

## INTERRELATIONSHIP BETWEEN SEED VIGOUR TRAITS AND FIELD PERFORMANCE IN NEW RICE FOR AFRICA (NERICA) GENOTYPES (*Oryza sativa* L.)

M. A. ADEBISI<sup>1</sup>, F.S. OKELOLA, C.O. ALAKE,  
M.A AYO-VAUGHAN AND M.O. AJALA

Department of Plant Breeding and Seed Technology, University of Agriculture, Abeokuta, P.M.B 2240, Abeokuta, Ogun State, Nigeria.

<sup>1</sup>Corresponding author: mayoadebisi@yahoo.co.uk

---

### ABSTRACT

The study was conducted to examine the relationships between seed vigour traits and field performance in 24 interspecific rice (*Oryza sativa* L.) genotypes specifically for Africa. Seeds of these genotypes were evaluated in the late cropping season of 2003 and early cropping season of year 2004 in the laboratory for seed vigour traits. Field performances were evaluated at the Teaching and Research Farm, University of Agriculture, Abeokuta, Nigeria for field performance traits. Data were collected from the laboratory studies on six seed vigour traits while seven performance traits were assessed on the field. The data were subjected to Pearson's correlation to compute correlation coefficient ( $r$ ) and step-wise multiple regression analysis to determine percentage contribution of each trait to field emergence. The results of correlation analyses in the 2003, 2004 and across the two seasons revealed that standard germination, energy of germination, seedling vigour index-11, seedling vigour index-1 and speed of germination index exhibited significant positive relationships with field emergence, seedling establishment, plant height, seedling dry weight and seed yield/plant. 100- seed weight significant correlation with plant height. From these results, all the laboratory seed vigour traits examined except 100 seed weight were identified to be good predictors of field performance in NERICA rice. Regression analysis ranked speed of germination index as the major contributor to field emergence, accounting for 58% of the total variation. Also, seedling establishment, standard germination and field emergence were identified as the major contributors to seed yield/plant, accounting for 79, 77 and 66% of the total variation in seed yield/plant. Hence, prediction of field emergence and seed yield of NERICA rice genotypes from seed vigour traits in the laboratory is possible and was effective.

**Key words:** Correlation, inter-relationship, seed quality, vigour, NERICA.

### INTRODUCTION

Information on the relationship among different crop characteristics is of primary importance in crop improvement. Knowledge of inter-relationships among traits can be used to increase breeding efficiency by enhancing early selection and possibly reducing plant population size during selection.

Seed yield at a given density, may be influenced by seed quality. Seed vigour is defined as the effect of the seed quality on crop emergence and establishment (Heydecker, 1972). The term seed vigour can therefore be described as any subsequent effect of seed quality on crop growth and yield at a given density. Comparative laboratory and field

experiments by Odiemah (1991, 1995); Adebisi *et al.* (2003) showed that under certain environmental conditions, there are close relationships between seed testing results and field emergence. Carnago and Vaughan (1973) found a positive correlation between seed vigour and yield in maize. Similarly, Odiemah (1991) reported positive and significant correlation coefficients between six quality traits, field emergence and grain yield. Also specific gravity, standard germination and vigour test were excellent predictor of field maize emergence and grain yield per plant in maize hybrids.

Yamauchi and Winn (1996) observed seedling establishment in the field to be closely related to the vigour index in the tray and coleoptile lengths, suggesting that these characteristics would be useful in the prediction of seedling establishment in anaerobic soil. In another study, Adebisi and Ajala (2007) reported standard germination test to well correlate with field emergence, seedling vigour index and excess water stress germination in sesame. Similar results were observed by Kraak *et al.*, (1984) and Durant *et al.* (1985) in sugar beet.

Simple correlation was adequate as a rough guide to the magnitude and direction of the relationships between two traits. The step-wise regression analysis gave better insight into the interrelationships among many variables. Step-wise multiple-regression analysis has been used to assess the relative contributions of many components of seed vigour to field performance (Okelola, 2005, Adebisi *et al.*, 2006) and is remarkably accurate in predictive ability under laboratory and defined field conditions (Hertfield and Egli, 1974). Kim *et al.* (1994) found that field emergence was significantly correlated with grain yield of malting barley. Further-

more, percent tetrazolium vigour test, seedling vigour index, plumule length and percent germination were useful for predicting grain yield of barley. Seed weight, emergence index and emergence rate index were identified as the major contributors to field emergence in sesame, accounting for 30 to 36% of total variation in field emergence (Adebisi, 2004).

It has been frequently reported that standard germination tends to overestimate field performance (Delouche and Baskin, 1973; Woodstock, 1973; Yaklich, *et al.*, 1979, Adebisi, 2004) under most planting conditions. It is important to understand the relationship between the various measurements of seed vigour and field performance across a wide range of crops. Although the relationships are well established for some cereals, there has been relatively little work for interspecific NERICA rice genotypes. A careful study of seed vigour traits and field performance relationships are necessary in order to ascertain the magnitude and direction of changes to be expected during crop improvement programme in NERICA rice.

Therefore, objective of the research was to examine the magnitude of relationships between seed vigour traits and field performance in newly developed interspecific NERICA rice genotypes.

## **MATERIALS AND METHODS**

### ***Seed Source***

Seeds of 24 newly developed West African lowland interspecific New Rice for Africa (NERICA) genotypes were examined for the study. The rice seeds were obtained from the West African Rice Development Association (WARDA) now Africa rice substation in the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria from the 2003

and 2004 cropping seasons under irrigation. Pure seeds of these genotypes were about one month old after harvest with initial germination of between 75 and 89% and 10-11.5% moisture content. Seeds collected were put inside glass jars and placed inside refrigerator at 8°C until completion of the test.

Two laboratory and two field experiments were conducted in the Seed Laboratory and Teaching and Research Farms, University of Agriculture, Abeokuta, Ogun State respectively in two seasons. The seeds were divided into two parts. (a) One for laboratory test and (b) one for field experiment as follows:

In the Laboratory, seed vigour tests were conducted on seed samples of the 24 rice genotypes. The first vigour test evaluation was carried out between November and December 2003 and repeated between May and June 2004. The experiment was a factorial experiment with two factors; 24 varieties and two seasons. There were three rep-

licates arranged in a completely randomized design.

Seed samples were investigated for seed vigour traits according to the following methods:

100-seed weight (g) (100-SW): - Weight in grammes of 100 seeds of each genotype was determined in three replicates.

Germination Percentage (G%): - One hundred seed per replicate was placed in moist filter paper in 11cm diameter petri dish in three replications. Germination count was recorded every 2 days for 8 days after sowing (DAS). The final count of germination was recorded on the 8th day according to International Seed Testing Association (ISTA) (1985) rules and number of normal seedlings was expressed as percent germination.

Speed of Germination Index (SGI): - This was calculated as described in the Association of Official Seed Analyst (1983) as follows:

$$SGI = \frac{\text{Number of germinated seed} + \dots + \text{Number of germinated seed}}{\text{Days of first count} + \dots + \text{Days of final count}}$$

Seedling Vigour Index-I (SVI-1): - This was calculated with the help of data recorded on germination percentage and seedling growth according to Kharb *et al.* (1994) using the formula:

$$\text{Seedling Vigour Index - I} = \frac{\text{Seedling length} \times \text{Germination Percentage}}{100}$$

Seedling Vigour Index -11 (SVI-11): - This was calculated by the formula adopted by Kharb *et al.*, (1994)

$$\text{Seedling vigour Index - II} = \frac{\text{Seedling dry weight} \times \text{Germination percentage}}{100}$$

Energy of Germination (EG): - This was recorded as the percentage of germinating seeds 3 days after planting relative to the number of seed tested. The larger the energy of germination, the faster the rate of germination (Ruan *et al.*, 2002)

The field experiment was a replicated trial designed as a factorial experiment with two factors; 24 genotypes and two seasons. The field was laid out in a randomized complete block design (RCBD) with three replicates. Each genotype was sown in plot of 3.0m x 0.2m width double row plot with a space of 1.0m between each genotype, and each replicate was separated by a 1 m alley. The field was ploughed, puddled two times and then drained during the two seasons. Seeds were sown on raised seedbeds in the field in late November, 2003 and harvested in March and April 2004, and was repeated in late May 2004 and harvested in September and October 2004. The total land area was 30m x 13m (0.03ha). Seeds were hand drilled along the row while seedlings were thinned 30 days after planting to 20cm x 20cm plant spacing. Following thinning, a post emergence fertilizer application of N. P. K. 15-15-15 was applied by drilling at a rate of 200kgN/ha. Urea was applied as top dressing at 65kg/ha at booting. The plots were weeded regularly to minimize weed infestation. Bird damage was controlled using bird scarers. Also the entire field was covered with waterproof rubber net from panicle initiation till harvesting to prevent bird pests attack. Rodents were checked with bamboo fence and trap constructed round the field.

The following agronomic traits were determined on the 24 rice genotypes

Emergence index (EI): - This was calculated according to the formula (Mock and Eberhart, 1972) as

$$EI = \frac{\sum (\text{Plants emerged in a day}) (\text{Days after planting})}{\text{Plant emerged by 9DAP}}$$

Emergence percentage (E%): - This was calculated using the formula

$$E \% = \frac{\text{Seedling emerged by 9DAP}}{\text{Number of seeds planted}} \times 100$$

Speed of emergence (SPE): - This was calculated using the formula (Dadlani *et al.*, 1990)

$$SPE = \frac{\text{Number of seedling emerged after 5DAS}}{\text{Number of seedling emerged after 11 DAS}} \times 100$$

Seedling Establishment (SE): - This was calculated as the percentage of seedlings established 14 DAS relative to number of seed sown (Yamauchi *et al.*, 1996).

Plant height at 30 DAS (PHT): - Plant height was measured from the ground to the tip of the tallest panicle in centimeter at 30 DAS.

Seedling Dry Weight at 30 DAS (SDW): - The five selected plants were further dried in a hot air oven at 80°C for 48h. Dry weight was measured in gramme (g)

Seed yield/plant (SY): - Grain yield was determined as grain yield per plant and then expressed as grain yield per ha.

### **Data Analysis**

All analyses were done using the SAS statistical package. Data on germination percentage, energy of germination, emergence percentage, speed of emergence and seedling establishment were analyzed after angular transformation (arcsine) of percentages. Pearson's correlation coefficients between laboratory seed vigour traits and field emer-

gence traits as well as seed yield were determined across the two seasons, for each of the seasons. Step-wise multiple regression analysis was used to assess the relative contribution of the vigour characteristics evaluated to field emergence and seed yield.

## RESULTS AND DISCUSSION

Results of Pearson's correlation coefficient between laboratory seed vigour and field performance traits of 24 West African rice genotypes in the two seasons are presented in Table 1, standard germination, speed of germination, seedling vigour I and II and energy of germination showed significant positive correlations with field emergence, seedling establishment, plant height, seedling dry weight and seed yield/plant in 2003 and 2004 seasons. Similarly, positive and high significant correlations occurred between 100-seed weight and plant height in both seasons and with seedling dry weight ( $r=0.42$ ) in 2003 season only. Conversely, significant but negative correlation was observed between seedling vigour index-1 or seedling vigour index-11 and emergence index ( $r=-0.44$  and  $r=-0.43$ , respectively) in 2004 season only.

Significant positive correlation suggests that selection for one character could be used to indirectly select for another character but this can cause difficulties during selection if the association is between desirable and undesirable traits (Adebisi, 2004). The results of correlations were almost the same for the two seasons with slight difference. The results of correlation analyses in the 2003, 2004 and across the two seasons revealed that standard germination, energy of germination, seedling vigour index-11, seedling vigour index-1 and speed of germination index exhibited strong positive relationships with field emergence, seedling establish-

ment, plant height, seedling dry weight and seed yield/plant. However, in the same seasons, 100- seed weight had strong and significant relationships with plant height, suggesting that increase in seed weight would lead to significant increase in plant height and seedling dry weight. Table 2 shows the results of Pearson's correlation coefficient between laboratory seed vigour and field performance traits of 24 West African rice genotypes across the two seasons. The results show that standard germination, seedling vigour index I and II, speed of germination index and energy of germination recorded significant and positive correlations with field emergence, seedling establishment, plant height, seedling dry weight and seed yield/plant. Similarly, 100-seed weight exhibited significant positive correlations with plant height ( $r= 0.47$ ) but not significant with other field performance traits.

The strong positive relationships observed between laboratory seed vigour traits and the field performance traits across seasons and across the two seasons indicates that a genotype with good laboratory performance will ordinarily produce a good field emergence and yield in NERICA rice. Therefore, selection for seeds of high germination, speed of germination, seedling vigour and energy of germination would considerably affect the field performance of NERICA rice. In general, the trait of standard germination has been shown to be a useful predictor of field emergence (Ajala, 2003; Adebisi *et al.* 2004; Adebisi *et al.*, 2006). Seed vigour test have been developed in laboratory where they were shown to predict field emergence better than germination test (Odiemah, 1990).

Step-wise multiple regression analysis has been used by many authors to assess the relative contributions of many seed compo-

**Table 1: Pearson's correlation coefficient between laboratory seed vigour and field performance traits of 24 West African rice genotypes in the two seasons**

Laboratory vigour traits	Field performance traits							
		E%	E.I	SPE	SE	PHT	SDW	Seed yield
Stion%	S1	0.68*	0.01	0.21	0.74**	0.40*	0.51**	0.78**
	S2	0.77**	-0.25	-0.04	0.77**	0.39	0.57**	0.75**
100 – S W (g)	S1	0.36	-0.10	0.03	0.31	0.48**	0.42*	0.38
	S2	0.12	-0.17	-0.12	0.12	0.42**	0.11	0.24
S G I	S1	0.74**	0.07	0.18	0.81**	0.41*	0.52**	0.78**
	S2	0.83**	-0.29	0.01	0.63**	0.43*	0.54**	0.76**
S V I-1	S1	0.78**	0.08	0.18	0.83**	0.41*	0.52**	0.78**
	S2	0.79**	-0.44*	-0.15	0.80**	0.49*	0.49**	0.82**
S V I-1	S1	0.79**	0.16	0.24	0.81**	0.38	0.52**	0.76**
	S2	0.63**	-0.43*	-0.22	0.63**	0.55**	0.43**	0.79**
E G	S1	0.65**	0.05	0.17	0.70**	0.30	0.49**	0.76**
	S2	0.77**	-0.27	-0.05	0.77**	0.42**	0.56**	0.73**

\*, \*\* Significant at 5% and 1% levels of probability respectively

S1= 2003 cropping season, S2= 2004 cropping season

100SW = 100-seed weight (g)

SGI = Speed of Germination Index

SVI-1 = Seedling Vigour Index-I-

SVL-11 = Seedling Vigour Index -11

EI = Emergence Index

EG = Energy of Germination

G% = Germination Percentage

E% = Emergence Percentage

SPE = Speed of Emergence

SE = Seedling Establishment

PHT = Plant height at 30 DAS

SDW = Seedling Dry Weight at 30 DAS

**Table 2: Pearson's correlation coefficient between laboratory seed vigour and field performance traits of 24 West African rice genotypes across the two seasons**

Laboratory vigour traits	Field performance traits						
	E%	E.I	SPE	SE	PHT	SDW	Seed yield
G%	0.79**	-0.22	-0.02	0.82**	0.41*	0.60**	0.60**
100 – S W (g)	0.24	-0.19	-0.08	0.22	0.47	0.27	0.27
S G I	0.82**	-0.14	0.14	0.85**	0.41*	0.56**	0.56**
S V I-1	0.84**	-0.23	0.04	0.86**	0.47*	0.53**	0.53**
S V I-1	0.80**	-0.27	0.02	0.82**	0.47*	0.53**	0.53**
E G	0.75**	-0.20	0.03	0.78**	0.37	0.57**	0.57**

\*, \*\* Significant at 5% and 1% level of probability, respectively.

100SW = 100-seed weight (g), G% = Germination Percentage

S GI = Speed of Germination Index, SVI-1 = Seedling Vigour Index-I-

SVI-11 = Seedling Vigour Index -11, EG = Energy of Germination

EI = Emergence Index, E% = Emergence Percentage

SPE = Speed of Emergence, SE = Seedling Establishment

PHT = Plant height at 30 DAS, SDW = Seedling Dry Weight at 30 DAS

nents to field performance (Kim *et al.*, 1994; Tiwari and Hariprasad, 1997, Adebisi, 2004; Adebisi *et al.*, 2006). The results of step-wise multiple regression between field emergence and laboratory seed vigour traits are presented in Table 3. The analysis ranked speed of germination index as the major contributor to field emergence accounting for 58% of the total variation in field emergence across seasons with high partial correlation value of 0.572. However, variations in field emergence were reduced when contributions of variables such as seedling vigour index-1. Seedling vigour index-11, energy of germination, 100-seed weight, and standard germination were added to the equation. these five traits had low contributions (0-10%) to variation in field emergence in regression equation. Using step-wise regression analysis, Adebisi (2004) pos-

tulated that seed weight, emergence index and emergence rate index, in this order of importance, together accounted for 30-36% of the variation in field emergence of 14 sesame genotypes evaluated. In contrast, none of these components were found to account for major variation in field emergence observed in the present study.

Summary of step-wise multiple regression analysis between seed yield and seed vigour traits in 24 West African rice genotypes across seasons is presented in Table 4. The step-wise multiple regression results revealed that seedling establishment, field emergence and standard germination traits accounted for 78.9, 77.4 and 66.5% of the total variation in seed yield/plant, respectively with a strong partial correlation values of 0.789, 0.770 and 0.661 across the two seasons.

**Table 3: Summary of step-wise multiple regression analysis between field emergence and laboratory seed vigour traits in 24 West African rice genotypes across the two seasons**

Characters	MR	R2	T	Partial correlation
Speed of germination index	0.758	0.575	13.86688	0.572
Seedling vigour index	0.108	0.010	0.433	0.066
Energy of germination	-0.006	-0.004	0.666	-0.036
100 seed weight	0.046	0.002	0.422	0.068
Seedling vigour index-ii	-0.044	-0.002	0.6496	-0.033
Percentage germination	0.036	0.001	0.801	0.021

Predictors: Speed of germination index (constant)

Dependent variable: Emergence Percentage

Regression is significant at the 0.01 level

\* Regression is significant at the 0.05 level

ns = not significant

M = Multiple regression

R<sup>2</sup> = coefficient of determination

t = 't' value statistic

**Table 4: Summary of step-wise multiple regression analysis between seed yield and seed vigour traits in 24 West African rice genotypes across two seasons**

Characters	MR	R2	T	Partial correlation
Seedling Establish	0.888	0.789	3.718	0.789
Percent germination	0.352	0.124	1.271	0.106
S V I-1	0.015	0.065	0.972	0.082
Seed dry weight	0.109	0.012	1.125	0.094
Emergence index	-0.087	-0.008	-1.082	-0.091
Speed of emergence	-0.074	-0.006	-0.920	-0.077
100 seed weight	0.051	0.003	0.616	0.052
S V I-11	0.032	0.001	0.279	0.023
Speed of germ index	0.026	0.001	0.194	0.016
Seedling dry weight	0.026	0.001	0.275	0.023
Energy of germination	0.011	0.000	0.092	0.008
Plant height	0.010	0.000	0.042	0.004

Predictors: Seedling establishment, Percentage germination, (constant)

Dependent variable: seed yield

\*\*Regression is significant at 0.01 Probability level

\* Regression is significant at 0.05 Probability level

ns = not significant

MR = Multiple Regression

R<sup>2</sup> = Coefficient of determination

t = 't' value statistics

Hence, the stepwise regression analysis identified seedling establishment, standard germination and field emergence as the major contributors to seed yield. Seedling vigour index -1, seedling dry weight and emergence index accounted for 12.4, 6.5 and 1.2%, respectively of the total variation in seed yield/plant.

## CONCLUSION

Conclusively, standard germination, speed of germination, seedling vigour index I and II and energy of germination of NERICA rice seeds had significant positive relationship with field performance traits in both years and across the years of investigation.

Among the seed vigour traits evaluated in NERICA rice, speed of germination index was identified as major contributor to field emergence in NERICA rice as revealed by multiple regression analysis.

The three vigour traits (seedling establishment, standard germination and field emergence) were identified as the major contributors to seed yield per plant in NERICA rice genotypes.

## REFERENCES

- Adebisi, M.A., Ajala, M.O., Rasaki, N.O.** 2003. Comparison of seed vigour of sesame in laboratory and field tests. *Journal of Tropical Forest Resources*, 19(3): 21-23.
- Adebisi, M.A.** 2004. Variation, stability and correlation studies in seed quality and yield characters of sesame. *Unpublished PhD Thesis*, University of Agriculture, Abeokuta.
- Adebisi, M.A., Oyekale, K.O., Akintobi, D.C., Abdul-Rafiu, A.M.** 2006. Variation in seed quality of West African rice (*Oryza sativa* (L.)). *Proceeding of the 31<sup>st</sup> Annual Conference of Genetic Society of Nigeria*, P. 60-66.
- Adebisi, M.A., Ajala, M.O.** 2006. Performance and stability of seed yield in rain-fed sesame genotypes as influenced by plant population density. *Tropical Agric. (Trinidad)* 83(2): 47-53.
- Adebisi, M.A., Ajala, M.O.** 2007. Effect of genotypes and seed production environment on seed quality of sesame (*Sesamum indicum* L.). *Tanzania Journal of Agricultural Sciences*, 2: 87-102.
- Adebisi, M. A.** 2008. Relation of seed testing traits to field performance of sesame genotypes under different environments. *ASSET Journal Series A* 8(1): 194 - 204.
- Ajala, M.O., Adebisi, M.A., Ojo, D.K.** 2003. Effect of moisture content, genotype and storage period on seed quality of thiram-treated maize seeds. *Nigerian Journal of Ecology*, 5: 21 - 27.
- Carnago, C.P., Vanghan, C.E.** 1973. Effect of seed vigour on the performance and yield of grain sorghum. *Proceedings of the Association of Official Seed Analysts*, 63: 135 - 147
- Dadlani, M., Seshu, D.V.** 1990. Effects of wet and dry heat treatment on rice seed germination and seedling vigour. *International Rice Research Newsletter*, 15: 21-22.
- Delouche, J. C., Baskin, C.C.** 1973. Accelerated ageing techniques for predicting the relative storability of seed lots. *Seed Sci. and Technol.*, 1: 427-452.
- Durrant, M.J., Bould, A., Brown, S.** 1985. The assessment of the quality of sugar-beet seed. *Journal of Agricultural Sciences, Cambridge* 104: 71 - 84.

- Heartfield, J.L., Egli, D.B.** 1974. Effect of temperature on the rate of soybean hypocotyls elongation and field emergence. *Crop Science*, 14:423 – 426.
- Heydecker, W.** 1972. *Vigour in viability of seeds* (E. H. Roberts pp. 209-252. Chapman & Hall, London.
- Kehinde, O.B. Adebisi, M.A., Lasisi, O. A.** 2005. Variability and correlation studies in seed quality of West African Okra (*Abelmoschus caillei* (A. Chev). Steevens) Accessions. *Nigerian Journal of Genetics*, 19: 9-22.
- ISTA (International Seed Testing Association)** 1995. International rules for seed testing. Rules 1995. *Seed Science and Technology*, 13: 322-326.
- Kharb, R.P.S., Lather, B.P.S., Deswal, D.P.** 1994. Prediction of field emergence through heritability and genetic advance of vigour parameters. *Seed Science and Technology*, 22: 461-466.
- Kraak, H.L., Vos, J., Perry, D.A., Beken-dam, J.** 1984. Studies on field emergence and vigour of sugar beet and onion seed. *Seed Sci. and Technol.*, 12: 731 – 745.
- Kim, S.H., Choe, Z.R., Kang, J.H., Copeland, L.O., Elias, S.G.** 1994. Multiple seed vigour indices to predict field emergence and performance of barley. *Seed Sci. and Technol.*, 22: 29-68.
- Mock, J.J., Eberhart, J.A.** 1972. Cold tolerance of adapted maize populations. *Crop Science*, 16: 230-469.
- Odiemah, M.** 1991. Relation of seed testing traits to grain yield of maize hybrids under different environments. *Seed Sci. and Technol.*, 19: 25-32.
- Odiemah, M.** 1995. The relationship of temperature and N.P.K. content of grain to properties of spring wheat seeds, produced under different protein treatments. *Cereal Research Communications*, 13: 239-245.
- Okelola, F.S.** 2005. Variation and relationship between seed vigour and seed yield of West African rice (*Oryza sativa* L). *M. Agric. Dissertation, Department of Plant Breeding and Seed Technology, University of Agriculture, Abeokuta, Nigeria.* 89p.
- Ruan, S. Xue, Q., Tylkowska K.** 2002. The influence of priming on germination of rice (*Oryza sativa* L.) seeds and seedling emergence and performance in Flooded Soil. *Journal of Seed Science and Technology*, 30: 61-67.
- Tiwari, S.P., Hariprasad, A.S.** 1997. Selection criteria for seed longevity in soybean (*Glycine max. (L.) Merr.*). *Tropical Agriculture (Trinidad)*, 74(1): 70-72.
- Yaklick, R.W., Kulik, M.M., Anderson, J.D.** 1979. Evaluation of vigour tests in soybean seeds relationship of ATP, conductivity and radioactive tracer multiple criteria laboratory tests to field performance. *Crop Science*, 19: 806-810.
- Yamauchi, M., Winn. T.** 1996. Rice seed vigour and seedling establishment in anaerobic soil. *Crop Science*, 36: 680-686.

(Manuscript received: 5th January, 2010; accepted: 30th July, 2010).