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Effect of grafting on chlorophyll characteristics in brinjal grafted on *Solanum torvum* under salt affected conditions

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Abstract
The present experiment was conducted at Department of Horticulture, VNMKV, Parbhani during the year 2020-2021. The pot experiment was laid out in Factorial Randomized Block Design which was replicated twice with two factors, *i.e.*, Grafts, and Salinity levels. In grafts, there were 4 varieties grafted on *Solanum torvum i.e.*, Phule Arjun, Phule Harit, Krishna and Manjari Gota by adopting cleft method and there were 5 salinity levels *i.e.*, 0, 2, 3, 4 and 5 dSm^{-1} which was imposed with the help of Sodium chloride (NaCl) salt to assess the response of rootstock towards the chlorophyll characteristics under various salinity stress conditions. The results revealed that among the grafts, significantly the maximum chlorophyll-a, b and total chlorophyll content was observed in Phule Arjun grafted on *Solanum torvum* (92.08, 39.63 and 131.70 mg^{-100g}, respectively) whereas, for CSI was found in Phule Harit grafted on *Solanum torvum* (98.18%). Phule Arjun grafted on *Solanum torvum* was proved to be maximum for chlorophyll-a at 3.00 and 4.00 dS m^{-1} (93.22 mg^{-100g} and 90.20 mg^{-100g}, respectively) but at 5.00 dS m^{-1} it was Krishna grafted on *Solanum torvum* (88.63 mg^{-100g}). Phule Arjun grafted on *Solanum torvum* was proved to be maximum for chlorophyll-b at 4.00 and 5.00 dS m^{-1} (39.19 and 38.76 mg^{-100g}, respectively) but at 3.00 dS m^{-1} (40.63 mg^{-100g}) it was Krishna grafted on *Solanum torvum*. Phule Arjun grafted on *Solanum torvum* was proved to be maximum for total chlorophyll at 3.00, 4.00 and 5.00 dS m^{-1} (133.01, 129.38 and 126.90 mg^{-100g} respectively). Phule Harit grafted on *Solanum torvum* was proved to be maximum for chlorophyll stability index at 3.00, 4.00 and 5.00 dS m^{-1} (98.28, 97.28 and 96.30%, respectively).

Keywords: Eggplant, grafting, chlorophyll, brinjal, *Solanum torvum*, salinity levels, chlorophyll stability index

Introduction

Brinjal (*Solanum melongena* L., (2n = 2x = 24)) is one of the widely distributed and cultivated species of Solanaceae family. Native of India and China is its secondary centre of origin. It is known as poor man's vegetable. It occupies an area of 0.73 million hectares with production of 12.98 million metric tons and productivity of 19.10 tons per hectare in India (Anon, 2022) [1]. It is well distributed in Orissa, Bihar, Karnataka, West Bengal, Andhra Pradesh, Maharashtra and Uttar Pradesh. Brinjal is highly productive, nutritious and used as a raw material in pickle making and dehydration industries. Cooked in curry and sambhar, mashed, fried or stuffed with spices and then fried, especially long fruits. Eggplant is a rich source of nutrients containing carbohydrates (6.4%), protein (1.3%), fat (0.3%), calcium (0.02%), phosphorus (0.02%), iron (0.0013%), 34 mg β-carotene, 0.05 mg riboflavin, 0.05 mg thiamine, 0.5 mg niacin and 0.9 mg ascorbic acid per 100 grams of fruit. It is low in calories and fats, contains mostly water, fiber, good source of minerals and vitamins and rich in total water-soluble sugars, free reducing sugars, amide proteins among other nutrients. Brinjal is valued for its medicinal properties, beneficial for diabetic patients. Salinity in soil or water is one of the major abiotic stresses that reduce plant growth and crop productivity worldwide (Arzani, 2008) [2]. More than 800 million hectares of land throughout the world are salt affected due to saline and sodic soils, corresponding to more than 6 per cent of the world total land area of which salinity is detrimental in limiting plant growth and crop productivity. Salinity in soil or water is a serious threat to plant growth that prevents plants in achieving their genetic potential. Its annual damage is about 20 per cent of the world's crops grown under irrigation. Salinity occurs when there is an excessive accumulation of salts (especially high Na^+, Cl^- and SO_4^-) in the soil (Parida and Das, 2005) [3] or irrigation water (Colla *et al.*, 2010) [4].

Continuous irrigation with saline water could also lead to deterioration of physical properties of the soil and decrease of crop production. Therefore, it is imperative to have more knowledge on salt stress to develop new technologies. Brinjal is moderately sensitive to salinity, consequently more attention is required in agricultural production of this crop with important rootstocks and its varieties. Grafting represents a viable alternative to solve the issues of salinity stresses in vegetable cultivation. Grafting on salt tolerant rootstock is considered to be an environmentally friendly technique for reducing the yield losses caused by salinity. The use of salt tolerant rootstocks has been suggested as a valid approach to enhance salt tolerance in many vegetable crops, particularly in Solanaceous crops.

Salinity inhibits the crop growth and productivity via limiting photosynthesis and energy conservation inhibition (Zhu, 2016) [5]. An increase in photosystem I activity and a decrease in photosystem II mediated oxygen evolution activity as a result of salt stress can cause some modifications in the thylakoid membrane proteins, leading to a decline in the electron transfer from light harvesting antenna to photosystem II (Sudhir *et al*., 2005) [6]. Overall negative effect of soil salinity on chlorophyll related parameters were clearly evident in past findings. The important alternative to overcome the problem of soil salinity is by adopting salt tolerant crops for growing. In particular vegetable crop like brinjal has the advantage to go for grafting, which enables to select salt tolerant rootstock with appropriate scion for production. That was the major objective the present investigation in which different scion varieties of brinjal were grafted on *Solanum torvum* and studies chlorophyll related characters under salinity imposed conditions.

Material and Methods

The present investigation was undertaken at the College of Agriculture, Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra) during the year 2020 and 2021. The experiment was laid out in Factorial Randomized Block Design with two replications and it consisted of two factors, *i.e.* Grafts and Salinity levels. There were 4 brinjal varieties grafted on *Solanum torvum* and 5 levels of salinity. Salinity stress has been imposed by using solution of sodium chloride (NaCl). Salt was applied in four different electrical conductivity (EC) values of 2, 3, 4 and 5 dS m^{-1} in weekly intervals starting from 20 days after transplanting and non-salt treated plants were kept as control. Wild rootstock *Solanum torvum* (Turkey Berry) and the brinjal varieties/hybrids adopted and released for Maharashtra region has been selected as scions *viz*., Phule Arjun (F_1), Phule Harit, Krishna (F_1) and Manjari Gota were obtained from Senior Vegetable Breeder, All India Co-ordinated Research Project (AICRP) on Vegetable Crops, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra.

The popular varieties of brinjal *viz*., Phule Arjun, Phule Harit, Krishna and Manjari Gota were sown in February which is one month after sowing of rootstock and seeds of rootstock were sown in January for both seasons which is one month before the scion seeds in order to get match with thickness (2 to 3 mm) of rootstock and scion. Seeds of both rootstock and scion were sown in portrays containing cocopeat and vermicompost in 3:1 ratio and watered regularly. Protrays were covered with polythene sheets for four days. After emergence of seedlings, trays were kept under a shade net. Foliar sprays of 19:19:19 @ 0.5% were provided weekly once to get quality seedlings. The rootstock seedlings were ready for grafting in 60 to 65 days (three to four true leaves), whereas, scions were ready for grafting after 30 to 35 days (Three to four true leaves) of sowing. Cleft grafting was done in the month of March. Grafting was carried out in the morning and evening hours in mist chambers. Height of rootstock seedling was kept 8 to 10 cm from base or surface with no leaves. The cut was made with a sharp razor blade through longitudinal downward with 1.0 to 1.5 cm deep on the rootstock to accommodate the precured scion. The lower stem was cut into a tapered wedge shape with equal faces on both sides to 2.0 mm length to place inside the depth cut of the rootstock. After placing the scion into the split made on the rootstock, graft unions were wrapped with silicon tape. Grafted seedlings were immediately placed in healing chamber for ten days. Successful healing requires a reduced light intensity, high relative humidity (85-95%) and moderate temperatures (25 – 30 °C) for five days to allow the graft union to heal then light was gradually increased and relative humidity was decreased. Then the seedlings were transferred to the normal nursery where healing process was allowed for 7 days before they were transplanted. Before the transplanting, seedlings were grown under natural light conditions for two to three days for hardening. The healthy and vigorous grafted brinjal grafts from protrays were transplanted to plastic pot at 30 days after grafting in April month. Each of pot size was 28 cm diameter and 30 cm height which is having 20 kg soil capacity filled with 18 kg media containing pot mixture of soil, vermicompost, FYM, digested coir pith, compost and sand at the ratio of 1:1:1:1:1. Before the transplanting seedlings were kept for hardening under open sunlight for 2 to 3 days. One seedling was transplanted per pot and irrigation was given immediately after transplanting. The grafted plants after transplanting in pots were supported by bamboo sticks to avoid lodging of the grafted plants. After successful grafting the silicon tapes were removed from the graft union.

Estimation of Chlorophyll a, b and total chlorophyll (mg^{-100g}): Chlorophyll-a, Chlorophyll-b and total chlorophyll was estimated by Hiscox and Israelstam, (1979) [7]. Leaf samples of brinjal plants were collected during morning hours. The fresh leaf tissues were cut into small pieces avoiding midrib and thick veins. 25 mg of fresh leaf samples were transferred in to each test tube contain 5 ml of DMSO. After that, all the test tubes were kept in dark chamber for 12 to 24 hours. Supernatant was decanted discarding the leaf tissue. Then volume was made up to 10 ml with DMSO, then the optical density of the extract or solution was measured at 663 and 645 nm wavelengths by using Spectrophotometer by using DMSO as a blank. Using the absorption coefficients, chlorophyll 'a', 'b' and total chlorophyll were calculated and expressed in mg g^{-1} fresh weight using the formula as given by Arnon (1949)[8].

Chlorophyll 'a' (C_a) = 12.7 (A_{663}) -2.69 (A_{645}) XV / 1000 XW
Chlorophyll 'b' (C_b) = 22.9 (A_{645}) -4.68 (A_{663}) XV / 1000 XW
Total chlorophyll = 20.2 (A_{645}) + 8.02 (A_{663}) XV / 1000 XW

Where,
A_{645} = Absorbance at 645 nm, A_{663} = Absorbance at 663 nm, V = Final volume of chlorophyll extract, W = Weight of leaf

sample in g, C_a = Chlorophyll 'a, C_b = Chlorophyll 'b'.

Estimation of chlorophyll stability index (CSI): CSI determined by adopting the method suggested by Koleyoreas (1958) [9] and also by Murthy and Majumdar (1962) [10]. Two clean test tubes were taken. 250 mg of leaf sample was weighed made into 8 to 10 leaf bits and transferred to test tubes. 20 ml of distilled water and hot water was added to the control and treatment tubes, respectively. One was kept as control and other tubes were then subjected to heat in water bath at 56 °C ± 1 °C for exactly 30 minutes. After the completion of the reaction time the leaf bits were taken out from the test tube and macerate in mortar and pestle with 10 ml of 80 per cent acetone for five minutes. The content was centrifuged at 3000 rpm for 10 minutes. The supernatant was collected and made up to 25 ml by using 80 per cent acetone. The OD was measured at 652 nm in the Spectrophotometer. The CSI was calculated by using following formula.

$$CSI = \frac{\text{OD at 652 nm of heated sample}}{\text{OD at 652 nm of nonheated or fresh sample}} \times 100$$

Where,
Heated sample = 250 mg of leaf sample kept in a test tube containing water at 55 °C for 30 min, Control/ Fresh sample/ Non heated = 250 mg of leaf sample kept in a test tube containing water at room temperature for 1h.

Result and Discussion

The data pertaining to chlorophyll-a, chlorophyll-b, total chlorophyll and chlorophyll stability index of brinjal as significantly influenced by different grafts, salinity levels and interactions were furnished in in Table 1 for the year 2020, 2021 as well as in the pooled mean

Among the grafts, data revealed that the significantly the maximum chlorophyll-a content was observed in A_1 *i.e.* Phule Arjun grafted on *Solanum torvum* for the year 2020 (92.27 mg^{-100g}), 2021 (91.88 mg^{-100g}) and in the pooled mean (92.08 mg^{-100g}). It was followed by A_3 *i.e.* Krishna grafted on *Solanum torvum* (91.12 mg^{-100g}, 90.96 mg^{-100g} and 91.04 mg^{-100g} in 2020, 2021 and pooled mean, respectively) and A_4 *i.e.* Manjari Gota grafted on *Solanum torvum* (89.17 mg^{-100g}, 89.03 mg^{-100g} and 89.10 mg^{-100g} in 2020, 2021 and pooled mean, respectively). While, significantly the minimum chlorophyll-a content was observed in A_2 *i.e.* Phule Harit grafted on *Solanum torvum* for the year 2020 (85.41 mg^{-100g}), 2021 (84.97 mg^{-100g}) and in the pooled mean (85.19 mg^{-100g}).

Under salt concentrations, the maximum chlorophyll-a content was observed in the control treatment B_1 *i.e.* 0 dS m^{-1} for the year 2020 (92.01 mg^{-100g}), 2021 (91.48 mg^{-100g}) and in pooled mean (91.74 mg^{-100g}). It was followed by B_2 *i.e.* 2.00 dS m^{-1} (90.62 mg^{-100g}, 90.21 mg^{-100g} and 90.42 mg^{-100g} in 2020, 2021 and pooled mean, respectively), B_3 *i.e.* 3.00 dS m^{-1} (89.80 mg^{-100g}, 89.58 mg^{-100g} and 89.69 mg^{-100g} in 2020, 2021 and pooled mean, respectively), and B_4 *i.e.* 4.00 dS m^{-1} (88.04 mg^{-100g}, 88.05 mg^{-100g} and 88.04 mg^{-100g} in 2020, 2021 and pooled mean, respectively). The minimum chlorophyll-a content was recorded in treatment B_5 *i.e.* 5 dS m^{-1} for the year 2020 (86.99 mg^{-100g}), 2021 (86.73 mg^{-100g}) and in the pooled mean (86.86 mg^{-100g}). Chlorophylls are the primary photosynthetic pigments that play a critical role in photosynthesis. Changes in pigment content were interpreted as changes in plant photosynthetic ability. The changes in Chlorophyll content caused by salt stress are used to select tolerant and sensitive crop cultivars (Doganlar *et al.* 2010) [11]. The current study's findings are consistent with those of Ahire and Nikam (2011) [12], who stated that chlorophyll-a content decreased significantly with increasing salinity. The lowest chlorophyll-a content was found in the MEBH 10 variety at 200 mM, and the highest in the control MHBJ 112 variety. Many authors have described a highly significant decrease in chlorophyll content with increasing salinity in salt sensitive rice genotypes compared to salt tolerant genotypes. (Misra *et al.* 1997; Lutts *et al.* 1996) [13, 14]. Similarly decrease in chlorophyll content with increasing salinity in salt sensitive cultivars was recorded by Patil *et al.* (2010) [15] in Niger. A decrease in photosynthetic rate with increased NaCl concentration might be associated with decreased in pigmentation.

Among the treatment combinations, T_1 (A_1B_1) *i.e.* Phule Arjun grafted on *S. torvum* with 0 dS m^{-1} was recorded significantly the maximum chlorophyll-content (95.80 mg^{-100g}) in the year 2020, 2021 and in the pooled mean. It was followed by treatment combination T_{11} (A_3B_1) *i.e.* Krishna grafted on *S. torvum* with 0 dS m^{-1} (93.74 mg^{-100g} and 93.31 mg^{-100g}) for the year 2020 and pooled mean; Whereas, in 2021 it was T_3 (A_1B_3) *i.e.* Phule Arjun grafted on *S. torvum* with 3 dS m^{-1} (93.38 mg^{-100g}). Phule Arjun grafted on *Solanum torvum* was proved to be maximum for chlorophyll-a at 3.00 and 4.00 dS m^{-1} (93.22 mg^{-100g} and 90.20 mg^{-100g}, respectively), but at 5.00 dS m^{-1} (88.63 mg^{-100g}) it was Krishna grafted on *Solanum torvum*. Whereas, significantly the minimum chlorophyll-a content was recorded in the treatment combination T_{10} (A_2B_5) *i.e.* Phule Harit grafted on *Solanum torvum* with 5 dS m^{-1} in the year 2020 (84.22 mg^{-100g}), 2021 (84.06 mg^{-100g}) and in the pooled mean (81.14 mg^{-100g}). Grafting offers an alternative to breeding and biotechnological approaches to rapidly enhance salt tolerance in vegetable crops (Keatinge *et al.*, 2014) [16]. Grafted plants grown under saline conditions can show better growth and yield, higher photosynthesis and leaf water content, greater root to shoot ratio and lower accumulation of Na^+ and or Cl^- in shoots than un grafted or self-grafted plants (Colla *et al.*, 2010) [4]. Ahire and Nikam (2011) [12] studied the effect of NaCl stress in nine commercial hybrids of brinjal under different (0-200 mM) salinity levels and reported that chlorophyll-a content was markedly decreased with increasing salinity. The lowest (0.007 mg g^{-1} FW) chlorophyll-a content was recorded at 200 mM in MEBH 10 variety and the highest (0.027 mg g^{-1} FW) at control MHBJ 112 variety.

Among the grafts, data revealed that the significantly the maximum chlorophyll-b content was noticed in A_1 *i.e.* Phule Arjun grafted on *Solanum torvum* was 39.63 mg^{-100g} (2020 and pooled mean), 39.62 mg^{-100g} (2021). It was followed by A_3 *i.e.* Krishna grafted on *Solanum torvum* (39.46 mg^{-100g}, 39.50 mg^{-100g} and 39.48 mg^{-100g} in 2020, 2021 and pooled mean, respectively) and A_2 *i.e.* Phule Harit grafted on *Solanum torvum* (38.60 mg^{-100g}, 38.29 mg^{-100g} and 38.45 mg^{-100g} in 2020, 2021 and pooled mean, respectively). While, significantly the minimum chlorophyll-b content was recorded in A_4 *i.e.* Manjari Gota grafted on *Solanum torvum* for the year 2020 (36.56 mg^{-100g}), 2021 (36.66 mg^{-100g}) and in the pooled mean (36.61 mg^{-100g}).

Under salt concentrations, the maximum chlorophyll-b content was observed in the control treatment B_1 *i.e.* 0 dS m^{-1} for the year 2020 (39.79 mg^{-100g}), 2021 (39.87 mg^{-100g}), pooled mean (39.83 mg^{-100g}). It was followed by B_2 *i.e.* 2.00 dS m^{-1} (39.33 mg^{-100g}, 39.40 mg^{-100g} and 39.37 mg^{-100g} in 2020, 2021 and pooled mean, respectively), B_3 *i.e.* 3.00 dS m^{-1} (38.93 mg^{-100g}, 38.73 mg^{-100g} and 38.83 mg^{-100g} in 2020, 2021 and pooled mean, respectively), and B_4 *i.e.* 4.00 dS m^{-1} (37.59 mg^{-100g}, 37.60 mg^{-100g} and 37.60 mg^{-100g} in 2020, 2021 and pooled mean, respectively). The minimum chlorophyll-a content was recorded in treatment B_5 *i.e.* 5 dS m^{-1} for the year 2020 (37.17 mg^{-100g}), 2021 (36.98 mg^{-100g}) and in the pooled mean (37.08 mg^{-100g}). These findings are in line with the findings of Ahire and Nikam (2011)[12], who studied the effect of NaCl stress in brinjal under different (0-200 mM) salinity levels and reported that chlorophyll-b content was markedly decreased with the increasing salinity.

Among the treatment combinations, T_{11} (A_3B_1) *i.e.* Krishna grafted on *S. torvum* with 0 dS m^{-1} was recorded significantly the maximum chlorophyll-b content in the year 2020 (41.26 mg^{-100g}), 2021 (41.49 mg^{-100g}) and in the pooled mean (41.38 mg^{-100g}). It was followed by treatment combination T_{12} (A_3B_2) *i.e.* Krishna grafted on *S. torvum* with 2 dS m^{-1} (41.01 mg^{-100g}, 41.07 mg^{-100g} and 41.05 mg^{-100g} in 2020, 2021 and pooled mean, respectively). Phule Arjun grafted on *Solanum torvum* was proved to be maximum for chlorophyll-b at 4.00 and 5.00 dS m^{-1} (39.19 mg^{-100g} and 38.76 mg^{-100g}, respectively), but at 3.00 dS m^{-1} (40.63 mg^{-100g}). Whereas, significantly the minimum chlorophyll-b content was observed in the treatment combination T_{20} (A_4B_5) *i.e.* Manjari Gota grafted on *Solanum torvum* with 5 dS m^{-1} in the year 2020 (35.29 mg^{-100g}), 2021 (35.46 mg^{-100g}) and in the pooled mean (35.38 mg^{-100g}). One of the important biochemical changes that occurs in plants subjected to salt stress is the production of reactive oxygen species (ROS) such as Superoxide radical (O^{-2}), Hydrogen peroxide (H_2O_2) and Hydroxyl radical (OH^-). The ROS can have a detrimental effect on normal metabolism of a plant through oxidative damage of lipids, proteins and nucleic acids (Mittler, 2002) [17].

Among the grafts, data revealed that the significantly the maximum total chlorophyll content was observed in A_1 *i.e.* Phule Arjun grafted on *Solanum torvum* for the year 2020 (131.90 mg^{-100g}), 2021 (131.51 mg^{-100g}) and in the pooled mean (131.70 mg^{-100g}). It was followed by A_3 *i.e.* Krishna grafted on *Solanum torvum* (130.58 mg^{-100g}, 130.46 mg^{-100g} and 130.52 mg^{-100g} in 2020, 2021 and pooled mean, respectively) and A_4 *i.e.* Manjari Gota grafted on *Solanum torvum* (125.73 mg^{-100g}, 125.69 mg^{-100g} and 125.71 mg^{-100g} in 2020, 2021 and pooled mean, respectively). While, significantly the minimum total chlorophyll content was observed in A_2 *i.e.* Phule Harit grafted on *Solanum torvum* for the year 2020 (124.01 mg^{-100g}), 2021 (123.26 mg^{-100g}) and in the pooled mean (123.64 mg^{-100g}). Chlorophyll content is a major index in photosynthetic capacity and can be used as a source of food and energy (Trinchera *et al.*, 2013) [18]. Under open field conditions, the chlorophyll content of grafted MCV1/TWR was higher (Musa *et al.*, 2020) [19]. Higher stomatal conductance in grafted plants may be due to their vigorous root systems, which are often capable of absorbing water, nutrients, and enhancing dry matter accumulation. Transpiration rate, defined as the rate of water loss by plant depending on the nature of stomata, was higher in MCV1 grafted onto both MWR and BWR (Musa *et al.*, 2020) [19]. Similar findings were reported by Moncada *et al.* (2013) [20], who reported that Longo brinjal cultivar grafting on *Solanum torvum* showed the maximum chlorophyll content as that of non-grafted plants.

Under salt concentrations, the maximum total chlorophyll content was observed in the control treatment B_1 *i.e.* 0 dS m^{-1} for the year 2020 (131.80 mg^{-100g}), 2021 (131.35 mg^{-100g}) and in pooled mean (131.57 mg^{-100g}). It was followed by B_2 *i.e.* 2.00 dS m^{-1} (129.95 mg^{-100g}, 129.62 mg^{-100g} and 129.79 mg^{-100g} in 2020, 2021 and pooled mean, respectively), B_3 *i.e.* 3.00 dS m^{-1} (128.74 mg^{-100g}, 128.31 mg^{-100g} and 128.53 mg^{-100g} in 2020, 2021 and pooled mean, respectively), and B_4 *i.e.* 4.00 dS m^{-1} (125.62 mg^{-100g}, 125.65 mg^{-100g} and 125.64 mg^{-100g} in 2020, 2021 and pooled mean, respectively). The minimum total chlorophyll content was recorded in treatment B_5 *i.e.* 5 dS m^{-1} for the year 2020 (124.16 mg^{-100g}), 2021 (123.71 mg^{-100g}) and in the pooled mean (123.94 mg^{-100g}). Similar results were also noted by Ahire and Nikam (2011) [12], who reported that the total chlorophyll content was markedly decreased with increasing salinity. The lowest total chlorophyll content was recorded at 200 mM in MEBH 10 variety and the highest at control in MHBJ 112 variety. These findings are in agreement with Uddin *et al.* (2016) [21] evaluated that screening the salt tolerant brinjal lines *i.e* ten lines coded from V_1 (Line - 1) to V_{10} (Line -10) were executed under different salinity conditions (S_0: control, S_1: 12 dS m^{-1} and S_2: 16 dS m^{-1}) in that maximum chlorophyll content was observed in control and minimum in V_{10} at 16 dS m^{-1} salinity level. Similar results were observed by Abd El-Wanis Mona *et al.* (2018) [22], who observed the highest chlorophyll content was due to graft onto *S. melongena* (Japanese white Eggplant) and *S. torvum*. The results were in line with Bayoumi *et al.* (2021) [23], who reported that the highest chlorophyll content was observed in the cucumber plants grafted on rootstock VSS-61 F_1. This was also corroborated with the findings of Ulas *et al.* (2021) [24], who supported that the graft combinations of 'Crisby/Ercole', and 'Crisby/ST' produced significantly higher leaf chlorophyll content under control conditions. While the non-grafted plants of 'CT' has significantly lower leaf chlorophyll content. This may be due to various factors such as increase in uptake of water and nutrients with the widespread root-system of the rootstock (Salehi *et al*, 2009) [25].

Among the treatment combinations, T_{11} (A_3B_1) *i.e.* Krishna grafted on *S. torvum* with 0 dS m^{-1} in the year 2020 (135.00 mg^{-100g}) and T_1 (A_1B_1) *i.e.* Phule Arjun grafted on *S. torvum* with 0 dS m^{-1} were recorded significantly the maximum total chlorophyll content was 136.00 mg^{-100g} in the year 2021 and 135.41 mg^{-100g} in the pooled mean. It was followed by treatment combination T_1 (A_1B_1) *i.e.* Krishna grafted on *S. torvum* with 0 dS m^{-1} (134.81 mg^{-100g}) for the year 2020; T_{11} (A_3B_1) *i.e.* Krishna grafted on *S. torvum* with 0 dS m^{-1} (134.36 mg^{-100g} and 134.68 mg^{-100g}) for the year 2021 and pooled mean. Phule Arjun grafted on *Solanum torvum* was proved to be maximum for total chlorophyll at 3.00, 4.00 and 5.00 dS m^{-1} (133.01 mg^{-100g}, 129.38 mg^{-100g} and 126.90 mg^{-100g} respectively). Whereas, significantly the minimum total chlorophyll content was recorded in the treatment combination T_{20} (A_4B_5) *i.e.* Manjari Gota grafted on *Solanum torvum* with 5 Ds m^{-1} in the year 2020 (121.75 mg^{-100g}) and T_{10} (A_2B_5) *i.e.* Phule Harit grafted on *Solanum torvum* with 5 Ds m^{-1} 2021 (120.73 mg^{-100g}) and in the pooled mean (121.27 mg^{-100g}). Chlorophylls are essential components of photosynthesis and are found as green pigments in chloroplasts in all photosynthetic plant tissues. Higher plants (ferns and mosses) contain chlorophylls a and b, whereas, algae and certain bacteria contain chlorophylls c, d, and e. Low or moderate salinity levels will cause osmotic stress, and decreased water potential will cause cell dehydration (Ondrasek *et al.* 2009) [26] which influence water and nutrient uptake, stomatal closure (partially or fully) leading to reduction in transpiration or carbon dioxide accumulation, reduction in cell growth and development, decreased leaf area and chlorophyll content, accelerated defoliation and senescence ultimately ends with mortality of plant (Shannon and Grive, 1999) [27]. Results are similar with the findings of Neocleous and Vasilakakis (2007) [28] in raspberry, Hajiboland *et al.* (2014) [29] and Khayyat *et al.* (2014) [30] in pomegranate.

The effect of grafts, salinity levels and interaction effect on chlorophyll stability index had significant influence in brinjal during both the years (2020, 2021) as well as in pooled mean data. Among the grafts, significantly the maximum chlorophyll stability index was observed in the treatment A_2 *i.e.* Phule Harit grafted on *Solanum torvum* (98.08%) in the year 2020, (98.27) 2021 and (98.18%) pooled mean. It was followed by A_4 *i.e.* Manjari Gota grafted on *Solanum torvum* (97.05%) and A_1 *i.e.* Phule Arjun grafted on *Solanum torvum* (96.84) for the year 2020; A_3 *i.e.* Krishna grafted on *Solanum torvum* (97.10) and A_4 *i.e.* Manjari Gota grafted on *Solanum torvum* (96.98%) for the year 2021; and A_4 *i.e.* Manjari Gota grafted on *Solanum torvum* (97.01%) and A_3 *i.e.* Krishna grafted on *Solanum torvum* (96.91%) in the pooled mean, respectively. Whereas, significantly the minimum chlorophyll stability index was found in A_3 *i.e.* Krishna grafted on *Solanum torvum* in the year 2020 (96.73%); and A_1 *i.e.* Phule Arjun grafted on *Solanum torvum* for the year 2021 (96.70%) and in the pooled mean (96.77%). The chlorophyll stability index (CSI) is the two important physiological traits that are directly related to salt stress. The high accumulations of chlorophyll in plants indicate that the plant did not have much problem to survive in salt stress environment. The high CSI value indicates the better availability of chlorophyll in the plant and helps the plant to withstand stress. This leads to increased photosynthetic rate, more dry matter production, and higher productivity. The CSI served as potent character in identifying tolerant genotypes to salt stress situation (Babu *et al.*, 2009) [31].

Chlorophyll stability index was decreased at higher level of salt concentration. Under salt concentrations, the maximum chlorophyll stability index was noticed in the control treatment B_1 *i.e.* 0 dS m^{-1} (100.00%) for the year 2020, 2021 and in the pooled means. It was followed by B_2 *i.e.* 2.00 dS m^{-1} (98.60%, 98.70%, and 98.65% in 2020, 2021 and pooled mean, respectively), B_3 *i.e.* 3.00 dS m^{-1} (97.68%, 97.69% and 97.69% in 2020, 2021 and pooled mean, respectively) and B_4 *i.e.* 4.00 dS m^{-1} (95.34%, 95.69% and 95.52% in 2020, 2021 and pooled mean, respectively). The minimum chlorophyll stability index was recorded in treatment B_5 *i.e.* 5 dS m^{-1} for the year 2020 (94.24%), 2021 and in the pooled mean (94.23%). The high CSI value indicates the better availability of chlorophyll in the plant and helps the plant to withstand stress. This leads to increased photosynthetic rate, more dry matter production, and higher productivity. A higher CSI helps the plants to withstand stress through better availability of chlorophyll, leading to increased photosynthetic rate, more dry matter production and higher productivity. The lowest CSI might be due to the degradation of chlorophyll pigments under salt stress. The findings are in accordance with those obtained by Mohan *et al.* (2000) [32] and Menakumari *et al.* (2004) [33].

Among the treatment combinations, T_1 (A_1B_1) *i.e.* Phule Arjun grafted on *S. torvum* with 0 dS m^{-1}, T_6 (A_2B_1) *i.e.* Phule Harit grafted on *S. torvum* with 0 dS m^{-1}, T_{11} (A_3B_1) *i.e.* Krishna grafted on *S. torvum* with 0 dS m^{-1} and T_{16} (A_4B_1) *i.e.* Manjari Gota grafted on *S. torvum* with 0 dS m^{-1} were observed significantly the maximum chlorophyll stability index (100.00%) in the year 2020, 2021, and in the pooled mean. Phule Harit grafted on *Solanum torvum* was proved to be maximum for chlorophyll stability index at 3.00, 4.00 and 5.00 dS m^{-1} (98.28%, 97.28% and 96.30%, respectively). Whereas, significantly the lowest chlorophyll stability index was recorded in the treatment combination T_{15} (A_3B_5) *i.e.* Krishna grafted on *Solanum torvum* with 5 dS m^{-1} in the year 2020 (93.05%) and T_5 (A_1B_5) *i.e.* Phule Arjun grafted on *Solanum torvum* with 5 dS m^{-1} in the year 2021 (92.88%) and pooled mean (93.24%). Salinity occurs when there is an excessive accumulation of salts (especially high Na^+, Cl^- and SO_4^-) in the soil (Parida and Das, 2005) [3] or irrigation water (Colla *et al.*, 2010)[4]. Continuous irrigation with saline water could also lead to deterioration of physical properties of the soil and decrease of crop production. The elevated level of salts generally causes a reduction of water potential in the root medium, thereby leading to a water deficit within plants (Rivero *et al.*, 2003) [34], besides their excess level can cause ion toxicity and nutrient imbalance, especially of K^+, Ca^{+2} and Mg^{+2} by disturbing their uptake and transport to the shoots (Colla *et al.*, 2012) [35]. Mohan *et al.* (2000) [32] reported that high CSI value means that the stress did not have much effect on chlorophyll content of plants. A higher CSI aids the plants to withstand stress through better availability of chlorophyll, leading to increased photosynthetic rate, more dry matter production and higher productivity in rice plants thus indicating how well the chlorophyll can perform under stress. Meenakumari *et al*. (2004) [33] reported that chlorophyll content as well as Chlorophyll stability index decreased in maize plants during drought condition.

Table 1: Effect of different salinity levels on chlorophyll characteristics of brinjal varieties grafted on *Solanum torvum*

Factors	Treatment Details	Chlorophyll-a (mg/100 g)			Chlorophyll -b (mg/100 g)			Total chlorophyll (mg/100 g)			Chlorophyll Stability Index (CSI) (%)		
		2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
Factor A: Grafts													
A_1	Phule Arjun grafted on *Solanum torvum*	92.27	91.88	92.08	39.63	39.62	39.63	131.90	131.51	131.70	96.84	96.70	96.77
A_2	Phule Harit grafted on *Solanum torvum*	85.41	84.97	85.19	38.60	38.29	38.45	124.01	123.26	123.64	98.08	98.27	98.18
A_3	Krishna grafted on *Solanum torvum*	91.12	90.96	91.04	39.46	39.50	39.48	130.58	130.46	130.52	96.73	97.10	96.91
A_4	Manjari Gota grafted on *Solanum torvum*	89.17	89.03	89.10	36.56	36.66	36.61	125.73	125.69	125.71	97.05	96.98	97.01
SE (m) ±		0.100	0.056	0.052	0.030	0.016	0.017	0.113	0.064	0.050	0.139	0.032	0.071
C.D at 5%		0.293	0.168	0.157	0.091	0.047	0.050	0.338	0.191	0.148	0.415	0.096	0.210
Factor B: Salinity levels													
B_1	0 $dS\ m^{-1}$	92.01	91.48	91.74	39.79	39.87	39.83	131.80	131.35	131.57	100.00	100.00	100.00
B_2	2.00 $dS\ m^{-1}$	90.62	90.21	90.42	39.33	39.40	39.37	129.95	129.62	129.79	98.60	98.70	98.65
B_3	3.00 $dS\ m^{-1}$	89.80	89.58	89.69	38.93	38.73	38.83	128.74	128.31	128.53	97.68	97.69	97.69
B_4	4.00 $dS\ m^{-1}$	88.04	88.05	88.04	37.59	37.60	37.60	125.62	125.65	125.64	95.34	95.69	95.52
B_5	5.00 $dS\ m^{-1}$	86.99	86.73	86.86	37.17	36.98	37.08	124.16	123.71	123.94	94.24	94.23	94.23
SE (m) ±		0.112	0.063	0.059	0.034	0.017	0.019	0.127	0.072	0.056	0.156	0.036	0.079
C.D at 5%		0.333	0.187	0.175	0.101	0.052	0.056	0.378	0.214	0.166	0.464	0.108	0.235
A x B: Interactions													
T_1	A_1B_1	95.80	95.80	95.80	40.41	40.20	40.31	136.21	136.00	136.11	100.00	100.00	100.00
T_2	A_1B_2	93.65	92.37	93.01	40.08	40.13	40.11	133.73	132.49	133.11	98.19	97.42	97.80
T_3	A_1B_3	93.07	93.38	93.22	39.81	39.78	39.80	132.87	133.15	133.01	97.55	97.91	97.73
T_4	A_1B_4	90.12	90.28	90.20	39.07	39.30	39.19	129.19	129.58	129.38	94.85	95.28	95.06
T_5	A_1B_5	88.70	87.59	88.15	38.78	38.73	38.76	127.48	126.32	126.90	93.60	92.88	93.24
T_6	A_2B_1	86.70	85.53	86.12	39.74	39.90	39.82	126.44	125.43	125.93	100.00	100.00	100.00
T_7	A_2B_2	85.75	85.41	85.58	39.07	39.17	39.12	124.82	124.58	124.70	98.72	99.33	99.02
T_8	A_2B_3	85.62	85.06	85.34	38.72	38.15	38.44	124.33	123.21	123.77	98.33	98.24	98.28
T_9	A_2B_4	84.78	84.80	84.79	37.88	37.55	37.72	122.66	122.35	122.50	97.01	97.55	97.28
T_{10}	A_2B_5	84.22	84.06	84.14	37.59	36.67	37.14	121.81	120.73	121.27	96.34	96.26	96.30
T_{11}	A_3B_1	93.74	92.87	93.31	41.26	41.49	41.38	135.00	134.36	134.68	100.00	100.00	100.00
T_{12}	A_3B_2	92.43	92.44	92.43	41.01	41.07	41.05	133.44	133.51	133.47	98.84	99.37	99.11
T_{13}	A_3B_3	91.15	91.20	91.18	40.44	40.26	40.36	131.59	131.47	131.53	97.48	97.85	97.67
T_{14}	A_3B_4	89.70	89.60	89.65	37.58	37.60	37.59	127.28	127.20	127.24	94.28	94.68	94.48
T_{15}	A_3B_5	88.59	88.67	88.63	37.03	37.08	37.06	125.62	125.75	125.68	93.05	93.59	93.32
T_{16}	A_4B_1	91.80	91.72	91.76	37.75	37.90	37.83	129.55	129.61	129.58	100.00	100.00	100.00
T_{17}	A_4B_2	90.65	90.64	90.65	37.17	37.25	37.21	127.82	127.89	127.85	98.67	98.68	98.78
T_{18}	A_4B_3	89.38	88.70	89.04	36.78	36.72	36.75	126.15	125.42	125.79	97.38	96.77	97.81
T_{19}	A_4B_4	87.54	87.51	87.53	35.83	35.96	35.90	123.37	123.47	123.42	95.23	95.26	95.25
T_{20}	A_4B_5	86.46	86.60	86.53	35.29	35.46	35.38	121.75	122.06	121.91	93.99	94.18	94.08
SE (m) ±		0.223	0.126	0.117	0.068	0.035	0.038	0.253	0.144	0.111	0.311	0.072	0.158
C.D at 5%		0.666	0.375	0.350	0.203	0.104	0.112	0.756	0.428	0.332	0.928	0.251	0.471

Conclusion

Among the grafts, results showed that Phule Arjun grafted on *Solanum torvum* was found significantly maximum values of chlorophyll-a, b and total chlorophyll. Whereas, Phule Harit grafted on *Solanum torvum* was shown maximum values for chlorophyll stability index. Phule Arjun grafted on *Solanum torvum* was proved to be maximum for total chlorophyll at 3.00, 4.00 and 5.00 $dS\ m^{-1}$ and chlorophyll- b was shown at 4.00 and 5.00 $dS\ m^{-1}$; and chlorophyll- a at 3.00 and 4.00 $dS\ m^{-1}$. While, Phule Harit grafted on *Solanum torvum* was proved to be maximum for chlorophyll stability index at 3.00, 4.00 and 5.00 $dS\ m^{-1}$. Krishna grafted on *Solanum torvum* was proved to be maximum chlorophyll- b content was recorded at 3.00 $dS\ m^{-1}$ and chlorophyll- a at 5.00 $dS\ m^{-1}$.

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