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Combnining Ability of Sweetpotato Yield in Endemic and Non-endemic Sweetpotato Weevil (*Cylas formicarius*) Environments in South West Nigeria

M. S. Afolabi[1*] and M. O. Akoroda[2]

[1]Department of Agronomy, Osun State University, Ejigbo Campus, Osun State, Nigeria.
[2]Department of Agronomy, University of Ibadan, Ibadan, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Introduction: Combining ability studies in sweetpotato marketable root yield were carried out using ten sweetpotato varieties and their F_1 hybrids in *Cylas formicarius* endemic (Omu Aran) and free (Ibadan) environments during 2012 cropping season.
Study Design: The genetic material used for this experiment was from the germplasm collection of the Department of Agronomy, University of Ibadan, Nigeria. This material comprised of 10 varieties of sweetpotato: 5 orange fleshed, 3 white fleshed and 2 yellow fleshed.
Place and Duration of Study: The field trial was carried out in *C. formicarius* endemic (Omu Aran) and Non-endemic (Ibadan) environments both in South West Nigeria during the raining season of 2012.
Methods: Collected data were subjected to diallel analysis using Griffing (15) approach in method I (parents, crosses reciprocals together), Model I (fixed effects). Both general combining ability (GCA) and specific combining abilities (SCA) were computed using PBTools, version 1.4. for the 10 parents and their F_1 hybrids with respect to *C. formicarius.*

**Corresponding author: Email: afolabimike97@gmail.com, afolabimike97@yahoo.com;*

Results and Discussion: The result obtained from this study showed that some parents were tolerant to *C. formicarius*, but level of tolerance varied probably due to differences in genetic background among the parental population or time of planting. Hybrids from the parents resisto, TIS 87/0087 displayed high performance in term of *C. formicarius* tolerance. These parents and their hybrids appeared to have gene pools for *C. formicarius* tolerance that can be manipulated and used to develop promising hybrids in South west, Nigeria.

Keywords: Sweetpotato; weevil; Cylas formicarius; cropping season; major pest.

1. INTRODUCTION

Sweetpotato weevil is the major pest constraint of sweetpotato production in south west Nigeria. Infestation causes substantial yield losses, averaging more than 70% of sweetpotato virus free environment [1]. It causes economic damage in areas with a marked dry season or in unseasonably dry years [2]. The weevil spends its entire life cycle on the host plant and both larval and adult stages damage the tubers and vines. Damage to tubers can reach up to 90% and relatively minor damage can both reduce yield and render infested tubers unmarketable due to the presence of feeding marks and oviposition holes. Weevil-infested tubers emit offensive odours due to the presence of terpenes produced by the insects and to a rise in the level of phenolic compounds in the tubers [3], rendering them unpalatable for human or animal consumption. Tuber shrinkage also occurs due to loss of water through feeding or oviposition cavities made by the weevils. The main damage is due to larvae developing inside the edible tubers [4] Weevil is the most important biotic yield constraints on sweetpotatoes although severity varies significantly by agro-ecology. Weevils, however, even in small populations, can affect the quality of the storage roots, rendering them commercially less valuable [5]. They become a problem towards the end of the season when soils are drying up and storage roots are left in the soil for too long. In some areas where weevils are endemic, damage is also recorded during the growth season and production losses reach up to 60-100% [6-9]. There have been mixed results regarding tolerance of sweetpotato cultivars to the weevil damage. For example, Sutherland [10] found that cultivars with high foliage weight showed lower levels of damage. Nwadili et al. [11] and Kanju [12] also found difference in weevil damage across cultivars but Odongo et al. [5] found no differences.

Sweetpotato weevil has reached an endemic status in south west Nigeria. It constitutes a serious threat to sweetpotato production and farmers are being compelled to abandoned their farmlands to *Cylas formicarius* or changed to production of less susceptible crop. The objectives of this study therefore were (i) to asses both general and specific abilities of 18 varieties of sweetpotato for tuber yield and other agronomic characters in both sweetpotato virus endemic and non-endemic environments and (ii) to identify hybrids that combined tolerance to *C. formicarius* with tuber yield and suitable traits in commercial sweetpotato production in *C. formicarius* endemic zones of south west of Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The experiments were conducted at the Teaching and Research Farms of the Department of the Agronomy, University of Ibadan, Ibadan, Oyo State and Landmark University Omu Aran, Kwara State. The University of Ibadan is located on Latitude 3º54'E Altitude is 210 m above sea level. Landmark University is located Latitude 8º36'E Altitude 945 m above sea level.

2.2 Description of Genetic Material

The genetic material used for this experiment was from the germplasm collection of the Department of Agronomy, University of Ibadan, Nigeria. This material comprised of 10 varieties of sweetpotato: 5 orange fleshed, 3 white fleshed and 2 yellow fleshed (Table 1).

2.3 Hybridization of Sweetpotato Clones

Planting of 25 cm long vine cuttings was done on the crest of each ridge after a light rain. Each vine was inserted at a slant, with two-thirds buried below the soil surface at a spacing of 1 m between the crest of one ridge and other. The plot size used was 3 m x 1 m.

Weeding was done at 4, 6 and 8 weeks after planting using hoe. No fertilizer or pesticide was applied. Wooding poles of 2 m long were used for the staking. The main vines were tied and trained up to the stakes to induce flowering as described by Afolabi and Akoroda [13].

Partial diallel crosses were made between the 10 varieties during 2011 cropping season at the teaching and research farm, University of Ibadan, Nigeria. The resultant 45 F_1 hybrids were harvested between 30 and 50 days after pollination between 7.00 am and 8.00 am to prevent scattering. The fruits were further air dried, shelled and kept in desiccators.

2.4 Scarification of Sweetpotato Seed and Nursery Establishment

Forty five F_1 hybrid seeds were soaked overnight in water to break the dormancy in order to improve germination. The seeds were then placed in polythene bags filled with top soil and watered. These were transferred to the nursery after 4 weeks to improve vine production.

2.5 Field Experiments

The field trial was carried out in *C. formicarius* endemic (Omu Aran) and Non-endemic (Ibadan) environments both in South West Nigeria during the raining season of 2012. Planting of 30 cm long vine cuttings was done on the crest of each ridge after a light rain. Each vine was inserted at a slant, with two-thirds buried below the soil surface at a spacing of 1 m between the crest of one ridge and other. The trial was laid out in a randomized complete block design with three replicates. Entries which included the hybrids and parents were made in one row of 3 x 1 m and planted at inter-row spacing of 1 m and within row spacing of 30 cm to enhance a plant population of 33,333 stands per hectare. Agronomic data were measured on plot basis, including number were collected. stand count at harvest, total root yield, marketable root yield, non marketable root yield, and total number of storage root/plant and marketable storage root, root size, percentage of tuber damage and weight of total roots, as well as the incidence and severity (scale of 1 - 5 where 1 = 0%; 2 = 1 - 25%; 3 = 26 - 50%; 4 = 51 - 75% and 5 = 76 - 100% root infestation according to [4] of root *Cylas* spp. infestation according to earlier report [4].

Data collected were subjected to diallel analysis using Griffing [14] approach in method I (parents, crosses reciprocals together), Model I (fixed effects). Both general combining ability (GCA) and specific combining abilities (SCA) were computed using PBTools, version 1.4. for the 10 parents and their F1 hybrids with respect to *C. formicarius* related and sweetpotato characteristics with respect to sweetpotato tuber yield and other agronomic characters.

3. RESULTS

3.1 General and Specific Combining Ability Effects

Analysis of variance for GCA effects of parents for yield in the *Cylas formicarius* endemic environments are shown in Table 2. GCA effects for *Cylas formicarius* incidence and severity was very low probably due to tolerance of the parents to *Cylas formicarius*. Resisto genotype had positive and highly significant GCA effects for incidence and severity and number of tuber Damage. While, TIS87/0087 genotypes was positive and highly significant GCA effects for incidence and severity. The highest GCA effects (25.50) for number of damaged tuber was recorded on the parent TIS 8250 as against the least 1.02 from the parent Resisto.

Specific Combining Ability (SCA) effects for incidence and severity for *C. formicarius* endemic environment are presented in Table 3. SCA effects for incident and severity were generally low. However, significant effect in positive direction was observed in crosses 199024.2 x barth, barth X bleshbok, barth x 199034.1, bleshbok x TIS 87/0087 and 199034.1 x TIS 87/0087. Similarly, SCA effects for number of damage tuber as positive and significant for hybrid bleshbok x resisto, 440034 x Ak-wide, 440034 x barth and TIS 87/0087 x 199034.1. Values recorded in respect to the remaining crosses were non-significant.

Estimates of General Combining Ability (GCA) for tuber yield and related traits in *C. formicarius* endemic and free environments are presented in Table 4. General Combining Ability effects for sweetpotato agronomic character in *C. formicarius* endemic and free environments differed significantly in the parents.

Parents resisto recorded significant GCA effects only for number of storage root per plant for *C. formicarius* endemic environment and number of non-marketable root yield in *C. formicarius* free environment. Parent Ak-wide exhibited significant

Table 1. Description of sweetpotato parent material

Variety	Source*	Flesh color
Resisto	CIP Kenya	Orange
Ak-Wide	Akoroda	White
TIS 8250	IITA Ibadan	White
199024.2	CIP Kenya	Orange
Barth	Kaduna State	Yellow
Bleshbok	CIP Kenya	Orange
199034.1	CIP Kenya	Orange
440034	CIP Kenya	Orange
TIS87/0087	IITA Ibadan	White
W-151	CIP Kenya	Yellow

**CIP International Potato Centre, IITA, International Institute for Tropical Agriculture*

GCA effects number of storage root per plant and root weight per plant in *C. formicarius* free environment and also had significant GCA effects for both marketable yield and non-marketable yield in *C. formicarius* endemic environments. TIS 8250 only showed positive and significant effects for both root number plant and marketable yield in *C. formicarius* free environment. Parent 199024.2 only had significant GCA effects for root weight per plant and non-marketable root yield in *C. formicarius* free environments and also had significant effects in marketable yield and non-marketable yield in *C. formicarius* environments. Barth had significant GCA effects for root number per plant and non-marketable yield in *C. formicarius* free environments and also had significant effects in root weight per plant and non-marketable yield in *C. formicarius* environments.

General Specific Ability effects for marketable root yield in *C. formicarius* environments were generally low in many of the parents. However parent 440034 and TIS 87/0087 exhibited high GCA effects for marketable yield and some of the agronomic character in both *C. formicarius* and *C. formicarius* free environments. Resisto, Ak-wide and W-151 recorded high GCA effects for marketable yield in *C. formicarius* free environments.

Specific Combining Ability (SCA) for root number per plant (Table 5) in *C. formicarius* and *C. formicarius* free environments were highly significant in hybrids Barth x W-151, Ak-wide x TIS 8250 and Barth x Ak-Wie. Hybrid Resisito x Ak-wide had significant SCA effects for root weight per plant in both C. formicarius and C. formicarius free environments. Marketable yield assessment in *C. formicarius* free environments showed significant effects in crosses: Resisto x Ak-wide; Resisito x 440034; Resisto x TIS 87/0087; Barth x W-151; Barth x Ak-wide; TIS 87/0087 x Ak-wide; Ak-wide x TUS 8250; W-151 x 440034; 199024.2 x Bleshbok and 199024.2 x TIS 87/0087.

4. DISCUSSION

4.1 General and Specific Combining Ability Effects for *C. formicarius* Parameters

Diallel crosses have been widely used in genetic research to investigate the inheritance pattern of important traits, including the one controlling yield and other agronomic traits among a set of sweetpotato genotype (Gholizadeh et al., 2018). The diallel cross method have been devised specifically to show the combining ability of the parental lines for the purpose of identification of superior parents for use in hybrid development programme (Kumar & Reddy, 2016).

The presence of genetic variation among the parental genotypes and progenies across the two environments, confirmed the usefulness of diallel crosses in creating genetic variation in the breeding populations of sweet potato (Gholizadeh et al., 2018). Previous studies in sweetpotato reported high genetic variability resulting from diallel crosses [15,16,17], indicating an extensive genetic pool for selection purposes in breeding of a crop [18]. In breeding for *C. formicarius* tolerance, the lower the value obtained for *C. formicarius* related parameters, the better the genotypes with respect to these traits. Significant GCA and SCA effects recorded in *C. formicarius* endemic environments for marketable yield parameter such as root number plant and root weight per plant. These results showed that both additive and non-additive gene effects played major roles in the inheritance of

Table 2. Estimate of general combining ability effects for sweetpotato yield *Cylas formicarius* endemic environments of Omu Aran

Parents	Incidence and severity	Number of tuber damage
Resisto	0.01**	1.02**
Ak-Wide	1.50	0.22
TIS 8250	20.69	15.95
199024.2	0.05	1.27
Barth	13.94	0.23
Bleshbok	14.13	22.27
199034.1	7.56	11.05
440034	3.87	14.78
TIS87/0087	7.44**	25.50
W-151	2.05	1.25

**, * Significant at < 0.05, <0.01 levels of probability respectively

Table 3. Estimates of SCA effects for incidents and severity (Upper diagonal) and number of damage tuber (Lower diagonal) in *C. formicarius* endemic environment

Parents	Resisto	Ak-Wide	TIS 8250	199024.2	Barth	Bleshbok	199034.1	440034	TIS87/0087	W-151
Resisto	-	0.01	0.20*	3.64	3.45	24.12	11.47	9.39	12.87	2.66
Ak-Wide	1.89	-	2.58	5.33	4.10	4.71	36.28	0.03	28.90	4.67
TIS 8250	0.28	6.94	-	4.10	1.94	1.18	41.84	9.30	21.42	3.78
199024.2	1.05	0.24	0.01	-	0.01*	2.14	54.71	32.47	7.72	8.34
Barth	8.00	3.99	29.27	1.94	-	64.39**	105.15**	9.34	36.96	5.78
Bleshbok	48.23*	23.58	4.55	0.01	34.00	-	4.16	1.30	77.67**	2.45
199034.1	3.20	1.92	0.31	34.00	8.34	0.89	-	1.31	106.38**	6.46
440034	43.03	62.90*	20.84	8.34	64.27*	7.11	3.28	-	3.63	11.62
TIS87/0087	10.04	15.01	3.41	64.27	5.32	38.72	73.39**	30.56	-	7.53
W-151	1.78	5.87	5.87	5.32	3.45	4.86	7.32	8.56	4.34	-

*, ** significant at< 0.05 and <0.01 levels of probability respectively

Table 4. Estimate of GCA effects for sweetpotato root yield under *C. formicarius* endemic (Omu Aran) and non-endemic (Ibadan) environments

	Root no/plant (No/pt)		Rt wt/plt (g)		Marketable root yield(t/ha)		Non-marketable root yield (t/ha)	
	E	NE	E	NE	Endemic	NE	Endemic	NE
Parent								
Resisto	1.33*	8.2	90	230	24.2	12.83	18.6	3.1*
Ak-Wide	1.50	6.3*	98	200*	7.9*	11.92	7.9*	2.9
TIS 8250	2.5	4.2*	57	137	3.1	9.45*	6.3	2.3
199024.2	3.00	4.2	100	113*	6.8*	8.5	5.7*	2.1*
Barth	2.3	4.5*	82*	123	2.6	7.8	5.2*	1.9*
Bleshbok	2.3	3.7	45	127	1.9	5.9	3.9	1.4
199034.1	1.2	4.2*	32	133	2.8	8.6	5.7	2.1
440034	3.1	4.7	162	189	8.2	9.86	6.6	6.4
TIS87/0087	3.3	5.6	200	210	18.1	9.52	16.3*	5.3
W-151	1.50	5.5	99	213	3.8	11.5	7.7	2.8

E = Endemic, NE = Non-endemic, RT wt/[lt = Root weight per plant

Table 5. Estimates of SCA effects of selected crosses for sweetpotato yield and other agronomic traits in *C. formicarius* endemic (Omu Aran) and non-endemic (Ibadan) environments of the south west Nigeria

	Root no/plant		Rt wt/plt		Marketable root yield		Non-marketable root yield	
	E	NE	E	NE	E	NE	E	NE
Variety								
Resisto x Ak-wide	3.00	82.94	5.14*	9.25*	1.07	2.03*	0.17	0.76
Resisto x 440034	3.53	86.54	0.14	0.47	0.76	2.35*	2.28	2.18
Resisto x TIS 87/0087	1.40	0.15	1.05	1.98	0.49	1.87*	2.05	0.27
Barth x W-151	234.44*	240.61*	0.30*	0.24	0.36	1.07*	3.48	0.05
Barth x Ak-wide	60.84*	58.90*	0.27	0.96	0.14	1.19*	2.67	1.62
TIS 87/0087 x Ak-wide	37.25	43.90	0.44	0.01	0.29	1.15*	8.18	1.26
Ak-wide x TIS 8250	62.56*	4.30*	0.02	2.06	0.09	1.72*	0.01	1.27
W-151 x 440034	5.00	0.36	0.23	3.52	0.86	2.31*	5.57	8.75
199024.2 x Bleshbok	5.76	18.50	0.41	0.46	1.83	0.01*	1.17	2.47
199024.2 x TIS 87/0087	8.70	2.12	0.04	3.22	3.67	0.71*	0.02	3.70

, significant at<0.05 and <0.01 levels of probability respectively, E = Endemic, NE = Non-endemic, RT wt/[lt = Root weight per plant* tolerance to the parasites both in parental line and hybrid respectively. Low GCA effects for *C. formicarius* incidence and severity on sweetpotato suggest tolerance to *C. formicarius* infestations. Parents Resisto and 199024.2 with very high GCA effects for incidents and severity could be regarded as susceptible while parents 440034, Bleshbok and barth with low GCA effects have good tolerance to C. formicarius. [19] had earlier reported low GCA effects for *Cylas formicarius*. In this study additive gene action played a greater role in inheritance of tolerance to *C. formicarius* [20].

Generally, the result obtained from this study showed that some parents were tolerant to C. formicarius, but level of tolerance varied probably due to differences in genetic background among the parental population or time of planting. These results also support the findings of earlier study [21] who observed that sweetpotato differed significantly in their tolerance to biotic infestations. This would suggest that a significant portion of C. formicarius tolerance is derived from gene population [22], which may be best exploited in hybrid combinations where distribution through segregation would be minimised.

Significant SCA effects recorded for *Cylas formicarius* related characters indicated differential response of the crosses to these parameters, in other words, non-additive gene action played significant role in the inheritance of *Cylas formicarius* in most of the crosses. The most resistant crosses are those involving 4440034, Bleshbok and TIS 87/0087. This supported the earlier experiment [23] who reported that the highest level of tolerance can be obtained from crosses involving two resistant parents, while most of the susceptible hybrids were from crosses involving susceptible parents as observed in Ak-wide and TIS 8250. This suggests the genes for tolerance since C. formicarius tolerance appears more common in tolerance x tolerance crosses compared with tolerance x susceptible crosses.

4.2 General and Specific Combining Ability Effects for Sweetpotato Yield

The magnitudes of GCA and SCA variances indicated that additive and non-additive gene action were important in determining the inheritance of tolerance to *C. formicarius*. There were differential responses among the parents in both *C. formicarius* endemic and non-endemic environments. Low GCA effects recorded for sweetpotato marketable root yield in *C. formicarius* endemic environments in many of the parents indicate poor general combination in terms of marketable root yield under heavy *C. formicarius* infestation. However, two parents (Resisto and TIS8/0087) which exhibited high GCA effects for marketable root yield, will be suitable as parents for yield improvements in *C. formicarius* endemic environments.

Sweetpotato varieties behaved differently in different environments either under *C. formicarius* endemic and *C. formicarius* free environments [24]. The author also reported G X E interaction effect which affect growth and productivity.

The parents used in this study as well as the crosses generated exhibited different levels of significant GCA and SCA effects for *C. formicarius* tolerated trait. Several careful consideration ought to be placed on the role of parents when planning future crosses as cytoplasmic maternal effects are involved in the inheritance of tolerance to *C. formicarius.* parents (Resisto and TIS 87/0087) displayed the best possible quality of the *C. formicarius.* Tolerance is influenced by the cytoplasmic maternal effect and then be used as mother parent [25].

5. CONCLUSION

High genetic diversity exists among the sweet potato hybrids. Diallel analysis is crucial in the selection of best combiner to be used as parental lines for improvement of *C. formicarius* tolerant sweetpotato. Hybrids from the parents resisto, TIS 87/0087 displayed high performance in term of *C. formicarius* tolerance. This can be recommended for further field evaluation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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