Effect of Seed Age, Size and Moisture Content on Seed Quality of Sorghum

By

Adam Abaker Bahar Elddin

B.Sc. (agric.) Honour

University of Zalingie (1999)

Supervisor

Dr. Faisal Algasim Ahmed

A thesis submitted to the University of Khartoum in partial fulfillment of the requirements for the degree of Master of Science in Agronomy

Department of Agronomy

Faculty of Agriculture

University of Khartoum

March (2006)

DIDICATION

To my dear family

Father, mother, brothers, and sisters

To my dear friends and colleagues

To the people of Jabale Marra.

With love and respect

Adam Bahar Elddin

TABLE OF CONTENTS

AKNOWLEDGEMENTS

Praise to Allah, the Almighty, who gave me health, strength patience to finish this work successfully.

My deepest gratitude and censer thanks to Dr. Faisal Elgasim Ahmed for his supervision, support, suggestion, creative direction and scientific guidance.

Special thanks and gratitude to Dr. Abdel Wahab Hassan for his endurance, much needed support and invaluable guidance. Sincere thanks and gratitude are extended to my friends and colleagues.

My thanks also extended to staff members of Agronomy Department, Faculty of Agriculture, University of Khartoum.

I would like to express my great appreciation to many persons who made this work possible at its different stages. My thanks were due to the University of Zalingie for funds of study.

Finally my deeply grateful and my sincere appreciation to my family for their patience and consistent support.

LIST OF TABLES

LIST OF APPENDICES

Abstract

A set of laboratory and field experiments were conducted during 2005 to investigated the influence of seed age, size and moisture content on seed quality attributes of sorghum cultivar Tabat. Simple correlation coefficients were also conducted to determine the degree of association between the different vigor tests and seedling emergence under field conditions.

Parameters measured included germination percentage, speed of germination, seedling shoot length, seedling root length, seedling shoot to root length ratio, seedling fresh weight and seedling dry weight. Results obtained showed that all vigor attributes measured in this study were significantly affected by seed treatment particularly under laboratory condition. In this respect, the new, large seeds (>3.15mm) and seeds with medium moisture content (7.5%) consistently resulted in a better vigor attributes compared to the old, small (<3.15 mm) and seed with either high (10%) or low moisture content (5%).

The results also showed that field emergence was positively correlated with the speed of germination (r = 0.91), seedling length (r = 0.67) and seedling dry weight (r = 0.59) suggesting that these vigor attributes could be used to estimate field emergence of sorghum seeds.

Therefore, further vigor tests were required to enable ranking of seed lots in a manner that would reflect their stand establishment capabilities under varied field conditions.

بسم الله الرحمن الرحيم

ملخص البحث

أجريت مجموعة من التجارب المعملية وتجربة حقلية فى عام 2005.لتقييم تأثير عمر البذور وحجم البذور ومحتوى البذور من الرطوبة على خصائص وحيوية بذور الذرة(صنف طابت). علاوة على مدى علاقة الأرتباط بين الأختبارات المعملية لقوة الأنبات وارتباطها بالأنبات الحقلى.

القياسات التى أخذت دلت على أن نسبة الأنبات و سرعة الأنبات وطول ساق وجذر البادرة والنسبة بين طول ساق وجذر البادرة والوزن الجاف للبادرة تأثرت بمعاملات البذور. كما أظهرت النتائج أيضا أن كل قياسات خصائص حيوية البذور قد تأثرت معنويا بمعاملات البذور خاصة تحت الظروف المعملية. وعلى هذا الأساس البذور الجديدة(عمر سنة) والبذور كبيرة الحجم(<3.15) والبذور ذات محتوى الرطوبة المتوسطة أعطت نتائج أفضل مقارنة بالبذور القديمة(عمر سنتين) والبذور الصغيرة(<15. 3) والبذور ذات المحتوى الرطوبة العالية أو المنخفضة. كذلك أوضحت النتائج أن الأنبات الحقلى له علاقة ارتباط ايجابية مع سرعة الأنبات و طول البادرة والوزن الجاف للبادرة. لذا يمكن استخدام هذه الخصائص لتقييم الأنبات الحقلى للبذور. وكذلك يتطلب مزيد من الأختبارات للحصول على الأختبار الذى يمكن استخدامه للتنبؤ بالأنبات الحقلى تحت ظروف مختلفة فى الحقل.

CHAPTER ONE

INTROCUTION

Grain sorghum (*Sorghum bicolor*. L. Moench) is one of the main stable for the world poorest and more food-insecure people. The crop is genetically suited to hot and dry agroecologies, where it is difficult to grow other food grains. It ranks fourth in importance among the cereal crops in the world following rice, wheat and maize (Janick *et al*,. 1974).

It is difficult to determine when and where domestication of sorghum had occurred. However, archaeological evidence suggested that the practice of cereal domestication was introduced from Egypt to Ethiopia about 3000 B. C. (cited by Bushara, 1999). De Candille, (1976) classified the cultivated sorghum into five main races and the newly improved varieties and hybrids of grain sorghum have been produced from those types

In the Sudan, sorghum ranks first both in total tonnage of grain produced and total acreage cultivated. The average sorghum yield is about 574 kg/ha which is below the world average yield (1386 kg/ha). This low productivity is caused by many constraints among which is the failures in obtaining satisfactory stands, and replanting adds additional cost to an already expensive production programs. Also optimum plant population is a basic requirement for high crop productivity. Thus seed germinability and seedling vigor is a crucial factor in resolving field establishment problem.

One of the main problems observed in the field is poor establishment, which is influenced by seed quality, adverse climatic conditions and poor field management (Maiti and Carrillogutierrez, 1989). Seed quality includes several attributes that lead to near maximum germination capacity to produce seedlings, which emerge rapidly from the seedbed and continue to grow uniformly thereafter (Harrington, 1971). Seed vigor, as one of several quality attributes, has received much attention in seed quality evaluation and control program (Delouche, 1976). Seed vigor is defined as the ability of the seed to emerge rapidly and develops uniformly to establish a crop in a wide range of environmental conditions (Edje and Burris, 1970). Even among seed lots with high germination percentage, differences in field emergence can occur due to differences in vigor (Tekrony and Edje, 1991). The basic requirements of vigor testing include the ability to provide more sensitive index of seed quality than the germination test and to provide consistent ranking of seed lots in terms of potential performance in the field (McDonald and Wilson, 1980). Previous studies showed results some of them found that new and large seeds and moisture content had considerable superiority while other studies showed no differences between them. Therefore, the objectives of this study were to investigate the influence of seed age, seed size and seed moisture content on seed quality attributes and to examine the correlation between seed vigor tests and seedling performance under field conditions

CHAPTER TWO

LITERATURE REVIEW

2.1. Seed quality:

Seed is the basic unit which determines the stand establishment and possibly the growth and yield of all crops. Therefore, the use of high quality seeds for planting is a major requirement for high and reliable yield of crops. High quality seed is characterized as being the seed that has the ability to establish a full stand of vigorous and uniform seedling that will grow into productive mature plant (Delouche, 1969). Thomson (1979) indicated that the main aspects of seed quality include physical and genetical purity, high germinabilty, uniform size, free from seed-born diseases, and with low moisture content. In this context, seed quality can be subjected to various degrees of deterioration during seed processing, such as time of harvesting (Obenorf *et al.*, 1980; Tekrony *et al.*, 1980); and mechanical damage during harvesting, handling, conveying and cleaning (Abdul Baki and Anderson, 1973; Castillo *et al.*, 1992). Moreover, insects and diseases, moisture content, inappropriate, storage conditions and genetic constitution have their effect on seed quality (McDonald, 1975). Among seed quality attributes, seed germination and vigor are the main indices of quality that are affected during seed deterioration. As seed deteriorate, seed vigor decline at a much more rapid rate than seed viability (McGee, 1986). For example seed lots may have relatively high germination percentage but not suitable for planting purpose (Helmer *et al.*, 1962). Thus for farmers to gain maximum profits from their crops, seed vigor is an important aspect of seed quality that has to be taken into consideration.

2.2 Germination as index of quality:

Germination is defined as" the emergence and development from the seed embryo of those essential structures which for the kind of seed being tested, indicate the ability to develop into a normal plant under favorable conditions in the soil" (Anon, 1985). The simplest test used as an index of quality is the standard germination test as described by the International Seed Testing Association (ISTA). The main objectives of this test is to obtain information with respect to the field planting value of the seed and to provide information that can be used to compare the value of different seed lots (Johnson and wax, 1978). Since field conditions are often very far from optimal, many workers observed the failure of germination test in predicting the field performance of seed. For example, Hegarty (1977) and Baalbaki and Copeland (1987), demonstrated the failure of germination test to predict field performance of the field bean and wheat seeds, respectively. Yaklich and kulik (1979) attributed these differences to the vigor of the seed lots.

2.3 Seed vigor as index of quality:

One of the most important characteristics of high quality seed is vigor. Perry (1978) concluded that abroad sense definition based on effects is more appropriate rather than one based on causes. Accordingly, vigor test committee of the International Seed Testing Association (ISTA) adopted the definition that "seed vigor is the sum total of those properties of the seed which determine the potential level of activity and performance of the seed lot during germination and seedling emergence ". Generally, the peak of vigor coincides with the maximum dry weight of seed, which occurs at physiological maturity, beyond which deterioration processes start to occur. Deterioration involves loss of membrane integrity, slower respiration, and more leakage of electrolytes and decreased enzyme activity. The amount of deterioration (loss of quality) depends on field and storage conditions (Roberts and Osei-Bonsu, 1988). Seed vigor as an important quality attribute has gained significance because standard germination dose not reflect the field emergence potential of seed lot under varied environmental conditions. Although, standardized simple tests to measure seed vigor have been attempted, no single satisfactory vigor test for universal use has been identified yet (Hampton and Coolbear, 1990). However, Ibrahim and Tekrony (1994) conducted that the accelerated aging test (AA) would probably be a good vigor test for sorghum seed providing field emergence tests corroborate laboratory results.

2.4 Factors influencing seed vigor:

Seed quality and consequently seed vigor is influenced throughout the life of the seed from fertilization on the mother plant up to sowing in the field (Broklehurst, 1985). Among the several factors that affect seed vigor are seed age, seed size, seed moisture content and the genetic make-up of seeds (Ram and Weiner, 1988).

2.4.1 Seed age:

Crop seeds begin to deteriorate just after physiological maturity (Ellis and Roberts, 1980 a). According to Villiers, (1971) the causes of seed deterioration are the preoxidation reaction which results in membrane disintegration and decompartmentation of cell components. Therefore, seeds should be harvested as they reach a moisture content at which they can be safely stored (McGee, 1986). Storage conditions can seriously affect seed longevity, germination and vigor (Cantliffe, 1977). Storage at high temperature and high relative humidity can rapidly reduce seed vigor because this condition favors microorganism invasion (Halion, 1986; McGee, 1986). Seeds retain their vigor for longer periods if they are stored at relatively lower moisture content and low relative humidity. As temperature and humidity increased, the rate of quality loss increases and moisture content is more critical than temperature during storage (Mayer and Mayber, 1982).

2.4.2 Seed size:

Seed size and seed weight are important factors in seed vigor (Pandita and Randhawa, 1992). In this respect, Sing and Makne, (1985) showed that an optimum seed size is important for proper expression of seedling vigor in sorghum. Several reports have demonstrated that optimum nitrogen fertilization and ideal growing conditions result in larger, heavier and more vigorous seedling as compared with smaller seeds in cowpea (Sinha *et al.*., 1988), radish (Pandita and Dandhawa, 1992) and brassica (Dubey *et al.*, 1989).

Wide variation in seed size affects uniformity of crops, and will cause reduction in the total yield (Raveendranth and Singh, 1991). Fonseca *et al.*, (1990) reported that in birds foot trefoil, a pasture legume noted for poor seedling vigor, the small seed size is the major factor responsible for poor seedling vigor and the initial seedling growth was associated with the greater nutrient reserves of large seed. El Dessogi (1994) studied the effect of seed grade (in terms of seed weight) on vigor of cotton seed, she conducted that the sinker seed (115.9 mg. seed) showed superior vigorous level as determined by the rapidity of germination, greater seedling shoot and root length and higher dry weight as compared to floater seed (94.5 mg. seed). Bradbeer (1988) found that for some crops, large seeds might be desirable in that they tended to germinate more vigorously and to give large seedlings which might be reflected in higher yield. In addition, large seeds had capacity to contain large embryo and substantial food reserves which would enable them to achieve considerable growth of both roots and shoots before they become dependant on their own photosynthesis.

Uniformity in size is one of the desirable properties of seed quality and in many cases seed size is positively associated with vigor (Paul and Ramaswamy, 1979). Gill and Singh (1979) found that seed size in radish did not affect germination in the laboratory but larger seeds showed higher germination in the field. Pandita and Randhawa (1992) also found that vigor index values were higher for large seeds followed by medium and small seeds in radish, and field emergence increased with increased seed size. On the other hand, Rajendra *et al*, (1990) observed the superiority of smaller seeds in soybean varieties over large seeds with regard to vigor and emergence potential. Small seeds were found to start the process of germination earlier which lead to early emergence compared to large seeds (Milosevic *et al*, 1992).

2.4.3 Seed moisture content:

Seed moisture content is the most important determinant of longevity in storage. Harrington's (1977) rule of thum was that for each one percent decrease in seed moisture content, storage life doubled. Within seed lot, if the log of the average seed lifespan is plotted against the log of the moisture content a straight line results. This relationship exists in the range of water activities from 0.08 to 0.90 (Khan, Roberts and Ellis, 1989).

Through many experimentation and experiences scientists noticed that seed survive longer when they are stored dry or in drier environment. With regard to moisture content and seed survival, seeds are classified as orthodox or recalcitrant (Roberts, 1973). Recalcitrant seeds survive at relatively high moisture content and are killed if dried (Roberts, 1973). Orthodox seeds, on the other hand, survive longer at low moisture content. Stanwood and Base (1976) working on sorghum reported that as storage temperature and seed moisture content increase the germination percentage of seed lot decline. Similarly, Singh (1987) found that sorghum seeds remain viable maintaining the initial viability percentage of (95%) upto 21 months when stored in ambient condition but it decreased to 70% when those seeds were stored in cloth bags. Ibrahim and Roberts (1983) further reported that there was a decrease in longevity of lettuce seeds with increase in hydration upto a moisture content of 15%.

2.4.4 Genetic make-up:

The genetic make-up has a major effect on seed vigor and considerable differences exist among different species, different varieties, and even within a variety (Copeland, 1976). The same author also reported that maximum possible vigor is determined by genotype, but it may be modified by the environment during maturation, harvesting, post-harvesting, handling, and storage. Lakhani *et al.* (1986) found that genetic variability in seed vigor existed in lentil genotypes. Genetic changes such as chromosomal aberration and population shifts, which occur during aging of seeds, increase the number of abnormal seedling (Ross, 1980). Genetic factors such as hybrid vigor, seed coat, chemical composition and susceptibility to mechanical damage may influence seed vigor (Harman and stasz, 1986).

2.5 Correlation between vigor tests:

2.5.1 Speed of germination:

Speed of germination has been suggested as vigor test because vigorous seeds have been shown to germinate rapidly. Also the test is inexpensive, rapid, required no specialized equipment, and most importantly dose not require additional technological training. However, the test has been criticized as vigor test because factors such as temperature and moisture are difficult to standardize among laboratories.

Burris *et al,* (1969) kumar *et al*, (1988) showed that speed of germination is significantly correlated with seed vigor in soybean and green gram, respectively. On the other hand, BaalBaki (1989) found a weak correlation between speed of germination and vigor during storage. Maquire (1962) demonstrated that seed lots having the same speed of germination often differ in field emergence and growth indicating that speed of germination is not a good vigor test. But according to Shenoy *et al*, (1990) speed of germination contributes more towards predicting field emergence than other vigor tests.

2.5.2 Seedling dry weight:

Seedling dry weight is a test that further evaluate normal seedlings after standard germination and it was successfully used to assess seed vigor. Sinha *et al*., (1988) and Steiner *et al*., (1989) claimed that seedling dry weight is one of the best single vigor tests to predict seedling emergence of wheat and cowpea, respectively. Simple correlation studies carried out by Vanangamudi (1987) indicated that seedling dry weight showed good correlation with standard germination in bajra (*Pennisetum gluacum*). But Edje and Burris (1970) mentioned, however, that total seedling dry weight of soybean was not closely correlated with vigor. Moreover, kittock and law (1968) showed that there was no relationship between changes in seedling dry matter and seed vigor in wheat.

2.5.3 Shoot and root length:

Shoot and root length have been used as vigor test by many researchers. Kim *et al,* (1987) concluded that hypocotyl length provided a good estimate of seed quality in soybean. Similarly Alizaga *et al,* (1987) also observed that hypocotyl length declined with decreases in seed vigor in soybean. Furthermore, Steiner *et al,* (1989) observed that seedling root length accurately predicted seedling emergence in wheat. The correlation between seedling length and other vigor tests was studied by Vanangamudi (1987). He stated that there was positive correlation between seedling length and standard germination.

CHAPTER THREE

MATERIALS AND METHODS

3.1. General:

A set of laboratory and field tests were carried out on seed of sorghum (*Sorghum bicolor*. L.Moench) variety Tabat, to investigate the influence of seed age, seed size and seed moisture content on seed quality attributes and to examine the correlation between seed vigor tests and seedling performance under field condition. The laboratory tests were carried out at the Seed Research Laboratory, Agronomy Department, Faculty of Agriculture, University of Khartoum. The field tests were carried out at the Experimental Farm of the Faculty of Agriculture at Shambat (latitude 15° 40″N, longitude 32° 32″E and 380 meter above sea level). The soil of the area is clay with more than 50% clay content and alkaline (pH 8.6) in reaction (Caraing, 1991).

3.2. The Seed:

Two seed lots of sorghum cultivar (Tabat) were provided by Sudanese Arab seed Company, representing harvests of 2003 and 2004 and were therefore, presumed to have low and high vigor levels, respectively. Sub samples from each seed lot were graded into two size categories, using electrical mechanical shaker (RetschVibro, Nr.42805). The seed retained over 3.15mm sieve were considered as large seeds whereas those which passed through the 3.15 mm sieve and retained over 2.5mm sieve were considered as small seeds. The initial moisture content of two seed sub samples from each seed lot was determined by drying 20g samples replicated four times in an oven set at 80 $\pm$ 1°C for 24 hours (Anon, 1985). The seeds were then adjusted to two different moisture content one above 10% and one below 5%, the initial moisture content was 7.5%. To that end known weight of seeds was separately humidify at 8C°. The seeds were occasionally stirred and weighed and the change in moisture content was followed using the following formula:

$$M = \frac{w\,(100 - m)}{S} + m$$ (Ibrahim and Roberts, 1983).

Where:

M = desired moisture content (%)

m = initial moisture content (%)

w = weight of water taken up by seeds (g)

S = weight of seeds (g) at (m) moisture content

The seeds were removed from humidification when the desired moisture content was reached. To adjust the seeds to low moisture content, known weights of seeds were separately unhumidify at 40C, and they were periodically weighed and the change in moisture content of the seeds was calculated until the desired seed moisture content was reached. The seeds from all the categories were stored in airtight polythene bags and working samples were drawn to perform the following tests:

3.3. Laboratory tests:

3.3.1 Standard germination test:

From each category, 200 seeds in four replications of 50 seeds each were germinated in double moist filter papers. The seeds were placed two centimeters apart to avoid the contact of seedlings during germination. Seeds were germinated in the dark using incubator set at 27$\pm$1°C for ten days according to ISTA rules (Anon, 1985). At the end of the incubation period, the number of normal seedlings was recorded and the germination percentage was calculated as follows.

$$\text{Germination \%} = \frac{\text{Number of normal seedlings}}{\text{Number of seeds planted}} \times 100$$

3.3.2 Speed of germination:

The test was carried out as per standard germination test described above. Daily count of normal seedlings were recoded, and the speed of germination was obtained by multiplying the number of seeds germinated on a specific day by the reciprocal of the day on which the germinated seedlings were recorded using the following formula as described by Maguire, (1962).

$$X = \frac{\text{No. of normal seedlings}}{\text{Days of the first count}} +. +. + \frac{\text{No. of normal seedlings}}{\text{Days of the final count}}$$

3.3.3-Seedling dry weight:

The seedlings dry weight was assessed after the final count in standard germination test. The seedlings were cut free from their remnants and dried in an oven set at 80 $\pm$1°C for 24 hours (Fiala, 1987). The dried seedlings were weighed to the nearest milligram and the average seedlings dry weight was calculated.

3.3.4. Seedling shoot and root length:

Seeds from the different categories were germinated as per standard germination test. At the end of incubation period, shoot and root length of normal seedlings were measured. Shoot length was measured from the point of attachment to the seed to the tip of the seedling and the average shoot length was calculated by dividing the total shoot length by the number of normal seedlings measured. Similarly, the root length was measured from the point of attachment to seed to the tip of the root and the average root length was computed by dividing the total root length by total number of the normal seedlings measured (Fiala, 1987). All the laboratory tests were conducted as factorial experiments in a randomized complete block design.

3.4. Field tests:

Seed sub-samples similar to those described in the laboratory tests were tested under field conditions. Normal land preparation was carried out and the experiment was laid out in split-split plot design with four replicates. Each plot consisted of five ridges five meter in length. The main plots were allowed to age, the sub plot to seed size and the sub–sub plots to seed moisture content. Sowing was on the first week of July 2005. The seeds were sown in holes 25 cm apart and 2.5cm deep at a rate of five seeds per hole. The seedlings were thinned to one plant per hole two weeks after sowing. On seedling emergence the following tests were performed:

3.4.1. Seedling emergence:

Emerged seedlings were counted regularly until maximum emergence was reached. The emergence percentage for each plot was calculated as follow:

$$\text{Emergence \%} = \frac{\text{No. of emerging seedlings}}{\text{No. of sown seeds}} \times 100$$

3.4. 2Speed of seedling emergence:

The test was carried out by daily count of the seedling until no more seedlings emerged (15 days) and the vigor index was calculated as follow:

$$\text{Speed of emergence} = \frac{\text{No. of emerged seedlings}}{\text{Days of the first count}} +. +.+ \frac{\text{No. of emerged seedlings}}{\text{Days of the final count}}$$

3.4.3. Seedling fresh weight (mg):

Four samples (each sample consists of four plants) were randomly selected and removed from each plot for determination seedling fresh weight. The soil was washed off the roots and the fresh seedlings were weighed to the nearest milligram to obtain the average seedling fresh weight as follows:

$$\text{Fresh weight} = \frac{\text{Total weight of seedlings}}{\text{Number of seedlings}}$$

3.4.4. Seedling dry weight (mg):

After getting seedling fresh weight, the seedlings were placed in pitry dish and dried in an oven set at 80±1°C for 24 hours and the average seedlings dry weight was computed.

3.5 statistical analysis:

Data were subjected to the analysis of variance appropriate for the design used (Gomez and Gomez, 1984). Mean separation was done according to Duncan's multiple range (DMRT) for different characters. Simple correlation coefficients were calculated to test the association among the laboratory test results and between the laboratory and field emergence tests.

CHAPTER FOUR

RESULTS

4.1. Seed viability:

The overall mean seed viability as represented by germination percentage was relatively higher under the laboratory (56%) condition compared to the field (44%) condition (Table 1). Statistical analysis revealed that germination percentage was significantly affected by seed treatments particularly under the laboratory condition (Appendix table 1). In this regard, the new, large and medium moisture content seeds resulted in a significantly higher germination percentage compared to the old, small and either high or low seed moisture content, respectively (table 1). No significant interaction between treatments on germination percentage of seeds was observed in this study (Appendix table 1).

4.2. Seed vigor attributes:

4.2.1. Speed of germination (days):

Data presented in table (2) indicated that the effect of seed treatments on the speed of germination followed similar pattern to that described for germination percentage. Analysis of variance showed that, speed of germination was significantly affected by seed treatment under laboratory condition only (Appendix table 1). The new and medium moisture content seeds had a significantly higher speed of germination percentage compared to old and seed with either low or high moisture content, respectively (Table 2). Similar pattern was observed under field condition but the difference between treatments was not significant (Table 2). Differences due to seed size and the interactions on the speed of germination were not significant under both laboratory and field conditions (Appendix tables 1 and 2).

Table (1): Effect of seed age, size and moisture content on germination percentage under laboratory and field conditions.

Treatments	Germination percentage	
	Laboratory condition	Field conditions
Seed age		
New(1year)	51.3a	41.6a
Old (2years)	45.6b	40.7a
SE ±	1.87	1.38
Seed size		
Small(3.15-2.6mm)	45.6b	38.9a
Large (>3.15mm)	51.3a	43.4a
SE ±	1.87	4.11
Seed moisture content		
Low (5%)	45.1b	37.8a
Medium (7.5%)	51.9a	42.4a
High (10%)	48.5b	43.2a
SE±	2.29	3.72

For each treatment, means followed by the same letter (s) within a column are not significantly different ($p \leq 0.05$) according to Duncan Multiple Range Test (DMRT).

Table (2): Effect of seed age, size and moisture content on speed of germination under laboratory and field conditions.

Treatments	Speed of germination	
	Laboratory condition	Field conditions
Seed age		
New(1year)	19.4a	5.8a
Old (2years)	18.1b	6.2a
SE ±	0.27	0.31
Seed size		
Small(3.15-2.6mm)	18.6a	5.5a
Large (>3.15mm)	18.9a	6.5a
SE ±	0.27	0.62
Seed moisture content		
Low (5%)	18.0b	5.6a
Medium (7.5%)	19.4a	6.3a
High (10%)	18.8b	6.1a
SE±	0.34	0.34

For each treatment, means followed by the same letter (s) within a column are not significantly different ($p \leq 0.05$) according to Duncan Multiple Range Test (DMRT).

4.2.2. Seedling shoot length (mm)

The overall mean seedling shoot length was relatively higher under the field (190.0 mm) condition compared to the Laboratory (40.0 mm) condition (Table 3). Statistical analysis showed that seedling shoot length was significantly affected by treatment under both conditions (Appendix tables 3 and 4). In this regard, the new, small and higher moisture content seeds resulted in a significantly higher seedling shoot length particularly under laboratory condition compared to old, large and either medium or low seed moisture content, respectively (Table 3). Under field condition the large seeds resulted in a significantly higher seedling shoot length compared to small seed (Table 4). No significant interaction between treatments on seedling shoot length was observed in this study (Appendix tables 3 and 4).

4.2.3. Seedling root length (mm):

Data presented in table (4) indicated that the effect of seed treatments on seedling root length followed similar pattern to that described for seedling shoot length. Analysis of variance showed that seedling root length was significantly affected by seed treatments under both laboratory and field conditions (Appendix tables 3 and 4). The new and high moisture content seeds had a significantly taller seedling root length compared to the old and seeds with either low or medium moisture content, respectively (Table 4). Under field condition only the large seed produced taller seedling root length compared to small seeds (Table 4). Differences due to the interactions were not significant under field condition (Appendix table 4).

4.2.4. Seedling shoot to root ratio:

Statistical analysis revealed that seedling shoot to root length ratio was significantly affected by seed treatments particularly under laboratory condition (Appendix table 4). Under the laboratory condition the old, large and low moisture content seed resulted in a significantly lower seedling shoot to root ratio compared to the new, small and either high or medium seed moisture content, respectively (Table 5). No significant difference between seed treatments was observed under field condition (table 5). No significant interaction between treatments on seedling shoot to root length ratio was recorded in this study (Appendix tables 3 and 4).

4.2.5. Seedling fresh weight (mg):

Although the effect of seed treatments on seedling fresh weight followed similar pattern to those described for other vigor tests, there was no significant difference between treatments under both laboratory and field conditions (Table 6).

4.2.6 Seedling dry weight (mg):

Data presented in Table (7) indicated that the effect of seed treatments on seedling dry weight followed similar pattern to that described for seedling fresh weight. Statistical analysis revealed that, seedling dry weight was only significantly affected by seed age and seed size under laboratory and field conditions, respectively (Appendix tables 3 and 4). No significant interaction between treatments on seedling dry weight was observed in this study (Appendix tables 3 and 4).

4.3. Correlation analysis:

Simple correlation coefficients study (Table 8) showed that standard germination percentage was positively correlated only with speed of germination (r = 0.91) among the measured vigor tests. Field emergence was also well correlated with the speed of germination (r = 0.63), shoot length (r = 0.67) and seedling fresh and dry weight (r = 0.59, Table 8). No significant correlation was found between field emergence and the standard germination test (Table 8).

Table (3): Effect of seed age, size and moisture content on seedling shoot length (mm) under laboratory and field conditions.

Treatments	Seedling shoot length	
	Laboratory condition	Field conditions
Seed age		
New(1year)	44.3a	196.1a
Old (2years)	36.5b	184.0a
SE ±	0.17	0.76
Seed size		
Small(3.15-2.6mm)	43.8a	176.0a
Large (>3.15mm)	37.0b	204.1b
SE ±	0.17	0.58
Seed moisture content		
Low (5%)	32.4b	197.9a
Medium (7.5%)	38.3b	192.0a
High (10%)	50.4a	180.3a
SE±	0.21	0.58

For each treatment, means followed by the same letter (s) within a column are not significantly different ($p \leq 0.05$) according to Duncan Multiple Range Test (DMRT).

Table (4): Effect of seed age, size and moisture content on seedling root length (mm) under laboratory and field conditions.

Treatments	Seedling root length	
	Laboratory condition	Field conditions
Seed age		
New(1year)	96.4a	83.8a
Old (2years)	84.1b	82.0a
SE ±	0.22	0.10
Seed size		
Small(3.15-2.6mm)	88.3a	74.0b
Large (>3.15mm)	92.1a	91.8a
SE ±	0.22	0.30
Seed moisture content		
Low (5%)	83.2b	84.4a
Medium (7.5%)	82.6b	88.6a
High (10%)	104.9a	75.7a
SE±	0.28	0.55

For each treatment, means followed by the same letter (s) within a column are not significantly different ($p \leq 0.05$) according to Duncan Multiple Range Test (DMRT).

Table (5): Effect of seed age, size and moisture content on seedling shoot to root length ratio under laboratory and field conditions.

Treatments	Seedling shoot to root length ratio	
	Laboratory condition	Field conditions
Seed age		
New(1year)	4.6a	24.9a
Old (2years)	4.3a	22.8a
SE +	0.02	0.10
Seed size		
Small(3.15-2.6mm)	4.9a	24.4a
Large (>3.15mm)	4.0b	23.3a
SE +	0.02	0.14
Seed moisture content		
Low (5%)	3.9b	23.1a
Medium (7.5%)	4.7a	23.6a
High (10%)	4.9a	25.0a
SE +	0.03	0.15

For each treatment, means followed by the same letter (s) within a column are not significantly different ($p \leq 0.05$) according to Duncan Multiple Range Test (DMRT).

Table (6): Effect of seed age, size and moisture content on seedling fresh weight (mg) under laboratory and field conditions.

Treatments	Seedling fresh weight	
	Laboratory condition	Field conditions
Seed age		
New(1year)	950a	5570a
Old (2years)	850a	3880a
SE $\pm$	0.05	1.51
Seed size		
Small(3.15-2.6mm)	940a	4130a
Large (>3.15mm)	1010a	5320a
SE $\pm$	0.05	1.70
Seed moisture content		
Low (5%)	670a	5550a
Medium (7.5%)	870a	6260a
High (10%)	960a	6090a
SE$\pm$	0.06	1.35

For each treatment, means followed by the same letter (s) within a column are not significantly different ($p \leq 0.05$) according to Duncan Multiple Range Test (DMRT).

Table (7): Effect of seed age, size and moisture content on seedling dry weight (mg) under laboratory and field conditions.

Treatments	Seedling dry weight	
	Laboratory condition	Field conditions
Seed age		
New(1year)	6.0a	131.0a
Old (2years)	5.0b	108.0a
SE ±	0.01	0.01
Seed size		
Small(3.15-2.6mm)	5.0a	96.0b
Large (>3.15mm)	5.0a	143.0a
SE ±	0.01	0.01
Seed moisture content		
Low (5%)	4.0a	124.0a
Medium (7.5%)	5.0a	116.0a
High (10%)	6.0a	119.0a
SE±	0.05	0.02

For each treatment, means followed by the same letter (s) within a column are not significantly different ($p \leq 0.05$) according to Duncan Multiple Range Test (DMRT).

Table (8) Correlation among the various vigor tests and between the vigor tests and field emergence.

	1	2	3	4	5	6
Standard germination	-					
Speed of germination	0.91*	-				
Seedling shoot length	Ns	Ns	-			
Seedling root length	Ns	Ns	Ns	-		
Shoot to root ratio	Ns	Ns	0.75**	Ns	-	
Seedling fresh weight	Ns	Ns	0.93**	Ns	0.63*	-
Seedling dry weight	Ns	Ns	0.89**	Ns	0.59	0.94**
Field seedling emergence	Ns	0.63*	0.67*	Ns	0.59*	0.59*

1-germination percentage
5- seedling shoot to root ratio
2-speed of germination
6- seedling fresh weight
3- Seedling shoot length
7- seedling dry weight
4- Seedling root length
8- Field seedling emergence

NS: No significant different

*: Significant at (0.05) level of probability.

**: significant at (0.01) level of probability.

CHAPTER FIVE

DISCUSSION

In the present study, the influence of seed age, seed size and seed moisture content on seed quality attributes were consistently significant, particularly under laboratory conditions. The lack of significant difference under field conditions may be attributed to the seldom optimal nature of the field conditions and the small differences between seed quality attributes under laboratory condition in predicting the planting value of the seed in the field. In the present study, the analysis of the laboratory tests proved that seed age had a highly significant effect on seed viability as monitored by the standard germination test and the highest germination percentage was realized by the new seeds. This result agreed with the findings of Cantliffe (1977) in soybean. The low germination percentages of the old seeds may be attributed to seed deterioration during storage. The loss of vigor in aged seed also may be due to impairment of specific biological or physiological function, as reported by Aschermann-Koch *et al*, (1992).

Similarly, the highest speed of germination was recorded by the new seed indicating that seed index in sorghum increases with decreasing seed age. Such results may be ascribed to deterioration with age as reported by Nauliyal *et al* (1988) in pearl millet. In addition, significant differences were observed among the two seed lots in the test of shoot and root length and seedling dry weight particularly under laboratory condition. Similar trend was observed by many workers (Edji and Burris, 1970; Nautiyal et al, 1988; khah, Roberts and Ellis; 1989). They reported that these vigor attributes diminished with seed deterioration.

In this study, seed size affected germination percentage and the highest values were realized by the large seed fraction under laboratory condition. Previous studies revealed that, the greater the seed size the higher would be the germination percentage (Cortes, 1987). This may explain the superiority of the large seed fraction over the small seed fraction on germination percentage test observed in this study. The low germination percentage of the small seeds may partially be attributed to the presence of immature and shriveled seeds. The non significant effect of the seed size on germination percentage under field condition is in accord with the previous findings (Agrwal, 1982; sung, 1992). They stated that, germination percentage was almost the same in all grades of the seed tested under field conditions. Seed vigor in terms of rapidity of germination was assessed by the speed of germination. Differences between seed sizes were not significant under both laboratory and field conditions. This result may be ascribed to the fact that the effect of carbohydrate required for germination in this stage was not crucial.

Seed vigor attributes were used to prove a good prediction for seedling vigor and subsequent crop performance. In the present study, the effect of seed size on seedling vigor was investigated as seedling shoot and root length, shoot to root ratio, seedling fresh weight and seedling dry weight. The results showed that seedlings raised from large seeds had significantly better vigor attributes compared to those derived from small seeds. These results support the previous findings of Raveendranth and Singh (1991) in sunflower. Moreover, Agrawal (1982) working with Lentil mentioned that large seeds had greater shoot dry weight compared to small ones. Also, Singh and Pai (1988) found that shoot and root length increased with increasing seed size in cowpea and attributed this to the large carbohydrate reserve of large seeds.

The superiority of small seeds over the large seeds on some vigor attributes (e.g. shoot length and shoot to root ratio) may be attributed to its high speed of germination. Similar results were reported by Sahoo *et al* (1988). Differences between seed grades in shoot to root ratio may be attributed to the effect of seed size on seedling shoot length.

In the present study the significant effect of seed moisture content on seed viability in terms of germination percentage and speed of germination is in accord with the previous research. In this regard, Ibrahim and Roberts (1983) reported that seed viability in lettuce decreased with increases in seed hydration upto 15% moisture content. The effect of seed moisture on seed viability observed in this study may be attributed to the short storage duration between seed treatment and planting (5days) which acted as pre-irrigation to the seed. Supporting evidence was reported by Aziz (1983) who showed that the duration of storage had notable effect on seed germination. The significant effect of high and medium moisture content on shoot and root length and on shoot to root ratio observed in this study may be also attributed to short storage duration of seed after moisture treatment.

Since field conditions are seldomly optimum, and differences in quality between seed lots might not be too wide, the germination percentage test may not always be sufficient to accurately predict the planting value of the seeds. This might explain the non significant correlations between standard germination test and field emergence test measured in this study. Therefore, further vigor tests were required to enable ranking of seed lots in a manner that would reflect their stand establishment capabilities under varied field conditions (Heydecker, 1972). In the present study, speed of germination, seedling length and dry weight were positively correlated with field emergence. Similar results were reported by many workers (Kumar, et al, 1988; Steiner et al., 1989).

SUMMARY AND CONCLUSIONS

1- A set of laboratory and field tests were conducted during 2005 to investigate the effect of seed age, seed size and seed moisture content on seed viability and seed vigor attributes of sorghum cultivar Tabat.

2- The results indicated that seed treatments had significant effects on all measured parameters under laboratory condition only. In this respect, the new, large seeds (>3.15mm) and seeds with medium moisture content consistently resulted in better vigor attributes compared to the old, small and seed with either high or low moisture content.

3- The results also showed that field emergence was positively correlated with the estimate, under laboratory condition speed of germination, seedling length and seedling dry weight, suggesting that these vigor attributes could be used to estimate field emergence of sorghum seeds.

4- Further study is needed to determine the appropriate seed treatment that leads to better vigor attributes.

References

Abdul Baki, A. A. and Anderson, J. D., (1973). Vigor deterioration in soybean seed by multiple criteria 13:630-633.

Agrawal, P. K., (1982). The effect of seed size on germination, vigor and field emergence of lentil. Lens 9: 28-29.

Alizaga, G. Alizaga, R. and Herrera, J., (1987). Evaluation of soybean (*Glycine max* [L.] Merr.) Seed vigor and its relationship with emergence and yield. Agronomia costarricense 11(2):195-203

Anon (1985) international rules for seed testing. Seed Science and Technology. 13, 356-513.

Aschermann-Koch, C. Hofmann, P. and Stiener, A. M., (1992). Pre-sowing treatment for improving seed quality in cereals. Seed Science and Technology 20: 435-440.

Baalbaki, R. and Copeland, L. O., (1987). Vigor testing of wheat and its relationship to field performance, storage and seed quality. Newsletter of association of official seed analysis 61 (2):15.

Baalbaki, R. Z., (1989). The effect of seed size, density and protein content on field performance, vigor and storability of two winter wheat varieties: science and engineering 50 (3): 815B.

Bradbeer, J. W. (1988). Seed structure and composition. In: seed dormancy and germination, 18-26. Chaman and Hall, New York.

Brocklehurst, P. A. (1985). Factors effecting seed quality in vegetable crops. Scientific Horticulture. 36, 48-57.

Burris, J. S., Edje, O. T. and wahab, A. H., (1969). Evaluation of vigorous indices of seed and seedling vigor in soybean (Glycine max [L.] Merr) proceedings of association of official seed analysis 59:73-81

Bushara, M. A. (1999). Line x tester Analysis for hetrosis and combining ability in some genotypes of grain sorghum (sorghum bicolor .L). M. Sc. Thesis, Faculty of Agriculture University of Khartoum.

Cantliffe, D. J., (1977). Vigor measurements of endosperm mutant corn. Seed men's Digest 10:12-28.

Castillo, A. G. Hampton. J. G. and coolbear, P., (1992). Effect of time and methods of harvest on seed vigor in garden peas (*Pisum sativum L.*) Journal of applied seed production 10:31-35.

Copeland, L. O. (1976). Principle of seed science and technology. Burgess publishing company, Minneapolis, Mnnesota, U.S.A.

Cortes, J. E. (1987). Relationships of seed size and density to seed quality in sorghum (sorghum bicolor).Ph.D. Thesis, Mississipi state University, Mississipi-USA.

Craig, G. M., 1991. The agriculture of the Sudan. 468p, Oxford University press, Waltson Street, ox2 6dp, England.

De Candolle, A. (1976). Origin of cultivated plants pp. 380-384.

Delouche, J. C., (1969). Planting seed quality. Beitwide cotton production. Mechanization conference. Jan.a-10, 1969. New Orleans, U.S.A.

Delouche, J. C., (1976). Standardization of vigor tests. Journal seed technology 1(2): 75-85.

Dubey, A. K., Singh, P., Goyal, R. D. and Katiyar, R. P., (1989). A comparison of vigor between large and small seeds in mustard. Seed research 17(2):204-207.

Edje, O. T. and Burris, J. S., (1970). Seedling vigor in soybean. Proceeding of Association of official seed Analysts 60:149-157.

El Dessogi, H. I. (1994). Investigations into acid delinting of cotton (*Gossypium spp*.) seed. M.Sc. thesis, University of Khartoum.

Ellis, R. H. and Roberts, F. H. (1980a). Improved equations for predicting seed longevity. Ann. Bot. 45: 13-30.

Fiala, F., (1987). Handbook of vigor test methods, 2nd addition, pp 28-36. International Seed Testing Association. Zurich, Switzerland.

Fonseca, M. L., McGraw, R.L.and Buselinnck**,** P.R. (1990). Cotyledon cell number and size in birdsfoot trefoil. Crop Science. 30, 266-270.

Gill, B. R. and Singh, H., (1979). Effect of seed size and sowing date on germination and yield of radish (*Raphunus sativus L*.) roots. Seed Research 7(1): 58-61.

Gomez, K. A. and Gomez, A. A. (1984). Split plot deign. In: Statistical procedures for Agricultural Research. John Willey and Sons, New York.

Hellion, J. M., (1986). Microorganisms and seed deterioration. In: McDnald, M.B.Jr. and Nelson, C. T. (eds) physiology of seed deterioration, PP 89-90. Crop society of America, inc. Madison, Wisconsin, U.S.A.

Hamton, J. G. and Coolbear, P., (1990). Potential versus actual seed performance-can vigor testing provide an answer. Seed science and technology 18:215-228.

Harrington, J. E. (1977). Seed storage and longevity. Seed Biology. 3: 45-57.

Harman, G. E. and Stasz, T. E., (1986). Influence of seed quality and soil microbes and roots. In; west, S. H. (eds) physiological-pathological interactions affecting seed deterioration, pp 11-37. Crop Science Society of America, inc. Madison, Wisconsin, U.S.A.

Harrington, J. F., (1971). The necessity for high quality vegetables. Hortscience 6:550-551.

Hagarty, T. W., (1977). Seed vigor in field beans (*Vicia faba* L.) and its influence on plant stand. Journal Agricultural Science. Cambridge. 88:168-173.

Helmer, J. D., Delouche, J. C. and Lienlard, M., (1962). Some indices of vigor and deterioration in seed of Crimson clover. Proceedings of the Association of official seed Analyst 52:154-161.

Heydecker, W. (1972). Vigor. IN: viability of seeds. (E. H. Roberts, ed.)209-252. Syracuce University Press.

Ibrahim, A. E. and Roberts, E. H. (1983). Viability of lettuce seed. I. hermatic storage. J.EXP. Bot. 34: 620-630.

Ibrahim, A. E. and Tekrony, D. M. (1994). The relationship between laboratory seed vigor tests and field establishment of sorghum (*sorghum bicolor* L. Moench). University of Khartoum Journal of Agricultural Science. 2(2), 1-16.

Janick, J., Cheery, R. W., Woods, F. W. and Ratlan, V. W. (1974). Plant Science. An interaction to world crops. pp 413. 2nd ed.

Johnson, R. R. and Wax, L. B., 1978. Relationship of soybean germination and vigor tests to field performance. Agronomy Journal 70 (2): 273-278.

Khah, E. M., Roberts, E. H. and Ellis, R. H. (1989). Effect of seed aging on growth and yield of spring wheat at different plant population. Field Crop Research. 20: 175-190.

Kim, S. H., Copeland, L. O. and BaaLBKi, R., (1987). The use of multiple tests in predicting the vigor of soybean seed. Korean Journal of crop science 32(3):268-276.

Kittock, D. L. and Law, A. G., (1968). Relationship of seedling vigor to respiration and tetrazolium chloride reduction by germinating Wheat seeds. Agronomy Journal 60:286-288.

Kumar, R., Tyagi, C. S. and Ram, C., (1988). Association between Laboratory seed vigor tests and field performance in green gram (*Vigna radiata* [C.]Wilezek) Seed and farms 14(5):26-31.

Lahkani, J. P., Holkas, S. and Mishra, R., (1986). Genetics of seedling vigor and hard seed in Lentil. Lens 13(2)781-784.

Maguire, J. D., (1962). Speed of germination-aid in selection and evaluation for seedling emergence and vigor. Crop Science 2(2):176-177.

Maiti, R. K. and carrillogutierrez, M. DE. J. (1989). Effect of plating depth on seedling emergence and vigor in sorghum (*sorghum bicolor* [L.] Moench). Seed science and technology 17, 83-90.

Mayer, A. M. and Mabyer, A. P., (1982). The germination of seed. 3rd addition, pp 22-49. pergamon press ltd, Headington Hill Hall, oxford OX3 OBW, England.

McDonald, M. B., (1975). A review and evaluation of seed vigor tests. Proceeding of Association of official seed analysts 65:109-139.

McDonald, M. B. and Wilson, D. O., (1980). ASA-610 to detect changes in soybean seed quality. Journal seed technology 5(1):56-66.

McGee, C. S., (1986). Environmental factors associated with preharvest deterioration of seed. In: west, S. H. (eds) physiological-pathological interactions affecting seed deterioration, pp 53-64. Crop Science Society of America, inc. Madison, Wiscosin, U.S.A.

Milosevic, M., Rajnprcht, J. and Dokic, P., (1992). Effect of different seed size fraction on germination in sugar beet (*Beta vulgari* L.). Seed Science and technology 20 703-710.

Nautiyal, P. C., Vasantha, S., Suneja, S. K. and Thakkar, A. N., (1988). Physiological and biochemical attributes associated with loss of seed viability and vigor in groundnut (*Arachis hypogaea L.)*. Olĕaginex 43 (12): 459-463.

Obendorf, R. L. Ashworth, E. N. and Rytko, G. T., (1980). Influence of seed maturation on germinability in soybean. Crop Science 20:483-486.

Pandita, V. K. and Randhawa, K. S., (1992). Seed quality in relation to seed size in radish. Research 20(1):47-48.

Paul, S. R. and Ramaswamy, K. R., (1979). Relationship between seed size and seed quality attributes in cowpea (*Vigna sinensis* L. Savi). Seed Research 7(1)63-70.

Perry, D. A., (1978). Report of vigor test committee 1974-1977. Seed science and technology 6(1):159-181.

Rajendra, P. V., Kumar, R., Prakash, V. and Kaliyar, R. P., (1990). Germinability of soybean seed after harvest in subsequent storage. Seed Research 18(1):44-46.

Ram, C. and Wiesner, E. (1988). Effect of artificial aging on physiological and biochemical parameters of seed quality in wheat. Seed Science and Technology 16:579-587.

Raveendranth, V., and Singh, B. G., (1991). Effect of seed size on seedling vigor in sunflower (*Helianthus annus*). Seed Research 19(1):37-40.

Roberts, E. H. (1973). Predicting the storage live of seed. Seed Science and Technology. 1: 494-514.

Roberts, E. H. and Osei-bonsu, K., (1988). Seed and seedling vigor. In: Summerfield, R.J. (eds) World crops: Cool Season Food Legumes, pp 879-910. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Roos, E. E., (1980). Physiological, biochemical, and genetic change in seed quality during storage. HortScience, vol. 15:781-784.

Sahoo, A. K.; Kulkarni, G. N. and Vyakaranahal, B. S. (1988). Effect of seed size on yield and quality in bunch groundnut. Seed Research 16, 136-142.

Shenoy, V. V., Dadlani, M. and Seshu, D. V., (1990). Association of laboratory assessed parameters with field emergence in rice: The nonionic acid stress as a seed vigor test. Seed Research 18(1) 60-68.

Singh, A. R. (1987). Relative storability of three seed grades under different storage environment in sorghum. Current Research University of Agricultural. Science. Banglore 16: 67-69.

Singh, A. R. and Makne, V. G., (1985). Correlation studies on seed viability and seedling vigor in relation to seed size in sorghum *(sorghum bicolor* L. Moench). Seed science and technology 13:627-631.

Singh, J. N., Tripathi, S.K. and Negi, P. S., (1972). Note on the effect of seed size on germination, growth and yield of soybean. Indian Journal Science of Agriculture 42(1):83-86.

Singh, S. P. and Pai, P. N. (1988). Effect of seed size upon germination and early stage of plant growth of cowpea (*vigna unguiculata L*.). ACTA horticuturae 218, 71-76

Stanwood, P. C. and base, L. N. (1976). Sealed storage of sorghum seed. Crop Sc. 4: 761-774.

Steiner, J.J., Grabe, D.F. and Tolu, M., (1989). Single and multiple tests for predicting seedling emergence of wheat. Crop Science 29(3):782-786.

Sung, F. T. M. (1992). Field emergence of edible soybean seeds differing in seed size and emergence strength. Seed Science and Technology 20, 527-532.

Tekrony, D. M. and Egli, D. B., (1991). Relationship of seed vigor to crop yield: Areview. Crop Science 31:816-822.

Tekrony, D. M., Egli, D. B. and Phillips, A.D., (1980). Effect of field weathering on viability and vigor of soybean. Agronomy Journal 72(5): 749-753.

Thomson, J. R., (1979). An introduction to seed technology. 1-16. John Wiley and Sons inc., New York, U.S.A.

Vanangamudi, K., 1987. Evaluation of seed vigor tests in bajra. Madras Agricultural Journal 74(1):18-20.

Villiers, T. A. (1971). Cytological studies on dormancy I. Embryo maturation during dormancy. New phytol. 70:751-760.

Yaklich, R. W. and Kulik, M. M., (1979). A valuation of vigor tests in soybean: Relationship of the standard germination, seedling vigor classification, seedling length, and tetrazolium choloride staining to field performance. Crop Science 19(2): 247-252.

Appendix table (1): mean squares of germination percentage and speed of germination as affected by seed age, seed size, moisture content and their interaction under laboratory condition.

Source of variation	D.F	Germination %	Speed of germination
Blocks	3	122.08	4.82
Seed age (A)	1	981.02**	21.90**
Seed size (S)	1	1291.69**	1.60
AXS	1	2.52 NS	4.75
Moisture content(C)	2	437.27*	8.55
AXC	2	125.27 NS	3.71
SXC	2	252.43 NS	2.68
AXSXC	2	13.77 NS	1.39
Error	33	83.93	1.81
C.V%		16.33	7.18

NS: No significant different

*: Significant at (0.05) level of probability.

**: significant at (0.01) level of probability.

Appendix table (2): mean squares of germination percentage and speed of germination as affected by seed age, seed size, moisture content and their interaction under field condition.

Source of variation	D.F	Germination %	Speed of germination
Blocks	3	463.22	10.112
Seed age (A)	1	0.33 NS	1.928 NS
Error (a)	3	45.44	2.378
Seed size (S)	1	867.00 NS	11.05 NS
AXS	1	56.33 NS	3.97 NS
Error (b)	6	404.56	9.26
Moisture content(M)	2	223.00 NS	2.17 NS
AXM	2	6.33 NS	0.31 NS
SXM	2	67.00 NS	0.57 NS
AXSXM	2	162.78 NS	3.95 NS
Error (c)	24	221.78	1.81
C.V%	9	15.23	25.84
C.V%	6	45.45	50.9
C.V%	2	33.65	22.51

NS: No significant different

*: Significant at (0.05) level of probability.

**: significant at (0.01) level of probability.

Appendix table (3): mean squares of growth attributes as affected by seed age, size, moisture content and their interaction under laboratory condition.

S. of variation	blocks	Age(A)	Size(S)	AXS	Moisture(M)	AXM	SXM	AXSXM	error	C.V%
D.F	3	1	1	1	2	2	2	2	33	-
Shoot length	0.67	7.37**	5.58**	0.29ns	13.45**	0.52ns	0.58ns	0.23ns	0.67	20.34
Root length	0.94	18.26**	1.73ns	1.86ns	25.73**	5.51*	1.63ns	1.93ns	1.21	12.21
Shoot to root ratio	0.004	0.01ns	0.11*	0.004ns	0.05*	0.01*	0.001ns	0.007ns	0.009	21.35
fresh weight	56	79ns	61ns	50ns	81ns	82ns	51ns	45ns	54	12.43
Dry weight	1.2	2.1**	1.05ns	1.03ns	2.12**	1.012ns	1.00ns	1.24ns	1.001	12.81

NS: No significant different *: Significant at (0.05) level of probability **: significant at (0.01) probability.

Appendix table (4) mean squares of growth attributes as affected by seed age, size, moisture content and their interaction under field condition.

S.of variation	blocks	age(A)	Error(a)	Size(S)	AXS	Error(b)	moisture(M)	AXM	SXM	AXSXM	Error(C)	C.V% C.V% C.V%
D.F	3	1	3	1	1	6	2	2	2	2	24	a b c
shoot length	58.21	17.8 ns	13.71	94.36*	1.8ns	8.16	13.ns	0.64ns	2.78ns	2.81ns	5.37	19.5 15.03 12.19
root length	9.9	0.37ns	0.23	37.88**	6.27ns	2.14	6.96ns	9.25ns	0.6ns	5.96ns	4.9	5.8 17.7 26.7
Shoot / root	0.77	0.54ns	0.71	0.14ns	0.38ns	0.47	0.16ns	0.7ns	0.44ns	0.29ns	0.38	35.3 28.8 25.65
Fresh weight	253.3	392.7ns	53.3	174.7ns	15.8ns	69.29	21.21ns	62.5ns	2.85ns	15.57ns	29.17	36.3 41.4 26.8
Dry weight	9.0	6.0ns	1.45	27.0*	0.4ns	0.3	0.19ns	0.45ns	0.35ns	2.4ns	1.18	31.2 28.9 26.3

NS: No significant different *: Significant at (0.05) level of probability **: significantat (0.01) probability.