

ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
<http://ansijournals.com/ja>

JOURNAL OF AGRONOMY



ANSI*net*

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308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Correlation and Path Analysis in Sweet Potato and their Implications for Clonal Selection

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Abstract: Understanding interrelationships among various agronomic traits is vital to plan an effective breeding program in sweet potato (*Ipomoea batatas* (L.) Lam.). This study was undertaken to determine associations among yield and yield related traits in the crop plant so as to identify the major traits of importance that could be used as a basis for clonal selection. A replicated field experiment was carried out using thirty sweet potato genotypes selected at random from the germplasm collection of diverse origin. Observations were made on ten characters. Phenotypic as well as genotypic correlation coefficient analyses revealed that storage root yield had positive and significant correlation with individual storage root weight, harvest index and storage root girth. Number of storage roots per plant was negatively and significantly correlated with individual storage root weight and storage root girth indicating the presence of compensatory relationship between number of storage roots per plant and the latter two traits. Path coefficient analysis for storage root yield also revealed that individual storage root weight, number of storage roots per plant and harvest index were the most important determinants of storage root yield. It could be concluded that due to the high estimated positive correlation and positive direct effect of individual storage root weight and harvest index on storage root yield, these traits would be most suitable for indirect selection in sweet potato improvement programs that aim at increasing storage root yield.

Key words: Agronomic traits, correlation, path analysis, storage root yield, sweet potatoes

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) is a highly heterozygous cross-pollinated crop in which many of the traits show continuous variation. Jones *et al.* (1986) suggested that mass selection with few cycles of recurrent selection could be practiced for its improvement. Selection for storage root yield, which is a polygenic trait, often leads to changes in other characters. Therefore, knowledge of the relationship that exists between storage root yield and other characters and also interrelationships among various characters is necessary to be able to design appropriate selection criteria in sweet potato breeding programs. According to Grafuis (1959) increasing total yield would be made easier by selecting for components because the components are more simply inherited than the total yield itself. Thus, studies on correlation enable the breeder to know the mutual relationship between various characters and determine the component characters on which selection can be used for genetic improvement. Although correlation coefficients are helpful in determining the components of complex traits like yield, they do not provide an exact picture of the relative importance of direct and indirect influences of each of the component characters. The ultimate storage

root yield depends upon a large number of factors that influence the final expression of the trait. Such a complex scheme of relationship that is based on cause and effect relationship could be partitioned by path coefficient analysis as suggested by Wright (1921) and adopted by Dewey and Lu (1959). In agriculture path analysis can be used to assist plant breeders in identifying traits that are useful as selection criteria to improve crop yield.

There are reports of studies conducted to partition the correlation coefficients of relationship between yield related traits and storage root yield in sweet potato. Path coefficient analysis and correlation studies in sweet potato grown under varying degrees of shades in Uganda indicated that individual storage root weight, storage root dry mater content, marketable root number, root bulking rate, harvest index and fresh vine yield had a maximum direct effect on dry root yield in a decreasing order (Mwanga and Zamora, 1991). In study by Hossain *et al.* (2000), average root weight and number of roots per plant had a maximum positive direct effect on sweet potato root yield. The work of Alam *et al.* (1998) also indicated that number of roots per plant and root girth had maximum positive direct effect on root yield. On the contrary, Naskar *et al.* (1986) in their studies observed that girth of root had a negative direct effect on yield.

Several sweet potato germplasm accessions have been introduced to Ethiopia from International Potato Center (CIP), International Institute for Tropical Agriculture (IITA), Asian Vegetable Research and Development Center (AVRDC) and a few have been collected from farmers' fields for evaluation and utilization. However, information is lacking on the nature and extent of interrelationships among yield and yield related characters of the available germplasm accessions. Consequently, no selection criteria have been set to date. Thus, this study was undertaken to determine interrelationships among yield and yield related characters so as to identify component characters whose selection lead to improvement in storage root yield.

MATERIALS AND METHODS

The study was carried out at Awassa Agricultural Research Center in South Ethiopia during 2003 growing season under rainfed condition. Awassa is located 7° 04' N and 38° 31' E, at an elevation of 1700 masl. The average annual rainfall of Awassa is 1033.6 mm with a minimum/maximum mean air temperature of 13.2°C/27.4°C. The soil is volcanic in origin and is classified as Vitric Andosol. The textural class is a well-drained sandy loam with a pH of 7 and CEC of 22.6 meq per 100 g.

Thirty sweet potato genotypes randomly taken from the germplasm collection of materials introduced from CIP, IITA and AVRDC over different years and maintained at Awassa Agricultural Research Center were used for this study. The experiment was arranged in a randomized complete block design with four replications. Each genotype was planted on a 3 m long and 2.4 m wide plot consisting of four rows, which accommodated ten plants per row and thus forty plants per plot. A distance of 1 m was maintained between the plots. Vine cuttings from the top portion of 3-4 months old mother plants were taken for planting. The vine cuttings were then cut into a length of 30 cm and thereafter planting was done on 29th July 2003 with a spacing of 60 cm between rows and 30 cm between plants. Earthing up was done twice, 45 and 75 days after planting. Fertilizers were not applied during the course of the experiment. Weeding was done as required. During the course of this experiment, no serious disease or insect pest infestations were noticed and thus no crop protection measures were taken.

For each character under study, data were recorded on five randomly taken plants from the middle two rows of each plot and expressed on per plant basis. The mean of five plants was used for statistical analysis. The following ten characters were measured during the course of this study: vine length (cm), above ground fresh weight per plant (g), above ground dry weight per plant (g), number of storage roots per plant, storage root length (cm),

storage root girth (cm), individual storage root weight (g), harvest index per plant (on dry weight basis), storage root dry matter content (%) and storage root fresh yield per plant (g). The phenotypic and genotypic correlations between all possible pairs of characters were calculated according to Miller *et al.* (1958). Path coefficient analysis was computed using the method described by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Correlation coefficient analysis: The genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for most of the characters indicating inherent association among most characters (Table 1). The low phenotypic correlation could arise due to the modifying effect of environment on the association of characters at genetic level. The results of this study indicated that significant positive phenotypic associations were observed between storage root fresh yield per plant and storage root girth, harvest index and individual storage root weight. The genotypic correlation coefficients of these traits with storage root fresh yield per plant were also high (Table 1). The positive association of these characters with storage root fresh yield per plant seems to indicate that selection based on these characters particularly, storage root girth, harvest index per plant and individual storage root weight may improve storage root fresh yield per plant. These results are consistent with those of Kamalam (1977) and Hossain *et al.* (2000) who reported high positive correlations of storage root girth and individual storage root weight with storage root fresh yield per plant at both phenotypic and genotypic levels. High positive association between harvest index and storage root yield was reported also by Ravindran (2000). On the other hand, a strong negative association was exhibited between storage root fresh yield per plant and storage root dry matter content at genotypic level, which may disrupt simultaneous improvement of the two important traits as an increase in one of the characters may lead to a decrease in the other. This investigation is in agreement with the finding of Li (1982) that revealed high negative correlation between storage root dry matter content and storage root fresh yield at both phenotypic and genotypic levels.

Apart from information on the association between storage root yield and other agronomic characters, an understanding of the interrelationships among various agronomic traits is necessary for the intelligent choice of breeding procedures which would make possible selection for simultaneous improvement of desirable traits. In the present investigation many of the characters were positively and negatively correlated with each other.

Table 1: Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients of 10 characters in sweet potato genotypes grown at Awassa, 2003

Character	VL	AGFW	AGDW	SRN	SRL	SRG	SRDMC	HI	ISRW	SRFY
VL		0.378*	0.368*	-0.037	0.223	-0.195	0.045	-0.312	0.003	-0.033
AGFW	0.377*		0.976**	0.108	-0.066	-0.192	0.253	-0.819**	-0.199	-0.185
AGDW	0.378*	0.989**		0.108	-0.095	-0.205	0.300	-0.828**	-0.216	-0.215
SRN	-0.013	0.196	0.198		0.005	-0.402*	-0.053	0.096	-0.509**	0.143
SRL	0.318	-0.212	-0.222	-0.068		-0.017	-0.007	0.270	0.257	0.337
SRG	-0.270	-0.368*	-0.382*	-0.473**	-0.242		-0.332	0.280	0.681**	0.441*
SRDMC	0.085	0.350	0.414*	-0.050	0.102	-0.547**		-0.163	-0.273-	0.359
HI	-0.333	-0.884**	-0.873**	0.055	0.417*	0.381*	-0.328		0.374*	0.575**
ISRW	-0.007	-0.307	-0.328	-0.531**	0.343	0.853**	-0.398*	0.424*		0.643**
SRFY	-0.055	-0.320	-0.347	0.177	0.382*	0.552**	-0.542**	0.617**	0.684**	

*, ** Significant at 5 and 1% probability level, respectively. VL= Vine length, AGFW= Aboveground fresh weight plant⁻¹(g), AGDW= Aboveground Dry Weight plant⁻¹ (g), SRN= Storage Root Number plant⁻¹, SRL= Storage Root Length (cm), SRD = Storage Root Girth (cm), SRDMC = Storage Root Dry Matter Content (%), HI = Harvest Index plant⁻¹ (%) ISRW= Individual Storage Root Weight (g) and SRFY = Storage Root Fresh Yield plant⁻¹ (g)

Table 2: Phenotypic direct (underlined) and indirect effects of some characters on sweet potato storage root fresh yield per plant at Awassa, 2003

Character	No. of s. roots plant ⁻¹	Storage root length	Storage root girth	S. root dry matter content	Harvest index Plant ⁻¹	Individual s. root weight	r _p
Number of storage roots plant ⁻¹	<u>0.5325</u>	0.0005	-0.0260	0.0038	0.0179	-0.3856	0.143
Storage root length	0.0027	<u>0.0899</u>	-0.0011	0.0005	0.0504	0.1947	0.337
Storage root girth	-0.2141	-0.0015	<u>0.0647</u>	0.0237	0.0522	0.5159	0.441
S. root dry matter content	-0.0282	-0.0006	-0.0215	<u>-0.0714</u>	-0.0304	-0.2068	-0.359
Harvest Index plant ⁻¹	0.0511	0.0243	0.0181	0.0116	<u>0.1865</u>	0.2834	0.575
Individual s. root weight	-0.2711	0.0231	0.0441	0.0195	0.0698	<u>0.7576</u>	0.643

Residual effect = 0.49

Table 3: Genotypic direct (underlined) and indirect effects of some characters on sweet potato storage root fresh yield per plant at Awassa, 2003

Character	No. of s. roots plant ⁻¹	Storage root length	Storage root girth	S. root dry matter content	Harvest Index Plant ⁻¹	Individual s. root weight	r _p
No. of storage roots plant ⁻¹	<u>0.6487</u>	-0.0075	-0.0252	0.0058	0.0064	-0.4512	0.177
Storage root length	-0.0441	<u>0.1106</u>	-0.0129	-0.0118	0.0487	0.2915	0.382
Storage root girth	-0.3069	-0.0268	<u>0.0533</u>	0.0630	0.0445	0.7248	0.552
S. root dry matter content	-0.0324	0.0113	-0.0292	<u>-0.1152</u>	-0.0383	-0.3382	-0.542
Harvest Index plant ⁻¹	0.0357	0.0461	0.0203	0.0378	<u>0.1169</u>	0.3603	0.617
Individual s. root weight	-0.3445	0.0379	0.0455	0.0458	0.0495	<u>0.8497</u>	0.684

Residual effect = 0.31

Among significant associations exhibited between pairs of characters at phenotypic level, highly significant positive correlation was observed between storage root girth and individual storage root weight. This suggested that improvement aimed at any of the character would automatically lead to improvement in the other. The work of Lowe and Wilson (1974b) also linked an increase in storage root girth with an increase in individual storage root weight and change in storage root shape.

On the other hand, highly significant negative associations were observed between harvest index and above ground fresh as well as dry matter weights. This may signify that as the accumulation of dry matter increases in the storage root there could be a reduction in the accumulation of assimilates in the foliage which in turn may indicate that a genotype that possesses vigorous vegetative growth tends to produce less storage root yield. This may also imply the presence of competition between the shoots and the storage roots for photosynthate. Consistent with this finding, Wilson (1982) also indicated that in some sweet potato cultivars the shoot system served as an alternative sink for assimilate during early growth period and resulted in delayed storage root bulking. However, he suggested that

a highly competitive shoot sink early in the ontogeny of storage root resulted in low yield only when there was poor distribution of assimilates to storage roots during the later growth period. Storage root number was negatively and significantly correlated with storage root girth and individual storage root weight, which may suggest that an increase in number of roots per plant could result in a stiff competition among storage roots within a plant. This may in turn result in the production of small sized but relatively more number of storage roots per plant. Similar conclusions were drawn by Lowe and Wilson (1975a) from the existence of significant negative correlations between root number and mean root weight in five of six sweet potato cultivars. This may be indicative of the existence of a compensatory relationship between storage root number and mean storage root weight as well as between storage root girth in sweet potato. The genotypic correlation coefficients between all pairs of characters were in the same direction with that of corresponding phenotypic correlation coefficients even though they slightly differed in magnitude.

Path coefficient analysis: In the present study the phenotypic and genotypic correlation coefficients of

storage root yield with other characters were further divided into direct and indirect effects using path coefficient analysis. In computing the path analysis, storage root fresh yield per plant was considered as a resultant (dependent) variable while the rest of the variables that were significantly correlated with the resultant variable were used as causal (independent) variables. However, some root traits considered as immediate yield components were included in the analysis to see whether or not they had important indirect effects even though their correlations were non significant in this study.

Path analysis at phenotypic level (Table 2) showed that individual storage root weight had the maximum positive direct effect (0.7576) on storage root fresh yield per plant. This favorable direct effect constitutes the major portion of the total correlation between storage root dry yield per plant and individual storage root weight ($r_p = 0.643$). The maximum positive direct effect of individual storage root weight on storage root yield was reported by Hossain *et al.* (2000). Storage root number also exerted a highly positive direct effect (0.5325) on storage root fresh yield per plant. Nevertheless, its negative indirect effect *via* individual storage root weight (-0.3556) resulted in low correlation between storage root number and storage root fresh yield per plant. The positive direct effect of storage root number on storage root yield per plant was earlier confirmed by Kamalam (1977), Alam *et al.* (1998) and Hossain *et al.* (2000). Harvest index showed a positive direct effect on storage root fresh yield per plant (0.1865). It also exhibited a positive indirect effect through all other characters mainly *via* individual storage root weight (0.2834). Thus, the effect of harvest index on storage root fresh yield per plant was not only due to its direct positive effect but also owing to its positive indirect effect by favorably influencing all other characters. Storage root girth also exerted a negligible direct positive effect on storage root fresh yield per plant. However, the highly positive indirect effect of storage root girth *via* individual storage root weight contributed more to its significant positive association with storage root fresh yield per plant. Besides, either the positive or negative indirect effects of all characters *via* individual storage root weight were high compared to other indirect effects.

At genotypic level (Table 3) similar to the results obtained at phenotypic level, individual storage root weight (0.8497) exerted the maximum positive direct effect on storage root fresh yield per plant. This was followed by storage root number (0.6487) and harvest index (0.1169). Individual storage root weight also exerted a relatively high indirect negative effect *via* storage root number (-0.3445). However, this negative indirect effect

was outweighed by the highest positive direct effect resulting in a high positive correlation between individual storage root weight and storage root fresh yield per plant. The indirect effect of storage root number through individual storage root weight was also negative and high (-0.4512) compared to all other indirect effects. This high indirect negative effect *via* individual storage root weight counterbalanced the high positive direct effect of storage root number on storage root fresh yield per plant resulting in lower correlation coefficient between storage root number and storage root fresh yield per plant. The direct positive effect of harvest index on storage root fresh yield per plant was low compared to its high association with storage root fresh yield per plant. Thus, its high correlation is mainly due to its high positive indirect effect *via* individual storage root weight. Storage root girth had a negligible direct positive effect on storage root fresh yield per plant. However, its high correlation with storage root fresh yield per plant was due to its high positive indirect effect *via* individual storage root weight (0.7248). It also exerted a considerable negative indirect effect *via* storage root number (-0.3069). On the other hand, storage root dry matter content exerted a negative direct effect on storage root fresh yield per plant. The indirect effect of storage root dry matter content was also negative *via* all other characters except storage root length. The high negative indirect effect of storage root dry matter content *via* individual storage root weight (-0.3382) along with its direct negative effect resulted in a high negative correlation between storage root dry matter content and storage root fresh yield per plant.

The residual effect determines how best the causal factors account for the variability of the dependent factors. In the present study its estimates, 0.49 and 0.31 for phenotypic and genotypic path coefficient analyses, means that 51 and 69% of the total variation in storage root yield per plant were explained at phenotypic and genotypic levels, respectively. Thus, some other factors (49% at phenotypic and 31% at genotypic levels) that were not considered in this study need to be included in the analysis to account more appropriately for the total variation of the storage root yield.

CONCLUSIONS

Phenotypic as well as genotypic correlation coefficient analyses indicated that storage root fresh yield per plant was found to be primarily dependent upon individual storage root weight, harvest index and storage root girth in that order of importance. The phenotypic as well as the genotypic path coefficient analyses indicated that individual storage root weight, harvest index, number

of storage roots per plant, storage root length and girth showed a positive direct effect on storage root fresh yield per plant. However, the former two characters had a high positive correlation with storage root fresh yield per plant along with high positive direct effects. On the contrary, storage root dry matter content had a negative direct effect on storage root fresh yield per plant at both levels. This may hamper simultaneous selection for high storage root yield as well as quality. In sweet potato palatability quality is related to an increase in storage root dry matter content. Hence, simultaneous selection with optimum balance to the two traits might be useful to achieve concurrent improvement in storage root yield and quality. From the present investigations it is concluded that individual storage root weight and harvest index per plant were best fitting for indirect selection in a sweet potato improvement program that aims at increasing storage root yield per plant.

ACKNOWLEDGMENTS

We are grateful to the Agricultural Research Training Project of EARO and Southern Agricultural Research Institute for financially funding the research and thanks are due to Alemaya University for facilitating M.Sc. study of the first author. This study was part of M.Sc. thesis research work submitted to the School of Graduate Studies, Alemaya University.

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