Morpho – physiological characteristics determining yield in semi determinate tomato *(Lycopersicum esculentum)* germplasm

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ABSTRACT

Increasing yield through selection for yield *per se* is slow and sometimes difficult to achieve, since yield is a quantitatively inherited trait with low heritability. Yield can be indirectly increased by selecting for yield components that are highly correlated with yield but possess higher heritability. Semi determinate tomato comprised five genotypes and a check variety were evaluated at Sebele Horticultural Research Station during 2010/11 growing season to determine yield and yield components, and the correlation among the components that explain most of the variation in tomato yield. It was also done to determine the direct and indirect effects of the morpho – physiological traits on the yield in tomato. The experiment was laid out in randomized complete block design with four replications.

Data collected was yield, marketable fruit number, plant height, fruit number per truss, number of trusses per plant, weight of fruits per truss, fruit number per plant, weight of fruits per plant, single fruit weight, flower numbers per truss, days to 50 percent flowering, fruit dry mater and total soluble solids. Four statistical tools used to analyse the collected data was ANOVA, correlation, stepwise multiple regression and path coefficient analysis.

The analysis of variance for yield and its components revealed significant difference $p<0.05$) between the cultivars in the following components; yield, marketable fruit number, fruit weight per truss, Days to 50% flowering and plant height. Stepwise multiple regressions revealed that the identified components which explain variation in yield accounted for 81.84% as per the result of coefficient of multiple determinations (R^2).The path coefficient analysis identified marketable fruit number (0.989) and fruit weight per truss (0.592) as the most important components of tomato fruit yield. This is in as much as the correlation of marketable fruit number ($r = 0.68$) was significant at $p<0.05$. However, the correlation of the second component fruit weight per truss ($r= 0.352$) was not significant at $p<0.05$. Marketable fruit numbers have a strong positive direct influence on yield. Two other important components to consider for yield improvement in tomato are fruit weight per truss and single fruit weight.

INTRODUCTION

Tomato, *(Lycopersicum esculentum)* belongs to the family *Solanaceae*. It is one of the most widely cultivated and important vegetable crops in Africa and in the world as a whole [33,16]. Tomatoes are an excellent source of minerals and vitamins[15]. In Botswana the crop is ranked among the top three vegetable crops namely, cabbage, tomato and onions in their order of importance[16, 29]. The yield potential of tomato in the SADC region has been reported to range from 60 to 100 tons per hectare (4 & 31). However, the productivity of tomatoes in Botswana and some SADC countries among small scale farmers is low. This can be attributed to the lack of tomato breeding efforts to develop tomato cultivars that are adapted to the local target environment. There are also some constraints such as pests, diseases, lack of water for irrigation, expensive inputs and the difficulties of breeding temperate crops in tropical environment.

Increasing yield through selection for yield *per se* is slow and sometimes difficult to achieve, since yield is a quantitatively inherited trait with low heritability. Yield can be indirectly increased by selecting for yield components that are highly correlated with yield but possess higher heritability. A method to improve yield indirectly is to select for traits that are highly correlated with yield but possess higher heritability[5]. These traits are often referred to as yield components and may include, the number of harvests per plant, number of branches per plant and marketable yield. According to[10], the consideration of yield components in selection is based on the assumption that a strong positive correlation exists between yield and yield components and that these component characters have higher heritability than yield. The changes or increase in yield must be accompanied by change in one or more of the yield components[21]. High genetic variation has been observed in plant height, number of days to fruit set, number of fruit clusters per plant, number of fruits per plant,

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Key words: *Tomato Yield, Morpho-physiological, Multiple determination, Direct effect, Indirect effect and heritability.*

fruit weight per plant and fruit yield per plant in tomatoes[25]. The high genetic variation for these traits offer an opportunity for indirect selection for yield in tomatoes.

Yield being a complex trait, it is difficult to exploit various yield contributing characters merely through the knowledge of correlation which is simply a measure of association between yield and the yield components. It is important to establish the cause and effect relationships between yield and the yield enhancing components of the crop species that are amenable to the indirect selection approach for yield. Other Statistical tools such as the Path Coefficient Analysis originally proposed by Wright in 1921 but first used for plant selection by Dewy and Lu in 1959, provides a clear indication for indirect selection criterion [7,12]. The coefficients generated by path analysis measures the cause and effect relationships, that is, direct and indirect influence of, for instance yield components as independent variables upon another character such as yield, as a dependent variable[7,12]. Yield components have also been used to improve yield in crops such as wheat[7] and cucumber [1, 28, 19, 18, 34, 35, & 6]. Yield contributing traits in tomato had been found to be traits such as plant height and fruit weight. Among the traits subjected to path analysis, fruit weight exerted very high direct effect upon yield per plant [21].

The use of indirect selection for yield based on important morpho-physiological yield parameters that have a great influence on yield in tomatoes may provide a new scope for improving tomato yield in our climatic environment. However, identification of the important yield enhancing traits in tomatoes in the SADC environment could form a basis for tomato improvement research in the region. Therefore, the purpose of this study was to identify the morpho-physiological components of yield that influence yield in Semi Determinate tomato and to estimate their direct and indirect effects on yield as a basis for an indirect selection model for tomato improvement research programs.

MATERIALS AND METHODS

The experiment was carried out at the Department of Agricultural Research, Sebele Research Station, in Gaborone, Botswana. Sebele Research Station is Located at Latitude 240 34'S and Longitude 250 57'S at an altitude of 994 meters above sea level[14]. The soil type at the site is Ferric Luvisol, medium grained sandy loam soil [11].

Six genotypes including one variety as a check of semi determinate type tomato were used in the study. Five of these were elite lines developed by the Asian Vegetable Research and Development Centre (AVDRC) obtained from Africa Regional Program (ARP), at Arusha, Tanzania. The variety use as a check was a commercial tomato variety from South Africa. The elite lines were: LBR – 6, LBR – 9, LBR – 10, LBR – 11, LBR – 16 and a commercial variety was Expresso. The commercial variety was used as a check variety.

Experimental Design and Cultural Practices

Seeds were planted in a greenhouse in June 2010 and transplanted in September 2010 under field conditions. Drip irrigation system was used for watering. Each plot was made up of three rows of 2.0 meters long, separated by 1.2 meters. The intra row spacing was 0.40 meters giving five plants per row. The design used was the Randomised Complete Block Design with four replications. The cultural practices were done according to the need of the plants [4]

Data collection

At harvest, data for yield components was collected from the middle six tagged plants in a plot. Two plants were tagged from each row. For total yield all the plants in a plot were used. The yield components recorded from the six tagged plants in a plot were; plant height, fruit number per truss, number of trusses per plant, weight of fruits per truss, weight of fruits per plant, single fruit weight, flower numbers per truss and number of fruits per plant. Other yield components such as days to 50 percent flowering were also recorded on a whole plot basis. Data for total soluble solids was determined from fruits sampled from the trusses of the tagged plants at harvest from each plot.

Data analysis and interpretation

Data collected was subjected to Analyses of Variance, Correlation, Stepwise Multiple Regression and Path Coefficient analyses. Analysis of Variance was done using the General linear model procedure of SAS (SAS, 2002). The Path coefficient analysis was done with the application of excel computer program using the matrix methods[26].

RESULTS AND DISCUSSION

The Analysis of Variance was done for total yield, plant height, fruit number per truss, number of trusses per plant, weight of fruits per truss, weight of fruits per plant, single fruit weight, marketable fruit number, flower numbers per truss, days to 50 percent flowering, fruit dry mater, fruit number per plant and total soluble solids to compare the performance of different genotypes for these traits as shown in Table 1 on the next page.

Means performance results show that there were significant differences among genotypes in yield, plant height, single fruit weight, fruit number per plant, truss number per plant, fruit weight per truss, days to 50 percent flowering, marketable fruit number and flower number per truss (Table 1). Similar observations have been reported by (23, 27, & 3) on these characters in tomato. There were no significant differences in fruit weight per plant, total soluble solids, dry matter and fruit number per truss among the cultivars. These findings are not in agreement with (23, 27, & 3). These workers observed significant differences in some of these traits. The difference between the findings of this study with theirs could be attributed to difference in climatic conditions under which the experiments were done.

Table 1: Means performance of fruit yield and yield components of six semi – determinate genotypes

Variety	(t/ha)	Plant height (cm)	Single fruit weight (kg)	Fruit number plant^{-1}	Marketable fruit number	Fruit no truss^{-1}	Truss no plant^{-1}
LBR-6	59.10	65	0.10	27.5	427.0	2.00	14.00
Expresso	67.04	61.5	0.12	27.0	425.7	2.20	12.25
LBR - 9	58.76	67.05	0.13	22.0	332.0	2.13	10.00
LBR-10	53.96	69.95	0.11	19.5	351.2	1.86	10.50
LBR-11	64.10	62.35	0.13	24.5	432.0	2.19	11.25
LBR - 16	51.58	55.75	0.10	18.7	335.5	1.87	9.25
Means	59.09	63.6	0.11	23.20	383.91	2.04	11.20
CV%	7.22	14.70	17.43	24.54	8.35	12.85	19.15
LSD (0.05)	6.43	5.86	0.024	8.58	48.3	1.12	3.23

Variety	Fruit weight truss^{-1}	Total soluble solids	Day to 50% flowering	Dry matter	Fruit weight plant^{-1}	Flower number truss^{-1}
LBR - 6	0.21	5.07	30.25	0.035	2.97	6.04
Expresso	0.25	4.87	32.00	0.037	3.12	6.12
LBR - 9	0.29	5.03	30.75	0.040	2.99	5.58
LBR - 10	0.21	5.00	39.75	0.040	2.21	5.37
LBR - 11	0.22	4.69	34.75	0.040	2.52	6.08
LBR - 16	0.22	4.84	31.00	0.040	2.18	5.37
Means	0.20	4.91	33.08	0.03	2.66	5.76
CV%	13.34	14.51	8.69	11.46	27.98	8.45
LSD (0.05)	0.04	0.44	4.33	0.0067	1.12	0.734

Simple Correlations

Simple correlation analyses were conducted between yield and various characters measured to determine the degree of association between yield and these components. The results as shown in Table 2 show that some components were significantly correlated to yield at $p<0.05$, while others were not. Results show that yield was positively correlated to number of trusses per plant, fruit number per plant, fruit number per truss, fruit weight per plant, marketable fruit number and flower number per truss. However, results showed no significant correlation between yield and the other six components as shown in Table 2.

Table 2: Simple correlation between yield and other components / characters

Character	Correlation (r)
Plant height	0.10
Total soluble solids	-0.11
Single fruit weight	0.32
Dry matter	-0.25
Days to 50% flowering	-0.21
Truss number per plant	0.41*
Fruit weight per truss	0.35
Fruit number per plant	0.54*
Fruit number per truss	0.44*
Fruit weight per plant	0.50*
Marketable fruit number	0.68*
Flower number per truss	0.47*

*Indicates significant at ($p<0.05$).

Stepwise multiple regression

A stepwise multiple regression analysis was done to identify those components which explained the variability observed in tomato yield. Yield was used as a dependent variable and other components as independent variables. The results showed that only four characters explain most of the variation that is found. The coefficient of the multiple determination R^2 increases greatly only with the addition of the four components. The R^2 ranged from 0.4751 to 0.0599. Results in Table 3 show that, marketable fruit number is the most important component since it accounted for 0.4751% of the observed variability in tomato fruit yield. The second most important contributor to the observed yield variation is single fruit weight with 0.2079%. In totality the remaining two components, fruit weight per truss and fruit number per truss explain only 0.1354% variability. Since the four components, that is, marketable fruit number, single fruit weight, fruit weight per truss and fruit number per truss have the highest cause and effect relation to yield as identified by the stepwise multiple regression analysis, we decided to use these four traits in a path coefficient analysis to estimate the direct and indirect effects of these traits on yield.

Path coefficients analysis

Path coefficient analysis was carried out to partition the components effects into direct and indirect effect. Yield, being a complex trait, is difficult to increase by simply exploiting the strength shown by correlation coefficient. According to[12], it is important to carry out other analysis including path coefficient that provide a clear indication for selection criterion. Components identified by step wise multiple regressions were partitioned into direct and indirect effect. The diagram shown in Figure 1 facilitates the understanding of the nature of the cause and effect system. The double arrows indicate mutual association as measured by simple correlation coefficient. The single arrows represent direct influences as measured by path coefficients,[10]. The direct and indirect path coefficients of the identified components are as presented in Table 4. The direct effect coefficient values were found using the matrixes method[26].

The direct and the indirect effects on yield of the components in Figure 1 are as presented in Table 4. Table 4 reveals that marketable fruit number which exhibited the highest direct effect of 0.989 could be used as the selection criteria for improving tomato yield. The next yield components that can be used for tomato yield improvement is, fruit weight per truss which has direct effect of 0.592. Similar findings had been reported by the following scholars [24, 17, 22 & 21]

CONCLUSIONS

The study showed that there were significant differences among genotypes involved in the study on yield and yield components. However, there were also no significant differences in some characters. Results showed that the South African variety performed better than the AVRDC materials for most components including yield as can be seen in Table 1. This can be attributed to the fact that the South African variety used as check was adapted to the Botswana conditions.

Stepwise multiple regressions identified marketable fruit number, single fruit weight, fruit weight per truss and fruit number per truss (Table 3) as being the most important components explaining variation in yield. The four components accounted for 81.84% of variation in yield.

Results obtained by the path coefficient analysis lead to the conclusion that marketable fruit number and fruit weight per truss were important components directly affecting tomato fruit yield. Marketable fruit number had the greatest direct effect of 0.989. The second important component was fruit weight per truss with 0.592. Single fruit weight came up as the third important component with 0.369. The path coefficient results of this study on single fruit weight and fruit weight per truss are similar to the findings of [21]. The findings confirm the reliability of fruit weight per truss, single fruit weight and marketable fruit number in selecting a superior type for yield improvement in tomato plant. The heritability of number of fruits per plant had been reported to be 87.05%, 64.40% and 94.51% (30, 9, and 8). Single fruit weight had been reported to be highly heritable as follows 97.60%, 94.70%, and 99.31% (20, 13, & 2).

Table 3: Stepwise multiple regression of semi determinate tomato yield on the components

Variable	Partial R-Sqaure	Model R-Sqaure	F - Value	Pr>F
Marketable fruit No	0.4751	0.4751	19.92	0.0002
Single fruit weight	0.2079	0.6830	13.77	0.0013
Fruit weight per truss	0.0755	0.7585	6.25	0.0212
Fruit No per truss	0.0599	0.8184	6.27	0.0215

Stepwise multiple regression and path coefficient analysis are important and useful statistical tools in identifying components that can be used as selection criteria in plant breeding programs for yield improvement.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the assistance given by Mr J. Makore in the statistical analysis of the data. Also we are grateful to SCARDA for funding the research. The authors would also like to thank Mmapula.T. Moseki – Monamodi and Gorata Matsaunyane for editing the paper. Thanks to the Field Assistances staff members working for the Horticultural Research Program for their support in planting and data collection especially Mr Morake Morake who was always available and willing to help.

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