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Tomato genotypes grafted on eggplant: Physiological and biochemical tolerance under waterlogged condition

Anant Bahadur*, KK Jangid, Amit K Singh, Umesh Singh, KK Rai, Manish K Singh, Nagendra Rai, PM Singh, AB Rai and B Singh

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Abstract

Grafting has been used to reduce infections by soil-borne pathogens and to enhance the tolerance against abiotic stresses. Under natural environmental conditions, tomato plants often get exposed to transient waterlogging situation. Eggplant as a rootstock for tomato has ability to tolerate waterlogging condition to some extent. An experiment was conducted to evaluate 20 tomato genotypes grafted on brinjal rootstock 'IC-111056' at ICAR-Indian Institute of Vegetable Research, Varanasi, India under waterlogged condition during 2016. Grafted plants were exposed to waterlogged condition in a big water tank for 96 h. Various physiological, biochemical and yield parameters such as, chlorophyll content index (CCI), *chl* a, *chl* b and total *chl* content, chlorophyll fluorescence yield (Fv/ Fm), H_2O_2, CAT, SOD, proline, MDA, etc were recorded after 96 h of waterlogging, and subsequently 24 h after relieving the stress condition. All 20 combinations of tomato and brinjal grafted plants showed high variation in physiological, biochemical and yield parameters under waterlogging stress. Highest yield was obtained in scion EC-528422 followed by Kashi Aman, WIR-13706, D-3-1, EC-620354 and EC-620401grafted over eggplant rootstock IC-111056. These graft combinations have also registered better physiological and biochemical adaptations during and after relieving from waterlogging stress.

Keywords: Grafting, tomato, waterlogging tolerance, physiological and biochemical traits

Introduction

Grafting was initially started with the objective to reduce infections by soil-borne pathogens, but recently to enhance the tolerance to abiotic stresses such as soil salinity, drought and waterlogging (Bray *et al.*, 2001, Yassin and Hussen, 2015, Bhatt *et al*, 2015, Bahadur *et al*, 2015). Grafting elite, commercial cultivars onto selected vigorous rootstocks are able to counteract environmental stresses (Lee and Oda, 2003). It is nowadays regarded as a rapid alternative tool to the relatively slow breeding methodology aimed at increasing environmental-stress tolerance of fruit vegetables (Flores *et al*., 2010). In northern Indian plain, tomato plants often get exposed to transient waterlogging situation during early vegetative stage. Tomato plants are very sensitive to waterlogging conditions, and they can survive for 48 h of waterlogging situations (Bahadur *et al*, 2015). The plants growing on the waterlogged soil face the stressful environment in terms of reduced availability of oxygen; this may be hypoxia (deficiency of O_2) or anoxia (absence of O_2). Water logging stress causes harmful symptoms such as epinasty, leaf chlorosis and reduced fruit yield in tomato (Ezin *et al*., 2010). The success of grafting largely depends on the selection of the rootstock and the grafting technique employed. Rootstock-scion combinations need to be tested in order to optimize the crop performance and promote commercial acceptance of the technique.

Plants display a variety of physiological and biochemical responses at cellular and whole-organism levels towards prevailing abiotic stresses in order to obtain an increase in the plant protective mechanisms. To prevent or alleviate the deleterious effect of abiotic stresses, plants produce a complex antioxidants system to detoxify reactive oxygen species (ROS), which includes low-molecular mass antioxidants as well as antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT) and enzymes involved in the ascorbate–glutathione cycle. The activities of these antioxidant enzymes are increased in response to abiotic stresses. A simultaneous increase in several components of the anti-oxidative defense system would be necessary in the plant adoption to abiotic

ICAR-Indian Institute of Vegetable Research, Varanasi– 221305, Uttar Pradesh
*Corresponding author, Email: singhab98@gmail.com

stresses (Jaleel *et al.*, 2009). Keeping in view the above facts, the present investigation was carried out to study the effect of waterlogging stress on survival, physiological, biochemical and yield traits of tomato plant grafted on eggplant rootstock.

Materials and Methods

Plant materials and exposure to waterlogging stress: The experiment was conducted at ICAR-Indian Institute of Vegetable Research, Varanasi in 3 cemented open water pond (LBH= 2.5 × 1.25 × 0.60 m^3) with maintaining 8 to 10 cm water above the pot soil surface for 96 h during vegetative stage using eggplant (*Solanum melongena* L.) rootstock IC-111056 grafted with twenty different tomato (*Solanum lycopersicum*) scions (1–20) where (1= CLN-2026; 2= C-9-1; 3= EC-715382; 4= E-4-1; 5= Kashi Aman; 6= E-5-1; 7= WIR-13706; 8= C-1-1; 9= DARL-66; 10= EC-528422; 11= EC-620456; 12= EC-620354; 13= CLN-1621; 14= D-3-1; 15= E-1-1; 16= Kashi Chayan; 17= EC-621661-B; 18= EC-620402; 19= EC-521047 and 20= EC-620401). After 96 h of waterlogging stress, water was released from tank and plants were kept in recovery period of 24 h.

Chlorophyll content and Chlorophyll fluorescence yield (Fv/Fm): Chlorophyll *a*, *b* and total chlorophyll contents of 96 h waterlogged stressed and 24 h recovered tomato leaves were estimated according to method of Arnon (1949) and expressed as mg/ g fresh weight of leaves. Tomato leaves (200 mg) were homogenized in 5.0 mL of acetone and centrifuged at 4000 x g for 20 min. The supernatants were combined and volume was made to 20 mL with 80% acetone. Absorbance was measured at 645, 663 and 480 nm using IMPLEN nano-photometer, with 80% acetone as blank. The amount of chlorophyll was calculated as under:

$$\text{Chlorophyll } a = 12.7\ (A663) - 2.69\ (A645) \times \frac{V}{1000 \times w \times a}$$

$$\text{Chlorophyll } b = 22.9\ (A645) - 4.68\ (A663) \times \frac{V}{1000 \times w \times a}$$

$$\text{Total chlorophyll} = 20.2\ (A645) + 8.02\ (A663) \times \frac{V}{1000 \times w \times a}$$

Where: a = Path length of light (1 cm); A = Absorbance of the chlorophyll extract at the specified wavelength and V = Final volume of the 80% acetone chlorophyll extract.

Chlorophyll concentration index (CCI) of leaf was measured with CCM-200 Portable Chlorophyll Meter (Opti-Sciences, Tyngsboro, MA) at the ratio of 655/ 940 nm. This parameter was recorded 24 h after relieving from waterlogging stress. Leaf chlorophyll fluorescence was measured with Plant Efficiency Analyzer (Hansatech Instrument Co. Norfolk, UK). The minimal fluorescence (Fo), maximum fluorescence (Fm) and the ratio of variable fluorescence (Fv = Fm - Fo) to maximum fluorescence (Fv/Fm) were recorded 24 h after relieving from waterlogging stress at the adaxial surface of top third leaf adopted for 30 minutes in dark.

Hydrogen peroxide (H_2O_2): H_2O_2 levels were estimated according to Jana and Choudhuri (1981). 200 mg tomato leaf sample after 96 h waterlogging and 24 h recovery were extracted in 5 ml of 50 mM phosphate buffer (pH 6.5). It was centrifuged at 7,000 x g for 20 min. Solution of 1 ml of 0.1 % titanium sulfate in 20 % H_2SO_4 was mixed with 3 ml extracted solution and centrifuged again at 7000 x g for 15 min. Yellow colored solution was produced after reaction. OD was measured at 410 nm by IMPLEN nano-photometer. H_2O_2 calculation was done with an extinction coefficient of 0.28 µ mol/cm and expressed as µ mol/ g fresh weight.

Catalase (CAT) activity: Catalase activity was estimated in 96 h water logging stressed and 24 h recovered tomato leaves according to Teranish *et al.* (1974). Reaction mixture (3 mL) consisted of 1ml of 6 mM H_2O_2 and 1.9 mL of 0.1 M phosphate buffer (pH-7.0) in test tubes and the reaction was initiated by adding 0.1 mL of diluted enzyme extract. The reaction was stopped after 5 min by adding 4ml of titanium reagent which also formed coloured complex with residual H_2O_2. The reaction mixture without enzyme served as the control and developed maximal colour with titanium reagent. Aliquots were centrifuged at 10000 x g for 10 min and the absorbance recorded at 415 nm using IMPLEN nano-photometer. The residual H_2O_2 content in sample was computed with the help of standard curve.

Proline content: Proline level of 96 h water logging stressed and 24 h recovered tomato leaves were estimated by Bates *et al.* (1973). Tomato leaf sample (0.5 gm) was homogenized in 5 mL of 3% sulpho-salicylic acid. It was centrifuged at 6000 x g for 10 min and supernatant was saved. 2 mL of this extract was taken in the test tube and 2 mL each of ninhydrin reagent and 2 mL glacial acetic acid was added. The reaction mixture was put in boiling water bath for 30 min. After cooling, the reaction mixture was added with 5 mL toluene. Then solution mixture was shaken vigorously and toluene fraction was separated using separating

funnel. The absorbance of toluene fraction was read at 520 nm with the help of IMPLEN nano-photometer against toluene blank. Concentration of proline in the plant samples was estimated by referring to a standard curve of proline.

Malondialdehyde *(*MDA*)* content: Heath and Packer (1968) method was used for the estimation of MDA content in 96 h water logging stressed and 24 h recovered tomato leaves. Leaf sample (500 mg) of 96 h stressed and 24 h recovery were homogenized in 5.0 ml of 0.1 % TCA comprehended with 0.5 % of butylated hydroxyl-toluene and 1% PVP. It was centrifuged at 12000 x g for 30 min 0.5 and 20 % of TBA and TCA were added in 4.0 ml supernatant and boiled for 30 min. After boiling it was transferred to ice solution for immediate cooling. Centrifuged again at 12000 x g for 10 min. OD of supernatant was measured at 532 and 600 nm by IMPLEN nano-photometer. Calculation was made an extinction coefficient of 155 n mol/ g and the concentrations were expressed as µ mol/ g fresh weight. The MDA equivalent was calculated as follows:

$$\text{MDA [µM /g FW]} = [(A_{532}–A_{600})/155] \times 10^6$$

Superoxide dismutase (SOD) activity: Estimation of Superoxide dismutase (SOD) activity in 96 h waterlogging stressed and 24 h recovered tomato leaves was assayed by the method of Dhindsa *et al*. (1981). Tomato leaf samples (1.0 gm) was grinded with 10 mL of extraction buffer (0.1 M phosphate buffer, pH 7.5 containing 0.5mM EDTA) and centrifuge machine at 10000 x *g* for 10 min. Reaction mixture (3 mL) containing 0.1mL of 1.5 M sodium carbonate, 0.2 mL of 200 mM methionine, 0.1mL of 2.25mM NBT, 1.5mL of 100mM potassium phosphate buffer, 0.1mL of 3mM EDTA, 0.1 mL of enzyme extract and 1mL of distilled water were taken in test tubes in duplicate for each enzyme sample. Control was taken as two tubes without enzyme extract. The addition of 0.1 mL riboflavin (60 µM) started the reaction. The tubes was kept below a light source of two 15 W fluorescent lamps for 15 min. Reaction was stopped by switching off the light and covering the tubes by black cloth. Tubes without enzyme extract developed maximum colour. A non-irradiated complete mixture served as blank. Absorbance was recorded at 560 nm in spectrophotometer.

Enzyme Unit (EU) =

$$\frac{\text{Enzyme}^{(-)}{}_{\text{light}} - (\text{Enzyme}^{(+)}{}_{\text{light}} - \text{Enzyme}^{(+)}{}_{\text{dark}})}{\text{Enzyme}^{(-)}{}_{\text{light}} / 2}$$

Where: (-) = without enzyme and (+) = with enzyme

The EU was expressed on per gram fresh weight basis.

Statistical analysis: In this experiment, completely randomized design (CRD) with three replications was used and one-way analysis of variance (ANOVA) was applied by using SPSS (version 16.0). Within the columns same letters are not significant. Data were presented in the form of mean ± standard error mean (SEm). At 0.05 probabilities level Duncan's multiple range test (DMRT) was used for separation of means.

Results and Discussion

Physiological attributes

Chlorophyll fluorescence yield (Fv/Fm): Significant differences in terms of chlorophyll fluorescence yield (Fv/Fm) were observed in grafted tomato genotypes. Fv/Fm ranges from 0.53 to 0.79 in 96 h waterlogging and 0.44 to 0.75 after 24 h recovery, presented in Fig. 1. After 96 h waterlogging treatment maximum chlorophyll fluorescence was recorded in EC-528422 (0.79) followed by WIR-13706 (0.77), D-3-1 (0.75) and EC-620401(0.75), while E-5-1 showed minimum fluorescence yield (0.53). After 24 h of relieving water stress, chl. fluorescence showed slight reduction, and maximum Fv/Fm was noticed in EC-528422 (0.75) followed by CLN-2026, E-4-1 and Kashi Aman (0.73). In contrast, Kashi Chayan showed minimum fluorescence yield (0.27). According to Ezin *et al.* (2010) chlorophyll fluorescence reduced in some tomato genotypes under waterlogging stress. In our findings, some tomato genotypes such as EC-528422 (0.79), WIR-13706 (0.77) and D-3-1 (0.75) have showed better fluorescence yield (Fv/Fm) then others, the higher Fv/Fm can be good selection criteria for abiotic stress tolerance (Percival, 2004). Chlorophyll fluorescence is an important photosynthetic parameter to estimate the performance of plants under abiotic stress (Maxwell and Johnson, 2000). Reduced Fv/Fm shows damage in thylakoid membranes and disturbance in photosynthetic electron transport system (Havaux and Lannoye, 1983). Earlier, Bahadur *et al* (2015) also reported that non-grafted plants have registered 39.6-41% reduction in Fv/Fm and 41-100% reduction in CCI at 96 h after exposing the waterlogging stress. In contrast to our findings, Bhatt *et al.* (2015) have not reported significant changes in Fv/Fm due to waterlogging stress.

Chlorophyll concentration index (CCI): CCI of twenty tomato grafted genotypes were recorded 94 h after waterlogging stress, and 24 h of recovery (Fig. 2). It showed highly variation in different tomato grafts. After 96 h waterlogging CCI varies from the range of 21.09 to 62.43. During stress, the maximum CCI was showed by the genotype EC-528422 (62.43) followed by WIR-13706 (47.26) and Kashi Aman (41.47), while minimum

CCI was noticed in DARL-66 (21.09). After 24 h waterlogging recovery, CCI varies between 15.73 and 60.32. Maximum CCI was showed by the genotype EC-528422 (60.32) followed by WIR-13706 (35.29) and Kashi Aman (32.27), while minimum CCI was noticed in CLN-1621 (15.63). The Chl concentration was insignificantly influenced in eggplant rootstock grafted plants because of better adaptation of grafted plants as compared to self-grafted and un-grafted plants under waterlogging situation. The higher reduction in leaf Chl in self-grafted and un-grafted plants may be due to delayed synthesis or rapid breakdown of Chl pigments (Bhatt *et al*., 2015).

Chlorophyll a, b and total chlorophyll content (mg/ g FW): Chlorophyll *a*, *b* and total contents were highly variation after 96 h waterlogging situation and 24 h of recovery period (Fig. 3). Chl. *a* content ranged from 0.64 to 2.61 in 96 h waterlogging with maximum content was recorded in EC-528422 (2.61) followed by Kashi Aman (2.43) and D-3-1 (2.36), whereas minimum content was found in DARL-66 (0.69). After 24 h recovery chlorophyll *a* content decreased significantly, and ranged from 0.31 to 1.52. Highest chlorophyll *a* content was found in genotype EC-528422 (1.52) followed by EC-620401 (1.28) and EC-715382 (1.23). Chl. *b* content ranged from 2.21 to 3.76 in 96 h waterlogging (Fig. 4). The highest chlorophyll *b* content was found in genotype EC-620401 (3.76) followed by E-4-1 (3.74) and Kashi Aman (3.73). Minimum chlorophyll *b* was registered in EC-620402 (2.21). After 24 h recovery chlorophyll *b* content decreased and ranged from 1.10 to 3.16. Maximum chlorophyll *b* content was recorded in genotype EC-528422 (3.16) followed by E-4-1 (3.01) and EC-620401 (2.97) while minimum was found in CLN-1621 (1.10). Total chlorophyll content ranged from 2.84 to 5.59 in 96 h waterlogging stress (Fig. 5). Maximum total chlorophyll content was found in genotype E-4-1 (6.11) followed by D-3-1 (5.79) and EC-620401 (5.65). After 24 h recovery total chlorophyll content was ranged between 1.33 and 4.47. The highest total chlorophyll content was found in genotype EC-528422 (4.47) followed by EC-715382 (4.20) and E-4-1 (4.08), while minimum was found in CLN-1621 (1.33). Chlorophyll *a*, *b* and total Chl. content are directly related to photosynthesis and yield parameter and it indicates genetic information of plant screening high genetic variability (Thomas and Smart, 1993). Earlier, Bhatt *et al* (2015) reported that in self-grafted and ungrafted tomato plants, the chlorophyll contents were reduced by 24.0–28.0% at 6 days waterlogging situation, while in eggplant rootstock grafted tomato plants the Chl. reduction was 4.0–19.0%. Kato *et al.* (2001) also reported that Chl. content has increased by grafting of cucumber onto squash rootstocks under waterlogging.

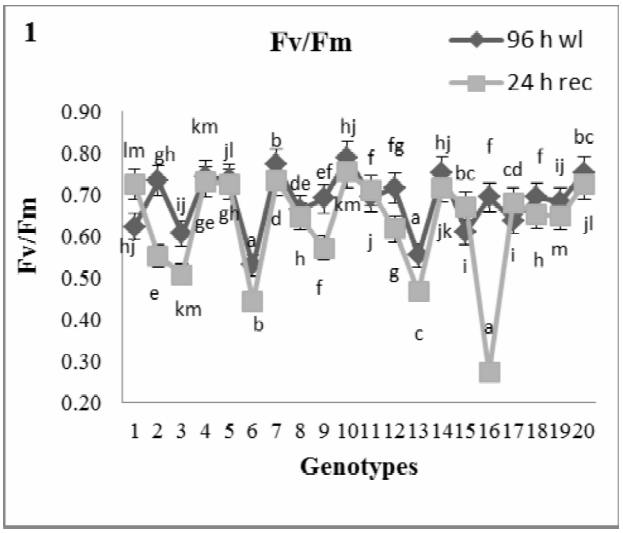
Biochemical attributes

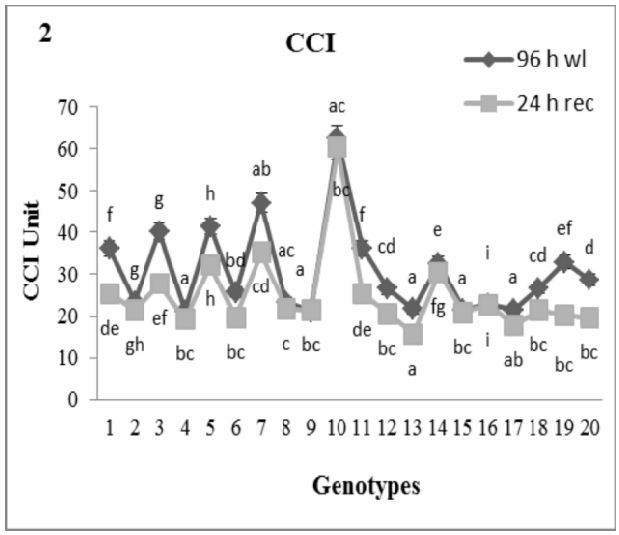
Malondialdehyde (MDA) content (iM /g FW): MDA content also showed variations in different tomato genotypes grafted on eggplant (Fig. 10). After 96 h waterlogged stress MDA content ranged from 2.13 to 8.13. Highest MDA content found in the genotype E-4-1 and Kashi Chayan (8.13) followed by EC-620456 (6.38). Minimum MDA content was found in D-3-1 (2.13) and EC-528452 (2.89). After 24 h recovery MDA content decreased in most of genotypes and slightly increase in few genotypes, it ranged from 2.11 to 6.45. Highest MDA content found in the genotype EC-621661-B (6.45) followed by CLN-1621 (6.22) and E-1-1 (6.15). Lowest MDA content was found in genotype EC-528452 (2.11) and Kashi Aman (2.14).

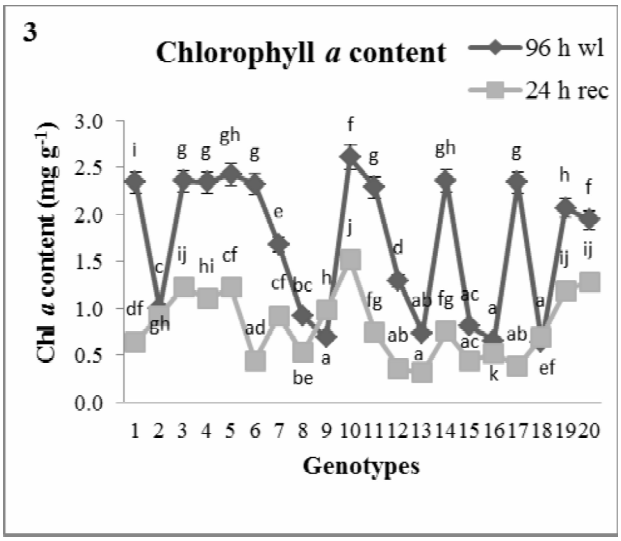
H_2O_2 content (µ mol /g FW): H_2O_2 content also showed variations in different tomato genotypes grafted on eggplant (Fig. 6). H_2O_2 content ranged from 23.42 to 82.18 after 96 h waterlogging stress. Maximum H_2O_2 content found in the genotype EC-528422 (82.18) followed by Kashi Aman (65.71) and WIR-13706 (59.27). Minimum H_2O_2 content was found in E-4-1 (23.42). After 24 h recovery H_2O_2 content increased in most of genotypes and decreased in few genotypes, it ranged from 27.75 to 77.33. Highest H_2O_2 content found in the genotype Kashi Aman (77.33) followed by EC-528422 (76.52) and WIR-13706 (61.60). Lowest H_2O_2 content was found in genotype EC-620456 (27.75).

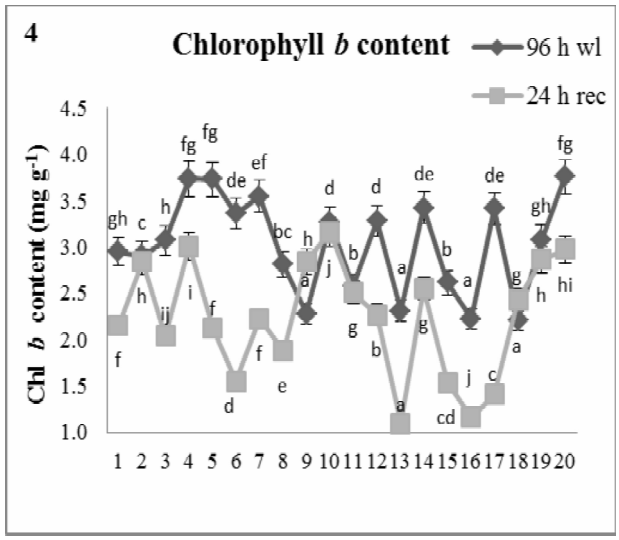
Catalase activity (µM /g FW/ min): Catalase activity also showed variations in different tomato genotypes grafted on eggplant (Fig. 7). After 96 h water logging stress, catalase activity ranged from 8.56 to 36.23. Highest activity found in the genotype EC-528422 (36.23) followed by CLN-1621 (27.61) and EC-620354 (27.54). Minimum catalase activity was found in C-1-1 (8.56). After 24 h recovery catalase activity decreased in most of genotypes, it ranged from 6.28 to 21.44. Highest catalase activity found in the genotype EC-528422 (21.44) followed by EC-620456 (18.51) and EC-620354 (18.31). Minimum catalase activity was found in C-1-1 (6.28).

SOD activity (unit /g FW/ min): SOD activity also showed variations in different tomato genotypes grafted on eggplant (Fig. 8). After 96 h water logging stress SOD activity ranged from 29.17 to 50.29. Highest SOD activity found in the genotype EC-528422 (50.29) followed by Kashi Aman (46.22) and EC-620354 (46.19). Minimum H_2O_2 content was found in C-9-1 (29.17). After 24 h recovery SOD activity decreased in


1
Fv/Fm
96 h wl
24 h rec
Fv/Fm
Genotypes


2
CCI
96 h wl
24 h rec
CCI Unit
Genotypes


3
Chlorophyll a content
96 h wl
24 h rec
Chl a content (mg g-1)
Genotypes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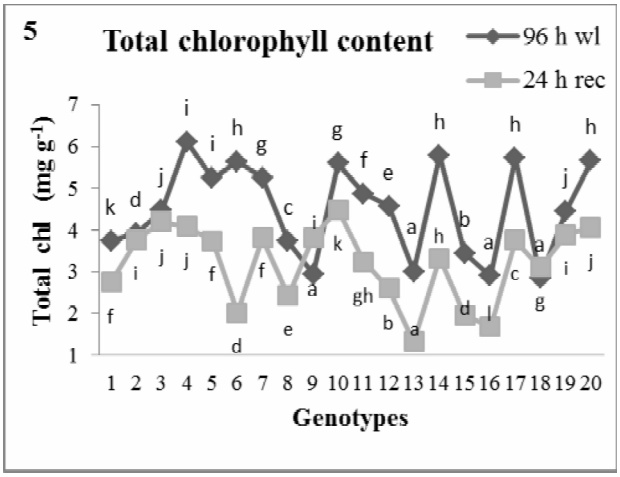
Chlorophyll b content
96 h wl
24 h rec
Chl b content (mg g-1)
Genotypes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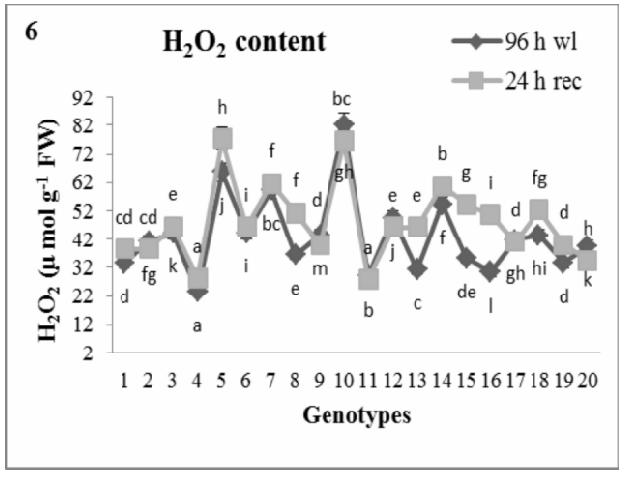
Total chlorophyll content
96 h wl
24 h rec
Total chl (mg g-1)
Genotypes


6
H2O2 content
96 h wl
24 h rec
H2O2 (µ mol g-1 FW)
Genotypes

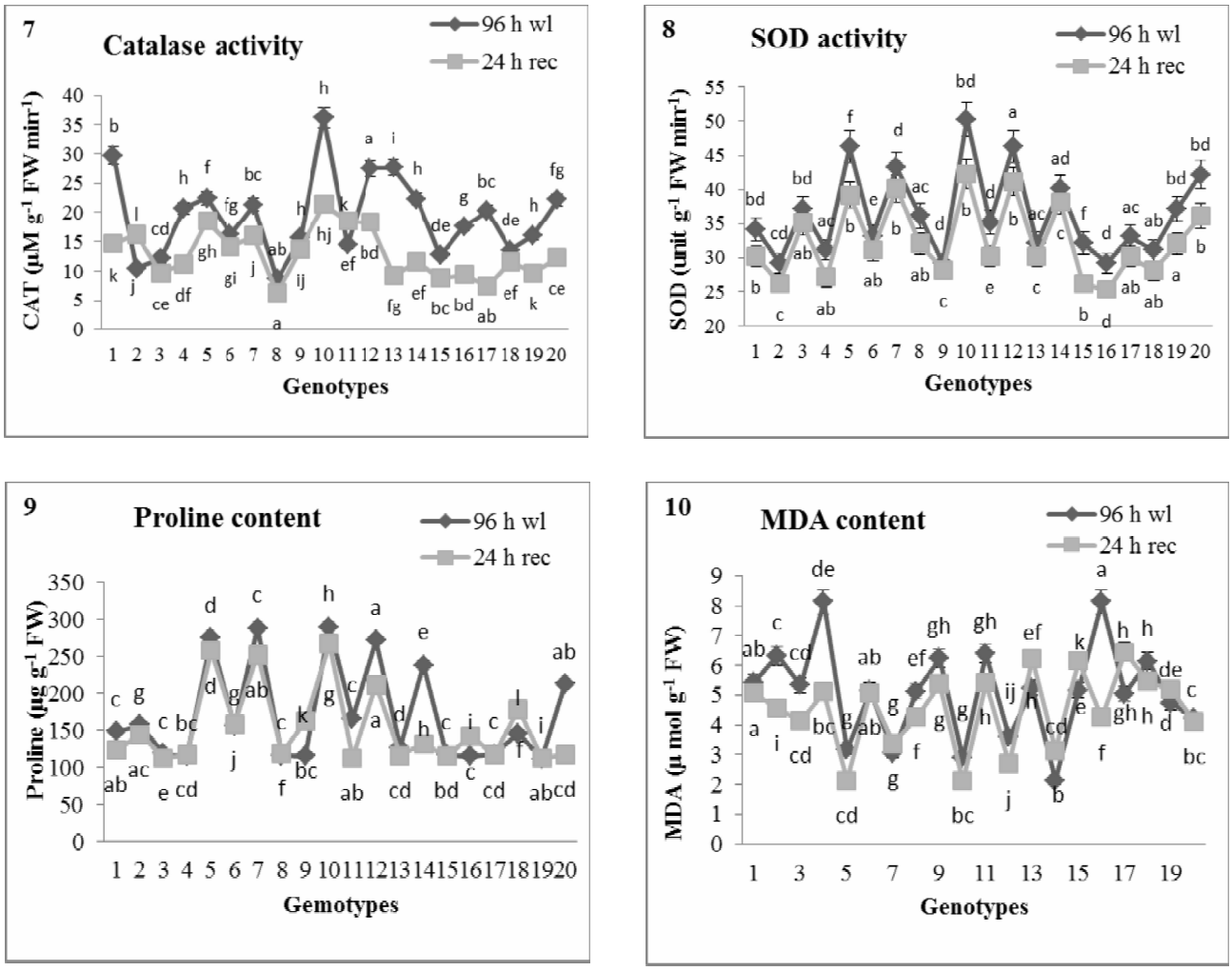
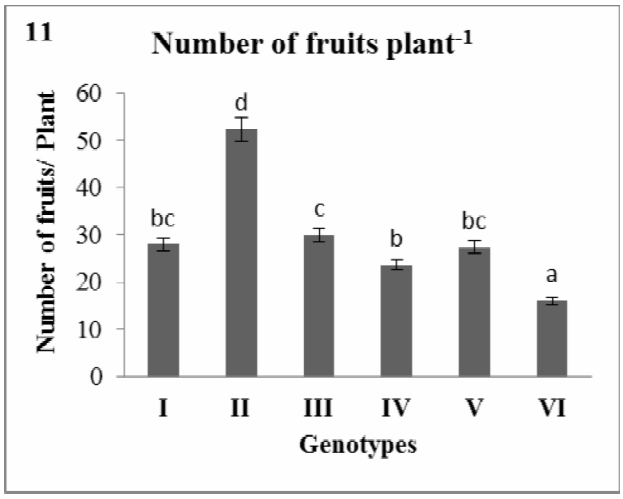


Fig 1-10: Effect of grafting of twenty scion tomato genotypes (1-20) on eggplant rootstock IC-111056 on (Fig 1.) chlorophyll fluorescence (Fv/Fm), (Fig 2.) chlorophyll concentration index (CCI) (Fig 3.), chlorophyll *a* content (Fig 4.), chlorophyll *b* content (Fig 5.), total chlorophyll content (Fig 6.), H_2O_2 content (Fig 7), CAT activity (Fig 8), SOD activity (Fig 9), proline content (Fig 10.) and MDA content after 96 h of waterlogging stress and 24 h recovery. Same letters within the columns are not significantly different at Pd"0.05 using DMRT. Data are presented in the form of mean ± SEM and means.
Where 1= CLN-2026; 2= C-9-1; 3= EC-715382; 4= E-4-1; 5= Kashi Aman; 6= E-5-1; 7= WIR-13706; 8= C-1-1; 9= DARL-66; 10= EC-528422; 11= EC-620456; 12= EC-620354; 13= CLN-1621; 14= D-3-1; 15= E-1-1; 16= Kashi Chayan; 17= EC-621661-B; 18= EC-620402; 19= EC-521047 and 20= EC-620401. All these tomato scions were grafted over eggplant rootstock IC-111056.

most of genotypes, it ranged from 25.27 to 42.24. Highest SOD activity found in the genotype EC-528422 (42.24) followed by EC-620354 (41.17) and WIR-13706 (40.11). Minimum SOD activity was found in Kashi Chayan (25.27).

Proline content (µg/ g FW): Proline content also showed variations in different tomato genotypes grafted on eggplant (Fig. 9). After 96 h water logging stress proline content ranged from 112.14 to 290. Highest proline content found in the genotype EC-528422 (290) followed by WIR-13706 (288.15) and Kashi Aman (275.04). Minimum proline content was found in EC-521047 (112.14). After 24 h recovery proline content decreased in most of genotypes, it ranged from 113.42 to 267.17. Highest proline content found in the genotype EC-528422 (267.17) followed by Kashi Aman (257.04) and WIR-13706 (252.74). Lowest proline content was found in genotype EC-715382 (113.42).

Plants show genetic differences in biochemical parameters adaptation to flooding/ waterlogging situations (Schmull and Thomas, 2000). MDA content indicates the oxidative damage in plant; it is increased in waterlogging stress. Decreased MDA content in some tomato genotypes showed that it has low amount of ROS and higher antioxidant enzymes' activity (Yazici *et al*., 2007). In waterlogging lack of oxygen creates



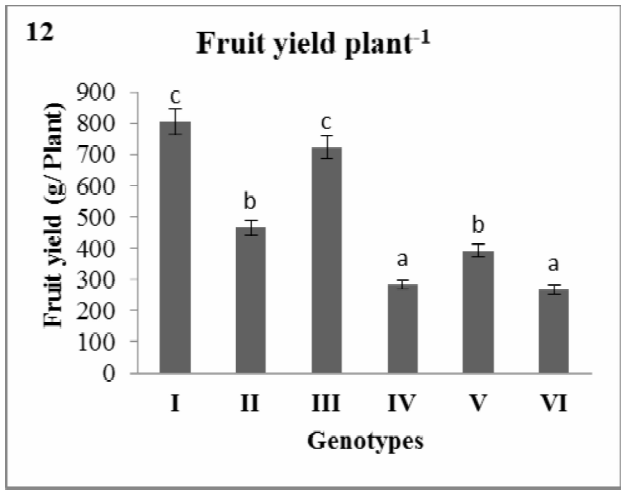


Fig 11-12: Fruit yield of six survived grafted tomato genotypes (I-VI) as scions on eggplant rootstock IC-111056 (Fig 11.) and number of fruits/ plant (Fig 12.). Same letters within the columns are not significantly different at Pd"0.05 using DMRT. Data are presented in the form of mean ± SEM. Where I= EC-528422, II= WIR-13706, III= Kashi Aman, IV= EC-620354, V= D-3-1 and VI= EC-620401. All tomato scions were grafted over eggplant rootstock IC-111056)

oxidative stress result in production of H_2O_2 and other reactive oxygen species (ROS) in plant cell (Konieczny *et al*., 2008). Plant cell maintain cellular homeostasis and remove toxic substances by accumulation of compatible solutes such as proline (Rontein *et al.,* 2002). Higher proline accumulation is an indicative of stress tolerant genotypes (Singh and Singh 1983, Aspinall *et al*, 1983). Genotypes with higher CAT activity show the ability to dismutase H_2O_2 into H_2O and O_2, and detoxify ROS in peroxisomes during stress condition (Sairam and Srivastava, 2001). Genotypes with higher SOD activity improve the ROS scavenging system (Ghahfarokhi *et al.,* 2015).

Fruit yield

Only six grafted tomato genotypes on IC-111056 (eggplant) survived after exposing to 96 h of waterlogged stress, which were EC-528422, WIR-13706, Kashi Aman, EC-620354, D-3-1 and EC-620401. Number of fruits/plant showed significantly difference in various genotypes, WIR-13706 showed highest number of fruits/ plant (50) followed by EC-538422 (27) and Kashi Aman (25), while minimum fruits/ plant was reported in EC- 620401 (16). Fruit yield /plant also varied significantly in six survived tomato genotypes after 96 h of waterlogging. Maximum fruit yield was recorded in EC-538422 (755 g/plant) followed by Kashi Aman (720 g/plant) and WIR-13706 (430 g/plant), while minimum fruit yield was recorded in EC-620401 (200 g/plant). Similar to our findings, Bhatt *et al* (2015) has also noticed minimum reduction (12%) in tomato yield under 6-days flooding conditions in the grafting combinations Arka Rakshak/ Arka Neelkanth. while the maximum reduction (55%) were detected in Arka Rakshak /BPLH-1 combination. Khah *et al* (2006) also observed 32.5, 12.8% and 11.0 and 11.1% higher fruit yield in Big Red tomato grafted onto Heman and Primavera (both hybrid tomato) than the un-grafted in the greenhouse and the open-field, respectively.

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सारांश

उत्तर भारत के मैदानी क्षेत्रों में दक्षिण–पश्चिम मानसून के दौरान कई बार अधिक जल–भराव के कारण टमाटर की अगेती खेती कर पाना संभव नहीं हो पाता है क्योंकि टमाटर 24 से 48 घंटे जल–भराव की स्थित में सूख जाता है। ऐसी दशा में टमाटर के पौध यदि बैंगन के मूलवृन्त पर ग्राफ्ट कर लगाये जायें तो 2–3 दिन तक जल–भराव की स्थित में टमाटर का पौधा आसानी से बच जाता है। इसी बात को ध्यान रखते हुए टमाटर की 20 प्रजातियों को बैंगन के मूलवृन्त ई.सी. 111056 पर लगाकर प्रारम्भिक अवस्था में 96 घंटों के लिए जल–भराव की स्थित में रखा गया। जल–भराव के तुरन्त बाद पौधों में दैहिकी, जैव–रासानिकी एवं अन्य आवश्यक पहलुओं का अवलोकन किया गया। अध्ययन से निष्कर्ष निकाला गया कि ग्राफ्टेड पौध विशेषकर टमाटर की छः प्रजातियाँ यथा–ई.सी. 528422, डब्लू.आई. आर–13706, ई.सी–620354, ई.सी. 620401, काशी अमन एवं डी. 3–1 ने 96 घंटे तक जल–भराव के बाद उनकी दैहिकीय एवं जैव–रासायनिक क्रियाओं पर सार्थक प्रतिकूल असर नहीं पड़ा था, और पौध पानी से निकालने के 24–48 घंटे बाद पूरी तरह स्वस्थ्य हो गये जबकि सभी बिना ग्राफ्टेड पौध मर गये। इससे यह निष्कर्ष निकाला जा सकता है कि टमाटर की उन्नत प्रजातियों का बैंगन के

मूलवृन्त जिनमें जड़ विकास ज्यादा होता है, पर ग्राफ्ट करके जल–भराव की संभावना वाले क्षेत्रों के लिए संस्तुति किया जा सकता है।

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