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**RESEARCH PAPER**

# Seed Physical Characteristics and Germination of Different Hybrid Combinations of Oil Palm (*Elaeis guineensis*, Jacq.) Developed from African Germplasm

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## ABSTRACT

**Variation in seed physical characteristics and germination potential were evaluated for twenty two hybrid combinations (E77(G59) × 65, E80(G57) × 65, E81(G57) × 66, E71(G59) × 435, E61(G53) × 435, E74(G54) × 66, E85(G56) × 66, E70(G58) × 435, E56(G54) × 435, E47(G54) × 435, E13(G34) × 435, E79(G55) × 66, E54(G57) × 435, E76(G54) × 435, E58(G55) × 435, E57(G59) × 435, E84(G56) × 435, E72(G57) × 214, E48(G59) × 435, E68 (G58) × 435, E52(G58) × 435 and E62 (G59) × 435) developed from African germplasm collections of 13 years old palms planted at Directorate of Oil Palm Research, Research Centre, Palode, Kerala, India. The percent distribution of big, medium and small seed groups varied among hybrids which was independent to individual crosses. The combinations namely, E61 (G53) × 435 and E58 (G55) × 435 showed best performance as they recorded low per cent distribution of small size seeds. The highest coefficient of variation was reported for kernel weight while seed weight and germination per cent had low Coefficient of Variation (CV) among different combinations. Highest seed weight coupled with other seed physical characteristics was observed in E54 (G57) × 435. Shell weight, seed volume, kernel weight were positively correlated with seed weight and comparatively low correlation value was recorded for shell thickness. Big and medium seed weight groups showed high germination per cent in majority of the cross combinations. According to present results, size grading of seeds of individual bunch is recommended and big, medium size seeds are preferred over small seeds to achieve high germination per cent.**

**Key words**: African germplasm, hybrids, seed size variation, physical characteristics, germination

## INTRODUCTION

In the next 10-15 years Dura × Pisifera hybrids will continue to play a major role as oil palm planting material (Rajanaidu, 2009). Sufficient availability and diverse nature of planting materials are pre-requisites for the success of oil palm expansion in potential areas in India having varied agro climatic conditions. Restriction of commercial planting of hybrids with narrow genetic base in many breeding programmes is undoubtedly starting to impose limitations as noted by Hardon and Corley (2000). Government of India is giving major thrust to production of Indigenous planting material to meet the growing demand and availability of high quality seed material is a key aspect for the sustainability of oil palm industry. Genetic variability exists within Dura × Pisifera seeds in view of cross pollinated nature of oil palm. Harun and Noor (2002) recorded variation in bunch characteristics of pollinated bunches. Palm to palm variation in bunch, fruit and nut weights of ASD Costa Rica and Palode hybrids were reported by Murugesan *et al*. (2010). There is evidence of genetic differences in germination of progenies and some progenies show consistently poor germination (Murugesan *et al*., 2009). Size is widely accepted measure of seed quality and large seeds have high seedling quality, growth and establishment (Jerlin and Vadivelu, 2004). Therefore, grading of seeds on the basis of size or weight will help to improve germination, seedling quality and uniformity. The existing variability and study of seed physical characteristics of material in question are prerequisites in commercial seed producing centres. With above facts in view, evaluation was carried out in different hybrid combinations developed from different African germplasm available at the Palode Research Centre of Directorate of Oil Palm Research (DOPR) with an objective to record extent of variation, relationship of physical characteristics and germination so as to develop base for seed quality standards utilizing experimental results.

## MATERIALS AND METHODS

Evaluation was conducted at Directorate of Oil Palm Research, Research Centre, Palode during 2008-2010. The experimental location receives an annual rainfall of 2815 mm, with maximum, minimum temperature of 32.1$^0$C and 22$^0$C, respectively. It has forest lateritic soil with a pH range of 5.0 to 5.5. Fruits from hybridized bunches of twenty two hybrid combinations (E77(G59) × 65, E80(G57) × 65, E81(G57) × 66, E71(G59) × 435, E61(G53) × 435, E74(G54) × 66, E85(G56) × 66, E70(G58) × 435, E56(G54) × 435, E47(G54) × 435, E13(G34) × 435, E79(G55) × 66, E54(G57) × 435, E76(G54) × 435, E58(G55) × 435, E57(G59) × 435, E84(G56) × 435, E72(G57) × 214, E48(G59) × 435, E68(G58) × 435, E52(G58) × 435 and E62(G59) × 435) were separated and seeds extracted from the fruits were first manually graded into big, medium and small seeds and after taking weight of individual seeds from each group they were once again grouped and % distribution of three sizes were calculated. All the seeds from bunch were equally divided based on single seed weight. Ten seeds from each group with three replications were subjected to estimation of physical characteristics *viz*., seed weight (g seed $^{-1}$), seed volume (cm$^3$ seed$^{-1}$), shell weight (g seed$^{-1}$), shell thickness (mm), and kernel weight (g seed$^{-1}$). Seeds with multi kernels were discarded and replaced with single kernelled ones wherever necessary. Germination test was conducted for all the seed size groups following procedure developed by Murugesan *et al*. (2008). Protuberance of radicle was considered as germination and expressed as percentage. A factorial experiment of CRD design was followed for statistical analysis with three seed weights categories as factor one (Big, medium and small) and twenty two treatments as factor two. An analysis of variance (ANOVA) was made to determine the statistical significance of mean difference of the variables. Means were separated using LSD at p = 0.05 and 0.01%. Seed physical characteristics *viz*., seed weight, seed volume, shell weight, shell thickness and germination % of 22 combinations was paired and correlation co-efficient and relationship of seed weight with shell thickness, shell weight, kernel weights and germination were studied. All the values of thirty seeds from each combination were used for correlation of physical characteristics. Mean values were used for correlation of germination with other parameters.

## RESULTS AND DISCUSSION

### Distribution of % of big, medium and small seeds

The details of % distribution of big, medium and small seeds of different hybrid combinations are given in Fig. 1. Distribution percentage of seed weight group and number of seeds of big, medium and small were found to be different among crosses. The cross number, E58 (G55) × 435 had high (84%) of big seeds followed by E61 (G53) × 435 (67%) whereas % medium seed group was high (43%) in E62 (G59) × 435 and E57 (G59) × 435) and small in E47 (G54) × 435 (59 %) followed by E76 (G54) × 435 (51%). The reasons for variation in seed size is mostly attributed to palm to palm variation resulted from genetic / environmental differences and inter fruit competition for light and nutrition (Harun and Noor, 2002). Corley and Tinker (2003) reported that there was variation in nut weight of different dura genotypes. The estimated average % distribution indicated that big and medium represent majority followed by small ones. Panyangnoi *et al.* (1997) recorded largest number of seeds of medium size in dura bunches. In this study % of distribution varied according to crosses, because hybridization was made from different individual mother palms and seed traits are mostly contributed by maternal tissues. Accordingly, E61 x 435 and E58 x 435 have showed best performance as they recorded low % distribution of small size seeds (4 and 5%, respectively).

### Physical characteristics of seeds and germination

All the physical characteristics of seeds were found to be significantly different among different cross combinations and interaction with seed size groups (Table1). The different combinations recorded co-efficient of variation of 13.36, 14.68, 19.76, 17.85 and 30.22 for seed weight, seed volume, shell weight, shell thickness and kernel weight, respectively. Ataga (1994) reported high variation in kernel size of Nigerian oil palm germplasm collection. Wide variation was observed among big, medium and small seeds in different crosses and average values recorded were 8.83, 4.91 and 2.72 seed $^{-1}$ respectively. Big seed group in all the crosses had high seed weight, shell weight, thick shell and seed volume. All the crosses recorded seed weight of more than 7g seed $^{-1}$ under big size category except E47 (G54) × 435, E13 (G34) × 435, E76 (G54) ×435, E84 (G56) × 435 and E48 (G59) × 435. Deli dura nuts recorded an average of 5-6g and range up to 13g (Corley and Tinker, 2003). Lowest seed weight recorded for medium group and small group are 2.68 g (E84 (G56) × 435) and 0.39 g (E13 (G34) × 435).The mean highest seed weight ( 9.12 g ) recorded in cross E54 (G57)

×435 followed by E62 (G59) × 435 (7.67g) and lowest mean weight (3.39g) was recorded in E76(G54) ×435. Seed weight varies due to the fruit location and position in the bunch as stated by Hartley (1988). Harun and Noor (2002) had recorded variation in seed size within fruit bunch as they observed big size seeds from outer spikelets. Occurrence of high seed weights obtained in some crosses is due to major contribution of shell weight. Seed volume was also found different among seed weight groups. The average seed volumes recorded for big, medium and small are 7.01, 4.09 and 2.12, respectively which are similar to seed weight and seed volume. For example highest mean seed weight, volume and shell weight were recorded in the same cross E54 (G57) × 435. The average weights of shell for big, medium small are 6.10, 3.35 and 1.87g, respectively. The thickness of shell is also different among seed weight groups and crosses. Highest mean thickness (3.36mm) was recorded in big seed group of E54 (G57) × 435 and lowest (1.85 mm) was recorded in E84 (G56) × 435. Corley and Tinker (2003) reported shell thickness of more than 3 mm in tenera and less than 3 mm in dura populations. There was distinct significant variation among different categories. It might be noted that the shell is a maternal tissue so all the seeds from dura mother palms will have thick shells whatever type of pisifera pollen parents used. Nut size varies greatly and depends on both thickness of shell and the size of kernel. Corley and Tinker (2003) observed variation of seed weight which depends upon the thickness of shell and this observation has been confirmed with present study that seed is heavier when shell is thicker. Significant variation of seed traits recorded in different crosses is due to contribution of different dura parents which are primary collection sourced from exotic sources. They are still under consideration for selection as parent for improvement. Reduced variation of shell thickness in seven crosses was recorded by Myint, *et al.* (2010) which might be due to advanced nature of planting material. Within each oil palm fruit forms considerable variation in shell thickness was observed under apparent polygenic control as reported by Moretzsohn *et al.* (2000). Observation on kernel variation is important for getting information on germination response as kernel is the main storage part which supply nutrition to the developing embryo. In all the crosses, significant variation was observed in respect of kernel weight. There are number of evidences of variation in nut size which depends on both thickness of shell and the size of the kernel. Corley and Tinker (2003) opined that if the kernel size increased the % of shell to fruit will also be increased. Rajanaidu *et al*. (2000) identified individual palms among Nigerian prospection material with maximum nut and kernel weight and opined that heritability of kernel content is generally quite high. The kernel average of 2.30, 1.28 and 0.76g $kernel^{-1}$ for big, medium and small seeds, respectively were observed in this study. There are several evidences of genetic differences in the germination behavior of oil palm cross combinations. Very low CV % was recorded for germination. In the present study, big size seed group of majority of the crosses (13 out of 22) showed high germination and eight crosses showed high germination in case of medium and only one cross (E52 (G58) × 435) showed high germination ( 61.2%) which is on par with medium group ( 60.35%). In case of germination potential of crosses, E74 (G54) × 66 and E48 (G59) ×435 had high mean germination (81.11 and 81.16%) and lowest (26.93%) was recorded in E85 (G56) × 66). Very low values were recorded in small (8.5%) and medium size group (17.4%) and relatively high (54.9%) in big size group while considering whole hybrid combinations. The big and medium seeds had significantly higher germination percentage than small seeds and similar findings were reported by Panyangnoi *et al*. (1997) who attributed it due to the presence of large endosperm food reserve in heavy seeds. The high germination % recorded in small seed group of one cross and several medium seed group might be due to independent maternal effect of mother palm and experimental and environment condition. Myint *et al.* (2010) reported effect of experimental conditions and materials on germination and other physical characteristics of seeds. According to Hartley (1988) and Corley and Tinker (2003) there were no difference in germination between seeds from outer and inner fruits and reported failure of germination in small seeds. Differences in germination might be mainly contributed by genetic background of different genetic resource than food reserve of kernel. There is also possibility of absence or problems exist in embryo development of small seeds which culminated in failure of germination. In this study significant interaction of cross and seed size group on germination were obtained. All the physical characteristics of seed showed highly significant positive correlation co-efficient when paired with seed weight, seed volume, shell weight, shell thickness, kernel weight. All the above had positive significant correlation with seed weight. Though germination had positive correlation with seed weight but showed no significant correlation ($r^2$= 0.02) due to specific germination response of individual cross combinations with varied seed sizes within a bunch. The present result indicated that seed weight influence germination which is independent to cross combinations or hybridized bunch and hence, the seed grading is possible and effective only within bunch. Germination % varied due to crosses and Corley and Tinker (2003) reported that there is evidence of genetic differences in the germination of progenies with some progenies showing consistently poor germination. Highest correlation was recorded for shell weight ($r^2$ = 0.91) followed by seed volume ($r^2$ =0.79), kernel weight ($r^2$ =0.52) and shell thickness had least $r^2$ value of 0.38 (Table 2 and Fig. 2). Panyangnoi *et al.* (1997) reported that shell thickness was not highly correlated with seed weight and it is confirmed by present study that shell thickness recorded least value of correlation when compared to other physical characteristics.

## CONCLUSION

The different hybrid combinations developed indigenously from exotic collections had exhibited significant variations in terms of seed traits and germination. The differences of seed physical characteristics *viz*., seed weight, seed volume; shell weight, shell thickness and kernel weight were interrelated. Highest correlation was reported for shell weight followed by seed volume and kernel weight and least correlation value was observed for shell thickness with seed weight. Since, seed weight of the crosses and their sizes decide % germination potential of individual mother palms and size grading of seeds of individual bunch is recommended and big, medium size seeds are preferred over small seeds.

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**Fig. 1 : Percent distribution of big, medium and small seeds in different cross combinations developed from exotic genetic resources**

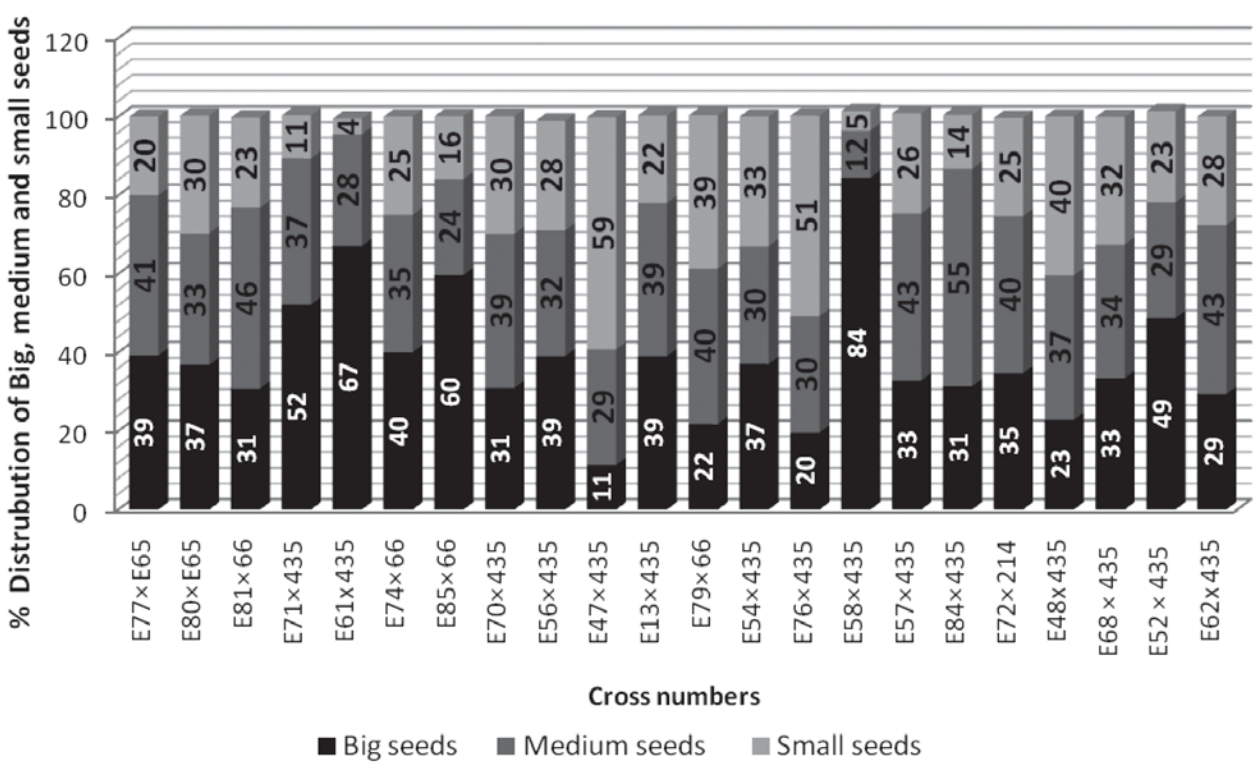

**Table 1 : Variation in seed weight , seed volume, shell weight , shell thickness and kernel weight of twenty two crosses of big, medium and small seed groups developed from African oil palm germplasm**

| Hybrid Combinations | Seed weight (g seed$^{-1}$) | | | Mean | Seed volume (cm³ seed$^{-1}$) | | | Mean | Shell weight (g seed$^{-1}$) | | | Mean | Shell thickness (mm) | | | Mean | Kernel weight (g seed-1) | | | Mean | Germination (%) | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | M | S | | B | M | S | | B | M | S | | B | M | S | | B | M | S | | B | M | S | |
| E77(G59) × 65 | 11.01 | 6.68 | 3.86 | 7.18 | 9.1 | 5.2 | 2.6 | 5.63 | 8.18 | 4.76 | 2.68 | 5.21 | 3.95 | 3.08 | 2.31 | 3.11 | 2.56 | 1.42 | 0.97 | 1.65 | 51.6 (45.9) | 67.6 (55.3) | 68.2 (55.8) | 62.47 (52.3) |
| E80(G57) × 65 | 11.98 | 4.35 | 1.81 | 6.05 | 9.3 | 4.1 | 1.4 | 4.93 | 8.65 | 3.4 | 1.42 | 4.49 | 3.87 | 3.24 | 2.32 | 3.14 | 3.11 | 1.37 | 0.41 | 1.63 | 66.4 54.8) | 68.1 (55.8) | 18.9 (25.6) | 51.13 (45.4) |
| E81(G57) × 66 | 10.68 | 6.48 | 3.62 | 6.93 | 8.2 | 5.4 | 2.7 | 5.43 | 7.89 | 4.54 | 2.59 | 5.01 | 4.05 | 2.98 | 2.51 | 3.18 | 2.12 | 1.43 | 0.95 | 1.5 | 64.7 (53.6) | 65.9 (54.4) | 55.2 47.9) | 61.93 (52) |
| E71(G59) × 435 | 7.67 | 3.04 | 0.58 | 3.76 | 6.0 | 2.4 | 0.55 | 2.98 | 5.23 | 1.94 | 0.45 | 2.54 | 2.89 | 1.91 | 1.71 | 2.17 | 2.06 | 0.81 | 0.21 | 1.03 | 56.5 (48.7) | 87.3 (70.6) | 61.8 (51.9) | 68.53 (57.1) |
| E61(G53) × 435 | 8.51 | 3.75 | 0.46 | 4.24 | 6.7 | 3.5 | 0.92 | 3.71 | 6.47 | 2.97 | 0.21 | 3.22 | 3.57 | 2.99 | 1.28 | 2.61 | 1.75 | 0.59 | 0.22 | 0.85 | 54.5 (47.6) | 81.6 (65.5) | 19.5 (25.6) | 51.87 (46.2) |
| E74(G54) × 66 | 8.57 | 6.12 | 4.28 | 6.32 | 7.2 | 5.3 | 3.3 | 5.27 | 6.52 | 4.81 | 3.36 | 4.9 | 3.86 | 3.44 | 2.94 | 3.41 | 1.67 | 1.35 | 0.97 | 1.33 | 93.34 (78.8) | 85.5 (67.8) | 64.5 (53.7) | 81.11 (66.7) |
| E85(G56) × 66 | 11.13 | 5.76 | 0.9 | 5.93 | 9.3 | 5.4 | 1.2 | 5.30 | 7.66 | 3.71 | 0.84 | 4.07 | 3.37 | 2.39 | 2.19 | 2.65 | 2.79 | 1.6 | 0.24 | 1.54 | 54.9 (47.8) | 17.4 (24.6) | 8.5 (16.9) | 26.93 (29.8) |
| E70(G58) × 435 | 9.99 | 5.52 | 3.15 | 6.22 | 7.6 | 4.4 | 2.4 | 4.80 | 6.47 | 3.56 | 2.04 | 4.02 | 2.64 | 2.28 | 1.85 | 2.26 | 2.95 | 1.64 | 0.91 | 1.83 | 94.0 (76.4) | 73.0 (58.8) | 54.17 (47.4) | 73.72 (60.9) |
| E56(G54) × 435 | 7.03 | 5.04 | 3.93 | 5.33 | 5.9 | 4.3 | 2.8 | 4.33 | 4.81 | 3.31 | 2.62 | 3.58 | 3.32 | 2.98 | 1.76 | 2.68 | 1.66 | 1.38 | 1.17 | 1.4 | 85.9 (68.2) | 35.94 (36.8) | 54.5 (47.6) | 58.78 (50.9) |
| E47(G54) × 435 | 6.74 | 3.65 | 2.36 | 4.25 | 5.6 | 3.25 | 2.25 | 3.70 | 4.26 | 2.11 | 1.65 | 2.67 | 2.25 | 2.33 | 1.75 | 2.11 | 2.00 | 0.89 | 0.76 | 1.22 | 83.6 (66.3) | 36.0 (36.9) | 53.0 (46.7) | 57.53 (50) |
| E13(G34) × 435 | 7.93 | 4.44 | 0.39 | 4.25 | 6.8 | 3.4 | 0.44 | 3.55 | 5.50 | 3.00 | 0.38 | 2.96 | 2.68 | 2.38 | 2.2 | 2.42 | 2.08 | 1.33 | 0.24 | 1.22 | 61.76 (51.8) | 45.62 (42.5) | 59.8 (50.7) | 55.72 (48.3) |
| E79(G55) × 66 | 5.82 | 3.6 | 2.76 | 4.06 | 4.95 | 2.8 | 2.0 | 3.25 | 4.15 | 2.67 | 1.99 | 2.93 | 2.41 | 2.45 | 2.38 | 2.41 | 1.52 | 0.75 | 0.74 | 1.01 | 50.8 (45.5) | 38.40 (38.3) | 49.37 (44.6) | 46.19 (42.8) |
| E54(G57) × 435 | 12.67 | 9.02 | 5.67 | 9.12 | 9.8 | 7.2 | 4.3 | 7.10 | 9.66 | 6.77 | 3.86 | 6.76 | 4.06 | 3.26 | 2.76 | 3.36 | 2.34 | 1.68 | 1.27 | 1.76 | 25.78 (30.5) | 42.29 (40.6) | 25.23 (30.1) | 31.10 (33.7) |
| E76(G54) × 435 | 4.81 | 3.03 | 2.32 | 3.39 | 3.5 | 3.0 | 2.25 | 2.92 | 3.3 | 2.03 | 1.61 | 2.31 | 1.84 | 1.87 | 1.94 | 1.88 | 1.25 | 0.86 | 0.65 | 0.92 | 69.96 (56.8) | 68.35 (55.8) | 25.2 (30.1) | 54.50 (47.6) |
| E58(G55) × 435 | 10.09 | 4.87 | 2.72 | 5.89 | 7.9 | 4.0 | 1.5 | 4.47 | 6.35 | 2.75 | 2.11 | 3.74 | 2.72 | 1.89 | 2.27 | 2.29 | 3.32 | 1.75 | 0.21 | 1.76 | 57.83 (49.5) | 43.8 (41.4) | 10.0 (18.4) | 37.21 (36.5) |
| E57(G59) × 435 | 9.12 | 4.68 | 3.44 | 5.75 | 5.4 | 2.5 | 1.15 | 3.02 | 6.06 | 3.22 | 2.23 | 3.84 | 2.41 | 2.38 | 2.38 | 2.39 | 2.26 | 0.99 | 0.83 | 1.36 | 52.07 (46.2) | 57.0 (49) | 30.0 (33.2) | 46.36 (42.8) |
| E84(G56) × 435 | 6.94 | 2.68 | 1.19 | 3.60 | 5.9 | 3.3 | 0.6 | 3.27 | 4.55 | 1.74 | 0.74 | 2.34 | 2.17 | 1.78 | 1.61 | 1.85 | 2.03 | 0.78 | 0.44 | 1.08 | 76.37 (60.9) | 66.06 (54.4) | 53.5 (47) | 65.31 (54.1) |
| E72(G57) × 214 | 7.49 | 4.62 | 0.65 | 4.25 | 4.6 | 3.45 | 2.7 | 3.58 | 4.83 | 2.86 | 0.54 | 2.74 | 2.99 | 2.52 | 2.26 | 2.59 | 2.00 | 1.38 | 0.28 | 1.22 | 64.3 (53.4) | 62.92 (52.5) | 54.64 (47.7) | 60.62 (51.2) |
| E48(G59) × 435 | 6.25 | 3.78 | 2.99 | 4.34 | 7.1 | 3.5 | 2.0 | 4.20 | 4.03 | 2.39 | 1.86 | 2.76 | 2.17 | 1.92 | 2.05 | 2.05 | 2.11 | 1.22 | 1.03 | 1.45 | 82.14 (65.1) | 87.15 (69.2) | 74.19 (59.6) | 81.16 (64.6) |
| E68(G58) × 435 | 9.32 | 5.14 | 3.53 | 6.00 | 7.3 | 4.2 | 3.05 | 4.85 | 6.03 | 3.24 | 2.28 | 3.85 | 2.95 | 2.38 | 2.84 | 2.72 | 2.86 | 1.67 | 1.06 | 1.86 | 30.4 (33.4) | 63.4 (52.8) | 49.98 (45) | 47.93 (43.8) |
| E52(G58) × 435 | 9.57 | 5.19 | 3.82 | 6.19 | 7.9 | 4.2 | 2.7 | 4.93 | 5.62 | 3.36 | 2.12 | 3.7 | 2.33 | 2.66 | 1.53 | 2.17 | 3.35 | 1.48 | 1.53 | 2.12 | 45.8 (42.6) | 60.35 (51) | 61.2 (46.8) | 55.78 (46.8) |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E62(G59× 435 | 11.01 | 6.63 | 5.36 | 7.67 | 8.2 | 5.1 | 3.8 | 5.70 | 7.91 | 4.45 | 3.63 | 5.33 | 3.87 | 2.67 | 2.63 | 3.06 | 2.72 | 1.69 | 1.53 | 1.98 | 51.27 (45.7) | 48.97 (44.4) | 25.21 (30) | 41.82 (40.1) |
| Average | 8.83 | 4.91 | 2.72 | 5.49 | 7.01 | 4.09 | 2.12 | 4.41 | 6.10 | 3.35 | 1.87 | 3.77 | 3.02 | 2.54 | 2.16 | 2.57 | 2.30 | 1.28 | 0.76 | 1.44 | 62.45 (53.2) | 59.2 (50.8) | 44.1 (41.0) | 55.3 (48.3) |
| | SED | CD (0.05) | 0.01 | | SED | CD (0.05) | 0.01 | | SED | CD (0.05) | 0.01 | | SED | CD (0.05) | 0.01 | | SED | CD (0.05) | 0.01 | | SED | CD (0.05) | CD (0.01) | |
| Cross (C ) | 0.28 | 0.55 | 0.72 | | 0.25 | 0.50 | 0.65 | | 0.20 | 0.39 | 0.51 | | 0.12 | 0.24 | 0.31 | | 0.11 | 0.22 | 0.29 | | 1.53 (1.08) | 3.01 (2.12) | 3.96 (2.8) | |
| Seed Size ( S ) | 0.10 | 0.20 | 0.27 | | 0.10 | 0.18 | 0.24 | | 0.07 | 0.14 | 0.19 | | 0.04 | 0.09 | 0.12 | | 0.04 | 0.08 | 0.11 | | 0.57 (0.39) | 1.11 (0.78) | 1.46 (1.03) | |
| C × S | 0.48 | 0.95 | 1.25 | | 0.44 | 0.86 | 1.13 | | 0.35 | 0.68 | 0.89 | | 0.21 | 0.41 | 0.54 | | 0.19 | 0.38 | 0.50 | | 2.65 (1.87) | 5.21 (3.67) | 6.85 (4.83) | |
| CV % | | 13.36 | | | | 14.68 | | | | 19.76 | | | | 17.85 | | | | 30.22 | | | | 10.44 (8.54) | | |

B: Big seed M: Medium seed S: Small seed, Figures in parenthesis indicates transformed arcsine value

**Table 2: Correlation coefficient (r value) of seed physical characteristics and germination of twenty two hybrids developed from African germplasm**

| | Seed weight | Seed Volume | Shell weight | Shell thickness | Kernel weight | Germination |
|---|---|---|---|---|---|---|
| Seed weight | 1.00 | 0.89*** | 0.96*** | 0.24* | 0.72*** | 0.17 |
| Seed volume | | 1.00 | 0.87*** | 0.23* | 0.67*** | 0.21* |
| Shell weight | | | 1.00 | 0.27** | 0.59*** | 0.16 |
| Shell thickness | | | | 1.00 | 0.07 | 0.10 |
| Kernel weight | | | | | 1.00 | 0.21* |
| Germination | | | | | | 1.00 |

| | | | |
|---|---|---|---|
| Level of significance | 0.05 | 0.01 | 0.00 |
| Stat table | 0.20 | 0.25 | 0.32 |

*, ** and *** significance at 0.05, 0.01 and 5% levels respectively

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