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RESEARCH ARTICLE

Study on genetic variability, heritability and genetic advance among genotypes of pepper in Uyo Nigeria

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Abstract

Pepper genotypes were evaluated to estimate the magnitude of genetic variability, relationship of traits and their contributions to yield. Results showed highly significant differences (P≤0.01) among the genotypes of pepper as Scotch bonnet genotype produced the highest fruit yield per plant and fruit yield per hectare of 315.8g and 12.6t/ha when compare to other genotypes. High broad sense heritability was recorded for all the plant attributes. Cluster analysis grouped the genotypes into three clusters. Principal component analysis showed that number of fruits per plant, fruit yield per plant and fruit yield per hectare contributed more to the variations observed in pepper. Correlation analysis showed that fruit yield per hectare had positive and significant associtio with fruit yield per plant (r=0.9**), number of fruits per plant (r =0.6*), fruit length (r=0.6*) and fruit circumference (r=0.6*), indicating that fruit yield per hectare can indirectly increased by selection of plants with the above mention traits. Applications of breeding strategy will improve productivity of pepper since there is existence of genetic variability among genotypes as progress in breeding depends on it.

Keywords: Pepper, variability, heritability, genetic variance, correlation

Introduction

Pepper belongs to the genus Capsicum of the family Solanacea which is an essential group of vegetables (Berke, 2002). Pepper is originated from South and Central America and it spread to and grown widely in tropical and sub-tropical ecologies of the world (Berke, 2002). In the Solanaceae family, after tomatoes, peppers are the second most important vegetable in the world. They are widely grown for their spices and vegetables (Hasanuzzaman and Golam, 2011). The majority of the world cuisine use pepper as one of the primary spices; a meal is scarcely complete without the addition of at least one type of pepper due to its taste, pungency and appealing flavour (Bosland and Votava, 2000). The fruits include combinations of antioxidants, including carotenoids, ascorbic acid, flavanoids, and polyphenols, in addition to vitamins A and C (Nadeem *et al.,* 2011). Comparatively, pepper yield in the developing countries is about 10 – 30% of that in developed countries (Grubben and Tahir, 2004).Therefore, It is important to improve the productivity of the crop per unit area so as to satisfy the demands of dietary needs through vigorous breeding programmes.

The success of increasing the productivity of any crop through breeding largely depends on the presence of variability among the breeding materials (Adeyemo and Ojo, 1991). Additionally, the selection of breeding programmes depends on understanding the nature and extent of variations in the available material to find suitable candidates for breeding; the degree to which these characters are heritable and the impact of the environment on them; and the magnitude of the association between characters and yield to help with selection (Aruah *et al.,* 2012). Therefore, the aim of the research was to evaluate genetic variability among ten pepper genotypes collected from different parts of the country and to identify agronomic traits that will be used a guid for yield improvement of pepper.

Materials and methods

The experiment was conducted at the teaching and research farm of Crop Science Department, University of Uyo, Uyo is strategically located within the humid tropical rainforest zone of southeastern Nigeria. It has coordinates of latitudes $4^0$30'N and $5^0$27'N, and longitudes $7^0$50'E and $8^0$25'E and altitude 38.1m above sea level. Uyo is characterized by two seasons, the wet rainy season and the dry season (Udo-Inyang and Edem, 2012). The experimental material comprises of ten (10) genotypes of pepper namely (Piquante yellow, Scotch bonnet, Antillais, Big sun, Tatse, Jalapeno, Ntuen okpo, Efia, Avenir, Piquante red) obtained from difference seed company and institutions across Nigeria. However, Ntuen okpo a local genotype used as a check as was obtained from a local farm in Uyo. The experimental design used was Randomized Complete Block Design (RCBD) with three replications. A land area of 273m2 was manually cleared, tilled and demarcated into three blocks and paths of 1 m were used to separate the blocks. Each block contained ten plots, each measuring 3 x 1.5m, and 0.5m paths were used to separate the plots giving a total of 30 plots. Planting was done at a spacing of 0.5m intra and 0.5m inter rows giving a total of eighteen (18) plants per plot of each genotype. Treated poultry manure was incorporated one week before transplanting of seedlings into the soil at the rate of 3tonnes/ha and NPK 15:15:15 fertilizer was applied four (4) week after transplanting (WAT) at the rate of 250kg/ha to provide required nutrients for better growth and yield of pepper. Weeding was done manually at 4WAT and 8WAT. The data collected comprised: plant height (cm), number of leaves per plant, number of branches per plant, stem girth (cm), days to first flower initiation, days to 50% flowering, days to 100% flowering, fruit circumference (cm) fruit length (cm), number of fruits per plant, fruit yield per plant (g), and fruit yield per hectare (t/ha). The data collected were subjected to analysis of variance (ANOVA). The phenotypic variation for each trait was partitioned into genetic and non-genetic (environmental) factors according to (Sharma, 1988):

$Ve = MSe$;

$Vg = (MSg - MSe)/r$;

$Vp = Vg + Ve$

Where Vp, Vg and Ve are phenotypic variance, genotypic variance and environmental variance, respectively, and MSg, MSe and r are the mean squares of genotypes, mean squares of error and number of replications, respectively. To compare the variations among traits, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV) were computed according to (Burton, 1952):

$$GCV = \frac{\sqrt{Vg}}{x} \times 100$$

$$PCV = \frac{\sqrt{Vp}}{x} \times 100$$

$$ECV = \frac{\sqrt{Ve}}{x} \times 100$$

Where, x is the grand mean for the trait under consideration.

Broad sense heritability (h^2bs) expressed as the percentage of the ratio of the genotypic variance (Vg) to the phenotypic variance (Vp) was estimated as described by Uguru (2005), Acquaah (2007) and Bassey (2020):

$$H_{bs} = \frac{Vg}{Vp} \times 100$$

Genetic advance (GA) was estimated by the methods of (Johnson *et al*., 1955) as:

$$GA = K \times \frac{GV}{\sqrt{PV}}$$

Where K is a constant (2.06) at 5% selection intensity, PV is the phenotypic variance and GV is genotypic variance.

Principal Components Analysis (PCA) was also done to estimate the contribution of each trait to the total variation observed among the pepper genotypes. Cluster analysis was done to group the genotypes base on their similarity and Correlations analysis was done to examine inter-relationship among the traits.

Results and discussion

The cluster analysis shown in Figure 1 grouped the pepper genotypes into three clusters (A,B and C) based on the diversity of the traits studied using rescaled distance of 10. Cluster A consists of Tatse, Jalapeno, Big sun and Piquante red; Cluster B comprises of Efia, Ntuen okpo and Scotch bonnet while Cluster C consists of Antillais, Piquante yellow and Avenir genotype. The results presented in Table 1 showed that Cluster C had the highest mean number of fruits per plant of 53.2 followed by Cluster B (46.7) while the least was obtained in Custer A (40.6). For fruit yield per plant and fruit yield per hectare, it was Cluster B that had the highest mean yield per plant and per hactare of 285.5g and 11.4t/ha respectively, followed by Cluster A and C with the same mean yield per plant and per hactare of 249.0g and 9.9t/ha respectively. This is in line with Preethi *et al.*, (2018), Birhanu and Tiegist (2020) and Reshma *et al.*, (2022) who reported wide genetic diversity in pepper. Plant breeders frequently conduct genetic assessments of germplasm to identify patterns of genetic diversity and to comprehend genetic variation in the germplasm. Plant breeders are assisted in selecting the best parents to utilize in their breeding programs by the analysis of genetic diversity levels in germplasm (Acquaah, 2007). The mean squares and genetic parameters of pepper genotypes used were evaluated and the results are presented in Table 2 and 3. Analysis of variance showed that the genotypes differed significantly ($p < 0.01$) for all character studied with exception of stem girth which shows non-significant effect.

This suggest the existence of sufficient inherent genetic variability among pepper genotypes. This result is in accordance with the findings of Sharma *et al.*, (2010), Rao *et al.*, (2017), Chakrabarty *et al.*, (2019) and Reshma *et al.*, (2022). The amount, kind, and magnitude of variability must be estimated in order to realize response to selection, as breeding progress is dependent on it (Kumar et al. 2013), as the variation observed can be exploited for further yield improvement of pepper programme. High phenotypic and genotypic variance values of 3337.1 and 3116.3, 160.9 and 150.2, and 1027.4 and 1023.3 were obtained for number of leaves per plant, plant height and fruit yield per plant, respectively. High environmental variances value of 220.8, 10.64 and 8.87 were obtained for number of leaves per plant, plant height and number of branches per plant, respectively. Phenotypic variance of traits under study were partitioned into heritable (genotypic variance) and non-heritable (environmental variance) components. The magnitude of environmental variance was lower than their corresponding genotypic variance for all the traits. This is an indication that the genotypic component of the variation was the major contributor to the total variation in the traits studied, similar result have been obtained by Fekadu *et al.*, (2009), Rosmaina *et al.*, (2016), Abrham (2019) and Deresa *et al.*, (2023).

High amount of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was obtained in number of leaves per plant (39.1% and 37.7%) followed by number of branches per plant (33.0% and 30.3%) and fruit length (27.7% and 26.9%) while the least was obtained in days to 100% flowering (5.0% and 4.6%) respectively. A high enironmental coefficient of variation (ECV) was observed in number of branches per plant (12.9 %) followed by number of leaves per plant (10.0 %) and stem girth (7.9%) while the least ECV was obtained in fruit yield per hectare (0.7%).

The genetic variability found in different quantitative traits is measured by the genotypic coefficient of variation, or GCV. High genetic variability for these traits is indicated by a high GCV, which may help with selection (Yandav *et al.*, 2009) while high phenotypic coefficient of variation (PCV) is an indication of the existence of greater scope for selection of the trait under consideration which is dependent on the amount of variability present (Khan *et al.*, 2009). Estimating the genotypic coefficient of variation (GCV) in relation to the phenotypic coefficient of variation (PCV) provides a more accurate assessment of the degree of genetic variation in pepper characters. In this study, a small difference between GCV and PCVwas observed in all characters studied indicating that variations among pepper genotypes were mostly due to genetic factors and successful selection may be achieved using their phenotypic values. This indicates a high significant effect of genotypic on phenotypic expression with very little effect of environment. This corroborates with the findings of Manju and Sreelathakumary (2002) and Usman *et al.*, (2014) who earlier reporte slight difference between GCV and PCV in pepper.

High broad sense heritability (h^2bs) estimates of above 70% were recorded for all the traits except stem girth that exhibite low broad sense heritability of 32.1 %. In the present study, high heritability coupled with high genetic advance was observed for fruit yield per plant, number of fruit per plant, number of branches per plant, number of leaves per plant and plant height, which suggested that the selection based on these traits, can bring about significant improvement in fruit yield of pepper genotypes.

Fig 1: Dendrogram showing the classification of 10 genotypes of pepper

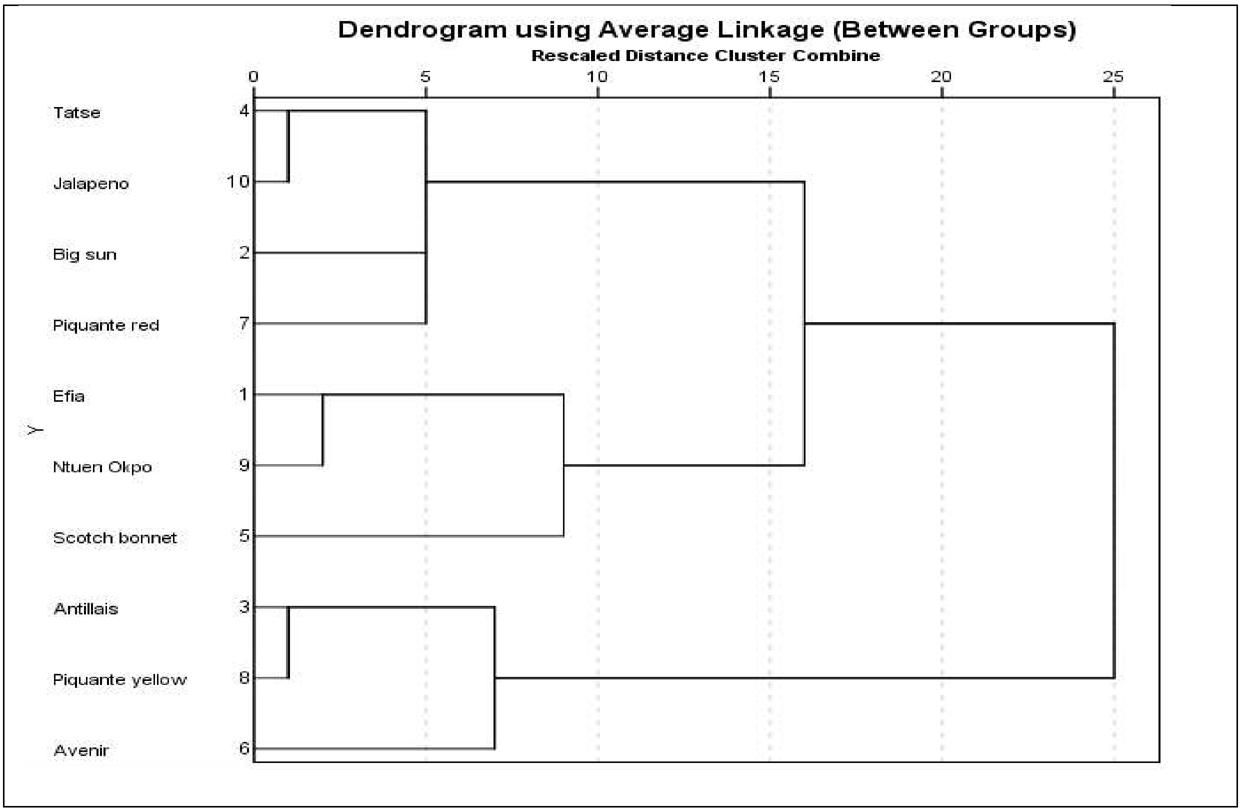

Table 1: Mean performance of pepper genotypes on growth and yield traits for each cluster and standard deviation

Traits	Cluster A		Cluster B		Cluster C	
	Mean	SD	Mean	SD	Mean	SD
Number leaves per plant	144.8	13.8	83.3	27.9	215.8	9.7
Number of branches per plant	22.7	4.6	17.3	9.2	28.7	3.9
Plant height (cm)	57.4	12.0	43.7	10.1	60.2	11.6
Stem girth (cm)	4.1	0.1	3.6	0.2	3.7	0.1
Fruit length (cm)	7.5	1.5	5.7	0.7	4.7	1.1
Fruit circumference (cm)	10.8	1.7	9.1	1.8	7.6	0.7
Number of fruits per plant	40.6	3.7	46.7	1.6	53.2	4.2
Days to first flower initiation	24.6	3.5	24.2	2.3	26.3	0.8
Days to 50% flowering	31.7	1.7	31.2	1.5	29.8	2.1
Days to 100% flowering	40.3	1.8	38.6	0.8	35.6	6.2
Fruit weight per plant (g)	249.0	22.4	285.5	35.5	249.2	34.6
Fruit yield per hectare (tonnes/ha)	9.9	0.8	11.4	1.4	9.9	1.3

Table 2: Mean performance of some traits pepper genotypes studied

Genotypes	Plant height	Number of branches per plant	Number of Leaves per plant	Stem girth (cm)	Days to first flower initiation	Days to 50% flowering	Days to 100% flowering	Number of fruits per plant	Fruit Length (cm)	Fruit circumference (cm)	Fruit weight per plant (g)	Fruit yield per hectare (tonnes/ha)
Efia	36	12.6	72	3.4	26.3	33.0	39.6	46.0	5.1	7.7	294.4	11.7
Big sun	43	18.1	134	4.0	22.3	30.3	39.3	43.6	8.1	11.6	269.8	10.7
Antillais	49	30.6	204	3.8	26.0	29.0	38.0	50.0	4.4	8.0	273.7	10.9
Tatse	69	20.3	140	3.9	21.0	30.3	38.3	39.3	9.3	12.7	244.7	9.7
Scotch bonnet	55	28.0	115	3.9	24.6	30.0	38.0	45.6	6.6	11.1	315.8	12.6
Avenir	72	31.3	219	3.6	25.6	28.3	36.6	51.6	3.8	6.7	209.6	8.3
Piquante red	65	28.8	165	4.2	27.6	32.3	41.3	43.6	5.7	8.6	262.4	10.4
Piquante yellow	58	24.1	223	3.7	27.3	32.3	41.3	58.0	6.1	7.9	264.4	10.5
Ntuen Okpo	39	11.3	62	3.6	21.6	30.6	38.3	48.6	5.3	8.2	246.3	9.8
Jalapeno	52	23.8	140	3.9	27.6	34.0	42.3	36.0	6.9	10.3	219.3	8.7
$LSD_{(P<0.05)}$	5	5.1	25	non-significant	1.1	1.4	1.2	2.5	0.7	0.4	3.4	0.1

Table 3. Variance, broad sense heritability and genetic advance estimates for some traits of the pepper genotypes studied

Traits	Mean	Msg	Environmental variance	Genotypic variance	Phenotypic variance	GCV	PCV	Environmental coefficient of variation	Broad sense heritability (%)	GA
Number leaves per plant	147.7	9569.8**	220.8	3116.3	3337.1	37.7	39.1	10.0	93.3	111.1
Number of branches per plant	22.9	154.2**	8.8	48.4	57.3	30.3	33.0	12.9	84.5	13.1
Plant height (cm)	54.1	461.5**	10.6	150.2	160.9	22.6	23.4	6.0	93.3	24.4
Stem girth (cm)	3.8	0.2^{ns}	0.1	0.1	0.1	5.4	9.6	7.9	32.1	0.2
Fruit length (cm)	6.1	8.4**	0.2	2.7	2.9	26.9	27.7	6.8	94.1	3.3
Fruit circumference (cm)	9.3	11.9**	0.1	3.9	4.0	21.2	21.4	2.7	98.5	4.0
Number of fruits per plant	46.2	117.9**	2.2	38.5	40.8	13.4	13.8	3.2	95.2	12.4
Days to first flower initiation	25.0	19.0**	0.4	6.2	6.6	9.9	10.3	2.6	93.2	4.9
Days to 50% flowering	31.1	9.7**	0.7	3.0	3.7	5.5	6.2	2.8	79.8	3.1
Days to 100% flowering	39.6	10.6**	0.6	3.3	3.9	4.6	5.0	1.9	84.7	3.4
Fruit weight per plant (g)	260.0	3074.0**	4.1	1023.3	1027.4	12.2	12.3	0.7	99.6	65.7
Fruit yield per hectare (tonnes/ha)	10.4	4.9**	0.01	1.6	1.6	12.2	12.3	0.7	99.3	2.6

** Significant at 1% probability level, ns= non ignificant

This is in conformity with the findings of Bento *et al.,* (2016), Deresa *et al.*, (2023), Adday (2017), Abrham (2019), Rosmaina *et al.,* (2016), Yunandra (2018). Furthermore, the involvement of additive genetic variance was demonstrated by high heritability combined with high expected genetic advancement; as a result, simple selection may be useful for improving these traits (Akpan et al., 2016).The result of correlation coefficient analysis for agronomic traits of pepper are shown in table 4. The result revealed that fruit yield per hectare had positive and significant association with fruit yield per plant (0.9**), fruit circumference (0.6*), fruit length (0.6*) and number of fruits per plant (0.6*) indicating that fruit yield per hectare can indirectly increased by selection. Indirect genotype selection for increased yield is aided by the correlation between yield and other traits (Machikowa and Laosuwan 2011). According to Akpan *et al.,* (2016), when there is a significant and positive correlation between two characters, it indicate that these characters can be simultaneously improved in a selection programme. This is because it demonstrates how characters are related to one another and how choosing one will result in choosing and improving the other (Fayeum *et al.*, 2012). This result conforms with the findings of Bekele *et al.,* (2022) who observed significant and positive correlation of number of fruits per plant with dry fruit yield per plot of pepper, Sood *et al.,* (2009) who reported positive and significant correlation of number of fruits per plant and fruit yield and Birhanu and Tiegist (2020) observed positive and significant correlation of average fruit weight, number of fruits per plant with dry fruit yield per plant. PCA which was carried out to partition the variables into four main component axes, (Table 5).The four principal components contributed 98.9% of the total variability. The first principal component (PCA1) with eigen value of 5.6 contributed 48.3% of the total variability in the pepper genotypes, the PCA2 with eigen value of 3.5 contributed 26.1% of the total variability and the PCA3 with eigen value of 2.0 contributed 16.3% of the total variability, while PCA4 with eigen value of 1.0 contributed 8.1% of the total variability among pepper genotypes used in this study. In PCA1, the traits that accounted positively for the 48.3% observed variability among the pepper genotypes were plant height with a vector load of 0.8, number of leaves per plant with a vector load of 0.7, number of branches per plant with a vector load of 0.9, stem girth with a vector load of 0.4, number of fruits per plant with a vector load of 0.5, fruits yield per plant with a vector load of 0.8 and fruit yield per hectare with a vector load of 0.8. The percentage of each character's relative contribution to the overall variation in plant genotypes was explained PCA. (Sarmah *et al.*, 2018). The result of PCA on pepper genotypes indicate that number of leaves per plant, number of branches per plant, plant height, days to first flower initiation, fruit yield per plant, number of fruits per plant and fruit yield per hectare were the highest contributors to the total variation observed among pepper genotypes, this result corroborate with the findings of Birhanu and Tiegist (2020) and Sarmah *et al.*, (2018) reported that days to first harvest, days to 50% flowering, number of fruits per plant, plant height and dry fruit yield per plant contributed highest to the total variation in pepper genotypes. Estimation of variability shows the existent of genetics diversity among pepper genotypes, knowing the amount and magnitude of genetics variability is the first step in learning how to enhance or create new plants. In this study, high variability observed among the genotypes through morphological characterization which was done using different method such as analysis of variance, cluster analysis and PCA. The result showed a wide genetic variability among the pepper genotypes as Scotch bonnet genotype produced the highest fruit yield per plant and fruit yield per hectare when compare to other genotypes and can be employed in future breeding programmes such as hybridization to improve the yield of pepper.

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Table 4: Correlation coefficients among traits of pepper genotypes for growth, phonological, yield and yield component traits

Traits	Plant height	Number of branches per plant	Number of leaves per plant	Stem girth (cm)	Days to first flower initiation	Days to 50% flowering	Days to 100% flowering	Number of fruits per plant	Fruit Length (cm)	Fruit circumference (cm)	Fruit weight per plant (g)	Fruit yield per hectare (tonnes/ha)
Number leaves per plant	1											
Number of branches per plant	0.7*	1										
Plant height (cm)	0.7*	0.8**	1									
Stem girth (cm),	0.5	0.5	0.5	1								
Fruit length (cm)	0.2	0.5	0.4	-0.1	1							
Fruit circumference (cm)	-0.4	-0.4	-0.4	-0.4	0.4	1						
Number of fruits per plant	-0.2	-0.1	-0.1	-0.2	0.6*	0.9**	1					
Days to first flower initiation	0.4	0.6*	0.5	0.1	0.2	-0.3	-0.2	1				
Days to 50% flowering	0.1	-0.2	-0.2	0.2	-0.4	0.2	0.2	-0.6*	1			
Days to 100% flowering	0.1	-0.1	-0.3	0.2	-0.5	-0.1	-0.1	-0.7*	0.9**	1		
Fruit weight per plant (g)	0.4	0.1	0.1	0.3	0.1	-0.1	-0.1	0.6*	0.6*	0.6*	1	
Fruit yield per hectare (tonnes/ha)	0.4	0.2	-0.1	0.3	0.1	-0.1	-0.1	0.6*	0.6*	0.6*	0.9**	1

*, ** Significant at 0.05 and 0.01 probability level (2 tailed), respectively

Table 5. Principal component analysis (PCA) on growth, yield and phonological traits of pepper parent genotypes

Traits	PCA1	PCA2	PCA3	PCA4
Number leaves per plant	0.8	0.1	-0.6	-0.1
Number of branches per plant	0.7	-0.6	0.3	0.1
Plant height (cm)	0.9	0.2	-0.1	0.3
Stem girth (cm)	0.4	-0.7	0.3	0.1
Fruit length (cm)	0.7	0.2	-0.3	0.4
Fruit circumference (cm)	-0.7	-0.1	0.1	0.4
Number of fruits per plant	-0.8	0.1	-0.2	0.2
Days to first flower initiation	-0.1	0.8	0.5	0.2
Days to 50% flowering	-0.1	0.7	0.5	0.1
Days to 100% flowering	0.8	0.5	-0.2	0.1
Fruit weight per plant (g)	0.5	0.4	0.6	-0.4
Fruit yield per hectare (tonnes/ha)	0.8	0.5	-0.2	0.1
Eigen value	5.6	3.5	2.0	1.0
% of Variance	48.3	26.1	16.3	8.1
Cumulative %	48.3	74.5	90.8	98.9

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