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COMPARATIVE ASSESSMENT OF TOMATO MUTANTS BASED ON MORPHO-PHYSIOLOGICAL, BIOCHEMICAL AND REPRODUCTIVE CHARACTERS, YIELD AND QUALITY

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Abstract

A field experiment was conducted at the experimental farm of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during the period from October 2012 to March 2013 to investigate some morphological, growth, reproductive characters, yield attributes and fruit yield in ten tomato mutants/varieties. The tested mutants/varieties were Binatomato-4, Binatomato-5, TM-113, TM-127, TM-128, TM-131, TM-132, TM-133, TM-134 and TM-160. Results revealed that in general, high yielding genotypes showed superior performance in leaf area, total dry mass production, absolute growth rate, nitrate reductase activity and total sugar content in leaves, number of flower cluster and flowers plant^{-1} which resulted higher number of fruits plant^{-1} compared to low yielding ones. Chlorophyll and reproductive efficiency had no contribution to fruit yield. Fruit yield had highly significant positive correlation with leaf area, total dry mass, absolute growth rate, number of flower clusters and fruits plant^{-1}. On the other hand, fruit size had significant negative association with fruit number. This result indicates that the improvement of fruit number plant^{-1} could be achieved by selecting increased number of effective flower cluster plant^{-1}. The mutant, TM-133 maintained superiority in most of the yield related traits and produced the highest fruit yield (100.1 t ha^{-1}).

Key words: Growth, biochemical parameters, reproductive characters, yield, tomato.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important popular and nutritious vegetable crops in the world. It ranks next to potato and sweet potato in respect of production in the world (FAO, 2015). But in South Asia, it ranks 2nd which is next to potato (SAARC, 2015) and top the list of canned vegetables. Its food value is very rich because of higher contents of vitamin A, B and C including calcium, minerals, carotene and iron (Mondal *et al*., 2016). It is extensively used in the canning industry.

The yield of tomato in this country is not satisfactory in comparison with other advanced tomato growing countries (FAO, 2015). The average yield of tomato is 26.72 t ha^{-1}

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(BBS, 2015) that is quite low than the tomato growing countries (54.55 t ha^{-1}) according to FAO (2015). To meet nutritional demand of population, it is highly important to increase the yield of tomato per unit area of land. Increase of production depends upon many factors such as use of improved varieties and proper management practices. So, using different types of techniques such as conventional breeding methods, nuclear technique and genetic engineering may improve production level and quality under the existing environmental conditions.

Varietal improvement of tomato is essentially needed to increase fruit yield by creating variability in the available germplasm followed by appropriate selection procedures. The induced mutation breeding is an effective technique for creating substantial genetic variability in plant species. Many workers have attempted to exploit somaclonal variation for crop improvement through physical mutagens particularly gamma radiation (Begum, 2005). This technique has been successfully utilized by BINA and many other research institutes in the world. The mutation breeding can play an efficient role in developing an ideal plant type having superior physiological performance as well as high yield (Malek *et al*., 2014). To increase productivity in tomato, it is therefore necessary to create variability and select desirable type with stable yield. However, biochemical properties are related to yield of tomato plant (Dutta, 2004). The higher chlorophyll, nitrate reductase activity and total sugar are helpful in increasing fruit yield in tomato (Dutta, 2001). On the other hand, component characters for yield are interdependent to each other while one character may express at the expense of other (Sharma *et al*., 2006). The importance of correlation in any breeding programme is well documented for various crop species as if provides a basis for effective selection. Correlation index acts as a guide to the reliability of phenotypic and genotype values and determines success in crop improvement (Mondal *et al*., 2011).

Under these circumstances, the scientists of BINA have developed several promising mutants of tomato with high yield potentials. These mutants need to be assessed for their morphological and physiological manoeuvring that takes place compared to the existing tomato cultivars. The present research work was therefore designed to assess the performances of eight tomato mutants along with two local improved varieties on the basis of morpho-physiological features and yield attributes.

Materials and Methods

The field experiments were conducted at the experimental field of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during winter season (November-April) of 2012-13. Eight promising mutants and two released varieties were undertaken in this study. The name of the genotypes/varieties is presented in Table 1. The soil of the experimental area is silty loam having 0.06% nitrogen, 1.15% organic matter, 18.5 ppm available phosphorus, 0.28 meq/100g exchangeable potassium, 18 ppm sulphur and 6.8 pH. The experiments were laid out in a randomized complete block design with three replicates.

The unit plot size was 4.0 m × 3.5 m with plant spacing of 50 cm × 50 cm. All agricultural practices of cultivation were performed as recommended by the Hand Book of Agricultural Technology Published by BARI (2014), Bangladesh.

Seeds were sown in seed bed and the seedlings were transplanted in the field at 25 days after sowing. Gap filling was made at seven days after transplanting (DAT) to keep same plant population density for every plot. After 30 DAT, each plant was staked with bamboo sticks to keep them erect. Recommended intercultural practices such as weeding, irrigation, application of pesticides were followed for proper growth and development of the plants. Urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and cowdung were applied at the rate of 280, 250, 180, 80 and 10000 kg ha^{-1}, respectively (BARC, 2012). Total amount of TSP, MP, gypsum and cowdung were applied as basal doses during final land preparation. Half of urea was applied as top dress at 21 days after transplanting and rest half was applied at 45 days after transplanting.

To study growth characteristics, a total of two harvests were made. The second rows of each plot were used for sampling. The first and second crop sampling was done at 45 and 65 DAT. From each sampling, five plants were randomly selected from each plot and uprooted for collecting data on necessary parameters. The plants were separated into roots, stems, leaves and fruits, and the corresponding dry weights were recorded after oven drying at 80 ± 2 ^{0}C for 72 hours. The leaf area was measured by automatic leaf area meter (Model: LICOR 3000, USA) at 80 DAT, just before starting of harvesting fruits. The growth analysis like absolute growth rate (AGR) and relative growth rate was carried out following the formula of Hunt (1978). All biochemical parameters were recorded at 50-60 DAT, the fruiting stage. Nitrate reductase (NR) activity was determined by following the method of Steward and Orebanjo (1979). Total sugar, reducing sugar and chlorophyll were determined following the method of Yoshida *et al*. (1976). Photosynthesis was measured at flowering and fruit development stage using portable photosynthesis meter (LI- 6400XT, USA).

At harvest, ten plants from each plot were selected randomly for data recording on morpho-physiological, reproductive, yield and yield related traits. Per cent fruit set to opened flowers i.e. reproductive efficiency (RE) was estimated as: % fruit set = (Number of fruits plant^{-1} ÷ Number of flowers plant^{-1}) × 100. The number of effective and non-effective flower clusters plant^{-1} was counted of the sampled plant at 80 DAT. The effective flower cluster denotes as when it bears at least one fruit. The non-effective effective flower cluster denotes as when it bears no fruits. Fruit yield was collected from each plot excluding border line and converted into tonnes per hectare. Harvesting was done at different dates depending on fruit ripening.

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C.

Results and Discussion

Morphological parameters

There were significant genotypic variations on morphological characters such as plant height, branch and leaf number and leaf area (Table 1). Results showed that high yielding genotypes maintained moderate plant height, medium branch number, increased leaf number and leaf area. In contrast, low yielding genotypes showed shorter plant, fewer branches (except Binatomato-5) and leaves. However, among the genotypes, the longest plant was recorded in TM-113 (110.2 cm) and the shortest was in TM-160 (68.7 cm). Results indicated that the plants those produced higher number of leaves, also showed higher leaf area. TM-128 having second highest leaves number with the highest leaf area might be due to broader leaves. In contrast, Binatomato-5 produced the highest number of leaves with lower leaf area might be due to shorter/narrower leaf. Genotypic variability in plant height, branch and leaf production was also observed by many workers in tomato (Asati *et al*., 2008; Prashanth *et al*., 2008) that also supported the present experimental results. The differential response of branching and leaves in the genotypes could be attributed to its genetic potentiality. The variation in leaf area might occur due to the variation in number of leaves and the expansion of leaf. The result obtained from the present study is consistent with result of Heuvelink (1999) in tomato who stated that variation in LA could be attributed to the changes in number of leaves. The results are also supported by the result of Andriolo *et al*. (1998) in tomato.

Table 1. Genotypic effect on morphological characters of tomato

Mutants/varieties	Plant height (cm)	Branches/plant (no.)	Leaves/plant† (no.)	Leaf area/plant† (cm^2)
Binatomato-4	70.5 e	4.89 ef	45.1 bc	1867 g
Binatomato-5	99.0 bc	6.89 a	53.3 a	3320 ef
TM-113	110.2 a	6.11 bc	42.4 c	5565 cd
TM-127	86.6 d	5.29 de	43.3 c	5230 d
TM-128	104.0 b	6.44 ab	49.6 ab	7937 a
TM-131	83.1 d	4.67 f	36.1 d	6065 bc
TM-132	68.3 e	4.78 ef	33.8 de	2091 g
TM-133	93.9 c	5.78 cd	49.7 ab	6206 b
TM-134	83.1 d	5.00 ef	36.0 d	3721 e
TM-160	68.7 e	4.00 g	30.2 e	2783 f
F-test	**	**	**	**
CV (%)	3.78	5.97	6.70	7.91

In a column figures having same letter (s) do not differ significantly at $P \leq 0.05$;
** indicates significant at 1% level of probability; †: Data was collected at 80 DAT.

Growth parameters

The effect of genotypes on root and total dry mass (TDM), absolute growth rate (AGR) and relative growth rate (RGR) was significant (Table 2). Results showed that high yielding genotypes maintained increased leaf number and leaf area, root weight and TDM plant^{-1} and AGR. RGR had no relation with yield. In contrast, low yielding genotypes showed shorter plant, fewer branches (except Binatomato-5) and leaves, lower AGR and also produced lower TDM plant^{-1}. However, among the genotypes, TM-128 showed higher/highest branch number, leaf number, leaf area, root weight and TDM plant^{-1} and showed higher fruit yield. In contrast, two low yielding mutants, TM-132 and TM-160 produced lower branches, leaves and leaf area, root weight, TDM, AGR and RGR. Increased TDM in TM-128 and TM-133 was possibly might be due to greater LA. Many researcher reported that TDM was positively correlated with leaf area in tomato (Andriolo *et al*., 1998; Mehta and Asati, 2008) that supported present experimental results.

Table 2. Effect of genotype on growth characters of tomato

Mutants/varieties	Root weight/ plant† (g)	Total dry mass/ plant† (g)	Absolute growth rate at 45-65 DAT (g/plant/day)	Relative growth rate at 45-65 DAT (mg/g/day)
Binatomato-4	4.90 f	40.0 f	1.52 ef	71.1 a
Binatomato-5	6.18 e	84.9 c	3.11 bc	66.0 ab
TM-113	6.40 e	57.7 e	2.19 d	71.1 a
TM-127	8.35 c	93.8 b	3.40 ab	64.4 ab
TM-128	11.2 a	102.5 a	3.23 bc	49.0 cd
TM-131	9.37 b	87.9 bc	2.87 c	52.9 c
TM-132	4.31 f	41.0 f	1.21 f	44.5 d
TM-133	8.82 bc	107.3 a	3.75 a	60.1 b
TM-134	7.30 d	71.5 d	2.19 d	47.3 cd
TM-160	4.49 f	54.2 e	1.78 de	53.4 c
F-test	**	**	**	**
CV (%)	5.91	5.28	9.05	6.30

In a column figures having same letter (s) do not differ significantly at $P \leq 0.05$;
** indicates significant at 1% level of probability; †: Data was collected at 80 DAT.

Biochemical parameters

The effect of genotypes on chlorophyll, nitrate reductase (NR) and total sugar in leaves and Vit-C in ripen fruits was significant (Table 3). High yielding genotypes, in general, showed higher NR and total sugar than low yielding ones. Vit-C was greater in small size fruits than bolder ones. Chlorophyll had no relation with yield. Mondal *et al.* (2016) reported that fruit yield was positively correlated with chlorophyll content in leaf. In the present investigation, the mutant TM-133 was high yielder with medium chlorophyll content in leaves. This result indicates that chlorophyll content in leaves is not obligatory for getting higher fruit yield in tomato. However, the highest NR and total sugar was recorded in TM-133, a high yielding genotype. The lowest NR and total sugar was recorded in TM-132, a low yielding genotype. Vit-C was higher in Binatomato-4 and TM-160 whilst TM-127 showed the lowest. Result indicated that in general, small size fruit had higher Vit-C than large size ones. Genotypic variation in chlorophyll content in leaves of tomato was also observed by BINA (2007) that supported the present experimental results.

Table 3. Genotypic effect on biochemical characters of tomato†

Mutants/varieties	Chlorophyll (mg/gfw) †	Nitrate reductase (µmol NO_2^- /gfw) †	Total sugar (mg/gfw) †	Vit-C in ripen tomato (mg/100 gfw)
Binatomato-4	2.65 ab	6.40 c	72.4 cde	20.6 a
Binatomato-5	2.36 b	7.88 a	75.6 a-d	19.1 abc
TM-113	2.68 ab	7.86 a	80.2 ab	18.4 a-d
TM-127	2.60 ab	7.22 b	74.3 bcd	14.8 e
TM-128	2.46 ab	7.90 a	80.6 ab	16.4 cde
TM-131	2.36 b	6.30 c	78.3 abc	15.5 de
TM-132	2.64 ab	5.41 d	66.3 e	20.1 ab
TM-133	2.42 ab	8.11 a	82.5 a	17.3 b-e
TM-134	2.75 a	7.62 ab	73.2 cd	20.0 ab
TM-160	2.64 ab	5.63 d	68.7 de	21.0 a
F-test	*	**	**	**
CV (%)	7.38	4.28	4.89	8.73

In a column figures having same letter (s) do not differ significantly at $P \leq 0.05$;
* and ** indicate significant at 5% and 1% level of probability, respectively;
†: Data was collected at 65 DAT i.e. flowering and fruiting stage.

Reproductive characters

The effect of genotypes on reproductive characters such as number of effective flower clusters plant^{-1}, non-effective flower clusters plant^{-1}, flowers plant^{-1} and reproductive efficiency was significant (Table 4). High yielding genotypes in general produced higher number of effective flower clusters and flowers plant^{-1} than low yielding ones. The highest number of effective flower clusters plant^{-1} as well as reproductive efficiency was recorded in TM-133. The lower number of effective flower clusters, flowers plant^{-1} and reproductive efficiency was observed in TM-113 and TM-132, the low yielding mutants. Result revealed that fruit yield had no relation with non-effective flower cluster plant^{-1}. For example, TM-128, the high yielding mutant, produced the highest number of non-effective flower clusters plant^{-1} (10.0) where as Binatomato-5, the low yielding variety, produced higher number of non-effective flower clusters plant^{-1} (9.89). The lowest number of non-effective flower clusters plant^{-1} was recorded in TM-160 (5.78). Genotypic variation in flower number was also observed by BINA (2008) in tomato that supported the present experimental result.

Table 4. Reproductive characters of ten tomato mutants/varieties

Mutants/varieties	Effective flower clusters/plant (no.)	Non-effective flower clusters/plant (no.)	Flowers/ Plant (no.)	Reproductive efficiency (%)
Binatomato-4	14.9 cd	9.11 cd	69.2 cd	73.0 a
Binatomato-5	18.4 b	9.89 ab	81.7 a	52.8 cd
TM-113	10.1 g	6.22 fg	52.3 f	56.5 cd
TM-127	13.5 ef	9.33 bc	62.0 e	66.4 b
TM-128	16.0 c	10.0 a	80.2 a	58.7 c
TM-131	14.6 de	6.66 f	67.7 cd	54.9 cd
TM-132	13.2 f	9.11 cd	74.6 b	51.9 d
TM-133	19.7 a	7.33 e	70.9 bc	78.2 a
TM-134	18.4 b	8.62 d	65.5 de	75.7 a
TM-160	13.8 def	5.78 g	43.1 g	78.9 a
F-test	**	**	**	**
CV (%)	4.28	4.41	4.21	5.11

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** indicates significant at 1% level of probability.

Yield contributing characters and fruit yield

The effect of genotypes on yield contributing characters and yield was significant (Table 5). Result revealed that five mutants out of eight showed higher fruit yield than the two check cultivars. The highest fruit yield both per plant and hectare was recorded in TM-133 (2.86 kg plant^{-1} and 100.1 t ha^{-1}) due to production of highest number of fruits plant^{-1}. The lower fruit yield was recorded in TM-113 (1.48 kg plant^{-1} and 51.8 t ha^{-1}) and TM-132 (1.35 kg plant^{-1} and 47.3 t ha^{-1}) due to production of fewer fruits plant^{-1}. Most of the researchers reported that fruit yield in tomato mostly depend on fruit number and fruit size (Mondal *et al*., 2004; Sharma *et al*., 2006; Mondal *et al*., 2016) that supported the present experimental results.

Table 5. Genotypic effect on yield and yield attributes of tomato

Mutants/varieties	Fruits/plant (no.)	Single fruit weight (g)	Fruit weight/plant (kg)	Fruit yield (t/ha)
Binatomato-4	44.0 d	43.6 e	1.92 d	67.2 e
Binatomato-5	48.3 cd	38.0 f	1.84 d	64.4 e
TM-113	19.5 g	75.7 a	1.48 e	51.8 f
TM-127	47.2 cd	48.3 cd	2.28 c	79.8 d
TM-128	49.8 bc	60.4 b	2.67 ab	93.4 b
TM-131	54.0 ab	53.0 c	2.54 ab	88.9 bc
TM-132	28.9 f	46.7 de	1.35 e	47.3 f
TM-133	58.1 a	49.2 cd	2.86 a	100.1 a
TM-134	51.2 bc	48.9 cd	2.40 bc	84.0 cd
TM-160	35.4 e	51.4 cd	1.82 d	63.7 e
F-test	**	**	**	**
CV (%)	6.88	6.03	9.38	5.48

In a column figures having same letter (s) do not differ significantly at $P \leq 0.05$;
** indicates significant at 1% level of probability.

Correlation

Phenotypic correlation coefficients among different quantitative characters are presented in the Table 6. Fruit yield plant^{-1} was positively and significantly correlated with leaf area (r = 0.62**), total dry mass (r = 0.78**), nitrate reductase (r = 0.42*), total sugar (r = 0.52**), absolute growth rate (r = 0.69**), the number of flower cluster (r = 0.58**) and fruits plant^{-1} (r = 0.81**) but showed negative association with chlorophyll (r = -0.34) and relative growth rate (r = -0.15). Therefore, fruit yield could be improved by selecting increased leaf area, TDM and increased number of flower cluster in tomato.

However, number of fruits plant^{-1} was highly significant and positively correlated with TDM plant^{-1} (r = 0.70**), AGR (r = 0.63**) and number of flower cluster plant^{-1} (r = 0.80**) but significantly negative associated with fruit size (r = -0.46**). It means fruit size and number is negatively associated with each other. Interestingly, chlorophyll and RGR had no significant positive association in most of the plant characters indicating chlorophyll content in leaves and RGR should not be considered for tomato improvement but nitrate reductase and AGR should be considered. The above results are supported by many workers in tomato (Singh and Raj, 2004; Sharma *et al*., 2006).

Table 6. Simple correlation coefficient among different characters of tomato mutants/variety†

Characters	Leaf area plant^{-1} (cm^2)	Total dry mass plant^{-1} (g)	Chlorophyll (mg g^{-1} fw)	Nitrate reductase (µmol NO_2^- /gfw)	Total sugar (mg g^{-1} fw)	Absolute growth rate (g p^{-1} d^{-1})	Relative growth rate (mg g^{-1} d^{-1})	Flower clusters plant^{-1} (no.)	Flowers plant $^{-1}$ (no.)	Reproductive efficiency (%)	Fruits plant^{-1} (no.)	Single fruit weight (g)
Fruit yield	0.62**	0.78**	- 0.34	0.42*	0.52**	0.69**	- 0.15	0.58**	0.26	0.30	0.81**	0.09
Fruit number	0.44*	0.70**	- 0.45*	0.45*	0.34	0.63**	- 0.18	0.80**	0.45*	0.32	---	- 0.46**
Single fruit weight	0.52**	0.003	0.12	0.26	0.38*	0.01	0.07	- 0.55**	- 0.42*	- 0.15	- 0.46*	---
Plant height	0.71**	0.57**	- 0.22	0.84**	0.67**	0.62**	0.30	0.06	0.21	- 0.30	0.04	0.54**
Branch number	0.44*	0.47**	- 0.23	0.77**	0.51**	0.52**	0.36*	0.25	0.53**	- 0.41*	0.08	0.14
Leaf area	---	0.80**	- 0.31	0.60**	0.72**	0.74**	- 0.09	0.08	0.16	- 0.15	0.44*	0.52**
Total dry mass		---	- 0.51**	0.64**	0.61**	0.95**	- 0.08	0.51**	0.35*	0.002	0.70**	0.003
Chlorophyll			---	- 0.22	- 0.25	- 0.42*	- 0.04	- 0.28	- 0.31	0.23	- 0.45*	0.12
Nitrate reductase				---	0.68**	0.66**	0.31	0.42*	0.29	0.05	0.45*	0.26
Total sugar					---	0.64**	0.29	0.22	0.16	- 0.10	0.34	0.38*
Absolute growth rate						---	0.13	0.44*	0.30	0.004	0.63**	0.008
Rrelative growth rate							---	- 0.19	- 0.14	0.03	- 0.18	0.07
Flower cluster number								---	0.54**	0.34	0.80**	- 0.55**
Flower number									---	- 0.42*	0.45*	- 0.42*

*, ** significant at 5 and 1% level of probability; †: Fruit yield and other yield attributes had no significant positive correlation with plant height and branch number.

Conclusion

From the results above, it may be concluded that (i) Leaf area was the most important sources that determined TDM yield, (ii) Number of flower cluster was the main sink determining organ of flowers and fruits production and (iii) Correlation analysis indicated that number of flower clusters plant^{-1}, fruits plant^{-1} and fruit size contributed maximum to fruit yield in tomato, and the mutants TM-133 and TM-128 maintained superiority in the above characters, resulting higher fruit yield. This information may be implemented in the future plant breeding programme.

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