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Path analysis of fruit yield components of *cucurbita moschata* Duch.

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ABSTRACT

Traits contributing to *Cucurbita moschata* fruit yield were investigated to identify selection aids. Twenty-nine land races were grown at two sites in Zambia during the 1994/95 and 1995/96 wet seasons. The contribution of traits to fruit yield were partitioned by path analysis. Mid-season traits (internode with first female flowers, length of internode with first female flowers, length of primary axis, number of primary branches and number of leaves per plant) exhibited insignificant phenotypic (P) and genotypic (G) direct effects (P, G <0.17) on fruit yield. The length of the primary axis, number of primary branches and number of leaves per plant had genotypic indirect effects of intermediate magnitude on the fruit yield through the number of fruits per plant (-0.27, 0.33, 0.42; respectively). Late season traits (weight of first mature fruit and number of fruits per plant) had significant genotypic direct effects on fruit yield (G=0.67 for both characters). Therefore, in selecting for pumpkin yield, special attention should be given to number of fruits per plant and weight of first mature fruit of each plant.

Key words: *Cucurbita moschata*, correlation, direct and indirect effects, fruit yield, pumpkin.

INTRODUCTION

The most important use of tropical pumpkin, *Cucurbita moschata* Duch. in Zambia is vegetable fruit consumption (Gwanama and Nichterlein 1995). This species is known locally as pumpkin and elsewhere as 'calabaza', 'calabash', 'ayote', 'zapallo' or 'winter squash'. The yield of pumpkins is influenced by many traits individually and jointly (Whitaker and Davis 1962). Although there may be many traits with high correlation to the ultimate product, not all of them may be significantly and directly contributing to it. Path analysis separates the direct and indirect effects of yield contributing traits (Solanki and Shah 1989). Identification of traits with high direct effects on fruit yield would be useful in a breeding program.

One major problem in *C. moschata* breeding is large size of the plants. Single vines can be as long as 15 meters with profuse branching. Recommended production planting densities, of around 1,700 plants per hectare (Van Zijl *et al.* 1978) are not suitable for selection plots because plants form a web with neighbours and observation of individual characters becomes difficult. Therefore, substantial experimental space is required. This is seldom obtainable and when available, introduces high environmental variation and increases the cost of trials.

Therefore reduced number of replications and use of single plant experimental units have been practiced in *C. moschata* breeding (Wessel-Beaver and Flores 1996). Implementation of these solutions results in failure to completely separate environmental variance from treatment variance. Therefore, identification of highly correlated early season selectable traits would be helpful so that inferior plants can be discarded early.

The objective of this study, therefore, was to identify the characters, which are important in selecting for higher fruit yield in tropical pumpkin.

MATERIALS AND METHODS

Twenty-nine land races of *C. moschata* were grown for two seasons at the University of Zambia (UNZA) and Zambia Seed Company (ZAMSEED) farms. Both farms were within 15 kilometers of Lusaka City. Nineteen of the varieties were S_1 genotypes obtained by self pollinating field collected accessions in the 1993/94 season. The remainder was half sib families obtained directly by collecting one pumpkin fruit per land race in 1994.

A randomised complete block design with three replications was used at each site. Each plot consisted of four plants sown on 15 cm high beds. The spacing between beds was 2 m and between plants in a bed also 2 m. The four plants per plot sample size was chosen as the best compromise between single plant, single harvest and large plot, multiple harvest trials (Wehner and Miller 1984). Large plot testing was reserved for advanced trials after the number of genotypes has been trimmed.

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One meter wide borders were left between blocks while no borders were left between plots in a block. Sowing dates were 17 (UNZA) and 23 (ZAMSEED) December 1994 and 21 and 27 December 1995, respectively. An equivalent of 400 kg ha^{-1} 'Compound D' fertiliser ($N:P_2O_5:K_2O$ = 10:20:1) was applied. Standard cultural practices were observed. Natural rain was the source of moisture throughout the experiment. The total amount of rainfall received at UNZA was 570 mm in 1994/95 and 790 mm in 1995/96. The ZAMSEED trial received 650 mm and 815 mm, respectively. An abundance of honeybees for adequate pollination was assured from insect pollinated crops grown at the stations for seed production.

Two sets of characters were observed. The first group were mid-season traits observed at 50% flowering (48-65 days after planting), viz. internode with first female flowers, its length (cm), the length of the primary axis (m), the number of primary branches and the number of leaves per plant. The second group were late season characters taken at harvest, namely, the weight of the first mature fruit (kg), the number of fruits per plant and the total fruit yield per plant (kg), while the mean fruit weight (kg) was recorded as a derived variable. Harvesting of all mature fruits was done once for all plots when vines began to wither (at 120 days after planting in first season and 135 days in second season). Maturity of fruits was ascertained by pricking with a forefinger nail. All immature fruits were discarded.

Data analysis

The procedure suggested by Singh and Chaudhary (1985) was employed in the calculation of phenotypic (r_P) and genotypic (r_G) correlations as well as path coefficients at the phenotypic (P) and genotypic (G) levels. This procedure uses plot means in the calculation of phenotypic correlations and genotype means pooled for seasons and locations for genotypic correlations. Phenotypic and genotypic direct and indirect effects were obtained from operations on the respective correlation matrices. Effects of yield components were considered to be:

(1) significant if r_P or $r_G > 0.6$ and significant at $p \leq 0.05$ and P/r_P or $G/r_G > 0.9$

(2) intermediate if r_P or r_G was significant at $p < 0.05$ and $0.6 < P/r_P$ or $G/r_G < 0.9$

(3) low in all other cases

RESULTS

The first year experienced a drought at the time of pollination which reduced the number of fruits set and the mean fruit weight. The second year had sufficient rain and comparatively better yield. Data for both years was included because drought is a fairly common occurrence in the country. There was considerable variation in the yield performance of genotypes. Some genotypes yielded very small fruits (< 1 kg) while others had large fruits (5 kg). The mean fruit yield on hectare basis varied from 2.5 Mg to over 23 Mg (Table 1).

Correlations between the yield components were in most cases low and insignificant both at phenotypic ($-0.11 \leq r_P \leq 0.22$) and genotypic ($-0.21 \leq r_G \leq 0.37$) levels. No significant negative correlations were observed either between the yield components or between the yield components and the fruit yield. Phenotypic correlations of mid-season traits to the fruit yield were insignificant, with the exception of number primary branches which was highly significant. However, at the genotypic level, both the length of the primary axis and the number of primary branches had significant correlations to fruit yield. On the other hand late season traits had high and highly significant phenotypic and genotypic correlations ($0.54 \leq r_P \leq 0.71$; $0.60 \leq r_G \leq 0.70$) (Table 2).

Most of the direct and indirect effects of traits on fruit yield were very low. Mean fruit weight and number of fruits per plant had intermediate and significant direct phenotypic effects (P = 0.50, 0.68), respectively. However, the intermediate direct phenotypic effect of mean fruit weight was not associated with a corresponding genotypic effect (G = -0.02). At the genotypic level there were significant direct effects of weight of first mature fruit and number of fruits per plant (G = 0.67 for both characters) on fruit yield. Additionally, the mean fruit weight per plant exerted a significant genotypic effect through the weight of the first mature fruit (G = 0.65). The length of the primary axis, the number of primary branches and the number of leaves per plant had intermediate indirect genotypic effects (G = 0.27, 0.33, 0.42 respectively) via number of fruits per plant (Table 2).

DISCUSSION

The range of fruit yield averaged for two seasons in this study (2.5 - 23.3 Mg ha^{-1}) is low compared to the findings of other investigators. For instance, vine and bush hybrids and inbreds developed in Florida, USA, have been reported to yield between 20-60 Mg ha^{-1} (Maynard 1996). The mean fruit weight in our trial was 1.8 kg and mean number of fruits per plant was 2.4, while in the latter case corresponding values were 3.1 kg and 3.8 fruits per plant. However, direct comparisons may be misleading because only mature (marketable) fruits were considered in our study and land race varieties were employed as the study material. The effect of the drought in the first season also contributed to the low yield.

Nonetheless, our results are indicative of the

Table 1. Performance of *C. moschata* genotypes grown at the University of Zambia and ZAMSEED during the 1994/95 and 1995/96 seasons.

Trait	1994/95		1995/96		Pooled		
	Range#	Mean#	Range#	Mean#	Range#	Mean#	CV (%)
1					14.6 - 22.6	19.0	16.32
2					13.4 - 28.2	22.3	20.46
3	2.5 - 4.5	3.4	2.7 - 5.2	4.2	2.8 - 4.8	3.8	28.45
4	4.9 - 16.5	11.7	5.1 - 18.6	13.3	5.8 - 18.2	12.5	26.11
5	90.7-205.3	162.3	102.9 - 251.7	186.3	112.7 - 225.8	174.3	39.01
6	0.6 - 4.5	1.5	0.6 - 6.2	2.5	0.6 - 5.1	2.0	39.20
7	0.5 - 2.0	1.4	0.7 - 4.8	2.2	0.5 - 2.4	1.8	42.95
8	0.3 - 5.0	1.8	1.2 - 5.5	3.0	0.7 - 5.0	2.4	62.14
9a	0.6 - 3.3	2.4	2.4 - 23.1	6.7	1.0 - 9.3	4.3	59.65
9b	1.5 - 8.2	6.0	6.0 - 57.8	16.7	2.5 - 23.3	10.6	

#: Range of genotype means across locations

1 = Internode with first female flower, 2 = length of internode with first female flower (cm), 3 = length of primary vine (m), 4 = number of primary branches, 5 = number of leaves per plant, 6 = weight of first mature fruit (kg), 7 = mean fruit weight per plan (kg)t, 8 = number of fruits per plant, 9a = fruit yield per plant (kg), 9b = fruit yield per hectare (Mg).

situation in unimproved land races in a low yield, semi-arid environment.The significant phenotypic correlations of mean fruit weight per plant and of number of fruits per plant with yield agree with the findings of Gopalakrishnan *et al.* (1980) and Chigwe (1991). However, Chigwe (1991)

Table 2 Effects of fruit yield components on *C. moschata* fruit yield and correlation of yield traits. (Phenotypic (P) and genotypic (G) direct effects on diagonal, indirect effects above diagonal, phenotypic (r_P) and genotypic (r_G) correlation coefficients below diagonal.)

Trait	Trait 1	2	3	4	5	6	7	8	Trait
1	0.02	0.00	0.00	0.02	0.01	0.00	- 0.06	0.07	1 P
	0.03	0.00	0.00	0.04	- 0.04	- 0.14	0.00	0.01	G
2 r_P	0.22	0.00	0.02	0.01	0.01	- 0.01	- 0.05	0.14	2 P
r_G	0.01	- 0.02	0.02	0.02	- 0.03	- 0.09	0.00	- 0.11	G
3 r_P	0.05	0.34**	0.05	0.02	0.01	0.01	0.03	0.19	3 P
r_G	- 0.20	0.44*	0.04	0.04	- 0.05	0.12	0.00	0.27	G
4 r_P	0.30**	0.22	0.37**	0.06	- 0.01	0.01	0.05	0.29	4 P
r_G	0.36	0.16	0.40*	0.11	- 0.10	0.11	0.00	0.33	G
5 r_P	0.08	- 0.06	- 0.01	0.13	- 0.09	0.01	0.03	0.07	5 P
r_G	0.23	0.17	0.33	0.65**	-0.16	- 0.07	0.00	0.42	G
6 r_P	- 0.07	- 0.08	0.09	0.15	0.08	0.06	0.48	0.07	6 G
r_G	- 0.21	- 0.13	0.18	0.17	- 0.11	0.67	-0.02	0.01	G
7 r_P	- 0.11	- 0.10	0.05	0.09	0.06	0.97**	0.50	- 0.01	7 P
r_G	0.18	- 0.16	0.17	0.12	- 0.16	0.98**	-0.02	- 0.08	G
8 r_P	0.11	0.21	0.28*	0.42**	0.10	0.10	-0.02	0.68	8 P
r_G	0.01	0.23	0.40*	0.49**	0.63**	0.02	-0.11	0.67	G
9 r_P	0.05	0.13	0.29	0.41**	0.02	0.61**	0.54**	0.71**	
r_G	- 0.12	0.06	0.41*	0.47*	0.29	0.70**	0.60**	0.66**	

Residual effect: Phenotypic = 0.413, genotypic 0.294

***=significant at p-<0.05, ** =significant at p-<0.05, 1 = Internode with first female flower, 2= length of internode with first female flower, 3= length of primary vine, 4= number of primary branches, 5= number of leaves per plant, 6= weight of first mature fruit, 7= mean fruit weight per plant, 8= number of fruits per plant, 9= fruit yield per plant.**

suggested also that the mean fruit weight could be used directly in selecting for higher fruit yield. The results of this study show that, at the genotypic level, mean fruit weight only affected fruit yield through weight of first mature fruit. Hence restricted selection using primary vine, simultaneously with number of fruits per plant, would have to be applied. One cause for deviations from Chigwe's findings is due to the fact that only data of the 25 top yielding genotypes among his 121 test land races were reported. The mean yield of these selected land races was 25.5 Mg ha^{-1}. Our best yielding genotype (57.8 Mg ha^{-1}) during the second season out-yielded his best land race (41.9 Mg ha^{-1}). His results, therefore, were biased for elite land races and favourable environments. Traits observed in the middle of the growth season failed to show significant direct effects on fruit yield. Reducing selection populations on the basis of the length of the primary axis, the number of primary branches and the number of leaves per plant would be helpful since they had intermediate indirect and direct effects through the number of fruits per plant.

CONCLUSION

In the improvement of *C. moschata* land races maximum importance should be accorded to the number of fruits per plant and weight of first mature fruit as they have high genotypic and phenotypic direct effects on fruit yield. The length of the primary axis, the number of primary branches and the number of leaves per plant selected simultaneously with number of fruits per plant would also be helpful as early season selection aids.

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