International Archive of Applied Sciences and Technology
Int. Arch. App. Sci. Technol; Vol 10 [4] December 2019 : 158-163

[ISO9001: 2008 Certified Organization]
www.soeagra.com/iaast.html

IAAST
ONLINE ISSN 2277- 1565
PRINT ISSN 0976 - 4828

CODEN: IAASCA ORIGINAL ARTICLE

DOI: .10.15515/iaast.0976-4828.10.4.158163

Direct and indirect relationships among fruit yield and yield components in Tomato (*Solanum Lycopersicum* L.).

Saurabh Tomar*, Meenakshi Kumari, Budhesh Pratap Singh, and Vishal Gangwar
Department of Horticulture, Chandra Shekhar Azad University of Agriculture & Technology
Kanpur 208002 (U.P.) India
***E-mail:** chaudhary.csa@gmail.com

ABSTRACT
Tomato (Solanum lycopersicum L.) a worldwide economical vegetable crop, got importance as a source of income and a major contributor towards food security due to its nutritional and nutraceutical qualities. Path analysis was carried out in a single genotype of Tomato, Azad-T-6 at experimental block Kalyanpur, Department of Vegetable Science, Chandra Shekhar Azad university of agriculture and technology, Kanpur during rabi season of 2014-2015.The experiment was laid out in Randomized Complete Block Design (RCBD) and observations were recorded on thirteen quantitative morphological traits (Plant height, number of primary branches per plant at four different stages i.e, at 10, 30, 60 and 90 days after date of transplanting, number of secondary branches per plant at three different stages i.e, at 30, 60 and 90 days after date of transplanting, number of flowers per cluster, number of fruits per plant , average fruit length, fruit weight and fruit diameter. Among the characters studied, number of secondary branches at 90 days after date of transplanting, number of secondary branches at 60 days after date of transplanting, number of primary branches at 60 and 90 days after date of transplanting and number of fruits per plant had direct positive effect on fruit yield per plant at both phenotypic as well as genotypic level. However, the negative direct effect was found for number of secondary branches at 30 days after date of transplanting at both phenotypic and genotypic levels. Therefore, to increase the yield in tomato direct selection for these traits is beneficial.
***Key words**: Tomato, path analysis, phenotypic level, genotypic level, yield*

Received 20.05.2019 Revised 21.07.2019 Accepted 04.10.2019

CITATION OF THIS ARTICLE
S Tomar, M Kumari, B P Singh, and V Gangwar·Direct and indirect relationships among fruit yield and yield components in Tomato (*Solanum Lycopersicum* L.).. Int. Arch. App. Sci. Technol; Vol 10 [4] December 2019 :158-163

INTRODUCTION

Tomato is one of the most important, widely consumed vegetable crop in the world, both as fresh and processed form. It is originated in wild form in the Peru- Ecuador-Bolvia region of Andes (South America) and is grown in almost every corner of the world [11]. It is typical day neutral plant and is mainly self-pollinated, but a certain percentage of cross-pollination also occurs [2]. Both fresh fruit of tomato and its processed products are the reservoir of several bioactive compounds such as carotenes especially lycopene and beta carotene, ascorbic acid, phenolic compounds, etc. [9, 7]. Due to these compounds, tomato is universally known as 'Protective food' [14]. A survey made by M.A. Stens indicated that among the main fruits and vegetables, tomato ranks 16th as the source of both vitamins A and C [14]. Foods rich in lycopene are epidemiologically correlated with reduced risk of certain cancers, such as mouth, lung, prostate, colon cancers, coronary heart diseases and macular degeneration [1]. Yield of any crop is a dependent character which is the resultant of combined effect of several component characters and environment. The aim of any breeding programme is to increase the plant productivity also with its component that have a direct or indirect effect on yield. Now, this plant is used as a model to study plant physiology, biochemistry, genetics, genomics and breeding [3], in an effort to improve agronomic traits of interest [6, 4]. At present time, there is a need to develop new varieties with location specific and disease resistance with improve quality. We know that yield is a result of interaction among different direct as well as indirect effect of different characters and path coefficient analysis gives an idea about the contribution of each independent character on dependent character. It is a powerful tool to study the character association and their final impact on yield, which help the selection procedure accordingly. It determines the cause and effect which has been found beneficial in splitting the correlation into its direct and indirect effects contributing yield.

MATERIAL AND METHODS

The present investigation was carried out using single tomato genotypes Azad-T-6, which is characterized by its dark green, fruit red spherical, medium to large size. The experiment was laid out by using randomized complete block design with 3 replications during the Rabi season of 2014-15 at Vegetable Research Farm, Kalyanpur, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, (India). Each replication contain 50 plants. Geographically, Kanpur is situated at a longitude of 80° 24' E, latitude of 26° 28' N and an elevation of 115 meter above Mean Sea Level in the Subtropical climate of Central Uttar Pradesh. The climate of region is subtropical with maximum temperature ranging from 23 ^{0} C to 45 ^{0}C in summer, minimum temperature ranging from 5.5 ^{0}C to 13 ^{0}C in winter and relative humidity ranging from 45-55% in different season of the year. The soil of field may texturally be classified as sandy loam and slightly alkaline in reaction fertilized with 100 kg N_2, 50 kg P_2O_5, 50 kg K_2O ha^1. For further growth and development, standard cultural practices were used. The observations such as (Plant height, number of primary branches per plant at four different stages *i.e,* 10, 30, 60 and 90 days after date of transplanting, number of secondary branches per plant at three different stages *i.e,* at 30, 60 and 90 days after date of transplanting, Number of flowers per cluster, Number of fruits per plant , Length of fruit, Fruit Weight, Diameter of fruit and fruit yield per plant were recorded by adopting the standard procedure and the results were statistically analyzed.

RESULT AND DISCUSSION

The outcomes of experiment are briefly presented in Table 1and 2. The phenotypic and genotypic correlation coefficients between yield and other traits have been partitioned into direct and indirect effects by path coefficient analysis. Fruit yield is a complex character which is affected by many independent yield contributing characters, which are regarded as yield components. The result revealed that among the characters studied, number of fruits per plant, number of flowers per cluster, number of secondary branches at 60 and 90 days after date of transplanting, number of primary branches at 60 days after date of transplanting and number of primary branches at 90 days after date of transplanting had direct positive effect on fruit yield per plant at both phenotypic as well as genotypic level (Table 1 & 2). This indicates that direct selection for number of flowers per cluster, number of fruits per plant, number of secondary branches at 60 and 90 days after date of transplanting and number of primary branches at 60 and 90 days after date of transplanting in desired direction would be very effective for yield improvement.

Path coefficient analysis by Khapte and Jansirani [8] further revealed that number of primary branches, number of fruits per plant, average fruit weight were positively and significantly associated with yield per plant. Similar findings reported by Rathod *et al* [10], in which fruit yield had positively correlated with fruit weight, number of fruits per plant, number of primary branches per plant, number of flowers per cluster. At phenotypic level, number of primary branches at 60 days (0.364)after date of transplanting had highest positive direct effect on fruit yield followed by number of secondary branches at 90 days (0.336) after date of transplanting, number of secondary branches at 60 days (0.336) after date of transplanting and average fruit diameter (0.042) whereas, at genotypic level number of secondary branches at 90 days (0.456) after date of transplanting followed by number of secondary branches at 60 days (0.367) after date of transplanting had highest direct effect on yield. At both phenotypic and genotypic level number of secondary branches at 30 days after date of transplanting posses negative effect on fruit yield per plant. At both level fruit weight has positive direct effect on fruit yield (0.051). Similar trend for path analysis were reported by Ritonga *et al* [12], Singh *et al.*, [13] and Haydar *et al.*, [5].

The results of the present investigation indicated that number of fruits per plant, number of flowers per cluster, number of secondary branches at 60 and 90 days after date of transplanting, number of primary branches at 60 and 90 after date of transplanting exhibited maximum positive direct effect on fruit yield per plant at both phenotypic and genotypic level. Overall, number of fruits per plant, plant height, number of primary branches and number of flowers per cluster are the most important characters contributing towards fruit yield.

Table.1. Estimates of genotypic direct and indirect effects of 13 characters on yield per plant in Tomato during Rabi season, 2014-2015.

	PH	NF/C	NFT/P	AFL	AFD	FW	NPB(10 DAYS)	NPB(30 DAYS)	NPB(60 DAYS)
PH	**0.008**	0.008	0.008	0.007	0.007	0.007	0.007	0.007	0.007
NF/CT	0.034	**0.037**	0.036	0.026	0.029	0.030	0.030	0.030	0.030
NFT/P	0.061	0.063	**0.065**	0.051	0.057	0.058	0.061	0.060	0.060
AFL	0.008	0.006	0.007	**0.009**	0.009	0.008	0.008	0.008	0.008
AFD	-0.049	-0.045	-0.050	-0.056	**-0.057**	-0.057	-0.054	-0.054	-0.054
FW	0.043	0.041	0.046	0.049	0.051	**0.051**	0.049	0.049	0.049
NPB(10 DAYS)	0.003	0.003	0.003	0.003	0.003	0.003	**0.003**	0.003	0.003
NPB(30 DAYS)	0.071	0.067	0.077	0.076	0.078	0.079	0.083	**0.082**	0.082
NPB(60 DAYS)	0.122	0.113	0.131	0.129	0.132	0.134	0.140	0.140	**0.140**
NPB(90 DAYS)	0.063	0.058	0.067	0.066	0.068	0.069	0.072	0.072	0.072
NSB(30 DAYS)	-0.087	-0.081	-0.094	-0.091	-0.095	-0.096	-0.100	-0.100	-0.100
NSB(60 DAYS)	0.319	0.297	0.342	0.336	0.346	0.351	0.368	0.367	0.367
NSB(90 DAYS)	0.397	0.369	0.426	0.420	0.431	0.436	0.457	0.456	0.456
Y/P	0.870**	0.809**	0.935**	0.923**	0.944**	0.957**	1.003**	1.000**	1.000**

NPB(90 DAYS)	NSB(30 DAYS)	NSB(60 DAYS)	NSB(90 DAYS)
0.007	0.007	0.007	0.007
0.030	0.030	0.030	0.030
0.060	0.061	0.060	0.060
0.008	0.008	0.008	0.008
-0.054	-0.054	-0.054	-0.054
0.049	0.049	0.049	0.049
0.003	0.003	0.003	0.003
0.082	0.083	0.082	0.082
0.140	0.140	0.140	0.140
0.072	0.072	0.072	0.072
-0.100	**-0.100**	-0.100	-0.100
0.367	0.369	**0.367**	0.367
0.456	0.458	0.456	**0.456**
1.000**	1.005**	1.000**	1.000**

R SQUARE = 1.0002 RESIDUAL EFFECT =SQRT(1- 1.0002)
Bold values shows direct and normal values shows

Where, PH =Plant height, NF/C= number of flowers per cluster, NFT/P= number of fruits per plant, AFL= average fruit length, AFD= average fruit diameter, FW=fruit weight, NPB (10 Days), NPB(30 days), NPB(60 days), NPB(90days)= number of primary branches per plant at 10,30,60 and 90 days after date of transplanting respectively, NSB(30,60,90)= number of secondary branches at 30,60 and 90 days after date of transplanting respectively and Y/P= yield per plant.

Table.2. Estimates of phenotypic direct and indirect effects of 13 characters on yield per plant in Tomato during Rabi season, 2014-2015.

	PH	NF/C	NFT/P	AFL	AFD	FW
PH	**0.003**	0.002	0.002	0.002	0.002	0.002
NF/C	0.015	**0.018**	0.016	0.009	0.013	0.014
NFT/P	0.033	0.031	**0.036**	0.021	0.031	0.031
AFL	-0.007	-0.006	-0.007	**-0.013**	-0.009	-0.009
AFD	0.035	0.030	0.036	0.030	**0.042**	0.041
FW	0.027	0.024	0.028	0.022	0.032	**0.032**
NPB(10 DAYS)	0.019	0.016	0.020	0.015	0.021	0.021
NPB(30 DAYS)	-0.126	-0.107	-0.134	-0.097	-0.139	-0.140
NPB(60 DAYS)	0.313	0.268	0.332	0.243	0.343	0.347
NPB(90 DAYS)	0.137	0.116	0.144	0.105	0.149	0.151
NSB(30 DAYS)	-0.032	-0.027	-0.033	-0.025	-0.034	-0.035
NSB(60 DAYS)	0.276	0.235	0.293	0.212	0.302	0.305
NSB(90 DAYS)	0.290	0.248	0.306	0.223	0.317	0.320
Y/P	0.863**	0.738**	0.910**	0.660**	0.943**	0.953**

NPB(10 DAYS)	0.994**	0.334	0.319	-0.036	0.157	0.362	-0.146	**0.022**	0.030	0.039	-0.009	0.033	0.013	0.002
NPB(30 DAYS)	0.999**	0.336	0.320	-0.037	0.158	0.364	**-0.147**	0.022	0.031	0.039	-0.009	0.033	0.013	0.002
NPB(60 DAYS)	0.999**	0.336	0.320	-0.037	0.158	**0.364**	-0.147	0.022	0.031	0.039	-0.009	0.033	0.014	0.002
NPB(90 DAYS)	0.999**	0.336	0.320	-0.037	**0.158**	0.364	-0.147	0.022	0.031	0.039	-0.009	0.033	0.014	0.002
NSB(30 DAYS)	0.990**	0.334	0.318	**-0.037**	0.157	0.360	-0.146	0.022	0.030	0.039	-0.009	0.033	0.013	0.002
NSB(60 DAYS)	0.999**	0.336	**0.321**	-0.037	0.158	0.364	-0.147	0.022	0.031	0.039	-0.009	0.033	0.013	0.002
NSB(90 DAYS)	0.999**	**0.336**	0.320	-0.037	0.158	0.364	-0.147	0.022	0.031	0.039	-0.009	0.033	0.014	0.002

R SQUARE = 0.9997 RESIDUAL EFFECT = 0.0164
Bold values shows direct and normal values shows indirect effects

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