maturing ovule are maternal in origin (Glueck *et al.*, 1977). Thus, the grouping of groundnut cultivar were based on size of wax, joining of epidermal cells, thickness of cell walls and presence of cracks in the epidermal. For wild species, the seeds are almost similar but smaller than the cultivated ones.

### 2.3.1 Seed Size

Generally, groundnut seed length ranges from 7 to 21 mm with diameters of 5 to 13 mm as observed by Ramanatha (1988) and Retamal *et al.* (1990). On top of that, seed size and mass were used frequently in the agronomic classification of groundnut. Normally, larger seeds were used for confectionary purposes while medium and small size seeds were used for the extraction of oil. The smaller seed of wild *Arachis* usually has seed length ranges between 8 and 18 mm and diameter between 4 and 7 mm.

### 2.3.2 Seed Weight

Groundnut seed weight is also a vital economic and diagnostic characteristics. However, this characteristics varies according to the materials studied and site of evaluation. Nevertheless, several ranges on its weight has been discovered, 0.2–1.0 g (Seshadri, 1962); 0.17–1.24 g (Ramanatha, 1988); and 0.54–2.38 g (Retamal *et al.*, 1990). However, the variation in weight is usually dependant on the cultivars. For instance, cultivars of variety *hypogaea* tend to have larger and heavier seeds while those belonging to variety *fastigiata* have smaller and lighter seeds and the wild species shows lower seed mass.

### 2.3.3 Seed Colour

The colour of seed coat or testa is another important diagnostic character and an important market trait. Groundnuts can be mainly classified into possessing non-variegated seed coat (single solid colour) and variegated seed coat (more than single colour). Basically, seed colour turns deeper with prolong storage in shell or as shelled seed over a period of time (Bunting, 1955). Solid colours mainly white, rose, flesh, wine, red, light purple and dark purple can be distinguished easily.

### 2.3.4 Germination Characteristics of Groundnut

All the primordial leaves will appear within the first few days after germination. However, the hypocotyl appears white during early stages of growth but becomes indistinguishable from the root when reaching maturity. The plumule is formed by a central axis and the two cotyledon axes and contains readily nine embryonic leaves. These essential organs originate from tissue differentiation during the embryo's development inside the seed (Reddy *et al.*, 2003).

Germination of groundnut is epigeal, where the cotyledons of germinating seed will grow above the ground and the cotyledons may turn green soon after emergence. Normally, groundnuts requires 3 to 5 days to germinate and emerge from the soil at temperature of 30°C. Radicle may sprout out first and the primary root system is tap-rooted with many lateral roots which can be seen 3 days after germination (Smartt, 1994).

At the beginning of germination period, the developing seedlings are solely dependent on assimilates stored in the cotyledons. After 5 to 10 days, the seedling will become autotrophic and able to absorb mineral nutrients from the soil via the roots whilst the epicotyl that is exposed to solar radiation starts to photosynthesize. Nonetheless, these characteristics are also dependent on the cultivar as well as the environmental conditions.

## 2.4 Chemical Composition of Groundnut Seed

The chemical quality of groundnut seeds has been studied by numerous researchers but the results appeared to have variation. This variation may be attributed by the differences in groundnut variety, soil, climate and storage conditions. The seeds of most groundnut cultivars comprises of about 50% oil (Worthington and Hammons, 1971). Thus, there were relationship between the qualities of groundnut seeds with the oil fraction within the seeds.

The oil content of groundnut differs in quantity especially the relative proportion of fatty acids, geographical location, seasons and growing conditions (Brown *et al.*, 1975; Holaday and Pearson, 1974; Young *et al.*, 1974). Generally, groundnut seeds contains about 44 to 56% oil and protein content of 22 to 30% on a dry weight basis. Besides, it is also a rich source of minerals mainly phosphorus, calcium, magnesium and potassium including vitamins of group E, K and B (Savage and Keenan, 1994). According to Crocker and Barton (1957) and other researchers, the seeds were reported to contain 9.5 to 19% total carbohydrates with both soluble and insoluble form (Rao *et al.*, 1965; Oke, 1967; Abdel Rahman, 1962; Woodroof, 1983).

### 2.4.1 Carbohydrates Composition

Groundnut seeds are reported to contain 9.5 to 19% total carbohydrates as both soluble and insoluble forms (Croker and Barton, 1957; Oke 1967; Woodroof, 1983). Although it constitutes the least in the grains, it is an important energy constituent required for all germinated seeds. After emergence, this organic substance will be manufactured through photosynthesis and transpiration and the soluble sugar indicates the physiological activity of the seedlings.

## REFERENCES


Abdel Rahman, A. H. Y. 1982. *Changes in Chemical Composition of Peanut during Development and Ripening*. Rivista Italiana Delle Sostanze Grasse. **59(6)**: 285-286

Agrawal, R. L. 1980. *Seed Technology*. New Delhi, India: Oxford and IBH Publishing Coorperation Private Ltd.

AOSA. 1983. *Seed Vigour Testing Handbook*. Association of Official Seed Analyst. East Lansing: AOSA. pp. 88

AOSA. 2014. *Rules for Testing Seeds Volume 4: Seedling Evaluation*. Association of Official Seed Analysts.

Balesevic-Tubic, S., Tactic, M., Dordevic, V., Nikolic, Z. and Dukic, V. 2010. Seed Viability of Oil Crops Depending on Storage Conditions. HELIA, **33(52)**: 153-160

Basavegowda, G. S. and Hosamani, A. 2013. Effect of Commercial Cold Storage Conditions and Packaging Materials on Seed Quality of Chick Pea (*Cicer arietinum* L.). *Global Journal of Science Frontier Research of Agricultural Vet.* **13**: 23-28

Basha, S. M., Cherry, J. P. and Young, C. T. 1976. Change in Free Amino Acids, Carbohydrates and Proteins of Maturing Seeds from Various Peanut (*Arachis hypogaea* L.) cultivars. *Cereal Chemistry*. **53**: 586-597

Bass, L. N., Ching, T. M. and Winter, F. L. 1961. Packages that Protect Seeds. Washington, DC: United States Department of Agriculture. *Yearbook of Agriculture*, pp. 330-338

Bewley, J. D. and Black, M. 1985 *Physiology of Development and Germination*. 2nd edition. New York and London: Plenum Press.

Bewley, J. D. and Black, M. 1994. *Seeds: Physiology of Development and Germination*. New York: Plenum Press pp. 445.

Bexter, L. 2012. Anatomy, Physiology, Biology, Production, Processing and Storage. *Seed and Seed Technology Handbook*. Birmingham, United Kingdom: Koros Press Limited.

Birthal, P. S., Parthasarathy, R. P. and Nigam, S. N. 2010. Groundnut and Soybean Economies of Asia: Facts Trends and Outlook. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. pp. 92

Brown, D. F., Cater, C. M., Mattil, K. F. and Darroch, J. G. 1975. Effect of Variety, Growing Location and Their Interaction on the Fatty Acid Composition of Peanuts. *Journal of Food Science*, **40**:1055-1060

Braddock, J. C. Sims, C. A. and O'Keefe, S. K. 1995. Flavour and Oxidative Stability in Roasted High Oleic Peanuts. *Journal of Food Science, **60**:489-493*

Branch, W. D., Takayama, T., and Chinan, M. S. 1990. Fatty Acid Variation among U.S Runner Type Peanut Cultivars. *Journal of American Oil Chemistry Society*, **67**: 591-593

Bunting, A. H. 1955. A Classification of Cultivated Groundnuts. *Empire Journal Experimental Agriculture,* **23 (1)**: 158-170

Burries, J. S., Edge, O. T. and Wahab, A. H. 1969. Evaluation of Various Indices of Seed and Seedling Vigour in Soybean. *Proceedings of Association of Official Seed Analysts*. **59**: 73-81

Chuansin, S., Vearasilp, Srichuwong, S. and Pawelzik, E. 2006. Selection of Packaging Materials for Soybean Seed Storage. Proceeding of the Conference on International Agricultural Research for Development. Tropentag: University of Bonn. pp. 11-13

Coffelt, T. A. 1989. Natural Crossing of Peanut in Virginia. *Peanut Science. American Peanut Research and Education Society*. **16(1)**: 46-48

Copeland, L. O. 1976. *Principles of Seed Science and Technology.* Minneapolis, Minnesota: Burgess Publishing Cooperation. pp. 121-148

Copeland, L. O. and McDonald, M. B. 1995. Principles of Seed Science and Technology. 3rd edition. New York and London: Chapman and Hall. **33(1)**: 113-119

Copeland, L. O. and McDonald, M. B. 1999. *Principles of Seed Science and Technology.* Dordrecht: Kluwer Academic Publishers Group

Crocker, W. and Barton, L. V. 1957. *Physiology of Seed.* Waltham, Massachusetts: Chronica Botanica. pp.267

Douglas, J. 1980. *Successful Seed Programme.* A Planning and Management Guide. Baulder, Colarado: Westview Press.

Duke, J. A. 1981. Legume Species. *Handbook of Legumes of World Economic Importance.* New York and London: Plenum Press pp. 5-311.

Ellis, R. H., Hong, T. D. and Roberts, E. H. 1989. A Comparison of the Low Moisture-Content Limit to the Logarithmic Relation between Seed Moisture and Longevity in Twelve Species. *Annals of Botany,* **63**: 601-611

Ellis, R. H., Hong, T. D., Roberts, E. H. and Tao, K. L. 1990. Low Moisture Content Limits to Relations between Seed Longevity and Moisture. *Annals of Botany.* **65**:493-504

FAO. 2003. *The State of Food Insecurity in the World.* Food and Agricultural Organization of the United Nations, Rome, Italy.

FAO. 2007. *Agricultural Crop Production Statistics.* Food and Agricultural Organization of the United Nation, Rome, Italy.

Gibbons, R., Buntings, A. and Smartt, J. 1972. The Classification of Varieties of Groundnut, *Arachis hypogaea* L. *Euphytica* **21(1)**: 78-85

Glueck, J. A., Clark, L. E. and Smith, O. D. 1977. Testa Comparisons of Four Peanut Cultivars. *Crop Science* **17(5)**: 777-782

Grabe, D. F. and Isley, D. 1969. Seed Storage in Moisture Resistant Packages. *Seed World,* **104(2)**:4

Gregory, W. C., Smith, B. W., and Yarbrough, J. A. 1951. Morphology, Genetic and Breeding. *Peanut: The Unpredictable Legume.* The National Fertilizer Association. Washington D. C., USA. pp. 28-88

Gregory, W. C., Gregory, M. P., Krapovickas, A., Smith, B. W. and Yarbrough, J. A. 1973. Structures and Genetic Resources of Peanuts. *Peanuts: Culture and Uses* American Peanut Research and Education Association. Stillwater, Oklahoma. pp. 47-133.

Hammons, R. O. 1973. Early History and Origin of the Peanut. In Wilson, C. T. (Eds.). *Peanuts: Culture and Uses.* American Peanut Research and Education Association. Stillwater, Oklahoma. pp. 17-45.

Hammons, R. O. 1982. Origin and Early History of the Peanut. In Pattee, H. E. and Young, C. T. (Eds.). *Peanut Science and Technology.* American Peanut Research and Education Society. Yoakum, Texas. pp. 1-20.

Harrington, J. F. 1960. *The Value of Moisture Resistant Containers in Vegetable Seed Packaging.* California University Department of Vegetable Crops Series. 104, pp.8

Harrington, J. F. 1972. Seed Storage and Longevity. In Kozlowski, T. T. (Eds.). *Seed Biology.* New York: Academic Press. pp. 145-245

Harrington, J. F. 1973. Biochemical Basis of Seed Longevity. *Seed Science and Technology.* **1**: 453-461

Holaday, P. E. and Pearson, J. L. 1974. Effects of Genotype and Production Area on the Fatty Acid Composition, Total Oil and Total Protein in Peanuts. *Journal of Food Science,* **39**: 1206-1209

Isleib, T. G., Wynne, J. C. and Nigam, S. N. 1994. Groundnut Breeding. In Smartt, J. (Eds.). *The Groundnut Crop: A scientific basis for improvement.* World Crop Series. Netherlands: Springer

ISTA. 1995. Verification of Species and Cultivars. International Rules for Seed Testing. *Seed Science and Technology.* **24**: 253-270

ISTA. 1996. International Rules for Seed Testing. International Seed Testing Association. *Seed Science and Technology,* **21**: 1-288

ISTA. 1997. *Hand book for Seedling Evaluation.* In Techniques of Seed Science and Technology. International Seed Testing Association Publication. Zurich, Switzerland: South Asian Publishers. pp. 135-139

ISTA. 2009. *International Rules for Seed Testing.* Switzerland: International Seed Testing Association

James, S. L. H. and Young, C. T. 1983. Comparison of Fatty Acid Content of Imported Peanuts. *Journal of American Oil Chemistry Society,* **60**: 945-947

Justice, L. O. and Bass, L. N. 1978. *Principles and Practices of Seed Storage.* United States Department of Agriculture. Washington DC: Agricultural Research Service. Agricultural Handbook No. 506

Knauft, D. A., Moore, K. M. and Gorbet, D. W. 1993. Further Studies on the Inheritance of Fatty Acid Composition in Peanut. *Peanut Science,* **20**: 74-76

Kolowski, F. 1926. Temperature Relations to Germination of Vegetable Seeds. *Proceedings of American Society of Horticultural Science.* **23**: 176-184

Kumar, S. Singhal, N. C. and Prakash, S. 1997. Intervarietal Variability for Seed Longevity in Pea (*Pisum sativum*). *Indian Journal of Genetic Plant Breeding,* **57**:204

McCormack, J. H. 2004. Principles and Practices of Seed Harvesting, Processing and Storage: An Organic Seed Production Manual for Seed Growers in the Mid-Atlantic and Southern U.S. *Seed Processing and Storage.* pp. 8

McDonald, M. B. and Wilson, D. O. 1979. An assessment of the standardization and ability of the ASA-610 to rapidly predict soybean germination. *Journal of Seed Technology,* **4(2)**:1-12

Moss, J. P. and Ramanatha, R. V. 1995. The Peanut Reproductive Development to Plant Maturity. In Pattee, H. E. and Stalker, H. T. (Eds.). *Advance in Peanut Science.* American Peanut Research and Education Society. Stillwater, Oklahoma. pp. 1-13

Nakamura, S. 1958. Storage of Vegetable Seeds. In Sato, T., Skro, T. and Mine, T. (Eds.). Japan: *Journal of Horticultural Association,* **27**:32-44

Nawar, W. W. 1996. Lipids. In Fennema, O. R. (Eds.). *Food Chemistry.* 3rd Edition New York: Marcel Dekker. pp. 255-264

Ndjeunga, J., Ntare, B. R., Waliyar, F. and Ramouch, M. 2006. Groundnut Seed Systems in West Africa: *Current Practices, Constraints and Opportunities.* Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics

Oke, O. L. 1967. Chemical Studies on Some Nigerian Pulses. West Africa. *Journal of Biological Applied Chemistry,* **9**: 52-55

Oladiran, J. A. and Mumford, P. M. 1990. The Longevity of Large and Small Seeds of *Amaranthus gangeticus* and *A.hybridus. Seed Science Technology.* **18**: 499

Ramamoorthi, K. and Karivaratharaju, T. V. 1991. Mobilization Efficiency: A Direct Test to Assess Seed Viability in Groundnut. *Seeds and Farms,* **15(1)**: 28-30

Ramanatha, R. V. 1988. Botany: Morphology and Anatomy, In Reddy, P. S. (Eds.). *Groundnut.* New Delhi, India: Indian Council of Agricultural Research.

Ramanatha, R. V. and Murty, U. R. 1994. Botany: Morphology and Anatomy, Intraspecific Differentiation and Morphology of *Arachis hypogaea. Groundnut.* New Delhi, India: Indian Council of Agricultural Research.

Retamal, N., Lopez, V. and Duran, J. M. 1990. Seed Morphology of 75 Genotypes of Peanut *Arachis hypogaea* L. Grown in Spain. *Plant Genetic Resources Newsletter* **80(4)**: 1-4

Rao, S. K., Rao, S. D. T. and Murti, K. S. 1965. Compositional Studies on India Groundnut-111. *Indian Oilseed Journal,* **9**:5-13

Rao, R. G. S., Singh, P. M. and Mathura, R. 2006. Storability of Onion Seeds and Effects of Packaging and Storage Conditions on Viability and Vigour. *Science Horticulturae,* **110(1)**: 1-6

Reddy, T. Y., Reddy, V. R. and Anbumozhi, V. 2003. Physiological Responses of Groundnut (*Arachis hypogaea* L.) to Drought Stress and Its Amelioration. Netherlands: Kluwer Academic Publishers. *Plant Growth Regulation* **41**:75-88

Roberts, E. H. 1972. Storage Environment and the Control of Viability. In Roberts, E. H. (Eds.). *Viability of Seeds.* London: Chapman and Hall. pp. 14-58

Roberts, E. H. 1973. Predicting the Storage Life of Seeds. *Seed Science and Technology,* **1**: 499-514

Savage, G. P. and Keenan, J. I. 1994. The Composition and Nutritive Value of Groundnut Kernels. In Smart, J. (Eds.). *The Groundnut Crop: Scientific Basis for Improvement.* London: Chapman and Hall. pp. 173-213

Salunkhe, D. K., Chawan, J. K., Adsule, R. N. and Kadam, S. S. 1992. *World Oil Seeds Chemistry: Technology and Utilization.* Van Nastrand, New York. pp. 97-371

Sastry, D. V. S. S. R., Kameswara, R. N. and Bramel, P. J. 2003. Seed Drying Under Controlled Environment for Long-Term Conservation of Germplasm. *Seed Research,* **31(2)**: 148-153

Seshadri, C. R. 1962. *Groundnut, a monograph.* Indian Central Oilseeds Committee. Hyderabad, A. P., India. pp. 274.

Smartt, J. 1994. The Groundnut in Farming Systems and the Rural Economy. In Smartt, J. (Eds.). *The Groundnut Crop: A Scientific Basis for Improvement.* London, United Kingdom: Chapman and Hall. pp. 96-137

Stalker, H. T. 1997. Groundnut *Arachis hypogaea* L. *Field Crops Research.*, **53(3)**: 205-217

Stalker, H. T. and Simpson, C. E. 1995. *Germplasm Resources in Arachis hypogaea* L. *Advances in Peanut Society.* In Pattee, H. E. and Stalker, H. T. (Eds.). USA: American Peanut Research and Education Society.

Strelec, I., Ugarcic-Hardi, Z. and Hlevnjak, M. 2008. Accumulation of Amadori and Maillard products in wheat seeds aged under different storage conditions. *Croatica Chemica Acta.* **81(1)**: 131-137

Stumpf, C. L., Peske, S. T. and Baudet, L. 1997. Storage Potential of Onion Seeds Hermetically Packaged at Low Moisture Content. *Seed Science Technology,* **25**:25-33

Tripathi, P. C. and Lawande, K. E. 2014. Effects of Seed Moisture and Packaging Material on Viability and Vigour of Onion Seed. *Journal of Engineering Computers and Applied Sciences,* **3**:1-5

Trivedi, P. C. 2011. *Seed Technology and Quality Control.* India: Pointer Publishers

Vange, T., Ikyeleve, F. and Okoh, J. O. 2016. Effect of Packaging Materials and Storage Condition on Soybean Germination and Seedling Vigour in Makurdi. *Research Journal of Seed Science,* **9**:1-4

Vaughan, C. E., Gregg, B. R. and Delouche, J. C. 1967. *Seed Processing and Handling. Seed Technology Laboratory. Miss State: Miss State University.* Handbook No. 1, pp.295

Volenik, M., Rozman, V. Kalinovic, I., Liska, A. and Simic, B. 2006. Influence of relative humidity and temperature on changes in grain moisture in stored wheat and sunflower. *Proceedings of the 9th International Working Conference on Stored Product Protection*. Campinas, Brazil pp.24-29.

Woodroof, J. G. 1983. *Peanuts Production, Processing, Products*. 3rd Edition. Westport, Connecticut: Avi Publishing Company Inc.

Worthington, R. E. and Hammons, R. O. 1971. Genotypic Variation in Fatty Acid Composition and Stability of *Arachis hypogaea* L. oil. *Oleagineaux*. **26**:695-700

Young, C. T. and Hammons, R. O. 1973. Variations in the Protein Levels of a Wide Range of Peanut Genotypes (*Arachis hypogaea* L.) *Oleagineux*, **28**: 293-297

Young, C. T., Worthington, R. E., Hammons, R. O., Matlock, R. S., Waller, G. R., and Morrison, R. D. 1974. Fatty Acid Composition of Spanish Peanut Oils as Influenced by Planting Location, Soil Moisture Conditions, Variety and Season. *Journal of the American Oil Chemist Society*. **51(7)**: 312-315