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EFFECT OF SEED PRODUCTION ENVIRONMENTS ON SEED PHYSIOLOGICAL ATTRIBUTES OF AFRICAN YAM BEAN (Sphenostylis stenocarpa, Hoch)

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ABSTRACT

Studies were conducted to determine the effect of plant population on seed physiological attributes of African Yam Bean (Sphenostylis stenocarpa) at the Federal University of Agriculture, Abeokuta, Ogun State, Nigeria in 2013 and 2014. In the experiment , the effect of three plant populations (55,555, 24,975 and 10,000 plants ha^{-1}) were conducted in a factorial arrangement using completely randomized design in three replicates with genotype and plant population as factors in 2013 and 2014 in the laboratory. In this experiment, clean seeds obtained under each plant population and years were evaluated for four seed physiological attributes. Data collected from the experiment were subjected to analysis of variance. Mean separation was carried out by Tukey's HSD test. Pearson correlation coefficient (r) was used to determine the relationship among attributes. In the experiment, TSs83, TSs86 and TSs9 were superior in seed germination and seedling vigour under the 10,000 plants ha^{-1} across cropping years. All the 18 genotypes of AYB studied indicated genetic variability and similarity. The statistical analysis of mean values of all the genotypes confirmed variations in all the seed quality characters. The laboratory germination percentages ranged from 83.78 to 97.33 % ($p<0.01$) under the 2013 cropping year. However, the standard germination ranged from 83.11 to 96.67 % ($p<0.01$) under the 2014 cropping year. The effect of plant population on seedling dry weight showed that seed performance was influenced by population density. Among the seed quality traits, standard germination and seedling vigour index indicated significant responses to the three plant population densities in the two cropping years. Across the plant density and cropping years, TSs86, TSs83, TSs209, TSs42, TSs48, TSs331 and TSs311 were among the excellent performance genotypes with a consistent high standard germination and seedling vigour index. The highest standard germination was recorded in both years under the highest plant population density of 55,555 plants ha^{-1}. TSs9 had highest seedling vigour index of 23.48, seedling fresh weight of 1.13 g and dry weight of 0.55 g, respectively. Standard germination had positive and highly significant correlations with seedling vigour index ($r = 0.236$) and seedling dry weight ($r = 0.149$).

Key words: Planting density, Seed quality and Seedling vigour.

INTRODUCTION

African yam bean (Sphenostylis stenocarpa) Hochst ex. A Rich family leguminosae, sub-family papilionacaea, belongs to the class: Magnoliospseda, order: Fabales and is one of the most valuable legumes in the family Fabaceae. Porter (1992) reported that the domestication, cultivation and distribution of African yam bean are very evident in the tropics. It is one of the neglected pulses of tropical origin. The centre of diversity, according to the Genetic Resources Information Network (GRIN), spreads from West through the East and Southern parts of Africa (GRIN, 2009) and these areas are suspected to host the genetic resources of African yam beans (Adewale and Dumet, 2010). African yam bean is cultivated in West Africa, particularly in Cameroon, Cote D' ivoire, Nigeria, Togo and Ghana (Porter, 1992).

African yam bean (AYB) is classified as minor grain legume because it is under- exploited (Saka et al., 2004). It is an indigenous legume usually cultivated in association with yam, cassava, sorghum and maize and barely grown, sole in Ghana and Nigeria. (Okigbo, 1973: Klu et al., 2001). AYB provides two consumable products: the underground tubers, which grows as the root source and look like elongated sweet potatoes but tastes more like irish potatoes and the actual bean which develop in pods above ground. The slightly woody pods are usually linear, containing about 20-30 seeds which are up to 30 cm long and mature within 170 days (Hutchinson and Dalziel, 1958; Duke, 1981; Duke et al., 1997; Thomas et al., 2005). The seeds and tubers serve as food for human and livestock. The seeds vary in size, colour and colour pattern (Milne- Redheed and Polhill, 1971; Adewale, 2011). The crop contributes to sustainable agriculture and also helps agriculturally to enrich the soil by its ability to fix nitrogen from the atmosphere and survives well in weathered soils where rainfall can be extremely high (Assafa and kleiner, 1997, National Research Council, 2007; Olasoji et al., 2011). AYB is also cultivated for income generation in the eastern part of Nigeria (Moyib et al., 2008). AYB is extensively used in various dietary preparations and has a potential for supplementing the protein requirements of many families throughout the year (Klu et al., 2001). Asare et al. (1984) observed that AYB is a good source of fodder for ruminant animals and performed better in seed yield when intercropped with maize, okra and yam.

A primary objective of African yam bean seed production program is to provide farmers with seeds of high physiological quality which guarantee the establishment of a uniform stand of healthy seedlings even under less favourable field condition. Available genetic resources of AYB for research materials are the few accessions/landraces in the hands of market women and rural farmers. However, such genetic materials lack sufficient information on influence of plant population density on seed physiological quality characteristics. The objectives of the study were, therefore, to investigate the effect of seed production environment (plant population density) on seed physiological quality attributes of 18 AYB genotypes over two cropping years and to investigate the extent of relationships among seed physiological quality characteristics of AYB under each and across cropping years and plant population densities.

MATERIALS AND METHODS

Seeds of 18 AYB genotypes were sourced from International Institute of Tropical Agriculture, Ibadan, Oyo State, Nigeria. The seeds were sown under three plant populations during 2013/2014 cropping seasons under rain-fed field conditions at the Directorate of University farms, Abeokuta. These treatments formed environments as follows: Environments 1= 60 cm x 30 cm with 55,555 plants ha^{-1}, Environments 2 = 91 cm x 44 cm with 24,975 plants ha^{-1} and Environments 3 = 100 cm x 100 cm with 10,000 plants ha^{-1}.The plant populations and seasons, therefore, created six environments. Seeds were sown in the field in May 29th, 2013 and harvested in December, 2013 and repeated in June, 12th, 2014 and harvested in January, 2015. At each plant population in each year, the experiments were laid out in complete randomized design with three replicates. The plot size for the first plant densty (60 cm × 30 cm) was 3 m by 3 m with 50 plants for each replicate. The plot size for the second plant density (91 cm × 44 cm) was 3 m by 3 m with 28 plants for each replicate. The plot size for the third plant density (100 cm × 100 cm) was 3 m by 3 m with 9 plants for each replicate. Seedlings were thinned at 3 weeks after sowing. All cultural practices were carried out according to the peculiar local conditions. The seed samples were placed under laboratory room conditions for 12 months and thereafter subjected to the following physiological tests.

(i.) Germination percentage (%): Germination percentage was calculated based on the equation according to ISTA, 1995.

$$GP = \frac{Total\ seed\ germination\ after\ 9\ days}{Total\ seed\ sown} \times 100$$

(ii.) **Seedling Vigour Index:** Seedling vigour level of each genotype was calculated by multiplying percent normal germination by the average of plumule length of each genotype at 9 days of germination (Kim *et al.*, 1994) and divided by 100 (Adebisi, 2004).

(iii.) **Seedling fresh weight** (g): weight of ten randomly selected seedlings from each genotype was determined using digital weighing balance.

(iv.) **Seedling dry weight** (g): Dry weight of ten randomly selected seedlings from each genotype was dried for 24 hours in an oven at 70°C and later measured in grammes (Soltani *et al.*, 2002).

The experiment was carried out in the laboratory of the Department of Plant Breeding and Seed Technology, Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria. The experiment was a factorial in completely randomized design with three replicates. Two factors were examined (18 AYB genotypes and three plant densities) in each of the two cropping years (2013 and 2014) constituted the experimental factors. In each cropping year, there were 162 experimental units.

Data analysis

Data collected in the experiment were subjected to analysis of variance (ANOVA) using GENSTAT 10.0 for windows statistical software package and treatment means were separated using Tukey's HSD test at 5% level of probability. The relationships among various characters were estimated by Pearson correlation analysis.

RESULTS

Table 1 presents the mean square values for seed physiological attributes evaluated in 18 AYB genotypes. The data of 2013 cropping year reveals that genotype effect was highly significant ($p \leq 0.01$) on all the seed quality attributes. Similarly, plant density effect had highly significant ($p \leq 0.01$) effect on seedling dry weight. The interaction of genotype × plant density effect was highly significant ($P \leq 0.01$) on seedling fresh weight and seedling dry weight. In 2014 cropping year (Table 1), the result shows that genotype effect was highly significant ($p \leq 0.01$) on standard germination, seedling vigour index, seedling fresh weight and seedling dry weight. However, the genotype × plant density effect was highly significant ($p \leq 0.01$) on standard germination, seedling vigour index and seedling fresh weight, but recorded significant ($p \leq 0.05$) effect on seedling dry weight. In the combined cropping year (Table 1), genotype effect was highly significant ($p \leq 0.01$) on all the seed quality attributes. However, plant density effect was highly significant ($p \leq 0.01$) on seedling dry weight only. However, genotype × plant density interaction was highly significant ($p \leq 0.01$) on seedling vigour index and seedling dry weight but had significant ($p \leq 0.05$) effect on standard germination.

Table 2 presents the effects of plant densities on standard germination in 18 AYB genotypes in 2013, 2014 and combined cropping years. At 55,555 plants ha^{-1}, the genotype performance in 2013 shows that TSs86 had highest standard germination of 98.67 % followed by TSs50, TSs311 and TSs331 with values of between 96.67 and 96.00 %, while TSs24 had lowest value of 81.33 %. In the corresponding 2014 cropping year, at 55,555 plants ha^{-1}, TSs50 gave highest standard germination of 98.67 % but not statistically different from 96.67, 96.66 and 95.33 % observed in TSs209, TSs48, TSs22, TSs86 and TSs9, respectively whereas TSs77 and TSs81 recorded least values of 81.67 and 82.66 %. In the combined cropping year, TSs50 and TSs86 had highest values of 97.67 %, followed by TSs311, TSs331, and TSs209 with (95.17 and 95.00 %). while TSs77 gave the least of 83.50 %. At 24,975 plants ha^{-1}, the genotype performance in 2013 reveals that TSs86 had highest germination of 98.00 % followed by TSs50, TSs331, TSs349, TSs370, TSs9 and TSs83 with values of between 95.33 and 96.67 % while TSs23 gave the lowest value of 82.33 %.

In the corresponding 2014 cropping year, four genotypes (TSs42, TSs48, TSs83 and TSs50) had highest standard germination of (96.00 and 97.33 %), followed by TSs23, TSs209, TSs370, TSs22, TSs86 and TSs24 with values of between 93.67 and 95.67 %, but TSs77 gave the least (82.00 %). In the combined cropping year, TSs50, TSs86 and TSs83 gave highest of 96.34, 96.00 and 95.67 %, respectively whereas TSs77 recorded lowest (84.17 %). At 10,000 plants ha^{-1}, the genotype performance in 2013 shows that TSs50 (98.67 %) and TSs83 (98.00 %) had the highest standard germination though were not statistically different from 97.33, 96.33 and 96.00 % observed in TSs370, TSs82 and TSs349 while TSs24 gave the least of 80.67 %. In the corresponding 2014 cropping year, TSs83 recorded highest value of 98.67 % closely followed by TSs9, TSs22, TSs50, TSs42 and TSs82 with values of 95.67, 95.33 and 95.00 %, respectively whereas the lowest value of 81.67 % was observed by TSs94. In the combined cropping year, TSs83 had the highest value of 98.34 % but not statistically different from TSs9, TSs82, TSs95.67 and TSs50 (94.84 and 97.00 %) while TSs94 recorded least of (83.50 %)

Table 3 shows the effect of three plant densities on seedling vigour index in 18 AYB genotypes in 2013, 2014 and combined cropping years. At 55,555 plants ha^{-1}, the genotypes performance in 2013 shows that genotype TSs9 recorded significantly highest seedling vigour index of 22.17 while TSs331 gave the least of 4.73. In 2014 cropping year, TSs9 had the significantly highest seedling vigour index value of 25.88 whereas TSs331 gave the lowest value of 4.08. In the combined cropping year, TSs9 gave the significantly significant of 24.03 while TSs331 recorded the lowest of 4.41.

At 24,975 plants ha^{-1} (Table 3), the genotype performance in 2013 reveals that two genotypes (TSs50 and TSs9) had significantly highest seedling vigour index of 18.83 and 18.67, respectively whereas TSs331 and TSs311 recorded the least values of 4.90 and 5.86, respectively. Also, in the corresponding 2014 cropping year, TSs9 had the highest significant seedling vigour index of 20.72 while TSs331 and TSs311 recorded the lowest of 4.32 and 5.10, respectively. In the combined cropping year, TSs9 had the highest significant of 19.70 whereas TSs331 and TSs311 recorded least values of 4.61, 5.48, respectively. At 10,000 plants ha^{-1} (Table 3), the genotype performance in 2013 reveals that TSs77 and TSs9 recorded the significantly highest seedling vigour index of 21.96 and 21.50, respectively while TSs331 gave the lowest value of 5.50. In the corresponding 2014 cropping year, TSs77 and TSs9 had highest seedling vigour index of 23.92 and 23.89, respectively while TSs 331 recorded the least value of 4.77. In the combined cropping year, TSs9 only gave the significantly highest value of 22.70 while TSs331 had lowest of 5.14.

Table 4 presents the effect of three plant densities on seedling fresh weight in 18 AYB genotypes in 2013, 2014 and cropping years. At 55,555 plants ha^{-1} the genotype performance in 2013 indicates that TSs83 had highest seedling fresh weight of 1.01 g, though not significantly different from TSs9 (0.99 g) but TSs24 recorded the least seedling fresh weight of 0.35 g. In the 2014 cropping year, TSs50, TSs83 and TSs9 recorded highest values of 0.95 and 0.92 g, followed by TSs82, TSs81, TSs370 and TSs209 with 0.90, 0.89, 0.88 and 0.86 g while TSs24 recorded the least of 0.39g. In the combined cropping year, TSs83, TSs9 and TSs50 had significantly highest values of 0.97, 0.96 and 0.91g, respectively while TSs24 gave least value of 0.37 g.

At 24,975 plants ha^{-1} (Table 4), the genotypes performance in 2013 cropping year shows that TSs9 recorded highest seedling fresh weight of 1.14 g, closely followed by TSs48 with 1.09 g while TSs94, TSs370, TSs209 and TSs50 gave least values of 0.49, 0.52 and 0.55 g. In the corresponding 2014 cropping year, TSs9 and TSs48 had significantly highest seedling fresh weight of 1.03 and 0.99 g whereas TSs94 recorded least value of 0.54 g. In the combined cropping year, TSs9 and TSs48 had significantly highest values of 1.09 and 1.04 g, respectively whereas TSs94 and TSs370 recorded lowest values of 0.52 and 0.55 g, respectively. At 10,000 plants ha^{-1} (Table 4), the performance of the genotypes in 2013 shows that TSs9 recorded the significantly highest value of 1.25g while TSs331 recorded the lowest of 0.35 g. Similarly, in the corresponding 2014 cropping year, TSs9 and TSs77 had significantly highest values of 1.14 and 1.10 g, respectively whereas TSs48 was with lowest value of 0.46 g. In the combined cropping year, TSs9 had significantly highest value of 1.20 g while TSs331 had least value of 0.37 g.

The effect of three plant densities on seedling dry weight in 18 AYB genotypes in 2013, 2014 and combined cropping years is shown in Table 5. At 55,555 plants ha^{-1}, the genotypes performance in 2013 cropping year shows that TSs24, TSs9 and TSs22 had significantly highest seedling dry weight of 0.48, 0.46 and 0.44 g whereas TSs331 gave the least of 0.11 g. In the corresponding 2014 cropping year, TSs9 had significantly highest seedling dry weight of 0.56 g while TSs331 recorded the lowest value of 0.18 g. In the combined cropping year, TSs9 was with highest value of 0.51, followed by TSs24 with 0.48 g whereas TSs331, TSs349 TSs42 and TSs48 showed the lowest with values of between 0.15 and 0.21 g.

Under the 24,975 plants ha^{-1} (Table 5), the performance of the genotypes in 2013 reveals that TSs82 recorded the significantly highest value of 0.43 g compared with the least value of 0.10 g observed in TSs94. In the corresponding 2014 cropping year four genotypes (TSs81, TSs9, TSs83 and TSs48) had highest values of between 0.50 and 0.54 g, followed byTSs24 with 0.49 g while the lowest of 0.23 g was recorded in TSs370. In the combined cropping year, TSs48 had highest value of 0.42 g, followed by TSs82 and TSs9 with 0.40 and 0.38 g, respectively but TSs370 had least of 0.22 g.

At 10,000 plants ha^{-1} (Table 5), the genotype performance in 2013 cropping year shows that TSs50 had the highest of 0.30 g though not statistically different from 0.28 g obtained in TSs82 whereas the least value of 0.10, 0.12 and 0.13 g were recorded in TSs311, TSs349, TSs331 and TSs209. In the corresponding 2014 cropping year, TSs24 had the highest of 0.56 g, closely followed by TSs 77 and TSs81 with 0.55 and 0.52g, respectively whereas the lowest value of 0.15 g was observed in TSs331. In the combined cropping year, TSs9 had highest of 0.37 g, though not significantly different from TSs82, TSs77, TSs24 and TSs81 with values of between 0.34 and 0.36 g while TSs331 had lowest value of 0.14 g.

Correlation coefficients among seed physiological attributes in 2013, 2014 and combined cropping years across plant population densities are presented in Table 6. In the 2013 cropping year, standard germination correlated positively and significantly with seedling vigour index (r = 0.446), but had negative and high significant correlation with seedling fresh weight (r = 0.269). Also, seedling vigour index showed positive and highly significant correlation with seedling fresh weight (r = 0.262). Seedling fresh weight, however, showed positive and highly significant correlations with seedling dry weight (r = 0.218). In the same Table 6, in the 2014 cropping year, standard germination had positive and highly significant correlations with seedling vigour index (r = 0.226) whereas negative and highly significant correlations were shown with seedling dry weight (r = 0.239) and had negative but significant correlation with seedling fresh weight (r = 0.152). From the same Table 6, in the combined cropping year, standard germination had positive and highly significant correlations with seedling vigour index (r = 0.236) and seedling dry weight (r = 0.149). Seedling vigour index, however, showed positive and significant correlation with seedling fresh weight (r = 0.140).

DISCUSSION

Significant interaction of genotype x plant population on all the seed qualities except seedling vigour index showed that variation in all the seed quality attributes among the selected African yam bean genotypes were as a result of differences in plant population.

The effect of plant population densities on seed physiological characters showed significant differences among the genotypes for all the seed quality attributes examined, suggesting that selection for good seed quality attributes among AYB genotypes for additional improvement is possible due to a considerable variability that was observed. Significant differences in seed quality parameters among genotypes have earlier been reported by different workers (Adebisi *et al*, 2011 in soybean, Adebisi *et al*., 2005 in NERCA rice, Okesola, 2005 in West African rice and Adebisi *et al*., 2013 in maize).

The effect of plant population on seedling dry weight showed that seed performance was influenced by population density. Among the seed quality traits, standard germination and seedling vigour index indicated significant responses to the three plant population densities in the two cropping years. In the second cropping year (2014), these seed quality attributes had highest performance under 55,555 plants ha^{-1} and lowest under the 24,975 plants ha^{-1}. This highest performance under 55,555 plants ha^{-1} may be as a result of inherent competition which resulted in quick filling of the pod as pod size develops beyond certain limit. This result could further be supported with the fact that spacing or plant population used in no way resulted in any harmful effect on seed yield as quality of seed indicated were still above 75%. These findings are in contrast with Adebisi *et al.* (2011) who reported that seed quality of sesame produced under the three plant population densities varied among the different genotypes in sesame.

Across the plant density and cropping years, TSs86, TSs83, TSs209, TSs42, TSs48, TSs331 and TSs311 were among the excellent performance genotypes with a consistent high standard germination and seedling vigour index. TSs50 followed by TSs42, TSs24, TSs77, TSs331 and TSs370 could be considered in selection for genotype with high potential seed longevity. Standard germination, seedling vigour index, seedling fresh weight as well as seedling emergence percentage were not affected by plant population density. The highest standard germination was recorded in both years under the highest plant population density of 55,555 plants ha^{-1}. This shows that standard germination is dependent of changes in the environmental conditions of the areas of production. The standard germination under the other two plant population densities was, however, similar.

All the 18 genotypes of AYB studied indicated genetic variability and similarity. The statistical analysis of mean values of all the genotypes confirmed variations in all the seed quality characters. The laboratory germination percentages ranged from 83.78 to 97.33 % ($p<0.01$) under the 2013 cropping year. However, the standard germination ranged from 83.11 to 96.67 % ($p<0.01$) under the 2014 cropping year. This finding was in agreement with the earlier work of Olisa *et al*. (2010) who reported no seed viability problem with AYB. Standard germination under the three plant population densities was similar in the two cropping years as the genotypes recorded similar values implying that plant population do not have direct effect on standard germination. The effect of plant-to-plant competition was obvious within the cropping years as the level of relationships between seed quality characters and plant population densities changed between years. This finding was in agreement with the discovery of Adebisi (2004) who stated that effects of plant-to-plant competition was evident within the years of production as the associations between seed quality attributes and plant population changed between seasons.

CONCLUSION

The effect of plant population on seedling dry weight showed that seed performance was influenced by population density. Among the seed quality traits, standard germination and seedling vigour index indicated significant responses to the three plant population densities in the two cropping years. The effect of plant-to-plant competition was obvious within the cropping years as the level of relationships between seed quality characters and plant population densities changed between years. TSs83, TSs86 and TSs9 were superior in seed germination and seedling vigour under the 10,000 plants ha^{-1} across cropping years. All the 18 genotypes of AYB studied indicated genetic variability and similarity. Across the plant density and cropping years, TSs86, TSs83, TSs209, TSs42, TSs48, TSs331 and TSs311 were among the excellent performance genotypes with a consistent high standard germination and seedling vigour index.

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Table 1**:** Mean square values for seed physiological attributes in 18 AYB genotypes under the three plant densities in 2013, 2014 and combined cropping years

Source of variation	DF	Standard germination	SVI	SFW	SDW
Rep	2	18.82	6.331	0.006	0.004
Genotype	17	146.12**	155.175*	0.209**	0.030**
Plant Den	2	9.45	4.714	0.010	0.039**
G x D	34	19.24	40.102	0.066**	0.022**
Error	105	12.94	2.864	0.006	0.003
2014					
Rep	2	51.17*	6.43	0.006	0.074
Genotype	17	125.52**	113.06**	125.00**	0.931**
Plant Den	2	2.46	2.39	0.09	0.005
G x P	34	32.82**	29.20**	0.07**	0.041*
Error	105	14.62	2.35	0.007	0.018
Combined					
Rep	2	34.995	6.3805	0.006	0.039**
Genotype	17	135.82**	134.118**	62.6045**	0.4805**
Plant Den	2	5.955	3.552	0.050	0.022**
G x P	34	26.03*	34.651**	0.068	0.0315**
Error	105	13.78	2.607	0.0065	0.0105

SVI – Seedling Vigour Index SDW - Seedling Dry Weight
SFW – Seedling Fresh Weight, ** Significant at 1 % probability level,
*Significant at 5 % probability level at 5 % probability level

Table 2: Effect of three plant densities on standard germination in 18 AYB Genotypes in 2013, 2014 and combined cropping years

Genotype	Standard germination (%) 55,555 plants ha^{-1}			24,975 plants ha^{-1}			10,000 plants ha^{-1}		
	2013	2014	Comb	2013	2014	Comb	2013	2014	Comb
TSs9	90.00^{cd}	95.33^{ab}	92.67^{bc}	95.33^{ab}	93.33^{b}	94.33^{ab}	94.00^{bc}	95.67^{ab}	94.84^{ab}
TSs22	92.00^{cd}	96.67^{ab}	94.34^{abc}	90.33^{c}	94.33^{ab}	92.33^{bcd}	89.67^{cd}	95.33^{ab}	92.50^{bcde}
TSs23	88.67^{d}	94.00^{b}	91.34^{c}	82.33^{f}	95.67^{ab}	89.00^{de}	88.67^{cd}	90.67^{c}	89.67^{ef}
TSs24	81.33^{d}	87.33^{cd}	84.33^{ef}	89.33^{cd}	93.67^{ab}	91.50^{bcd}	80.67^{e}	84.67^{de}	82.67^{g}
TSs42	89.67^{f}	93.00^{b}	91.34^{c}	92.33^{bc}	97.33^{a}	94.83^{ab}	91.67^{c}	95.00^{ab}	93.34^{bcd}
TSs48	91.67^{d}	96.67^{ab}	94.17^{abc}	94.00^{b}	96.67^{a}	95.34^{ab}	92.00^{c}	94.00^{b}	93.00^{bcde}
TSs50	96.67^{cd}	98.67^{a}	97.67^{a}	96.67^{ab}	96.00^{a}	96.34^{a}	98.67^{a}	95.33^{ab}	97.00^{ab}
TSs77	85.33^{ab}	81.67^{e}	83.50^{f}	86.33^{de}	82.00^{d}	84.17^{f}	86.67^{d}	85.67^{de}	86.17^{fg}
TSs81	86.67^{e}	82.66^{e}	84.67^{ef}	85.33^{ef}	86.00^{c}	85.67^{ef}	91.33^{c}	92.00^{bc}	91.67^{cde}
TSs82	88.67^{de}	86.33^{d}	87.50^{de}	90.00^{c}	87.33^{c}	88.67^{de}	96.33^{ab}	95.00^{ab}	95.67^{ab}
TSs83	92.67^{d}	94.33^{b}	93.50^{bc}	94.67^{ab}	96.66^{a}	95.67^{a}	98.00^{a}	98.67^{a}	98.34^{a}
TSs86	98.67^{a}	96.66^{ab}	97.67^{a}	98.00^{a}	94.00^{ab}	96.00^{a}	92.67^{bc}	88.00^{d}	90.34^{de}
TSs94	89.33^{d}	92.00^{bc}	90.67^{cd}	86.00^{de}	91.67^{b}	88.84^{de}	85.33^{d}	81.67^{e}	83.50^{g}
TSs209	93.33^{b}	96.67^{ab}	95.00^{ab}	92.00^{bc}	95.33^{ab}	93.67^{abc}	93.33^{c}	92.33^{bc}	92.83^{cde}
TSs311	96.00^{ab}	94.33^{b}	95.17^{ab}	92.00^{bc}	88.33^{c}	90.17^{cd}	92.00^{c}	90.33^{c}	91.17^{cde}
TSs331	96.00^{ab}	94.33^{b}	95.17^{ab}	96.00^{ab}	92.33^{b}	94.17^{ab}	94.67^{bc}	91.00^{c}	92.84^{cde}
TSs349	93.33^{b}	89.33^{c}	91.33^{c}	96.00^{ab}	92.00^{b}	94.00^{ab}	96.00^{ab}	93.00^{bc}	94.50^{bc}
TSs370	94.00^{b}	90.66^{c}	92.33^{bc}	96.00^{ab}	94.67^{ab}	95.34^{a}	97.33^{ab}	94.67^{b}	96.00^{ab}
Mean	91.33	92.26	91.80	91.81	92.63	92.22	92.17	91.83	92.00
SE	2.08	2.21	2.15	2.08	2.21	2.15	2.08	2.21	2.15

Means followed by the same alphabets along the columns are not significantly different from one another at 5 % probability level.
Comb- Combined cropping year

Table 3: Effect of plant three densities on seedling vigour index in 18 AYB genotypes in 2013, 2014 and combined cropping years

Genotypes	Seedling vigour index								
	55,555 plants ha^{-1}			24,975 plants ha^{-1}			10,000 plants ha^{-1}		
	2013	2014	Comb	2013	2014	Comb	2013	2014	Comb
TSs9	22.17^{a}	25.88^{a}	24.03^{a}	18.67^{a}	20.72^{a}	19.70^{a}	21.50^{a}	23.89^{a}	22.70^{a}
TSs22	17.53^{b}	20.26^{b}	18.90^{b}	12.93^{c}	14.63^{cd}	13.78^{de}	16.00^{c}	18.89^{b}	17.45^{c}
TSs23	11.53^{d}	13.52^{ef}	12.53^{e}	10.03^{e}	11.93^{e}	10.98^{g}	7.77^{h}	8.82^{g}	8.30^{i}
TSs24	7.80^{f}	7.58^{h}	7.69^{g}	13.43^{c}	15.63^{c}	14.53^{cd}	14.10^{d}	14.73^{c}	14.42^{d}
TSs42	14.13^{c}	16.10^{d}	15.12^{cd}	10.20^{e}	11.96^{e}	11.08^{g}	11.30^{ef}	11.99^{de}	11.65^{f}
TSs48	10.27^{de}	9.64^{g}	9.96^{f}	13.00^{c}	12.30^{e}	12.65^{ef}	8.41^{g}	7.36^{g}	7.89^{i}
TSs50	17.00^{b}	15.79^{de}	16.40^{c}	18.83^{a}	17.02^{b}	17.93^{b}	10.87^{f}	9.68^{fg}	10.28^{gh}
TSs77	5.97^{gh}	6.11^{i}	6.04^{h}	9.23^{ef}	7.80^{g}	8.52^{h}	21.96^{a}	23.92^{a}	12.94^{de}
TSs81	15.27^{c}	16.01^{d}	15.64^{cd}	13.36^{c}	12.34^{e}	12.85^{ef}	14.40^{d}	13.20^{cd}	13.80^{d}
TSs82	12.67^{d}	12.27^{f}	12.47^{e}	16.17^{b}	17.24^{b}	16.71^{bc}	18.67^{b}	20.27^{b}	19.47^{b}
TSs83	17.73^{b}	18.42^{c}	18.08^{b}	16.70^{b}	15.53^{c}	16.12^{c}	12.60^{e}	11.51^{de}	12.06^{ef}
TSs86	14.93^{c}	16.40^{d}	15.67^{cd}	13.20^{c}	14.34^{cd}	13.77^{de}	14.06^{d}	11.51^{de}	12.79^{ef}
TSs94	14.53^{c}	16.46^{d}	15.50^{cd}	11.83^{cd}	13.86^{de}	12.85^{ef}	9.03^{fg}	7.50^{gh}	8.27^{i}
TSs209	14.96^{c}	14.05^{e}	14.51^{d}	10.37^{e}	12.89^{de}	11.63^{fg}	13.87^{de}	12.12^{d}	13.00^{de}
TSs311	9.26^{ef}	8.25^{gh}	8.76f^{g}	5.86^{g}	5.10^{h}	5.48^{i}	9.83^{fg}	8.50^{g}	9.17^{hi}
TSs331	4.73^{h}	4.08^{j}	4.41^{i}	4.90^{g}	4.32^{h}	4.61^{i}	5.50^{i}	4.77^{h}	5.14^{j}
TSs349	8.60^{f}	7.47^{h}	8.04^{g}	10.40^{e}	8.94^{fg}	9.67^{h}	12.03^{de}	10.57^{ef}	11.30^{fg}
TSs370	13.03^{d}	11.40^{f}	12.22^{e}	10.60^{e}	9.52^{f}	10.06^{gh}	14.40^{d}	12.75^{d}	13.58^{de}
Mean	12.90	13.32	13.11	12.21	12.56	12.38	13.13	12.89	13.00
SE	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

Means followed by the same alphabets along the columns are not significantly different from one another at 5 % probability level

Comb- Combined cropping year

Table 4: Effect of plant population densities on seedling fresh weight in 18 AYB genotypes in 2013, 2014 and combined cropping years

	Seedling fresh weight (g)								
Genotypes	55,555 plants ha^{-1}			24,975 plants ha^{-1}			10,000 plants ha^{-1}		
	2013	2014	Comb	2013	2014	Comb	2013	2014	Comb
TSs9	0.99^{ab}	0.92^{a}	0.96^{a}	1.14^{a}	1.03^{a}	1.09^{a}	1.25^{a}	1.14^{a}	1.20^{a}
TSs22	0.92^{bc}	0.84^{bc}	0.88^{b}	0.99^{c}	0.90^{bc}	0.95^{b}	0.90^{c}	0.82^{bc}	0.86^{c}
TSs23	0.68^{e}	0.62^{e}	0.65^{de}	0.64^{f}	0.58^{gh}	0.61^{fg}	0.59^{f}	0.53^{e}	0.56^{gh}
TSs24	0.35^{h}	0.39^{h}	0.37^{g}	0.65^{f}	0.72^{de}	0.69^{de}	0.62^{f}	0.67^{d}	0.65^{ef}
TSs42	0.67^{e}	0.74^{d}	0.71^{d}	0.75^{d}	0.83^{c}	0.79^{c}	0.77^{de}	0.84^{b}	0.81^{c}
TSs48	0.89^{c}	0.80^{cd}	0.85^{b}	1.09^{ab}	0.99^{a}	1.04^{a}	0.51^{gh}	0.46^{f}	0.49^{h}
TSs50	0.86^{cd}	0.95^{a}	0.91^{a}	0.55^{h}	0.60^{gh}	0.58^{fg}	0.60^{f}	0.66^{d}	0.63^{e}
TSs77	0.58^{f}	0.64^{e}	0.61^{e}	0.58^{gh}	0.64^{fg}	0.61^{fg}	1.00^{b}	1.10^{a}	1.05^{b}
TSs81	0.81^{d}	0.89^{b}	0.85^{b}	0.65^{fg}	0.71^{de}	0.68^{def}	0.56^{fg}	0.61^{de}	0.59^{f}
TSs82	0.82^{cd}	0.90^{ab}	0.86^{b}	0.68^{f}	0.75^{de}	0.72^{de}	0.80^{d}	0.88^{b}	0.84^{cd}
TSs83	1.01^{a}	0.92^{a}	0.97^{a}	1.04^{bc}	0.94^{b}	0.99^{b}	0.84^{cd}	0.76^{c}	0.80^{c}
TSs86	0.68^{e}	0.74^{d}	0.71^{d}	0.62^{fg}	0.68^{ef}	0.65^{ef}	0.61^{f}	0.67^{d}	0.64^{f}
TSs94	0.66^{ef}	0.73^{d}	0.70^{d}	0.49^{h}	0.54^{h}	0.52^{g}	0.56^{fg}	0.62^{de}	0.59^{fg}
TSs209	0.80^{d}	0.88^{ab}	0.84^{b}	0.55^{h}	0.60^{gh}	0.58^{fg}	0.78^{de}	0.86^{b}	0.82^{c}
TSs311	0.83^{cd}	0.75^{d}	0.79^{c}	0.73^{e}	0.66^{fg}	0.70^{d}	0.63^{f}	0.57^{e}	0.60^{fg}
TSs331	0.43^{g}	0.47^{g}	0.45^{f}	0.78^{e}	0.85^{c}	0.82^{c}	0.35^{i}	0.39^{f}	0.37^{i}
TSs349	0.61^{ef}	0.55^{e}	0.58^{e}	0.82^{d}	0.75^{de}	0.79^{c}	0.75^{e}	0.68^{d}	0.72^{de}
TSs370	0.78^{d}	0.86^{ab}	0.82^{bc}	0.52^{h}	0.57^{gh}	0.55^{g}	0.45^{h}	0.85^{b}	0.65^{ef}
Mean	0.74	0.76	0.75	0.74	0.74	0.74	0.70	0.73	0.71
SE	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Means followed by the same alphabets along the columns are not significantly different from one another at 5 % probability level.
Comb- Combined cropping year

Table 5: Effect of three plant densities on seedling dry weight in 18 AYB genotypes in 2013, 2014 and combined cropping years

Genotypes	Seedling dry weight (g)								
	55,555 plants ha^{-1}			24,975 plants ha^{-1}			10,000 plants ha^{-1}		
	2013	2014	Comb	2013	2014	Comb	2013	2014	Comb
TSs9	0.46^{a}	0.56^{a}	0.51^{a}	0.22^{cde}	0.53^{a}	0.38^{ab}	0.25^{b}	0.48^{bc}	0.37^{a}
TSs22	0.44^{a}	0.43^{d}	0.44^{b}	0.19^{ef}	0.44^{bc}	0.32^{bc}	0.21^{c}	0.43^{cd}	0.32^{ab}
TSs23	0.16^{ef}	0.41^{de}	0.29^{d}	0.13^{fg}	0.33^{de}	0.23^{fg}	0.16^{de}	0.44^{cd}	0.30^{bc}
TSs24	0.48^{a}	0.48^{bc}	0.48^{ab}	0.17^{ef}	0.49^{ab}	0.33^{bc}	0.16^{de}	0.56^{a}	0.36^{ab}
TSs42	0.13^{fg}	0.24^{g}	0.19^{e}	0.16^{ef}	0.29^{ef}	0.23^{fg}	0.13^{f}	0.41^{de}	0.27^{dc}
TSs48	0.15^{efg}	0.26^{g}	0.21^{e}	0.34^{b}	0.50^{a}	0.42^{a}	0.24^{bc}	0.40^{de}	0.32^{abc}
TSs50	0.22^{d}	0.50^{b}	0.36^{c}	0.20^{de}	0.37^{de}	0.29^{cdef}	0.30^{a}	0.22^{fg}	0.26^{cd}
TSs77	0.21^{d}	0.35^{f}	0.28^{d}	0.18^{ef}	0.44^{bc}	0.31^{cd}	0.15^{ef}	0.55^{ab}	0.35^{ab}
TSs81	0.19^{de}	0.49^{bc}	0.34^{cd}	0.16^{ef}	0.54^{a}	0.35^{bc}	0.20^{cd}	0.52^{ab}	0.36^{ab}
TSs82	0.18^{de}	0.48^{bc}	0.33^{cd}	0.43^{a}	0.37^{de}	0.40^{ab}	0.28^{ab}	0.40^{cd}	0.34^{ab}
TSs83	0.18^{de}	0.47^{bcd}	0.33^{cd}	0.15^{f}	0.52^{a}	0.34^{bc}	0.13^{f}	0.36^{de}	0.25^{cd}
TSs86	0.34^{b}	0.29^{g}	0.32^{cd}	0.22^{cd}	0.34^{de}	0.28^{def}	0.20^{cd}	0.24^{f}	0.22^{de}
TSs94	0.34^{b}	0.36^{f}	0.35^{cd}	0.10^{g}	0.38^{cd}	0.24^{ef}	0.15^{f}	0.48^{bc}	0.32^{ab}
TSs209	0.12^{fg}	0.45^{cd}	0.29^{d}	0.25^{c}	0.35^{de}	0.30^{cde}	0.12^{f}	0.45^{cd}	0.29^{c}
TSs311	0.13^{fg}	0.38^{ef}	0.26^{d}	0.21^{cd}	0.31^{de}	0.26^{def}	0.10^{f}	0.21^{fg}	0.16^{ef}
TSs331	0.11^{g}	0.18^{h}	0.15^{e}	0.24^{cd}	0.29^{ef}	0.27^{def}	0.13^{f}	0.15^{g}	0.14^{f}
TSs349	0.12^{fg}	0.24^{g}	0.18^{e}	0.17^{ef}	0.42^{bc}	0.30^{cde}	0.13^{f}	0.34^{e}	0.24^{cd}
TSs370	0.28^{c}	0.36^{f}	0.32^{cd}	0.20^{de}	0.23^{f}	0.22^{g}	0.24^{bc}	0.38^{de}	0.31^{abc}
Mean	0.24	0.39	0.31	0.21	0.40	0.30	0.18	0.39	0.29
SE	0.03	0.08	0.06	0.03	0.08	0.06	0.03	0.08	0.06

Means followed by the same alphabets along the columns are not significantly different from one another at 5 % probability level.

Comb- Combined cropping year

Table 6: Pearson correlation coefficients among seed physiological attributes in 2013, 2014 and combined cropping years

Characters	Cropping year	SV1	SFW	SDW
SG	2013	0.446**	-0.261**	0.060
	2014	0.026	-0.152*	-0.237**
	Combined	0.236**	0.207	0.149*
SV1	2013		0.262**	-0.067
	2014		0.017	-0.023
	Combined		0.140*	-0.045
SFW	2013			0.218**
	2014			-0.057
	Combined			0.138

SG- Standard germination, SVI- Seedling vigour index, SFW- Seedling fresh weight, SDW- Seedling dry weight, SE-Seedling emergence, SEI- Seedling emergence index