Evaluating the Stability and Adaptability of Bambara Groundnut (*Vigna subterranea* (L.) Verd.) Landraces in Different Agro-Ecologies

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Abstract

Bambara groundnut has been planted in Indonesia for hundreds of years. Researchers have evaluated where the Indonesian Bambara groundnut landraces were introduced from but no-one has evaluated the stability and adaptability of Bambara groundnut in Indonesia. Thirty-six landraces were planted in Indonesia, together with putative Indonesian × African hybrids and their offspring. These were assessed for their stability and adaptability by the methods of Finlay and Wilkinson (1963) and Eberhart and Russel (1985). Results from seven landraces are presented. The seven landraces were: 'LunT' from Sierra Leone; 'AHM753'; 'SB165A' and 'S19-3' from Namibia; 'DODR' from Tanzania; 'Uniswa Red' from Swaziland; 'DIPC' from Botswana; and the Indonesian landrace 'Gresik' as control. Thirty plants of each landrace were planted in a randomised block design with three replicates at Gresik, Bojonegoro and Jatikerto in Indonesia in November 2009. Each location had a different altitude, soil type and rainfall. Gresik is the main Bambara groundnut growing region in the East of Java, Indonesia. Prior to this experiment, farmers in Bojonogoro and Jatikerto were not familiar with this crop. Many traits were assessed based on the list of descriptors of Bambara groundnut issued by IPGRI, but in this report we present only the results of stability and adaptability analysis for 50% flowering, days to maturity, pod number per plant and the 100 seeds weight traits. Analysis of variance showed highly significant differences in all three locations and combined analysis of variance over sites (Gomez and Gomez, 1983) indicated that location, landraces and location × landraces interaction are substantially different (1%). Stability and adaptability parameters were obtained as the linear regression coefficient (bi) of the mean of all data observed and deviation from the regression analysis (S^2_{di}) with the hypothesis that bi=1 and S^2_{di}=0. The results indicated that almost all landraces observed were stable, but only three landraces revealed good adaptability in all three locations, namely 'SB165A', 'Uniswa Red' and 'DIPC'. Meanwhile 'LunT' and 'S19-3' are considered promising landraces because they are well adapted in two of the four variables used. This information could prove useful for breeding programmes.

INTRODUCTION

Bambara groundnut is not a native crop of Indonesia. Records suggest that it came from South-West Africa in the early 18th century, through trade links. The seed coat has numerous colours namely: brown, cream, red, black or variegated testa. Due to farmers selectively planting certain colours, the colour of seed testa planted in Indonesia today is largely black, dark red, dark brown and dark purple. Indonesian farmers prefer to plant seed having dark coloured testa and a white hilum. Nutritional content of this crop is comparable to other legumes. Linnemann and Azam-ali (1993) estimated that the protein content of Bambara groundnut was between 16-25%.

This legume crop is suitable for semi-arid climates, is relatively resistant to diseases and pests (Linnemann and Azam-ali, 1993) and has the potential to generate high yields (Collinson et al., 2000). Even though this crop is broadly distributed in Africa and South East Asia, until recently Bambara groundnut did not receive appreciable research efforts, particularly for genetic improvement (Massawe et al., 2005) so Bambara groundnut currently exists as landraces rather than cultivars, which significantly complicates genetic analysis and breeding. However, it may assist crop survival under harsh environmental conditions (Zeven, 1998). Most researchers working on Bambara groundnut (Karikari, 2000; Basu et al., 2007; Mwale et al., 2007; Ntundu et al., 2006) consider it to have many useful traits for crop improvement.

In a study of 27 genotypes under optimal agronomic conditions in Ghana (Karikari, 1972), a simple correlation analysis indicated that number of stems per plant and 100 seeds weight were positively correlated with grain yield and these characters were used for selection. The characterisation and evaluation of Bambara groundnut at the International Institute of Tropical Agriculture (IITA) revealed enormous agro-morphological diversity which could be used for crop improvement. In a correlation matrix study of the IITA collection, Goli et al. (1997) found that the characters most strongly correlated with grain yield were number of leaves, pods, shell thickness and 100 seeds weight. Karikari (2000) found that 100 seeds weight was the most important character to consider during selection and breeding of Bambara groundnut in Botswana and areas with similar climates. Masindeni (2006) also showed that seed number per pod and 100 seed weight had a highly positive correlation to grain yield. In contrast, Misangu et al. (2007) found that there was a negative correlation between 100 seeds weight and pod number of Bambara groundnut in a screen house experiment in Tanzania. They also suggested that early flowering of landraces could represent an advantage in terms of forming pods for a longer period of time to generate more pods, while late flowering resulted in a decrease in the seed yield. Another experiment in Nigeria (Jonah et al., 2010) found a positive genotypic correlation between seed and pod number per plant. Makanda et al. (2009) have suggested that pod number per plant should be an important trait in the further development of Bambara landraces.

Some landraces may give good performance in a specific environment, but poor in others. The ability of some crops to perform well phenotypically across a wide range of environmental conditions has been examined by plant breeders and agronomists. Allard and Bradshaw (1964) considered that the stability of landraces is a reflection of their adaptability to environmental changes. A landrace may be stable across environments if it gives limited deviation in response to different environments (Becker and Leon, 1988). Finlay and Wilkinson (1963) characterised the stability of landraces based on a regression coefficient (bi) with the following classification: bi=0, absolute stability; bi=1, average stability; bi<1, above average stability and bi>1, below average stability. Moreover Eberhart and Russel (1966) examined adaptability which correlated bi and mean yield. A landrace which has a regression coefficient (bi) of 1 would, in general, be said to be adaptable. However, when general adaptability is correlated with a high mean yield, it can be said to be well adapted. Moreover, it can be said to be poorly adapted when correlated to a low mean yield. A landrace which has above average mean yield in an unfavourable environment, but is low yielding in a good environment, can be said to have a specific adaptability to that unfavourable environment, and vice-versa for a landrace with a specific adaptability to a favourable environment.

The current problem of Bambara groundnut in Indonesia is that it has a long life span and is low yielding (<1 t ha^{-1}). Even though it has a high market price, farmers are reluctant to plant it because of the time to maturity. Thus a new cultivar with desirable traits, such as high yielding and quick maturing, is needed, even though it may be difficult to achieve both at the same time. Several field experiments were conducted in Indonesia to assess the desirable traits of Bambara groundnut for development of a potential new cultivar.

The aims and objectives of this project were to evaluate Bambara groundnut landraces under Indonesian conditions. Selected Bambara groundnut landraces were planted and measured as single plants to examine their stability and adaptability in three different locations. We hypothesised that there are differences in stability and adaptability of Bambara groundnut landraces based on the coefficient of regression (bi=1), deviation from regression slope (S^2_{di}=0) and grand mean of the variable measured.

MATERIALS AND METHODS

This experiment was conducted during the rainy season from November 2009 to May 2010 in three locations, namely Gresik, Bojonegoro and Jatikerto in Indonesia. The detailed sites of the experiments are listed in Table 1. The material used was from the seed collection of the Tropical Crops Research Unit, School of Biosciences, at The University of Nottingham, United Kingdom. The landraces used and the country of origin are provided in Table 2.

A randomised block design with eight treatments (landraces) and three replications was used at each location. Randomisation of landraces was done for each block, which had an area of 2×1.5 m^2 per plot. The seeds were planted at a spacing of 40 cm between rows and 25 cm within rows. A single seed was planted in each hole at 5 cm deep, so that each landrace had 30 single plants. Any replanting for non-emergent seed was done two weeks after sowing. Each block was separated by drainage channels (50 cm between replication and 30 cm in depth) to keep the plants growing well during the rainy season. Weeding was done frequently due to high competition between the plants and the weeds during the rainy season. Data for many traits were collected, such as growth and yield variables, but in this paper we report only four illustrative traits, which include days to 50% flowering, days to maturity, pod number per plant, and 100 seeds weight. Fifty percent flowering is the number of days from sowing to when 50% of the plants in one plot had started flowering. Data were collected every day, starting from when the first flower appeared until at least 15 plants out of the 30 plants (50%) per plot had flowered. Date of maturity was calculated based on the time from sowing to harvesting (days after sowing=DAS). Each plant was harvested when the leaves were yellow and dry, pods had hardened and were white in colour. Pod number per plant represented the number of pods per plant grown in the field. It was measured at harvest time for the mature pods only. One hundred seeds weight was determined based on the weight of 100 seeds from three replicate plots.

Stability and Adaptability Analysis

Stability and adaptability can be analysed by linear regression (Finlay and Wilkinson, 1963; Eberhart and Russel, 1966; Perkins and Jinks, 1968; Freeman and Perkin, 1971). Analysis of variance in stability analysis was conducted based on the linear regression equation from Eberhart dan Russel (1966) and Roy (2000) as follows:

$$Y_{ij}=m_i+\beta_i I_j+\delta_{ij} \ (i=1,2,3, \ldots t \text{ and } j=1,2,3,\ldots s) \text{ -----} \rightarrow t=8 \text{ and } s=3 \quad (1)$$

where:

Y_{ij} = mean data for i- landrace in j- location;

m_i = grand mean;

β_i = regression coefficient of i- landrace;

I_j (Location index)= $\dfrac{\sum_i Y_{ij}}{t} - \dfrac{\sum_i \sum_j Y_{ij}}{t.s}$

δ_{ij} = deviation from regression for i-landrace and j-location.

Regression coefficient (*b*i) and deviation from regression (s^2_{di}) can be estimated as:

$$b_i=\frac{\sum_j Y_{ij} I_j}{\sum_j I_j^2} \quad (2)$$

where: $\Sigma_j Y_{ij}$=sum of mean data for i-landrace in j-location; $\Sigma_j I^2_j$ =sum square of location index.

$$\text{Deviation from regression}=S^2_d \text{ -----------}\rightarrow S^2_{di}=\frac{\sum_j \delta^2_{ij}}{\sum(s-2)}-\frac{S^2 e}{r} \qquad (3)$$

where: $\Sigma_j\delta^2_{ij}=[\Sigma_j Y^2_{ij}-(Y^2/t)]-[(\Sigma_j Y_{ij}\ I_j)/(\Sigma_j I^2_i]^2$; S^2 e=Pooled Error estimated; s is the number of locations andd r is the number of replicates. For further analysis we tested for significance of the sources of variance with the F-test 5% and 1%.

Data Interpretation

As explained previously, using the stability and adaptability analysis based on the Finlay and Wilkinson (1963) and Eberhart and Russel (1968) methods, we can conclude that:

1. When the approximated regression coefficient is nearly 1 it means that a landrace has average stability. An average stability landrace can have a general adaptability if the landrace mean is greater than grand mean of landraces overall in that environment. However, when an average stability of a landrace is associated with a low mean of the variable measured, that landrace is considered to be poorly adapted to all environments.
2. A regression coefficient of more than 1 (bi>1) means that a landrace has a below average stability and is more sensitive to environmental changes. It can be said to have specific-adaptability in a good environment.
3. A regression coefficient of below 1 (bi<1) suggests a landrace has above average stability and with more sensitivity to ‘low-yielding environments’.

RESULTS AND DISCUSSION

Variables in this experiment included ‘50% flowering’, ‘days to maturity’ (from days after sowing; DAS), ‘pod number per plant’ and ‘100 seeds weight’ (g). Mean squares of analysis of variances and coefficient of variance (%) are listed in Table 3. Landraces showed highly significantly differences for all yield variables used. Meanwhile there was no significant difference between blocks (replication) in the three individual locations (Gresik, Bojonegoro and Jatikerto). Further analysis of the mean of yield variables was done by LSD 5% (Gomez and Gomez, 1983). Table 4 lists the mean of eight landraces in three locations for ‘50% flowering’ (DAS), ‘days to maturity’ (DAS), ‘pod number per plant’ and ‘100 seeds weight’, respectively. Seven African landraces showed different responses.

In the Gresik field ‘LunT’, ‘SB165A’ and ‘DODR’ reached 50% flowering faster than the Gresik landrace used as control. Meanwhile in the Bojonegoro field, ‘LunT’, ‘DODR’ and ‘S19-3’ showed the earliest attainment of ‘50% flowering’, again compared to Gresik landraces. In the Jatikerto field, almost all African landraces planted reached ‘50% flowering’ earlier than the Gresik landrace (Table 4).

Days to maturity for the eight Bambara groundnut landraces planted in the Gresik field were almost the same, except ‘AHM753’ from Namibia. It had a date of maturity of 123.7 DAS and was quicker than other landraces used. Surprisingly, ‘AHM753’ in the Bojonegoro field had the same date of maturity as the landraces ‘DIPC’ and ‘Uniswa Red’ grown in Gresik, which was nearly 121.8 DAS. Earlier maturing landraces were ‘LunT’, ‘SB165A’, ‘DODR’ and ‘S19-3’. The Gresik landrace showed the highest number of days to maturity in all three locations.

The pod number per plant in the three locations showed various responses. ‘S19-3’ had the greatest number of pods per plant in the Jatikerto field. ‘SB165A’ and Gresik landraces tended to have the same weight of 100 seeds in Gresik and Bojonegoro. Meanwhile in Jatikerto, ‘SB165A’ and ‘DODR’ gave the highest yields.

Interaction between Landraces (G) and Environment (E)

Analysis of variance over the sites is listed in Table 5. Interaction between landraces and locations were highly significant (P<0.01) for 50% flowering, days to maturity, pods number per plant and 100 seeds weight. That means we can find at least one landrace which is suitable for a particular location or suitable for all locations used. The mean square of all variables used for data interaction analysis is displayed in Table 6.

Stability and Adaptability Analysis

Further analysis to observe stability and adaptability of landraces was conducted based on the analyses of Finlay and Wilkinson (1963) and Eberhart and Russel (1966). A landrace will be estimated as stable if it has deviation from regression (S^2_{di})=0, regression coefficient (bi)=1 and mean of the variable for that landrace is greater than its grand mean. Original data were transformed to a logarithmic scale (Finlay and Wilkinson, 1963). Analysis of variance in stability analysis for 50% flowering, days to maturity, pod number per plant and 100 seeds dry weight are displayed in Table 7.

Table 7 showed that only DODR was unstable in 50% flowering, because it had $S^2_{di}\neq0$, even though bi=1. In other words, seven landraces are stable for the 50% flowering trait. 'LunT', 'AHM753', 'SB165A' have good adaptability due to achieving 50% flowering faster, contrasting with the Gresik landrace and 'DIPC' which have greater than average times to 50% flowering. 'SB165A', 'Uniswa Red', 'DIPC' and 'S19-3' have average stabilities in the days to the maturity trait. However, 'S19-3' has a good adaptability in this trait due to its mean being below the grand mean of the overall data. As can be seen in Table 7, 'SB165A', 'Uniswa Red' and 'DIPC' showed good adaptability in the number of pods per plant. Those landraces have average stability and a greater mean pod number per plant than the average mean overall. 'LunT', 'SB165A', and 'Uniswa Red' are predicted to have not only good adaptability and stability, but also have greater 100 seeds weight than the average mean over all environments. Meanwhile 'DIPC' and 'S19-3' were considered to have average stability on 100 seeds weight. It can be highlighted that 'DODR' was unstable in all variables used, as was the Gresik landrace. In pod number per plant and 100 seeds weight variables, 'DODR' had a regression coefficient significantly more than 1 (bi>1) – that means it has stability below average. Meanwhile there are at least three promising landraces which were well adapted in all variables measured: 'SB165A', 'Uniswa Red' and 'DIPC'. 'LunT' has good adaptation for 50% flowering and 100 seeds weight. 'AHM753' has good adaptation in 50% flowering only, while 'S19-3' is well adapted in 50% flowering, days to maturity and 100 seeds weight traits.

In general, seven landraces saw decreased 50% flowering (DAS) and pod number per plant in Jatikerto. This case is the opposite of days to maturity (DAS) which tended to be increased in Jatikerto. Meanwhile some landraces increased their 100 seed weight in Jatikerto. When different landraces respond to the environmental changes differently, it can be said that a genotype × environment (G×E) interaction happens. The result of this project has confirmed that all of landraces planted in Gresik, Bojonegoro and Jatikerto gave different responses to the variables measured. Different soil types, monthly average rainfall and altitude (Table 1) could be among the many factors to affect the phenotypic variance. The original environment in which the landrace was developed could be another aspect affecting performance.

'LunT' is originally from Sierra Leone which has annual rainfall 3,500 mm. There seems to be a good chance to plant this landrace in Indonesia, because it shows 50% flowering and days to maturity lower than Gresik landrace used as control. Although pod number per plant and 100 seeds weight are lower than the Gresik landrace control, 'LunT' is predicted to be well adapted in all environments for 50% flowering and 100 seeds weight.

'AHM753', 'SB165A' and 'S19-3' landraces are originally from Namibia which has large areas of desert and has an average of only 100 mm annual rainfall. Comparing the three landraces from Namibia in the three Indonesian locations, 'SB165A' has a better performance due to being well adapted in 50% flowering, days to maturity, pod number per plant and 100 seed weight. ‘SB165A’ is the most promising landrace for the Indonesian farmer.

The ‘DODR’ landrace from Tanzania is unstable in the three sites for all variables measured, but it has 100 seed weight greater than other African landraces, even though it is not significantly different to the Gresik landrace in Gresik and Bojonegoro sites. ‘DODR’ has a big pod and a big seed with a purple testa colour.

The ‘Uniswa Red’ landrace from Swaziland, which has more than 1000 mm average annual rainfall, was well adapted in the three locations as was ‘SB165A’ from Namibia. Swaziland seems to have similar annual rainfall to the Gresik site, but altitude and temperature are far different.

The ‘DIPC’ landrace from Botswana is a landrace worth consideration, as it was well adapted in all three locations for all variables used. ‘DIPC’ has a good appearance in testa colour and has comparable protein content as a substitute legume crop.

In this study, the Gresik landrace control showed poor adaptation in 50% flowering due to having the longest time for flowering and was unstable in three another variables including days to maturity, pod number and 100 seeds weight.

Indonesia has various environments which are suitable for crops. Gresik, Bojonegoro and Jatikerto are agricultural areas. Gresik is the centre of Bambara groundnut growing in Indonesia, even though only a few Indonesian farmers know about it. Meanwhile Bojonegoro and Jatikerto are new locations for Bambara groundnut due to farmers being unfamiliar with this legume crop.

CONCLUSION

The results of stability and adaptability analysis suggested that three of seven African landraces, namely ‘SB165A’, ‘Uniswa Red’ and ‘DIPC’, are well adapted in Gresik, Bojonegoro and Jatikerto. Meanwhile ‘LunT’ and ‘S19-3’ are considered promising landraces because of being well adapted in two out of four variables used. This information could be useful for breeding programmes.

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Tables

Table 1. Details of site of the experiment.

Differences		Site of experiments		
		Gresik	Bojonegoro	Jatikerto
Soil type	Sandy (%)	17	53	35
	Loam (%)	54	32	27
	Clay (%)	29	15	38
Average rain fall per month (mm)		81	295.2	360.75
Altitude (m)		5	18	335
pH		6.0-6.7	6.8-7.2	5.4-6.2
Temperature min.-max. (°C)		22-35	22-35	21-33

Table 2. Landraces used and country of origin.

No	Landraces	Original country
1	LunT	Sierra Leone
2	AHM753	Namibia
3	SB165A	Namibia
4	DODR	Tanzania
5	Uniswa Red	Swaziland
6	DIPC	Botswana
7	S19-3	Namibia
8	Gresik	Indonesia

Table 3. Mean Square of analysis variance and CV (%) for ‘50% flowering’, ‘days to maturity’, ‘pod number per plant’ and ‘100 seeds weight’ in three locations.

Location	Source	df	50% flowering (DAS)	Days to maturity (DAS)	Pod number per plant	100 seeds weight (g)
Gresik	Landraces	7	13.23**	65.90**	897.18**	355.81**
	Block	2	14.00	6.50	0.63	43.94
	Error	14	1.29	13.12	1.48	29.54
	CV (%)		2.47	2.70	2.49	12.07
Bojonegoro	Landraces	7	4.48**	207.02**	232.52**	117.65**
	Block	2	0.29	120.79	4.96	42.31
	Error	14	0.82	38.51	1.76	10.62
	CV (%)		2.04	5.40	7.38	14.03
Jatikerto	Landraces	7	20.23**	218.04**	143.78**	192.03**
	Block	2	1.63	55.13	1.93	51.75
	Error	14	0.63	68.51	1.46	34.61
	CV (%)		1.87	5.46	4.13	12.75

DAS = days after sowing.
** and * indicated significant difference at F-test 1% and 5%, respectively.

Table 4. Mean of eight landraces in three locations for '50% flowering', 'days to maturity', 'pod number per plant' and '100 seeds weight'.

Landraces	50% Flowering (DAS)			Days to maturity (DAS)			Pods number per plant			100 seeds dry weight (g)		
	Gresik	Bojonegoro	Jatikerto	Gresik	Bojonegoro	Jatikerto	Gresik	Bojonegoro	Jatikerto	Gresik	Bojonegoro	Jatikerto
LunT	43.00	42.33	41.33	137.67	105.00	140.00	25.96	12.79	25.25	46.21	22.23	46.40
AHM753	43.33	43.67	41.33	123.67	117.67	150.33	83.92	23.64	27.29	24.98	18.89	33.64
SB165A	47.33	43.33	40.33	137.00	114.00	156.33	50.91	15.26	29.21	57.34	33.77	60.69
DODR	44.00	45.00	41.33	135.67	105.00	146.67	42.46	6.13	16.21	43.32	14.35	50.93
Uniswa Red	47.33	44.33	42.00	136.67	118.67	157.33	48.96	18.14	31.51	42.99	24.10	46.53
DIPC	47.33	45.00	44.33	136.67	124.00	153.00	43.42	20.10	32.00	39.84	22.72	41.24
S19-3	46.33	44.67	40.33	131.33	108.33	143.00	59.21	12.53	40.54	44.94	19.44	40.95
Gresik	48.33	46.33	48.00	133.33	126.67	166.33	36.29	35.35	31.59	60.56	30.26	48.60
LSD 5% (df=14) = 2.145	1.99	1.58	1.38	6.34	10.87	14.50	2.13	2.32	2.11	9.52	5.71	10.30

Table 5. Analysis of variance over sites for '50% flowering', 'days to maturity', 'pod number per plant' and '100 seeds weight'.

Source of variation	Degree of freedom		50% Flowering (DAS)	Days to maturity (DAS)	Pods number per plant	100 seeds dry weight (g)
Location (E)	s-1	2	75.85**	8089.27**	5872.74**	4005.39**
Replication within location	(r-1)s	6	5.31	60.81	2.51	46.00
Landraces (G)	t-1	7	25.96**	274.70**	547.38**	516.42**
G×E	(t-1)(s-1)	14	5.99**	108.14**	363.06**	74.53**
Pooled Error	s(r-1)(t-1)	42	0.91	40.04	1.57	24.92
Total	rst-1	71				

DAS = days after sowing.
** indicated significant difference at F-test 1%.

Table 6. Mean square of analysis of variance interaction.

Source	df	50% Flowering (DAS)	Days to maturity (DAS)	Pods number per plant	100 seeds dry weight (g)
Landraces	7	0.0025960**	0.00300**	0.13806**	0.07395**
Location	2	0.00738**	0.08930**	1.27150**	0.72275**
Landraces×location	14	0.00060**	0.00136**	0.06153**	0.01381**
Error	48	0.00015	0.00048	0.00065	0.00388

DAS = days after sowing.
** and * indicated significant difference at F-test 1% and 5%, respectively.

Table 7. Deviation from regression (S^2_{di}) and regression coefficient (bi) for '50% flowering' and 'days to maturity'.

No	Landraces	50% Flowering					Days to maturity				
		S^2_{di}	F_{value}	bi	t_{bi}	Mean	S^2_{di}	F_{value}	bi	t_{bi}	Mean
1	LunT	-0.00005	0.00219	0.50060	-1.23125	1.62544	0.00134**	9.36237	1.06492	0.22971	2.10200
2	AHM753	0.00005	1.93506	0.63311	-0.90455	1.63104	0.00079*	5.90795	0.86599	-0.47419	2.11282
3	SB165A	0.00001	1.14603	1.97183	2.39599	1.63910	-0.00015	0.04740	1.14916	0.52780	2.12874
4	DODR	0.00025*	6.05964	0.85221	-0.36436	1.63757	0.00049*	4.09374	1.19724	0.69794	2.10564
5	Uniswa Red	-0.00002	0.59662	1.47096	1.16112	1.64828	-0.00013	0.19317	1.01816	0.06426	2.13510
6	DIPC	0.00002	1.34571	0.78491	-0.53029	1.65822	-0.00011	0.33917	0.74907	-0.88794	2.13791
7	S19-3	0.00001	1.24087	1.75451	1.86020	1.64030	0.00001	1.06475	1.00667	0.02360	2.10265
8	Gresik	0.00015	4.04174	0.03187	-2.38685	1.67707	0.00117**	8.29525	0.94880	-0.18118	2.14933

F5%(1,42)=4.07; F1%(1,42)=7.28; t 5%(6)= 2.45.
** and * indicated significant difference at F-test 1% and 5%, respectively.

Table 7. Continued. Deviation from regression (S^2_{di}) and regression coefficient (bi) for 'pod number per plant' and '100 seeds weight'.

No.	Landraces	Pod number per plant					100 seeds weight				
		S^2_{di}	F_{value}	bi	t_{bi}	Mean	S^2_{di}	F_{value}	bi	t_{bi}	Mean
1	LunT	0.01118**	52.60105	0.68248	-1.14700	1.30759	-0.00115	0.10950	1.09907	0.54598	1.55229
2	AHM753	0.03563**	165.46711	1.17320	0.62566	1.57761	0.00590*	5.55889	0.63352	-2.01966	1.39804
3	SB165A	-0.00021	0.00877	1.13895	0.50195	1.45160	-0.00126	0.02796	0.80588	-1.06979	1.68878
4	DODR	0.00029	2.34149	1.82803*	2.99110	1.20751	-0.00052	0.59479	1.72298*	3.98430	1.49756
5	Uniswa Red	-0.00016	0.24176	0.93823	-0.22314	1.48222	-0.00112	0.13771	0.91157	-0.48735	1.55954
6	DIPC	0.00018	1.81851	0.73904	-0.94269	1.48036	-0.00129	0.00527	0.82809	-0.94740	1.52160
7	S19-3	0.01456**	68.20681	1.48041	1.73538	1.49264	0.00044	1.34196	1.17207	0.94827	1.51141
8	Gresik	0.00180**	9.31282	0.01967	-3.54127	1.53577	0.00444*	4.43256	0.82683	-0.95434	1.64895

F5%(1,42)=4.07; F1%(1,42)=7.28; t 5%(6)= 2.45.
** and * indicated significant difference at F-test 1% and 5%, respectively.