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Genetic variation in auxin sensitivity and its association with yielding ability in tomato (*Solanum lycopersicum* L.): An alternative approach for screening of high yielding tomato genotypes

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Abstract
Study on *ex-vivo* variation in auxin response of tomato genotypes has certain novelty as auxin is an important plant growth regulator. Significance of such variation in relation to yielding ability is quite interesting. In the present investigation, stem cuttings from epicotyls region of 25-30 days old seedlings of twenty two genotypes were treated with kept in IBA solution of 500 ppm concentration for 45 seconds to take observation on the root length (longest), roots produced from stem cutting, fresh roots weight and frequency of rooted cuttings. Coefficient of variation due to genotypes (GCV) for number of induced roots, root length and fresh root weight was 34.88, 29.84 and 51.15. The genotypes showed wide variation in their auxin induced rooting index (ARI) values that ranged from 0.25 to 3.50 with an average of 1.93. Based on ARI value tomato genotypes were classified as low auxin response (LAR) group and high auxin response (HAR) group. The mean ARI value of HAR group was 3.200 whereas it was 0.875 in case of LAR group. The frequency of high yielders in HAR group was 0.80 and that of in LAR group it was 0.17. ARI parameter exhibited significant and positive correlation with yielding ability (0.562). The relationship between auxin response and yield was confirmed from 2 x 2 contingency $\chi 2$ test. This study suggests that auxin sensitivity may be used as an alternative approach for screening of tomato genotypes having high yield potential. This approach is simple and cost effective.

Keywords: Tomato, auxin sensitivity, GCV, PCV, selection & high yield

Introduction

Auxins are important plant hormones known to control growth, development and physiological processes in plants. Auxins are usually used to promote adventitious root development of stem cuttings and encourage vegetative propagation. IBA (Indole butyric acid) is used to promote the formation of roots for vegetative propagation of hybrids as well as improved high yielding varieties through stem cuttings (Waheed *et al.*, 2015 & Kachru *et al.*, 2017) [10, 5]. Use of auxin for vegetative propagation of plants is a worldwide phenomenon but its use for screening of high yielders at early growth stage is completely a novel concept.

The most important objective of plant breeding is to increase yield. For identification of high yielding genotypes the breeder needs multi-location testing which is very expensive and time consuming. Development of simple, rapid and inexpensive methods for preliminary screening of high yielding genotypes in the laboratory could save time and expenses incurred in multi-location trials. With this idea the present experiment was undertaken to study variation in auxin induced rooting response of tomato genotypes at seedling stage and to establish relationship of auxin response with yielding ability. King and Stimart (1998) [6] observed difference in development of lateral roots due to auxin treatment among different ecotypes of *Arabidopsis thaliana.* It is worth to expect that differences in auxin (IBA) response may form an important part of the physiological process through which the genotypes show their action to produce genotypic variation. Such variation in auxin induced rooting at genotypic level may give some clues regarding its association with argonomically desirable traits like yield.

Many researchers used auxin (IBA) to induce roots for vegetative propagation of horticultural and forest plants. To the best of the authors' knowledge the use of auxin for screening of tomato genotypes (indirect approach) with high yielding ability at early stage has not been attempted. This experiment was undertaken to study variation in IBA induced rooting response of tomato genotypes and to correlate auxin response with yielding ability.

Materials and Methods

In this Investigation 22 tomato genotypes (name of genotypes is mentioned in Table 1) were used and seeds of these genotypes were collected from AICRP on Vegetable Crops, OUAT, Bhubaneswar.

Lab experiment

The stem of one month old seedlings was cut at a distance of ten centi-metres above the cotyledon and the excised stems (10 cuttings for each genotype) were kept in beakers containing 20 ml of 500 ppm aqueous IBA solution for 45 seconds. Then tap water was used for thorough washing of the treated stem cuttings. Finally, stem cuttings were transferred to beakers filled with distilled water to observe root formation in tomato genotypes. Randomly 5 numbers of cuttings were selected on 10th day of treatment. Observations were noted on the longest root length, number of roots formed, fresh weight of roots and number of stem cuttings having roots (frequency). The laboratory experiments were done following completely randomised design with 2 replications. The experiments were repeated 4 times.

Auxin induced rooting index (ARI) was estimated to reveal variation in auxin response of tomato genotypes. ARI parameter was determined in following manner. The traits considered for this study were scored as 'zero' and 'one' for below average and above average value in respect of each trait respectively. Then the scored values of all the traits of a genotype in an experiment were added to obtain ARI value. The data were analysed following SAS Software 9.3 version to estimate GCV and PCV for different traits. F-test and t-test was done to study the significance of differences among the genotypes for ARI parameter through critical difference (CD). High value of ARI parameter indicates high auxin response.

Field Experiment

Yield potential of the genotypes was evaluated in a randomised block design with three replications at Horticultural Research Station, OUAT, Bhubaneswar during the year 2018-19 and 2019-20. On 1st week of November tomato seeds of different genotypes were sown in nursery. Seedlings at the age of 25 days were transplanted in the main field with a spacing of 60 cm x 40 cm. Recommended dose of fertilisers (NPK @ 125:100:120 kg per ha) and farm yard manure @ 25 tonnes/ha were applied to raise the normal crop. Irrigation was given at the time of requirement. Different cultural practices were uniformly followed to grow the crop successfully. Five plants were selected randomly from each plot to record observations on fruit yield per plant.

Correlation analysis was done as described by Panse and Sukhatme (1985) [7] to find the association of ARI parameter with yielding ability. Twenty two genotypes were classified as high auxin response (HAR; those having above average ARI value) and low auxin response (LAR; those having below average value) groups. Again 22 genotypes were classified as above average yielders (high yielders) and below average yielders (low yielders). A 2 x 2 contingency classification table was also followed to confirm the association of ARI parameter with yielding ability. The frequencies of genotypes in the four contingency classes i.e. high ARI and high yield; high ARI and low yield; low ARI and high yield and low ARI with low yield were estimated to calculate chi-square value. A significant $\chi2$ value indicates the presence of relationship.

Results and Discussion

Genotypic variation in root traits

In this investigation, significant variation was observed between the genotypes for the root traits under study (Table 1). Longest root length of the genotypes ranged from 1.21 to 4.17 cm. Utkal Kumari (BT 10) recorded the highest root length (4.17 cm) and was significantly superior from others. The lowest root length was observed in case of BT 306-1-2. Number of lateral roots produced (NLR) per cutting ranged from 12.23 to 47.53 with an average of 27.07. The genotype BT-317 recorded the maximum number of lateral roots (47.53) and it was at par with BT 506-1(44.00). Fresh root weight (FRW) of the genotypes ranged from 0.018 to 0.120 g with an average of 0.070 g (Table 1). Frequency of stem cuttings that produced lateral roots when treated with IBA was found to vary from 0.30 (30%) to 1.00 (100%). BT 433-2-3 recorded the lowest frequency (0.30) whereas BT-101 (1.00) had the maximum frequency for number of rooted cuttings. Hybrid Arka Rakshak produced roots in 80% of the stem cuttings. This result indicated that vegetative propagation of hybrids could be encouraged to retain the quality of hybrids.

The parameters like range, genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were estimated to quantify the extent of variation for different root traits. Range, GCV and PCV parameters for the length of the longest root were 1.21 - 4.17, 29.84 and 34.81 respectively (Table 1). Range, GCV and PCV parameters for number of lateral roots were 12.23 – 47.53, 34.88 and 37.17 respectively. Range, GCV and PCV parameters for fresh root weight were 0.018 - 0.120, 51.15 and 61.69 respectively. Range, GCV and PCV parameters for frequency of rooted cuttings were 0.30-1.00, 26.72 and 35.35 respectively (Table 1).

Classification of Tomato Genotypes Based on Auxin Response

The ARI value of genotypes averaged over experiments varied from 0.25 to 3.50 (Table 2). BT 433-2-3 had the lowest ARI value, where as genotypes BT 12-2, BT 112-1, BT 428-3 and BT 506-1 recorded the highest ARI value of 3.50.

Based on ARI parameter, 22 tomato genotypes were classified into two classes. The genotypes having above mean ARI value (1.93) were considered to have high auxin response (HAR) and genotypes having below mean ARI value were considered to have low auxin response (LAR) (Table 2). The mean ARI value of high auxin response class was 3.20 whereas it was 0.88 in case of LAR class. The average root length, number of lateral roots, fresh root weight and frequency of rooted cuttings of the genotypes present in HAR class was 2.77 cm, 35.60, 0.095 g and 0.89. The average root length, number of lateral roots, fresh root weight and frequency of rooted cuttings of the genotypes present in LAR class was 1.80 cm, 19.97, 0.038 g and 0.57. Characterisation of HAR and LAR class was done on the basis of fruit yield per plant. Fruit yield of tomato genotypes is presented in Table 2. Fruit yield/plant ranged from 718.50 to 2437.00 g with a mean value of 1496.64 g. The highest yield of 2437.00 g was observed in case of Arka Rakshak and it was at par with BT 101 (2164.00 g). Pusa Ruby exhibited the lowest yield of 718.50 g. Genotypes having above mean yield (> 1496.64 g) were considered as high yielders and those had below mean yield (<1496.64 g) were considered as low yielders. Ten out of twenty two genotypes (Table 2) were noted to have above mean yield and others had below mean yield. The mean fruit yield of the genotypes included in HAR class was 1732.70 g and the mean yield of the genotypes in LAR class was 1299.75 gram.

Table 1: Variation in root traits of treated stem cuttings

Genotype	Root Length (cm)	No. of Lateral Roots	Fresh root weight (g)	Frequency of rooted cutting
V1. BT 1	2.09	21.13	0.039	0.60
V2. BT 10	4.17	35.89	0.120	0.88
V3. BT-17	1.63	13.61	0.018	0.53
V4. BT-101	2.05	33.61	0.089	1.00
V5. BT-106	2.34	24.53	0.052	0.65
V6. BT-136	2.84	33.20	0.093	0.98
V7. BT-317	2.19	47.53	0.114	0.95
V8. BT 12-2	2.89	35.84	0.098	0.88
V9. BT 112-1	3.20	35.41	0.073	0.85
V10. BT 428-3	2.54	34.48	0.075	0.98
V11. BT 442-2	2.19	18.06	0.055	0.68
V12. BT 506-1	3.11	44.00	0.119	0.98
V13. BT12-3-2	1.52	21.10	0.022	0.60
V14. BT 17-2-5	1.31	19.05	0.028	0.38
V15. BT 19-1-1-1	1.92	20.08	0.039	0.53
V16. BT 22-4-1	1.92	28.41	0.067	0.70
V17. BT 306-1-2	1.21	18.38	0.018	0.65
V18. BT 429-2-2	1.94	12.23	0.020	0.45
V19. BT 433-2-3	1.84	15.90	0.025	0.30
V20. Arka Vikas	1.68	27.13	0.074	0.78
V21. Pusa Ruby	1.98	25.50	0.094	0.63
V22. Arka Rakshak	2.69	30.58	0.072	0.80
Mean	2.24	27.07	0.064	0.71
CD (1%)	0.57	8.21	0.070	0.17
Mean sum of square	1.948**	367.36**	4.746**	0.170**
Range	1.21 – 4.17	12.23-47.53	0.018-0.120	0.30-1.00
GCV	29.84	34.88	51.15	26.72
PCV	34.81	37.17	61.69	35.35

Table 2: Characterisation of tomato genotypes included in HAR and LAR class

Genotype	ARI	RL	NLR	FRW	FRC	Yield/ plant (g)
HAR class						
V2. BT 10	3.25	4.17	35.89	0.120	0.88	1611.50
V4. BT-101	3.00	2.05	33.61	0.089	1.00	2164.00
V6. BT-136	3.25	2.84	33.20	0.093	0.98	1742.00
V7. BT-317	3.25	2.19	47.53	0.114	0.95	1881.00
V8. BT 12-2	3.50	2.89	35.84	0.098	0.88	1776.50
V9. BT 112-1	3.50	3.20	35.41	0.073	0.85	1385.00
V10. BT 428-3	3.50	2.54	34.48	0.075	0.98	1950.50
V12. BT 506-1	3.50	3.11	44.00	0.119	0.98	1661.00
V21. Pusa Ruby	2.25	1.98	25.50	0.094	0.63	718.50
V22. Arka Rakshak	3.00	2.69	30.58	0.072	0.80	2437.00
Mean	3.20	2.77	35.60	0.095	0.89	1732.70
LAR class						
V1. BT 1	0.50	2.09	21.13	0.039	0.60	970.50
V3. BT-17	0.50	1.63	13.61	0.018	0.53	1282.50
V5. BT-106	1.75	2.34	24.53	0.052	0.65	1119.50
V11. BT 442-2	1.75	2.19	18.06	0.055	0.68	1427.50
V13. BT 12-3-2	0.75	1.52	21.10	0.022	0.60	974.50
V14. BT 17-2-5	0.75	1.31	19.05	0.028	0.38	1927.50
V15. BT 19-1-1-1	0.75	1.92	20.08	0.039	0.53	1379.50
V16. BT 22-4-1	1.00	1.92	28.41	0.067	0.70	1098.00
V17. BT 306-1-2	0.50	1.21	18.38	0.018	0.65	1457.00
V18. BT 429-2-2	0.75	1.94	12.23	0.020	0.45	1178.50
V19. BT 433-2-3	0.25	1.84	15.90	0.025	0.30	1216.50
V20. Arka Vikas	1.25	1.68	27.13	0.074	0.78	1565.50
Mean	0.88	1.80	19.97	0.038	0.57	1299.75
Grand Mean	1.93	2.24	27.07	0.064	0.71	1496.64

Relationship between ARI Parameter and Yield/plant

The association between yield and ARI parameter was analysed following correlation study and 2 x 2 contingency classification tables. Correlation study revealed significant positive association of ARI parameter (0.562) with yield (Table 3). Correlation of individual root characters was tried to visualise which root parameter can give indication for preliminary screening of high yielding tomato genotypes. It was observed that number of roots produced per cutting (NLR), fresh root weight (FRW), and frequency of rooted cuttings (FRC) all exhibited significant and positive correlation with yield except root length which had only positive correlation. The correlation coefficient of RL, NLR, FRW, and FRC with yield was 0.278, 0.497, 0.483, and 0.535 (Table 3). The positive correlation of different auxin induced root parameters and fruit yield was explained through coefficient of determination (R^2) in Table 3. Higher value of R^2 indicates strong linear relationship between two parameters. The coefficient of determination in case of fruit yield and root length was low (0.077) because of lower correlation coefficient value; R^2 value in case of fruit yield and number of lateral roots was higher (0.247) as compared to root length because of significant positive correlation between fruit yield and number of lateral roots; R^2 value in case of fruit yield and fresh root weight was 0.154; R^2 value in case of fruit yield and rooted cuttings was 0.286. But the coefficient of determination in case of fruit yield and auxin induced rooting index (ARI) value was the highest (0.315).

Table 3: Relations of different root traits with fruit yield/plant

Correlation coefficient					
	ARI	**NLR**	**FRW**	**RL**	**FRC**
Fruit Yield	0.562**	0.497*	0.483*	0.238	0.535**
Coefficient of determination					
	ARI	NLR	FRW	RL	FRC
Fruit Yield	0.315	0.247	0.154	0.077	0.286

The 2 x 2 contingency table (Table 4) revealed that on the basis of ASI value, ten of twenty two tomato genotypes were included in high auxin response (HAS) class and eight of ten HAS genotypes were high yielders (HY). In contrast ten of the twelve LAS genotypes were low yielders (LY). Contingency chi-square value was found to be significant (8.79) and it indicated that the distribution of the genotypes was non random and HAS class had high frequency of high yielding genotypes. In conformity, the HAS class has higher average yield of 1732.70 g/plant against 1299.75 g/plant of the LAS class (Table 3). This indicates that auxin response has certain relationship with yielding ability.

Table 4: 2 x 2 contingency table of ARI parameter and yield

Class	**Number of genotypes**	**Yield class**		**$\chi 2$ value**
		HY	LY	
HAR	10	8	2	
				8.79*
LAR	12	2	10	

Adoption of high-yielding varieties is the most important prerequisite for substantial improvement in crop productivity. Therefore, developing crop varieties with high yield potential is a major breeding objective. Evaluations of newly bred crop genotypes for yield through field testing are expensive and time taking process. Thus, it was felt necessary to look for an alternative inexpensive and quick method that would enable breeders to make a preliminary evaluation of the large number of breeding lines.

IBA is a plant bio-regulators belonging to the auxin group. IBA regulate growth and influence various developmental processes, including stem elongation, early root formation, callus formation, enhances flowering, enzyme induction and leaf and fruits senescence (Waheed *et al.* 2015) [10]. IBA is the leading plant hormone used to promote the formation of roots and to generate new roots in the cloning of tomato plants through cuttings (Waheed *et al.* 2015) [10].

The investigation was undertaken with an objective of developing some easy, quick and inexpensive laboratory methods for evaluating yield potential of tomato genotypes before going for the more expensive multi-location trials such as initial evaluation trial (IET) and advanced varietal trials (AVT-I & AVT-II). Simple laboratory predictive techniques reduce the cost and help in preliminary and off-season evaluation of newly developed genotypes of different crop plants (Das *et al*., 2010) [3]. Chemical response of seedling is a simple approach to such laboratory evaluation of yield performance (Sinha *et al*., 2010; Das *et al*., 2010; Das, 2016) [9, 3, 4]. The use of GA to screen wheat germplasm for yield potential was reported by Boyd and Wade (1989) [1]. Use of malefic hydrazide to screen rice and finger millet genotypes for yield and adaptability was suggested by Das *et al.* (2008) [2]. IBA was used by Singh *et al.* (2011) [8] for laboratory evaluation of yielding ability and adaptability in green gram.

Induction of roots in IBA treated stem cuttings of tomato genotypes

Conclusion

The present investigation indicates that variation in auxin induced root traits of tomato genotypes may be used for preliminary screening of high yielding tomato genotypes at early stage. This new approach is simple, quick and cost effective.

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