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ORIGINAL RESEARCH

Analysis of fruit yield and its components in determinate tomato (Lycopersicon lycopersci) using correlation and path coefficient

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MEL, conceived idea, designed study, collected data, statistical analysis, prepared manuscript; LDM, proposal development, data collection, prepared manuscript; FGL, proposal development, data collection, prepared manuscript

ABSTRACT

A field experiment was carried out using six determinate tomatoes at Sebele Agricultural Research Station, during 2010/11 season. The objectives of the experiment were to; (1) determine the correlation among the components that explain variation in tomato yield, (2) determine the direct and indirect effects of the morpho-physiological traits on tomato yield. Data collected were fruit yield, marketable fruit number, single fruit weight, number of trusses *per* plant, number of fruits *per* truss, fruit weight *per* truss, plant height, total soluble solids, fruit dry matter, days to 50% flowering, fruit number *per* plant, fruit weight *per* plant and flower number *per* truss. Yield of Sixpack (control) was 62.4t/ha significantly ($P < 0.05$) higher from lines, CNL3022F2-154-22-9-3, CNL3022F2-37-29-10-17 and CNL3022F2-154-22-5-5.Yield was positive and significantly ($P < 0.001$) correlated to marketable fruit number ($r = 0.64$) and plant height ($r = 0.52$). The relationship between yield and the parameters measured was analysed using stepwise multiple regression. This analysis was used as a bridge leading to path coefficient analysis. Path coefficient analysis results showed that marketable fruit number and single fruit weight were directly related to yield with direct effect of 0.752 and 0.446 respectively. Results obtained suggest that fruit number and single fruit weight are relevant components to use as selection criteria for improving tomato yield. Using correlation coefficients alone would have lead to the erroneous conclusion that single fruit weight is not an important components as its correlation was low and not significant ($P > 0.05$) at ($r = 0.30$).

Keywords Correlation, determinate tomato, path coefficient analysis, yield, yield components,

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INTRODUCTION

Tomato, *(Lycopersicon lycopersci)* belongs to the family *Solanaceae* and is native of Peru Equador region (Rick, 1969).It is one of the most widely cultivated and important vegetable crops in Africa and in the world as a whole (Yamaguchi, 1983; Opena and Kyomo, 1990; Varela et al., 2003). Tomatoes are an excellent source of minerals and vitamins (Naika et al., 2005). In Botswana it is ranked among the top four most important vegetables among cabbage, tomato and onions (Opena and Kyomo, 1990; TAHAL report, 2000).

The yield potential of tomato in the Southern African Development Community (SADC) region has been reported to range from 60 to 100 tons *per* hectare (Varela et al., 2003). However, the productivity of tomatoes in Botswana and some SADC countries among small scale farmers is as low as 7 tons/ha, far below the potential of the crop. This can be attributed to the lack of breeding strategies to develop tomato cultivars that are adapted to the local environment. Other constraints such as pests, diseases, expensive inputs and difficulties associated with breeding temperate crops in a tropical environment have also contributed to low productivity in tomatoes in the SADC region. Due to these constraints, tomatoes are not produced on a large scale in Botswana, and therefore have to be imported as local production can met only 26% of local demand (Botswana Horticultural Council Study, 2007). There is therefore a need for further improvement of this crop through development of superior varieties and hybrids in order to meet national demand for this commodity.

Selection for yield based on multiple traits is always better than selection based on yield alone. Yield is a quantitative character controlled by many genes (Lungu 1978). Adequate knowledge about the magnitude and degree of association of yield with its attributing characters or components is of great importance to breeders. Using these components, breeders would understand strength of correlated traits that would assists in decision making process to select for simultaneous improvement of more than one character (Sivaprasad 2008). Cramer and Wehner (1998) indicated that a way about improving yield indirectly is to select for traits that are highly correlated with yield but possess higher heritability. 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 (Rani *et al*. 2008). According to (Lungu 1978), 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. For this assumption to be valid the changes or increase in yield must be accompanied by change in one or more of the yield components (Rani *et al*. 2008).

However, correlation alone does not provide information on the contribution of related characters, which necessitate the study of cause and effect relationship of different characters among themselves (McGiffens *et al.,* 1994). It has been observed that path coefficient analysis reveals the exact relationship of characters thereby providing more information than simple correlation analysis, suggesting that correlation analysis, is a weaker tool compared to path coefficient analysis; (Dewey and Lu, 1959; McGiffens *et al.,* 1994).Yield is a complex trait and 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, (Lungu 1978). Other statistical tools such as the Path Coefficient Analysis originally proposed by Wright (1921) but first used for plant selection by (Dewy and Lu 1959), provides a clear indication for indirect selection criterion; (Dewey and Lu, 1959; and McGiffens *et al.,* 1994).

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 (Dewey and Lu, 1959; and McGiffens *et al.,* 1994). Yield components have also been used to improve yield in crops such as wheat (Dewey and Lu 1959) and cucumber (AbuSalena and Dutta, 1988; Solanki and Shah, 1989; Prasad and Singh, 1994a; 1994b; Yi and Cui, 1994; Zhang and Cui, 1994; Cramer, 1997). (Rani *et al.,* 2008) found that in tomato, the yield contributing traits are plant height and fruit weight. Among the traits subjected to path coefficient analysis, fruit weight exerted very high direct effect upon yield *per* plant.

The success of any crop improvement programme depends on the presence of genetic variability and the extent to which the desirable trait is heritable. The presence of genetic variability in the breeding material has been emphasized by Singh (2009), so as to exercise critical selection pressure. Singh *et al.* (2002) observed high genetic variation in tomato for plant height, number of days to fruit set, number of fruit clusters *per* plant, number of fruits *per* plant, fruit weight *per* plant and fruit yield *per* plant. This genetic variations offer an opportunity for indirect selection for yield in tomatoes. High heritability has been reported in the following traits: plant height (Sivaprasad, 2008, Reddy and Gulshanlal,1987, Bora *et al*., 1993, Mohanty, 2000, Mohanty, 2002, and Upadhyay *et al.,* 2005); number of primary branches (Paranjothi and Muthukrishnan, 1979, Mohanty, 2000 and Veershetty, 2004, Sivaprasad, 2008), fruit shape index (Pujari *et al.,* 1995, Sivaprasad 2008); locules *per* fruit (Reddy and Gulshanlal,1987, Krishnaprasad and Muthurarai,1999, Upadhyay *et al.,* 2005 and Sivaprasad 2008); pericap thickness (Mittal *et al.,* 1996, Prashanth, 2003 and Sivaprasad 2008) and number of fruiting clusters (Sivaprasad, 2008). High heritability reported by these scholars clearly indicates that the improvement of these traits in tomato can be obtained by simple selection. Therefore, the purpose of this study was to estimate character associations and 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 Sebele Agricultural Research Station, Gaborone. The Station is located at latitude 240 34'S and longitude 250 57'S at an altitude of 994 meters above sea level (Monamodi *et al*., 2003). The soil type at the site is Ferric Luvisol, medium grained sandy loam soil (Mazhani, 1990).

Six genotypes of determinate tomato type including one variety Sixpack (control) were used in the study. Five of these are elite lines developed by the Asian Vegetable Research and Development Centre (AVDRC) and were obtained from Africa Regional Program (ARP), at Arusha, Tanzania. The variety used as a control, Sixpack is a commercial open pollinated tomato variety from South Africa and was recommended for production in Botswana (Bok *et al*., 2006). The elite lines were: CNL3022F2-37-29-9-17, CNL3022F2-37-37-12-19, CNL3022F2-37-29-10-17, CNL3022F2-154-22-5-5 and CNL3022F2-154-22-9-3. The rationale for the use of Sixpack as control was that it is readily available and popularly grown by farmers in Botswana. The elite lines from AVRDC were used, as they were reported to be resistant to tomato leaf curl virus (AVRDC Report, 2004).

Experimental Design and Cultural Practices

Seeds were planted in a greenhouse in June 2010 and transplanted in September 2010 under field conditions using the drip irrigation system. Each plot was made up of three rows of 2.0 m long, separated by 1.2 m. The intra row spacing was 0.40 m giving five plants *per* row. The design used was the Randomised Complete Block with four replications. The cultural practices were done according to the need of the plants (Bok *et al.*, 2006). During the growing stage, two plants were tagged from each row.

Data collection

At harvest, data for yield components was collected from the middle six tagged plants in a plot. 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. Days to 50 percent flowering was 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. Total soluble solids in the juice were measured with a Refratometer machine. Tomatoes were first rinsed with water to remove any surface dirt and were dried with a paper towel. A knife was used to cut the fruits along the equator. The fruits were put in a juice extractor machine to extract juice from them. Total soluble solids in the juice were measured by a digital refratometer (ATAGO PR – 101. TOKYO. JAPAN).

Data analysis and interpretation

Data collected was subjected to Analyses of Variance using General Linear Model procedure of SAS (SAS, 2002). The same statistical package was used for Correlation and Stepwise Multiple Regression. The Path coefficient analysis was done using excel computer program applying the matrix methods (Singh and Chaudhary, 2004).

The residual for path coefficient analysis was calculated using the following formula (Dewey and Lu, 1959):

$$1 = Px_7^2 + P_{17}^2+P_{27}^2+P_{37}^2+P_{47}^2+P_{57}^2+P_{67}^2) + (2P_{17}r_{12}P_{27}+2P_{17}r_{13}P_{37}+2P_{17}r_{14}P_{47}+ 2P_{17}r_{15}P_{57}+2P_{17}r_{16}P_{67}) +(2P_{27}r_{23}P_{37}+2P_{27}r_{24}P_{47}+2P_{27}r_{25}P_{57} +2P_{27}r_{26}P_{67})+ (2P_{37}r_{34}P_{47}+2P_{37}r_{35}P_{57}+2P_{37}r_{36}P_{67}) + (2P_{47}r_{45}P_{57}+2P_{47}r_{46}P_{67})+ (2P_{57}r_{56}P_{67})$$

$$1= P_{X7}^2 + 0.958 – 0.169 + 0.031 + 0.003 – 0.006 – 0.011$$

$$1 = P_{X7}^2 + 0.806$$

$$1 – 0.806 = P_{X7}^2$$

$$\sqrt{0.194} = Px_7^2$$

$$Px_7 = 0.440$$

RESULTS

The results obtained are shown in Table 1-5 and Figure 1.

Analysis of variance

Results for yield and yield components revealed that there were significant differences (P < 0.05) among the genotypes (Table 1). Mean performance results (Tables 1 and 2) showed that variety Sixpack yielded higher but it was not significantly different (P < 0.05) to two varieties; CNL3022F2-37-29-9-17 and CLN3022F2-37-37-12-19. However, the control variety was significantly different (P < 0.05) from the three varieties; CLN3022F2-37-29-10-17, CLN3022F2-154-22-5-5 and CLN3022F2-154-22-9-3. It yielded higher than the second yielding cultivar, CLN3022F2-37-37-12-19, by 4.7% and the lowest yielding cultivar, CLN3022F2-154-22-5-5, by 24.9%. Significant differences (P < 0.05) were also observed between the CLN series themselves. Variety CNL3022F2-37-29-9-17 and CLN3022F2-37-37-12-19 yielded significantly (P < 0.05) different from variety CLN3022F2-37-29-10-17, CLN3022F2-154-22-5-5 and CLN3022F2-154-22-9-3.

Sixpack had significantly (P < 0.05) higher single fruit weight as compared to the five CLN series. It was also superior in plant height though it was not significantly different from variety CNL3022F2-37-29-9-17, CNL3022F2-37-37-12-19 and CNL3022F2-154-22-9-3. It did well in most components as it was the best or second best, (Tables 1 and 2).

Character association

Correlations between yield and marketable fruit number (r = 0.64), yield and plant height (r = 0.52), and yield and days to 50 percent flowering (r = -0.42) were significant (P < 0.05) (Table 3). Antagonistic relationship occurred between fruit number *per* truss and single fruit weight (r = -0.13). As shown in Table 3, positive and significant (P<0.05) inter component correlations occurred between fruit number *per* truss with the following: fruit number *per* plant (r = 0.69), fruit weight *per* plant (r = 0.59) and fruit weight *per* truss (r = 0.73). There was also a highly significant (P < 0.001) and positive correlation between number of trusses *per* plant with fruit number *per* plant (r = 0.88), and fruit weight per plant (r = 0.87).

Stepwise multiple regression

Components that explained most of the yield variations observed was as presented in (Table 4).

Marketable fruit number had a highly significant (P < 0.001) influence on yield, explaining 40.96% of the total variation in yield. Variation on yield contributed due to single fruit weight (P < 0.01) and total soluble solids (P < 0.05) were highly significant. Their influence on yield variation was 22.7% and 9.7% respectively. Addition of other variables did not have much contribution to the total variation in yield as they were not significant (Table 4).

Path coefficient analysis

The direct effects of marketable fruit number (0.752) and fruit weight (0.445) on fruit yield were positive and large (Figure. 1). Fruit number per truss also showed positive direct effect on fruit yield. Figure 1 explains the nature of the cause and effect system of yield components to yield. Table 5 presents a summary of the path coefficient analyses

Table 1: Mean performance of plant characteristics of determinate tomato (*Lycopersicon lycopersci*) genotypes grown at Sebele, Gaborone in 2010/11 season

Variety	Plant height (cm)	Flower no truss^{-1}	Truss no plant $^{-1}$	Days to 50% flowering
Sixpack	54.16	7.25	9.45	24.50
CNL3022F2-37-29-9-17	52.91	5.75	7.58	35.0
CNL3022F2-37-37-12-19	49.16	6.75	10.20	25.50
CNL3022F2-37-29-10-17	47.08	6.25	10.91	25.0
CNL3022F2-154-22-5-5	44.99	6.75	8.29	33.50
CNL3022F2-154-22-9-3	48.96	6.50	10.16	26.0
Means	49.54	6.54	9.43	28.25
CV%	7.68	12.45	19.53	13.28
LSD(0.05)	5.74	1.22	2.77	5.654

Table 2: Mean performance of fruit yield and fruit characteristics of determinate tomato *(Lycopersicon lycopersci)* genotypes grown at Sebele, Gaborone. in 2010/11 season

Variety	Yield (t/ha)	Single fruit weight (kg)	Fruit dry matter (g)	Marketable fruit number	Fruit number plant^{-1}	Fruit number truss^{-1}	Fruit Weight plant^{-1} (kg)	Fruit Weight truss^{-1} (kg)	Total soluble solids ($^{\%}$Brix)
Sixpack	62.04	0.090	0.025	702.50	23.29	2.469	1.54	0.164	4.77
CNL3022F2-37-29-9-17	54.10	0.067	0.020	656.75	19.00	2.480	1.12	0.145	5.34
CNL3022F2-37-37-12-19	59.10	0.062	0.017	748.50	26.70	2.555	1.38	0.132	4.92
CNL3022F2-37-29-10-17	48.96	0.062	0.015	657.25	29.37	2.622	1.56	0.141	5.04
CNL3022F2-154-22-5-5	46.58	0.072	0.020	586.25	20.33	2.524	1.28	0.157	5.14
CNL3022F2-154-22-9-3	53.76	0.067	0.017	588.00	25.87	2.521	1.62	0.158	4.68
Means	54.09	0.07	0.019	656.54	24.09	2.52	1.42	0.149	4.98
CV%	9.83	13.02	23.33	11.72	27.96	17.00	23.29	14.19	5.07
LSD (0.05)	8.02	0.013	0.0251	116.0	10.15	0.648	0.499	0.032	0.381

Table 3: Inter components correlation of components correlated to yield for the determinate genotypes

	Marketable fruit No	Single fruit weight	Total soluble solids	Fruit No truss $^{-1}$	Dry Matter	Flower No truss $^{-1}$	Truss No plant $^{-1}$	Fruit no plant $^{-1}$	Fruit weight plant $^{-1}$	Plant height	Days to 50% flowering	Fruit weight truss $^{-1}$	Yield (t/ha)
Marketable fruit No	1.00	-0.24	0.06	0.14	0.13	0.26	0.06	0.11	-0.04	0.44*	-0.43*	-0.17	0.64*
Single fruit weight		1.00	-0.23	-0.13	0.11	0.18	0.02	-0.09	0.19	0.26	0.03	0.37	0.30
Total soluble solids			1.00	-0.14	-0.22	-0.42	-0.32	-0.32	-0.41*	-0.15	0.46*	-0.25	-0.36
Fruit No truss $^{-1}$				1.00	0.02	0.11	0.30	0.69*	0.59*	-0.0086	-0.014	0.73*	0.28
Dry Matter					1.00	0.18	0.11	0.09	0.044	-0.21	-0.036	-0.049	0.38
Flower No truss $^{-1}$						1.00	0.069	0.107	0.146	0.168	-0.135	0.211	0.30
Truss No plant $^{-1}$							1.00	0.88*	0.87*	0.078	-0.55*	0.147	0.23
Fruit no plant $^{-1}$								1.00	0.91*	0.047	-0.42*	0.40*	0.30
Fruit weight plant $^{-1}$									1.00	0.130	-0.37	0.59*	0.31
Plant height										1.00	-0.189	0.105	0.52*
Days to 50% flowering											1.00	0.160	-0.42*
Fruit weight truss $^{-1}$												1.00	0.231
Yield (ton/ha)													1.00

Table 4: Stepwise multiple regression of determinate tomato yield on the components

Variable	Partial R-Square	Model R- square	F-Value	Pr>F
Marketable fruit number	0.4096	0.4096	15.27	0.0008
Single fruit weight	0.2265	0.6361	13.07	0.0016
Total soluble solids	0.0986	0.7347	7.43	0.0130
Fruit number *per* truss	0.0391	0.7738	3.28	0.0858
Fruit dry matter	0.0285	0.8023	2.60	0.1244
Flower number *per* truss	0.0241	0.8264	2.36	0.1428

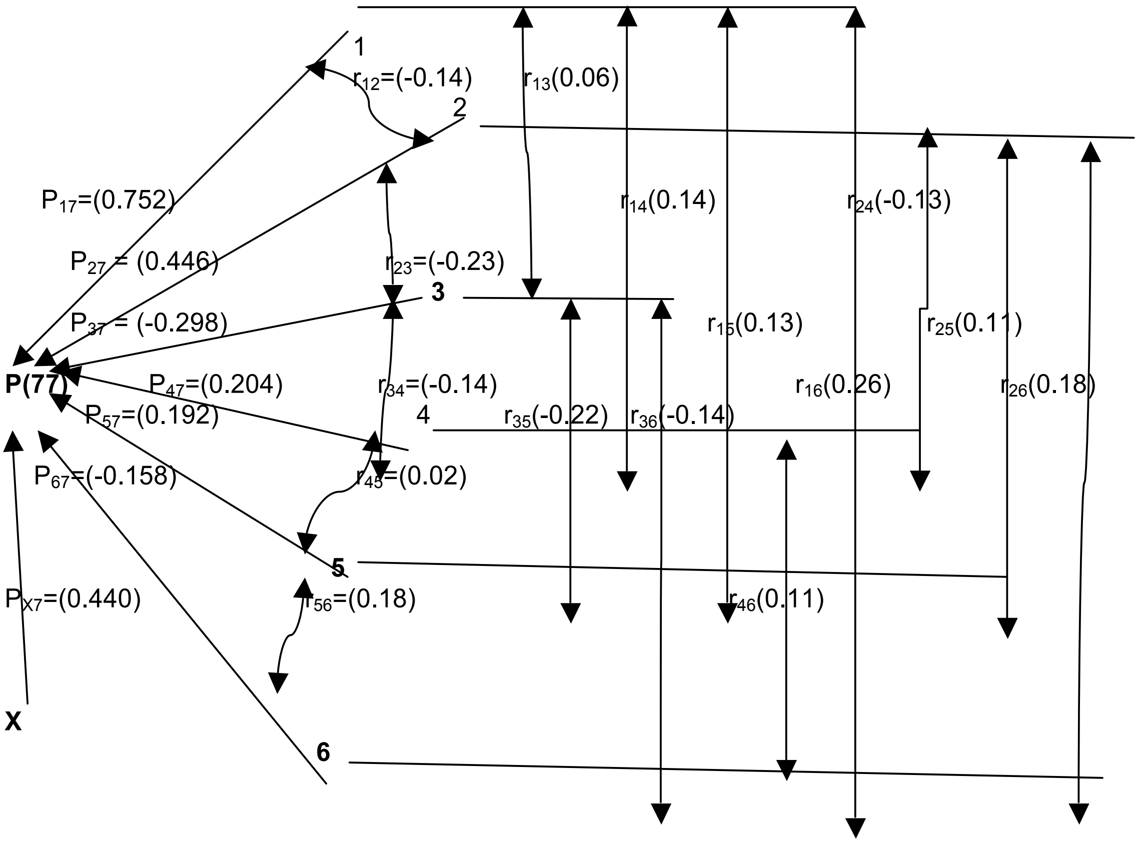

Figure 1: A Path diagram and coefficient of factors influencing determinate tomato fruit yield.
Key: 1 = Marketable fruit number, 2 = Single fruit weight, 3 = Total soluble solids, 4= Fruit number per truss, 5 = Dry matter and, 6 = Flower number per truss

Table 5: Direct and indirect effects of different components on fruit yield of determinate tomato under field conditions.

Type of effect	Coefficients
Marketable fruit number	
Direct effect	0.752
Indirect effect via Single fruit weight ($r_{12}P_{27}$)	-0.107
Indirect effect via total soluble solids ($r_{13}P_{37}$)	-0.018
Indirect effect via fruit number per truss ($r_{14}P_{47}$)	0.029
Indirect effect by fruit dry matter ($r_{15}P_{57}$)	0.025
Indirect effect via flower number per truss ($r_{16}P_{67}$)	-0.041
Single fruit weight	
Direct effect	0.445
Indirect effect via marketable fruit number ($r_{12}P_{17}$)	-0.180
Indirect effect via total soluble solids ($r_{23}P_{37}$)	0.069
Indirect effect via fruit number per truss ($r_{24}P_{47}$)	-0.027
Indirect effect via fruit dry matter ($r_{25}P_{57}$)	0.021
Indirect effect via flower number per truss ($r_{26}P_{67}$)	-0.028
Total soluble solids	
Direct effect	-0.298
Indirect effect via single fruit weight ($r_{32}P_{27}$)	-0.10258
Indirect effect via marketable fruit number ($r_{31}P_{17}$)	0.04512
Indirect effect via fruit number per truss ($r_{34}P_{47}$)	-0.02856
Indirect effect via fruit dry matter ($r_{35}P_{57}$)	-0.04224
Indirect effect via flower number per truss ($r_{36}P_{67}$)	0.06636
Fruit number per truss	
Direct effect	0.204
Indirect effect via total soluble solids ($r_{43}P_{37}$)	0.04172
Indirect effect via single fruit weight ($r_{42}P_{27}$)	-0.05798
Indirect effect via marketable fruit number ($r_{41}P_{17}$)	0.10528
Indirect effect via fruit dry matter ($r_{45}P_{57}$)	0.00384
Indirect effect via flower number per truss ($r_{46}P_{67}$)	-0.01738
Fruit dry matter	
Direct effect	0.192
Indirect effect via fruit number per truss ($r_{54}P_{47}$)	0.00408
Indirect effect via total soluble solids ($r_{53}P_{37}$)	0.06556
Indirect effect via single fruit weight ($r_{52}P_{27}$)	0.04906
Indirect effect via marketable fruit number ($r_{51}P_{17}$)	0.09776
Indirect effect via flower number per truss ($r_{56}P_{67}$)	-0.02844
Flower number per truss	
Direct effect	- 0.158
Indirect effect via dry matter ($r_{65}P_{57}$)	0.035
Indirect effect via fruit number per truss ($r_{64}P_{47}$)	0.022
Indirect effect via total soluble solids ($r_{63}P_{37}$)	0.125
Indirect effect via single fruit weight ($r_{62}P_{27}$)	0.080
Indirect effect via marketable fruit number ($r_{61}P_{17}$)	0.196

DISCUSSION

In the present study, Sixpack performed well in single fruit weight and other yield components. These findings are similar to those of (Barman *et al*., 1995, Shravan *et al*., 2004 and Singh and Raj, 2004) who observed significant difference in yield and other yield components in tomato studies.

Positive and significant association between fruit yield and plant height is in support of the findings of (Ara *et al*., 2009). The interesting relationship to note was that of total soluble solids which had a negative relationship with most components except with marketable fruit number and days to 50 percent flowering. Another antagonistic relationship occurred between fruit number *per* truss and single fruit weight. This negative relationship with total soluble solids suggests that there may be competition for resources between total soluble solids and other components. The negative correlation of fruit number with fruit weight means that if there are more fruits in a truss, the tomato fruit weight will tend to be smaller as fruits will compete for space for attachment in a truss as well as for the nutrients. This association was expected since it appears reasonable that as more fruits are produced *per* truss, the plant will have more fruits and the total weight of fruits *per* plant will increase as well.

As expected, there was a strong positive significant correlation between numbers of trusses *per* plant with fruit number *per* plant. This was because the more the truss number in a plant, such plant will produce more fruits resulting in more fruit weight. This is supported by the observed strong positive association between fruit number *per* plant and fruit weight *per* plant (r = 0.91), Correlation results of fruits number *per* truss with number of fruits *per* plant supported the findings of (Prashanth, 2003, Joshi *et al*., 2004, Singh *et al*., 2004) who found that these two components are positively correlated.

Stepwise multiple regression was done as a bridge leading to path coefficient analysis which is a stronger tool for use in indirect selection (Dewey and Lu, 1959; McGiffens *et al.,* 1994). Marketable fruit number, single fruit weight and total soluble solids were identified for their strongest relationships with fruit yield, using this screening tool.

Path coefficient analysis allows breeders to partition correlation coefficients into components of direct and indirect effect. The path involves measurement of influence of one trait upon the set of other traits through standardized partial regression coefficient to increase the efficiency of selection (Sivaprasad, 2008). Path coefficient analyses results in the current study showed that three components; marketable fruit number, single fruit weight and fruit number *per* truss are potential selection criteria for improving tomato fruit yield. This finding confirmed the findings of (Rani *et al*., 2008; Ara *et al*., 2009), who found that among the traits subjected to path analysis, fruit weight exerted very high direct effect upon yield *per* plant. Result on marketable fruit number is in agreement with those of (McGiffen *et al*., 1994), who found that fruit number had direct effect on plant yield. Fruit number *per* truss, like single fruit weight had been reported to be heritable as follows: 97.40%, 71.10% and 78.80% respectively (Singh *et al*. 2000; Prashanth, 2003 and Veershetty, 2004).

The highest effect of marketable fruit number on fruit yield observed in the present study is in accordance with study by Singh *et al.* (1989) who found that the number of fruits, fruit length and fruit weight influenced fruit yield. Padda *et al.* (1971) and Rathod, (1997) also observed that the number of fruits *per* plant had the highest positive direct effect on yield. Vikram *et al.,* (1988) and Rani et al (2008) found that mean fruit weight is the most important yield attributing trait after fruit number *per* plant. Sharma and Verma (2000) reported that the number of fruits *per* plant, average fruit weight and plant height had the highest direct effect on fruit yield *per* plant. Anikumar *et al.* (2003) reported that based on the path coefficient analysis, selection should be based on more number of fruits with higher average fruit weight. Joshi *et al.* (2004) found that the number of fruits *per* plant is the most important yield contributing traits

CONCLUSIONS

Performance was found to be variable among tomatoe lines. The presence of this variability is important because the success of any crop improvement depends on variability and to a larger extent to the parameter which is heritable. The control genotype came up as a better performing material in terms of yield and most of the measured components. Path coefficient analysis revealed that the marketable fruit number had a higher direct effect on yield. Single fruit weight was the second most important component with a better direct effect. From the present findings it is suggested that single fruit weight be considered when selecting for yield components, especially that this trait have previously been identified to have high heritability. However, results of this study come out from only six genotypes and more work need to be done with more genotypes to verify these results.

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Conflict of interest None

REFERENCES

AbuSalena, S. and O.P. Dutta, (1988). Interrelationship of yield components in cucumber. *Vegetable. Science.*15:79-85

Anikumar, V. R., Thakur, M.C and Hedau, N.K., (2003). Correlation and path coefficient analysis in tomato. *Annals of Agricultural Research New Series* 24:175-177.

Ara, A.R., Narayan, N and Khan, S.H., (2009). Genetic variability and selection parameters for yield and quality attributes in tomato. *Indian Journal of Horticulture.*66:73-78.

Asian Vegetable Research Development Center Report (2004) Geminivirus-resistant determinate tomato lines. Shanhua, Taiwan.

Barman, D., C.K.Sharma., I.P. Singh and S.De. L.C. Sardana. (1995) Genetic variability in exotic lines of tomato (*Lycopersicon esculentum* Mill). In off season. *International. Journal of .Tropical. Agriculture.*13:265-268.

Bok, I., M. Madisa., D. Machacha., M. Moamogwe and K. More.(ed), (2006) Manual for Vegetable Production in Botswana, 2nd Reprinted, Department of Agricultural Research.

Bora, G.C., Shadeque, A., Bora, L.C. and Phookan, A.K., (1993) Evaluation of some genotypes for variability and bacterial wilt resistance. *Vegetable Science*. 20:44-47

Botswana Horticultural Council, (2007) Situational Analysis of Horticultural Production and Marketing and the potential impact of Trade protocols on the Horticultural Industry in Botswana: Unpublished Final Report. Gaborone

Cramer C. S and Wehner T. C, (1998) Fruit yield and yield component means and correlations of four slicing cucumber populations improved through six to ten cycles of recurrent selection. *Journal of American Society of Horticultural Science* 123:388-395.

Cramer C.S., (1997). Specific combining ability for fruits yield and shape, yield and yield components of cucumber (*Cucumis sativus* L,) populations improved using recurrent selection. PhD.Thesis, *N.C. State University, Raleigh.*

Dewey, D.R. and K.H. Lu. (1959). A correlation and path coefficient analysis of components of crested wheatgrass seed production. *Agronomy Journal.* 51:515-518.

Joshi, A., Vikram, A. and Thakur, M.C., (2004) Studies on genetic variability, correlation and path analysis of yield and physic-chemical traits in tomato. *Progressive Horticulture.* 36:51-58.

Krishnaprasad, V.S.R and Mathurarai, (1999) Genetic variation, component association and direct and indirect selections in some exotic tomato germplasm. *India Journal. of Horticulture.*, 59: 262-266.

Lungu, M. D (1978) Classifying winter wheat environments into Adaptive zones as a basis for recommending a Reduction in the number of International Winter Wheat

Performance Nursery Test sites. MSc. Thesis, University of Nebraska, Lincoln.

Mazhani L.M., (1990) Evaluation of stability of performance of twenty five diverse grain sorghum (*Sorghum Bicolor* (L) Moench) genotypes in Botswana. PhD. Thesis, Lincoln, Nebraska August, 1990.

McGiffen, M.E., D.J. Pantone and J.B. Masiunas. (1994) Path analysis of tomato yield components in relation to competition with black and eastern black nightshade. *Journal of American Society of. Horticultural. Science.* 119:6-11

Mittal, P., Sant Prakash and Singh, A.K., (1996) Variability studies in tomato (*Lycopersiconesculentum* Mill) under sub humid conditions of Himachal Pradesh. *South Indian Journal*. 44:132-134

Mohanty, B.K., (2000,) Genetic variation, component association and direct and indirect selection in collections of tomato. *Progressive Horticulture*.32:26-31

Mohanty, B.K., (2002,) Variability, heritability, correlation and path coefficient studies in Tomato. Haryana *Journal of. Horticultural Science.*, 31:230-233.

Monamodi, E.L., Bok I.B. and Karikari S.K. (2003.) Changes in nutritional composition and yield of two sweet potato (*Ipomoea Batatas* L) cultivars during their growth in Botswana. *UNISWA Journal of Agriculture* 11:5-14

Naika S, van Lidt de Jeude J, de Goffau M, Hilmi M and van Dam B. (2005) Agrodok.Series No 17

Opena, R.T., and M.L. Kyomo. (ed.) (1990) Vegetable Research and Development in SADCC Countries: Proceedings of workshop held at Arusha, Tanzania, 9-3 July 1990. AVRDC Publication No. 90-328, 178p.

Padda, D.S., Saimbhi, M.S. and Singh, K., (1971) Genotypic and phenotypic variabilities and correlation in quality characters in tomato (*Lycopersicon esculentum* Mill.). *Indian Journal. Agriculture. Science.* 41:199-202.

Paranjothi, G. and Muthukrishnan, C.R., (1979) Studies on variability and association of characters in tomato. *Madras Agricultural Journal*. 66:300-304

Prasad, V.S.R.K. and D.P.Singh. (1994) Genetic association and interrelationship between yield components in cucumber. *Journal of. Maharashtra Agricultural. University. 19:147-148.*

Prasad, V.S.R.K. and Singh, D.P. (1994). Diallel analysis of yield components in slicing cucumber (*Cucumis sativus* L.). *Journal of Research. (BAU) 6:151-154.*

Prashanth, S.J. (2003) Genetic variability and divergence studies in tomato (*Lycopersicon esculentum* Mill).M.Sc. (Agri.) Thesis, Uni. Agric. Sci., Dharwad (India).

Pujari, C. V., Wagh, R.S. and Kale, P.N., (1995,) Genetic variability and heritability in tomato. *Journal of Maharashtra Agricultural. University*. 20:15-17

Rani, I., Veeraragavathatham D. and. Sanjutha, D. (2008) Studies on Correlation and Path Coefficient analysis on Yield Attributes in Root Knot Nematodes Resistant F1 Hybrids of Tomato. *Journal of Applied Sciences Research. 4:*287*-295.*

Rathod, S.J., (1997) Evaluation of tomato genotypes for productivity and processing traits during late rabi season. M.Sc. (Agri.) Thesis, Uni. Agric. Science., Dharwad (India).

Reddy, M.L.N. and Gulshanlal,G. (1987) Genetic variability and path coefficient analysis in tomato (Lycopersicon esculentum Mill.) under summer season. *Progressive Horticulture*, 19:284-288.

Rick, C.M., (1969) Origin of cultivated tomato, current status of the problem. Abstract XI International Botanical Congress.p.180

Sharma, K.C and Verma, S., (2000) Path coefficient analysis in tomato (Lycopersicon esculentum). *Indian Journal of. Agricultural. Science*. 70:700-702

Shravan, K., T.Singh, T., Singh, B. and Singh, J. P. (2004) Studies on heritability and genetic advance in tomato (*Lycopersicon esculentum* Mill). *Progressive.Agriculture 4:76-77.*

Singh, B.D., (2009) Plant Breeding Principles and Methods, Kalyani Publisher, New Delhi India

Singh, R.K and Chaudhary, B. D. (2004) Biometrical Methods in Quantitative Genetic Analysis, Kalyani Publishers New Delhi, India.

Singh, A.K and Raj, N. (2004) Variability studies in tomato under cold arid condition of Ladakh. *Horticulture.Journal. 17:67-72*

Singh, P.K., Singh, R.K. and Saha, B.C., (1989,) Correlation and path analysis in tomato (Lycopersicon esculentum Mill.). *Annals of Agricultural. Research*. 10:120-124.

Singh, J.P., Singh, D.K. and Gulshanlal, G. (2002) Variability pattern in agro-morphological characters in tomato (*Lycopersicon esculentum* L.). *Progressive Horticulture.* 32:79-81

Sivaprasad, K, (2008) Genetic variability and correlation studies in biparental mating populations of tomato (*Lycopersicon esculentum* Mill.). Wettsd. M.Sc. (Agri.) Thesis, University of. Agricultural .Science. Dharwad (India).

Solanki, S.S. and A.Shah, A. (1989) Path analysis of fruit yield components in cucumber. *Progressive Horticulture 21:322-225*

TAHAL, (2000) National Master Plan for Arable Agriculture and Dairy Development (NAMPAADD). Consultancy Report. Gaborone. Botswana.

Upadhyay, M., Singh, J.P., Singh, A. and Joshi, A. (2005) Studies on genetic variability in tomato (*Lycopersicon esculentum* Mill). *Progressive Horticulture.* 37:463-465.

Varela, A.M; A. Seif, and Lohr, B. (2003) A guide to IPM in tomato production in Eastern and Southern Africa. CTA/ICIPE/GTZ.

Veershetty, V. (2004) Studies on variability, character association and genetic diversity in tomato (Lycopersicon esculentum Mill.). M.Sc. (Agric). Thesis. University of. Agricultural. Science., Dharwad (India).

Vikram A. and Kohli, U.K. (1998) Genectic variability, correlation and path analysis in tomato. *Journal of Hill Research*, 11:107-111.

Wright S. (1921) Correlation and causation. *Journal.of Agricultural Research 20:557-585.*

Yamaguchi, M. (1983) World vegetables principles, production and nutritive values. AVI Publishing Co., Westport, CT.

Yin, M. and H. Cui. (1994) Analysis of component traits for early yield in cucumber. Cucurbit Genetics Cooperative Report. *17:27-29*

Zhang, M. and Cui, H. (1994) Some morphological parameters involving the mechanism of early yield in cucumber. Cucurbit Genetics Cooperative Report*17:24-26*