

## ***Physiological Response Of Banana (Musa Spp.) Genotypes To Flooding Stress At Vegetative Stage***

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### ***Abstract***

Cauvery Delta zone has a total geographical area of 14.47 lakh ha. The average rainfall of Cauvery Delta zone is 1268.38mm with a range of 544.7mm to 2098mm. However, the Cauvery Delta zone has periodically experienced with intermittent flood during the monsoon, particularly North East monsoon. Inundation of water in banana growing area of Cauvery Delta zone is very common that affects growth, yield and physiological function of banana crop. In the present investigation work on "Physiological response of banana (*Musa spp.*) genotypes to flooding stress at vegetative stage" was carried out at Horticultural Research Block, Department of Horticulture, Central University of Tamil Nadu, Thiruvavur during the period of 2024-2025. The pot culture experiment was laid out in Factorial Randomized Block Design (FCRD) with two factors and it was replicated twice. The planting time of season I is January, 2024 and season II is July, 2024 and the flooding treatment was given initial vegetative stage of 5<sup>th</sup> month after planting of suckers for Season -I (June, 2024) and Season- II (November, 2024) with 5cm soil flooding was maintained in each treatment combinations. The following physiological parameters viz., leaf area (cm<sup>2</sup>), leaf area index, chlorophyll 'a' and 'b' content, total chlorophyll content (mg/g), chlorophyll stability index, relative water content and proline content (µg/mg) were recorded in before flooding, at the time of flooding and 15 days after flooding and the statistical analysis of pooled mean of both season 5<sup>th</sup> month after flooding work done. In this present study results showed that, among the six genotypes screened the genotype Karpooravalli (V<sub>5</sub>) recorded highest leaf area (cm<sup>2</sup>), leaf area index, chlorophyll 'a' and 'b' content, total chlorophyll content (mg/g), chlorophyll stability index and proline content (µg/mg) was noticed during before flooded condition, 96hrs after flooded condition and 15 days after flooded condition. It was followed by Monthan (V<sub>6</sub>) respectively.

**Keywords:** Chlorophyll, Flood, FCRD, Genotypes, *Musa spp.* NEM and Proline

### ***Introduction***

India is the largest producer of banana in the world with production of 30 million metric tons from an area of 8.6 lakh hectare and a productivity of 34.0 MT/ha. In Tamil Nadu, banana grown in an area of 0.92 lakh ha and a production 3.987 million metric tons of with 43.14 MT/ha productivity. Banana being a crop with shallow root system requires optimal water supply throughout the cropping period. Cauvery Delta zone occupies a total geographical area of 14.47 lakh ha. The average rainfall of Cauvery Delta zone be 1268.38mm with a range of 544.7mm to 2098mm. Banana requires 25mm of rainfall per

week (Stover and Simmonds, 1987) for active growth and development. However, the Cauvery Delta zone periodically experienced with intermittent flood during the monsoon, exclusively North East monsoon. Inundation of water in banana growing area of Cauvery Delta zone remain very common that affects growth, yield and physiological function of banana crop. Flooding remain as one of the abiotic stress factors which been observed worldwide due to climate change. Agricultural food crops like banana face problem with extreme weather fluctuations in times of climate change impacts significant decline in productivity and yield (Sharma et al., 2021). Moreover, flooding results poor oxygen diffusion to the roots, leading hypoxia and more severe anoxic conditions (Herzog et al., 2016). The limited O<sub>2</sub> supply to roots results in aerobic to anaerobic respiration, with low ATP production (Ploschuk et al., 2018). Flooding stress also results decreased function in absorbing water and nutrients towards the shoot (Tong et al., 2021). Accumulation of ethylene and carbon di oxide due to flooding also causes root damage, decreased root activity and root hydraulic conductance thoroughly inhibiting root functions (Shaw et al., 2013; Voesenek and Bailey Serres, 2015). Flooding remains as a widespread phenomenon in banana growing areas but it impacts on the physiology of banana and plantains largely unexplored. Flooding, flooding or inundation legitimately influence the distribution of oxygen in tissues and various gases between cells that restricts the exchange of oxygen and respiration in mitochondria and finally affect the biochemical as well as physiological performance of the plant (Liu et al., 2016; Voesenek and Bailey- Serres, 2013). Flooding reduces growth by affecting one or several physiological process. Although, there have been a good number of reports on the excess moisture tolerance of other upland crops such as tomato (Keo and Chen, 1980), despite very little information remain available with the physiological response of banana to flooding.

The flooding tolerance of various banana genotypes differs due to their unique physiological and genetic characteristics. However, detailed studies on physiological response of banana genotypes limited necessitating further research to fully understand their responses to flooding stress in open field conditions of pot culture.

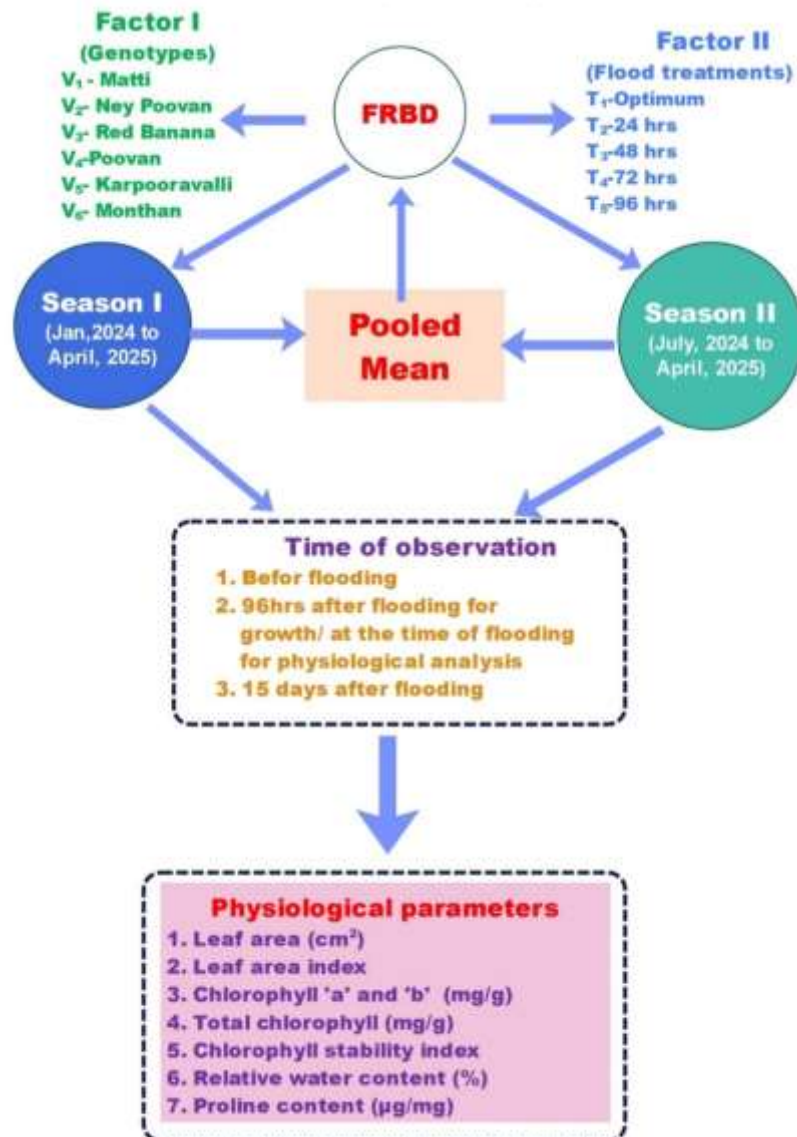
The resistance mechanism of plant to flooding depend mainly by species (Xu et al., 2017) genetic architecture, growth of the plant, the duration of exposure and the degree of flooding (Romina et al., 2014; Shao et al., 2013 and Wu et al., 2018). Setter and Waters (2003) suggested that it remain possible that flood tolerant genotypes may possess a mechanism of tolerance associated with escaping and have a rapid recovery following stresses. It's been therefore, evaluation of flood tolerance should be made based on physiological traits (Zhou, 2010).

### ***Materials and Methods***

The present work on "Physiological response of banana (*Musa* spp.) genotypes to flooding stress at vegetative stage" was carried out at Horticultural Research Block, Department of Horticulture, Central University of Tamil Nadu, Thiruvavur during the period of 2024-2025. The planting time of season I was January, 2024 and season II was July, 2024. The flood treatment was given by 5<sup>th</sup> month after planting (MAP) for both the crop during June, 2024 and November, 2024. The pot culture experimentation was laid out in Factorial Randomized Block Design (FCRD) with two factors and replicated twice. There are 30 different combinations including, Factor I considered as genotypes having 6 levels (V<sub>1</sub>-Matti, V<sub>2</sub>-Ney Poovan, V<sub>3</sub>-Red Banana, V<sub>4</sub>-Poovan, V<sub>5</sub>-Karpooravalli and V<sub>6</sub>-Monthan) and the Factor II considered as treatments having 5 levels (T<sub>1</sub>-Control (Optimum water requirement), T<sub>2</sub>-24hours flooding, T<sub>3</sub>-48hours flooding, T<sub>4</sub>-72hours flooding and T<sub>5</sub>-96hours flooding). The uniform planting material (Suckers) was used for both the seasons viz., Season-I (January, 2024 to April, 2025) and Season- II (July, 2024 to April, 2025). The planting time of season I is January, 2024 and season II is July, 2024 and the all the cultural

practices were followed by as per Crop Production Guide, 2020. The flooding treatment was given initial vegetative stage of 5<sup>th</sup> month after planting of suckers for Season-I (June, 2024) and Season-II (November, 2024) with 5cm soil flooding got maintained in each treatment combinations (Fig. 1). The following physiological parameters were recorded in before flooding, 96hours after flooding/at the time of flooding and 15 days after flooding and the standard methodologies are described below,

**Fig.1. Effect of flooding stress on physiological changes in banana (*Musa spp.*)**  
**Leaf area (cm<sup>2</sup>)**



The total leaf area was measured by non-destructive method suggested by Murray, 1960. The every third leaf length and breadth got measured and multiplying with lead area factor 0.80 (K). These values were expressed as centimetre square (cm<sup>2</sup>).

### 3.2. Leaf area index

According to the Williams (1946) suggested the leaf area index (LAI) of functional leaf of a plant was calculated by following formula,

$$\text{LAI} = \frac{\text{Leaf area per plant}}{\text{Ground area occupied by the plant}}$$

#### **Chlorophyll content (mg/g)**

The chlorophyll content was estimated as per the methods proposed by Arnon (1949) and Davies (1976). 0.500mg of fresh leaves were collected and chopped in to small pieces, the leaves are macerated with 80% Acetone. The material was centrifuged at 3000rpm for 5 minutes and collect the supernatant was measured optical density of (OD) 480nm, 645nm and 663nm in a Spectrophotometer - 2800 (Hitachi, Japan). Chlorophyll 'a', 'b' and total chlorophyll was calculated using formula suggested by Davies (1976).

$$\text{Chlorophyll 'a'} = [12.7 (\text{OD } 663) - 2.69 (\text{OD } 645)] \times V/1000 \times W$$

$$\text{Chlorophyll 'b'} = [22.9 (\text{OD } 645) - 4.68 (\text{OD } 663)] \times V/1000 \times W$$

$$\text{Total Chlorophyll} = [20.2 (\text{OD } 645) + 8.02 (\text{OD } 663)] \times V/1000 \times W$$

Where, V = Volume of the extract; W =Weight of leaf segments

#### **Chlorophyll stability index**

The leaf sample was collected, weighted 500mg and leaves was cut in to small bits 8 to 10 and transferred in to test tube. Add 20ml of distilled water into control tube and 20ml of 55 ° C hot water as a treatment test tube. The treatment test tube kept under hot water bath for 30minutes. After completion of the reaction phase test tubes of are both control and treated leaf bits are macerated with 10ml of 80 per cent acetone. Centrifuge the sample content at 3000rpm for 10minutes. After completion of centrifuge process, collect the supernatant and add the 80 per cent acetone for volume make up to 25ml. The supernatant leaf sample was measured the optical density (OD) of 652nm in a Spectrophotometer. The amount of total chlorophyll content was present in control and treated samples were calculated by using standard formula suggested by Sivasubramanian (1992).

$$\text{Total chlorophyll (mg/g)} = \frac{\text{OD at 652} \times 1000}{34.5} \times \frac{V}{1000 \times W}$$

The chlorophyll stability index persist ratio between total chlorophyll content of control and total chlorophyll content of treated samples were expressed as percentage.

$$\text{Chlorophyll Stability Index} = \frac{\text{Total chlorophyll content (Treated)}}{\text{Total chlorophyll content (Control)}} \times 100$$

#### **Relative water content (%)**

According to the Barrs and Weatherly (1962) described the method of relative water content of a leaf sample was estimated all the stages of a crop and it was expressed in percentage. The leaf sample were collected and cut in to small pieces around 1-2cm and immediately note the initial weight of the fresh sample (FW). After the leaves were transfer in to a petri dish, add distilled water leaves were floated and close the petri dish. The imbibition period of turgid leaves (TW) were weighted periodically, after wiping the water content from the leaf surface with tissue paper. End of the imbibition period of leaf sample were kept under hot air over at 80 ° C for 48hours in order to acquire the dry weight (DW).

$$\text{Relative Water Content (\%)} = \frac{\text{Fw} - \text{Dw}}{\text{Tw} - \text{Dw}} \times 100$$

### **Proline content ( $\mu\text{g}/\text{mg}$ )**

The leaf proline content was estimated as per the method suggested by Bates et al. (1973) and it was expressed microgram per milligram ( $\mu\text{g mg}^{-1}$ ). 500mg of fresh leaves were collected and macerated with 10ml of 3% aqueous salphosalicylic acid using pestle and mortar. Leaf extract was centrifuged at 4000rpm for 10minutes. After the centrifuge process the 2ml of supernatant was taken in a test tube, add 2ml of acid ninhydrin and 2ml of glacial acidic acid. The sample tube was kept under water bath for one hour at  $100^\circ\text{C}$  and it was cooler under tap water. After cooling of sample solution, it was transfer to separating funnel and add 4ml of toluene. The separating funnel was uniformly shaken for 30seconds and formed two different layers. The colourless bottom layer was discarded and the pink colour upper layer was collected and measured optical density (OD) of 520nm using blank solution of toluene.

$$\text{Amount of proline } (\mu\text{g mg}^{-1}) = \frac{X}{2} \times \frac{10}{500} \times 100$$

### **Statistical method**

The both season (Season I and Season II) crop physiological parameter data were statistically analysed and the result of the pooled mean present this paper. Statistical analysis was carried out using Agri Analyze online tool ([www.agrianalyze.com](http://www.agrianalyze.com)) using standard scientific software package. Differences between means were evaluated using Duncan's multiple range test at  $p \leq 0.05$ . Analysis of variance (ANOVA) will be used to determine the significance of difference among the treatments (Popat et al., 2024) and pool mean analysis suggested by Rangaswamy, (1995).

## **Results**

### **Leaf area ( $\text{cm}^2$ ) and leaf area index**

Leaves remain as a functional tool in plants for its better physiological function. The results pertaining to leaf area and leaf area index were presented in Table.1. From the table, it was observed that the traits leaf area and leaf area index were significantly differed for genotypes, flood treatments and their interactions. Among the six genotypes screened, the genotype  $V_5$  recorded higher leaf area and leaf area index at before flooding ( $736.5 \text{ cm}^2$  and 13.15), 96hrs after flooding ( $870.5 \text{ cm}^2$  and 13.71) and 15 days after flooding ( $1134.2$  and 14.84). It was closely followed by the genotype  $V_6$  (Table. 1) whereas, significantly the lowest leaf area and leaf area index values were recorded by the genotype  $V_1$  at all three stages viz., before flooding ( $722.3 \text{ cm}^2$  and 10.29), 96hrs after flooding ( $802.7 \text{ cm}^2$  and 10.06) and 15 days after flooding ( $1009.4 \text{ cm}^2$  and 11.29).

**Table. 1. Effect of flooding stress on leaf area ( $\text{cm}^2$ ) and leaf area index, before flooding, 96hrs after flooding and 15days after flooding in banana at 5<sup>th</sup> MAP**

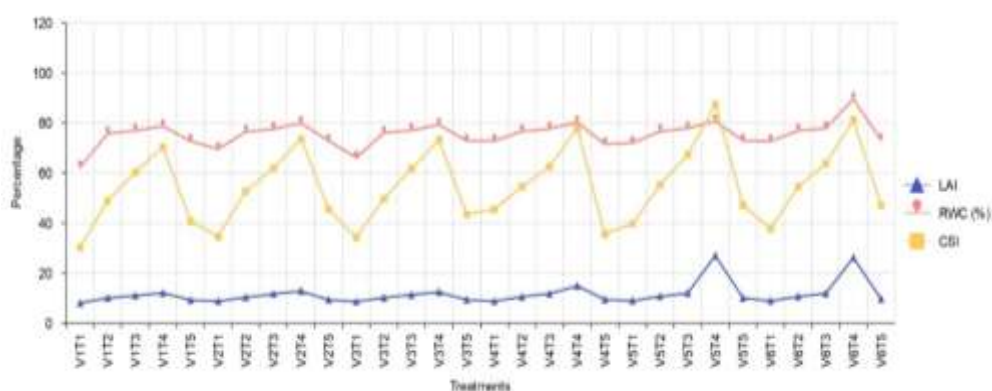
| Treatments | Leaf area ( $\text{cm}^2$ ) |                      |                       | Leaf area index |                       |
|------------|-----------------------------|----------------------|-----------------------|-----------------|-----------------------|
|            | Before flooding             | 96hrs after flooding | 15days after flooding | Before flooding | 15days after flooding |

|                                   |              |              |               |              |              |
|-----------------------------------|--------------|--------------|---------------|--------------|--------------|
| <b>V<sub>1</sub></b>              | 722.3        | 802.7        | 1009.4        | 10.29        | 11.29        |
| <b>V<sub>2</sub></b>              | 729.2        | 823.8        | 1053.0        | 10.41        | 11.69        |
| <b>V<sub>3</sub></b>              | 715.7        | 818.7        | 1022.1        | 10.29        | 11.49        |
| <b>V<sub>4</sub></b>              | 730.0        | 834.1        | 1064.4        | 10.77        | 11.88        |
| <b>V<sub>5</sub></b>              | 736.5        | 870.5        | 1134.2        | 13.15        | 14.84        |
| <b>V<sub>6</sub></b>              | 732.4        | 846.2        | 1122.6        | 12.64        | 14.54        |
| <b>SE.d</b>                       | <b>48.66</b> | <b>46.46</b> | <b>58.98</b>  | <b>0.697</b> | <b>0.508</b> |
| <b>CD 5%</b>                      | <b>97.33</b> | <b>92.94</b> | <b>117.98</b> | <b>1.394</b> | <b>1.016</b> |
| <b>T<sub>1</sub></b>              | 594.8        | 679.7        | 872.4         | 8.35         | 9.73         |
| <b>T<sub>2</sub></b>              | 720.5        | 824.9        | 1061.5        | 9.99         | 11.89        |
| <b>T<sub>3</sub></b>              | 775.2        | 880.9        | 1104.6        | 10.99        | 12.70        |
| <b>T<sub>4</sub></b>              | 858.3        | 998.6        | 1298.7        | 17.16        | 18.23        |
| <b>T<sub>5</sub></b>              | 689.6        | 779.3        | 1000.8        | 9.80         | 10.56        |
| <b>SE.d</b>                       | <b>44.42</b> | <b>42.42</b> | <b>53.84</b>  | <b>0.636</b> | <b>0.464</b> |
| <b>CD 5%</b>                      | <b>88.85</b> | <b>84.84</b> | <b>107.7</b>  | <b>1.273</b> | <b>0.927</b> |
| <b>V<sub>1</sub>T<sub>1</sub></b> | 531.6        | 653.1        | 803.1         | 7.59         | 9.09         |
| <b>V<sub>1</sub>T<sub>2</sub></b> | 754.6        | 810.4        | 1038.7        | 9.56         | 11.27        |
| <b>V<sub>1</sub>T<sub>3</sub></b> | 796.9        | 850.8        | 1089.6        | 10.49        | 12.50        |
| <b>V<sub>1</sub>T<sub>4</sub></b> | 817.1        | 929.0        | 1149.6        | 11.72        | 13.14        |
| <b>V<sub>1</sub>T<sub>5</sub></b> | 611.1        | 770.1        | 965.9         | 12.10        | 10.43        |
| <b>V<sub>2</sub>T<sub>1</sub></b> | 609.0        | 664.4        | 872.7         | 8.15         | 9.53         |
| <b>V<sub>2</sub>T<sub>2</sub></b> | 713.8        | 820.8        | 1052.5        | 9.80         | 11.76        |
| <b>V<sub>2</sub>T<sub>3</sub></b> | 771.5        | 877.9        | 1100.3        | 10.81        | 12.58        |
| <b>V<sub>2</sub>T<sub>4</sub></b> | 849.0        | 984.9        | 1241.2        | 13.19        | 14.13        |
| <b>V<sub>2</sub>T<sub>5</sub></b> | 719.0        | 770.8        | 998.5         | 10.12        | 10.47        |
| <b>V<sub>3</sub>T<sub>1</sub></b> | 584.6        | 663.9        | 804.6         | 8.12         | 9.50         |
| <b>V<sub>3</sub>T<sub>2</sub></b> | 759.4        | 819.3        | 1042.0        | 9.71         | 11.69        |
| <b>V<sub>3</sub>T<sub>3</sub></b> | 771.5        | 870.5        | 1097.9        | 10.71        | 12.57        |
| <b>V<sub>3</sub>T<sub>4</sub></b> | 817.1        | 969.8        | 1189.5        | 12.10        | 13.24        |
| <b>V<sub>3</sub>T<sub>5</sub></b> | 713.2        | 770.1        | 976.3         | 10.81        | 10.44        |
| <b>V<sub>4</sub>T<sub>1</sub></b> | 613.3        | 679.1        | 877.4         | 8.69         | 9.60         |
| <b>V<sub>4</sub>T<sub>2</sub></b> | 719.0        | 828.4        | 1064.1        | 10.12        | 11.95        |
| <b>V<sub>4</sub>T<sub>3</sub></b> | 777.4        | 893.7        | 1109.8        | 11.16        | 12.69        |
| <b>V<sub>4</sub>T<sub>4</sub></b> | 858.4        | 985.7        | 1259.3        | 14.57        | 14.58        |
| <b>V<sub>4</sub>T<sub>5</sub></b> | 681.9        | 783.4        | 1011.2        | 9.33         | 10.58        |
| <b>V<sub>5</sub>T<sub>1</sub></b> | 616.6        | 719.8        | 957.1         | 8.85         | 10.34        |
| <b>V<sub>5</sub>T<sub>2</sub></b> | 735.8        | 840.2        | 1088.2        | 10.44        | 12.47        |
| <b>V<sub>5</sub>T<sub>3</sub></b> | 796.0        | 897.8        | 1115.4        | 11.53        | 13.13        |
| <b>V<sub>5</sub>T<sub>4</sub></b> | 917.3        | 1098.8       | 1480.2        | 26.07        | 27.43        |
| <b>V<sub>5</sub>T<sub>5</sub></b> | 616.6        | 796.1        | 1030.1        | 8.85         | 10.84        |
| <b>V<sub>6</sub>T<sub>1</sub></b> | 531.6        | 697.7        | 919.5         | 7.59         | 10.32        |
| <b>V<sub>6</sub>T<sub>2</sub></b> | 730.0        | 830.2        | 1083.4        | 10.32        | 12.23        |

|                                   |               |              |              |              |              |
|-----------------------------------|---------------|--------------|--------------|--------------|--------------|
| <b>V<sub>6</sub>T<sub>3</sub></b> | 792.2         | 894.7        | 1114.7       | 11.26        | 12.72        |
| <b>V<sub>6</sub>T<sub>4</sub></b> | 911.1         | 1023.2       | 1472.7       | 25.34        | 26.86        |
| <b>V<sub>6</sub>T<sub>5</sub></b> | 613.8         | 785.2        | 1022.6       | 8.69         | 10.60        |
| <b>SE.d</b>                       | <b>108.8</b>  | <b>103.9</b> | <b>131.9</b> | <b>1.559</b> | <b>1.136</b> |
| <b>CD 5%</b>                      | <b>217.64</b> | <b>207.8</b> | <b>263.8</b> | <b>3.118</b> | <b>2.272</b> |

Regarding the flood treatments, significantly higher the leaf area and leaf area index was noticed in T<sub>4</sub> at three stages viz., before flooding (858.3 cm<sup>2</sup> and 17.16), 96hrs after flooding (998.6 cm<sup>2</sup> and 17.55) and 15 days after flooding (1298.7 cm<sup>2</sup> and 18.23). It was closely followed by T<sub>3</sub> (Table. 1). Whereas, the lowest leaf area and leaf area index was noticed in control (T<sub>1</sub>) all three stages viz., before flooding (594.8 cm<sup>2</sup> and 8.35), 96hrs after flooding (679.7 cm<sup>2</sup> and 8.68) and 15 days after flooding (872.4 cm<sup>2</sup> and 9.73). Similarly, the interaction effect also showed significant influence on leaf area and leaf area index. The highest leaf area and leaf area index was recorded in V<sub>5</sub>T<sub>4</sub> at before flooding (917.3 cm<sup>2</sup> and 26.07), 96hrs after flooding (1098.8 cm<sup>2</sup> and 26.95) and 15 days after flooding (1480.2 cm<sup>2</sup> and 27.43). It was followed by V<sub>6</sub>T<sub>4</sub> which recorded a leaf area and leaf area index of before flooding (911.1 cm<sup>2</sup> and 25.34), 96hrs after flooding (1023.2 cm<sup>2</sup> and 26.14) and 15 days after flooding (1472.7 cm<sup>2</sup> and 26.86) (Table. 1 and Fig. 2). However, V<sub>1</sub>T<sub>1</sub> recorded lowest leaf area (531.6 cm<sup>2</sup>, 653.1 cm<sup>2</sup> and 803.1 cm<sup>2</sup>) and leaf area index (7.59, 8.05 and 9.09) at before flooding, 96hours after flooding and 15 days after flooding.

**Fig. 2. Effect of flooding stress on leaf area index, relative water content (%) and chlorophyll stability index on 96hrs after flooding/ at the time of flooding in banana at 5<sup>th</sup> MAP**



### **Chlorophyll content (mg/g)**

The results pertaining to chlorophyll 'a', chlorophyll 'b' and total chlorophyll were presented in Table.2. From the table, it was observed that the traits chlorophyll 'a', chlorophyll 'b' and total chlorophyll were significantly differed for genotypes, flood treatments and their interactions. Among the six genotypes screened, the genotype V<sub>5</sub> recorded higher chlorophyll 'a', chlorophyll 'b' and total chlorophyll at before flooding (0.961 mg/g, 0.881 mg/g and 1.808 mg/g), at the time of flooding (0.938 mg/g, 0.840 mg/g and 1.771 mg/g) and 15 days after flooding (0.960 mg/g, 0.872 mg/g and 1.789 mg/g). It was closely followed by the genotype V<sub>6</sub> (Table. 2) whereas, significantly the lowest chlorophyll 'a', chlorophyll 'b' and total chlorophyll values were recorded by the genotype V<sub>1</sub> at all three stages viz., before flooding (0.862 mg/g, 0.796 mg/g and 1.653 mg/g), at the

time of flooding (0.853 mg/g, 0.763 mg/g and 1.621 mg/g) and 15 days after flooding (0.847 mg/g, 0.789 mg/g and 1.650 mg/g).

**Table. 2. Effect of flooding stress on chlorophyll “a” content (mg/g), chlorophyll “b” content (mg/g) and total chlorophyll content (mg/g) before flooding, at the time of flooding and 15 days after flooding in banana at 5<sup>th</sup> MAP**

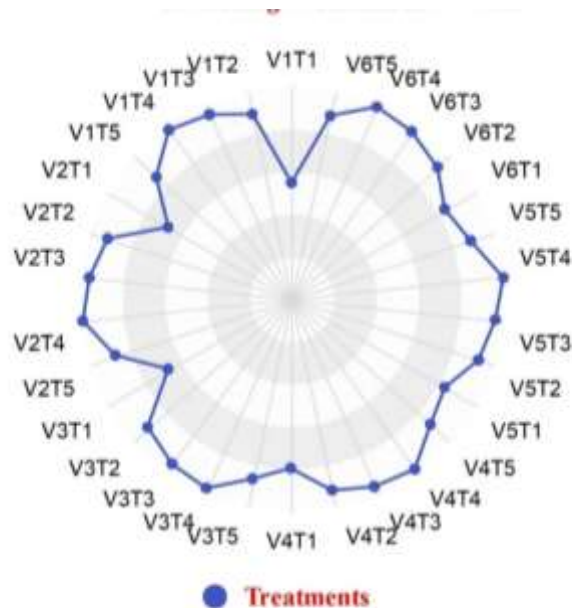
|                                   | Chlorophyll “a” content (mg/g) |                         |                       | Chlorophyll “b” content (mg/g) |                         |                       | Total chlorophyll content (mg/g) |                       |
|-----------------------------------|--------------------------------|-------------------------|-----------------------|--------------------------------|-------------------------|-----------------------|----------------------------------|-----------------------|
|                                   | Before flooding                | At the time of flooding | 15days after flooding | Before flooding                | At the time of flooding | 15days after flooding | Before flooding                  | 15days after flooding |
| <b>V<sub>1</sub></b>              | 0.862                          | 0.853                   | 0.847                 | 0.796                          | 0.763                   | 0.789                 | 1.653                            | 1.650                 |
| <b>V<sub>2</sub></b>              | 0.911                          | 0.893                   | 0.898                 | 0.824                          | 0.794                   | 0.835                 | 1.692                            | 1.692                 |
| <b>V<sub>3</sub></b>              | 0.885                          | 0.885                   | 0.875                 | 0.811                          | 0.772                   | 0.809                 | 1.675                            | 1.660                 |
| <b>V<sub>4</sub></b>              | 0.951                          | 0.900                   | 0.909                 | 0.841                          | 0.802                   | 0.845                 | 1.719                            | 1.748                 |
| <b>V<sub>5</sub></b>              | 0.961                          | 0.938                   | 0.960                 | 0.881                          | 0.840                   | 0.872                 | 1.808                            | 1.789                 |
| <b>V<sub>6</sub></b>              | 0.957                          | 0.917                   | 0.942                 | 0.864                          | 0.815                   | 0.857                 | 1.737                            | 1.760                 |
| <b>SE.d</b>                       | <b>0.045</b>                   | <b>0.030</b>            | <b>0.034</b>          | <b>0.029</b>                   | <b>0.036</b>            | <b>0.027</b>          | <b>0.041</b>                     | <b>0.044</b>          |
| <b>CD 5%</b>                      | <b>0.089</b>                   | <b>0.059</b>            | <b>0.067</b>          | <b>0.057</b>                   | <b>0.072</b>            | <b>0.053</b>          | <b>0.083</b>                     | <b>0.088</b>          |
| <b>T<sub>1</sub></b>              | 0.713                          | 0.573                   | 0.655                 | 0.652                          | 0.629                   | 0.659                 | 1.391                            | 1.307                 |
| <b>T<sub>2</sub></b>              | 0.959                          | 0.963                   | 0.955                 | 0.859                          | 0.817                   | 0.846                 | 1.822                            | 1.809                 |
| <b>T<sub>3</sub></b>              | 1.007                          | 0.994                   | 0.986                 | 0.898                          | 0.868                   | 0.897                 | 1.866                            | 1.851                 |
| <b>T<sub>4</sub></b>              | 1.028                          | 1.054                   | 1.045                 | 0.964                          | 0.942                   | 0.965                 | 1.899                            | 1.911                 |
| <b>T<sub>5</sub></b>              | 0.899                          | 0.904                   | 0.884                 | 0.807                          | 0.733                   | 0.806                 | 1.742                            | 1.704                 |
| <b>SE.d</b>                       | <b>0.041</b>                   | <b>0.027</b>            | <b>0.031</b>          | <b>0.026</b>                   | <b>0.033</b>            | <b>0.025</b>          | <b>0.038</b>                     | <b>0.040</b>          |
| <b>CD 5%</b>                      | <b>0.081</b>                   | <b>0.054</b>            | <b>0.061</b>          | <b>0.052</b>                   | <b>0.066</b>            | <b>0.049</b>          | <b>0.076</b>                     | <b>0.080</b>          |
| <b>V<sub>1</sub>T<sub>1</sub></b> | 0.518                          | 0.527                   | 0.524                 | 0.562                          | 0.562                   | 0.553                 | 1.080                            | 1.142                 |
| <b>V<sub>1</sub>T<sub>2</sub></b> | 0.926                          | 0.949                   | 0.950                 | 0.845                          | 0.796                   | 0.833                 | 1.804                            | 1.795                 |
| <b>V<sub>1</sub>T<sub>3</sub></b> | 1.000                          | 0.978                   | 0.979                 | 0.879                          | 0.851                   | 0.864                 | 1.849                            | 1.835                 |
| <b>V<sub>1</sub>T<sub>4</sub></b> | 1.014                          | 1.027                   | 1.000                 | 0.921                          | 0.896                   | 0.929                 | 1.881                            | 1.879                 |
| <b>V<sub>1</sub>T<sub>5</sub></b> | 0.851                          | 0.786                   | 0.784                 | 0.775                          | 0.709                   | 0.768                 | 1.653                            | 1.599                 |
| <b>V<sub>2</sub>T<sub>1</sub></b> | 0.688                          | 0.535                   | 0.631                 | 0.625                          | 0.615                   | 0.668                 | 1.149                            | 1.218                 |
| <b>V<sub>2</sub>T<sub>2</sub></b> | 0.945                          | 0.963                   | 0.951                 | 0.853                          | 0.815                   | 0.843                 | 1.814                            | 1.801                 |
| <b>V<sub>2</sub>T<sub>3</sub></b> | 1.005                          | 0.992                   | 0.985                 | 0.890                          | 0.864                   | 0.892                 | 1.873                            | 1.838                 |
| <b>V<sub>2</sub>T<sub>4</sub></b> | 1.025                          | 1.056                   | 1.016                 | 0.947                          | 0.949                   | 0.962                 | 1.887                            | 1.901                 |
| <b>V<sub>2</sub>T<sub>5</sub></b> | 0.894                          | 0.919                   | 0.906                 | 0.805                          | 0.727                   | 0.813                 | 1.736                            | 1.700                 |
| <b>V<sub>3</sub>T<sub>1</sub></b> | 0.581                          | 0.528                   | 0.626                 | 0.605                          | 0.584                   | 0.561                 | 1.119                            | 1.154                 |
| <b>V<sub>3</sub>T<sub>2</sub></b> | 0.933                          | 0.961                   | 0.950                 | 0.848                          | 0.808                   | 0.836                 | 1.807                            | 1.799                 |
| <b>V<sub>3</sub>T<sub>3</sub></b> | 1.004                          | 0.989                   | 0.980                 | 0.879                          | 0.856                   | 0.889                 | 1.851                            | 1.836                 |

|                                   |              |              |              |              |              |              |              |              |
|-----------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| <b>V<sub>3</sub>T<sub>4</sub></b> | 1.023        | 1.050        | 1.008        | 0.942        | 0.901        | 0.961        | 1.883        | 1.881        |
| <b>V<sub>3</sub>T<sub>5</sub></b> | 0.888        | 0.898        | 0.811        | 0.781        | 0.713        | 0.796        | 1.714        | 1.629        |
| <b>V<sub>4</sub>T<sub>1</sub></b> | 0.817        | 0.542        | 0.637        | 0.647        | 0.639        | 0.694        | 1.214        | 1.405        |
| <b>V<sub>4</sub>T<sub>2</sub></b> | 0.981        | 0.967        | 0.955        | 0.860        | 0.823        | 0.850        | 1.829        | 1.812        |
| <b>V<sub>4</sub>T<sub>3</sub></b> | 1.008        | 0.999        | 0.987        | 0.904        | 0.864        | 0.899        | 1.874        | 1.859        |
| <b>V<sub>4</sub>T<sub>4</sub></b> | 1.033        | 1.057        | 1.037        | 0.981        | 0.949        | 0.968        | 1.899        | 1.917        |
| <b>V<sub>4</sub>T<sub>5</sub></b> | 0.917        | 0.938        | 0.931        | 0.812        | 0.735        | 0.816        | 1.777        | 1.750        |
| <b>V<sub>5</sub>T<sub>1</sub></b> | 0.844        | 0.694        | 0.775        | 0.774        | 0.708        | 0.768        | 1.593        | 1.518        |
| <b>V<sub>5</sub>T<sub>2</sub></b> | 0.988        | 0.974        | 0.964        | 0.877        | 0.833        | 0.858        | 1.848        | 1.825        |
| <b>V<sub>5</sub>T<sub>3</sub></b> | 1.012        | 1.004        | 0.993        | 0.919        | 0.889        | 0.921        | 1.878        | 1.879        |
| <b>V<sub>5</sub>T<sub>4</sub></b> | 1.039        | 1.075        | 1.131        | 0.998        | 1.000        | 0.990        | 1.933        | 1.947        |
| <b>V<sub>5</sub>T<sub>5</sub></b> | 0.923        | 0.943        | 0.937        | 0.840        | 0.770        | 0.825        | 1.790        | 1.776        |
| <b>V<sub>6</sub>T<sub>1</sub></b> | 0.833        | 0.615        | 0.740        | 0.702        | 0.668        | 0.708        | 1.285        | 1.407        |
| <b>V<sub>6</sub>T<sub>2</sub></b> | 0.981        | 0.967        | 0.963        | 0.875        | 0.827        | 0.857        | 1.832        | 1.823        |
| <b>V<sub>6</sub>T<sub>3</sub></b> | 1.011        | 1.000        | 0.990        | 0.918        | 0.882        | 0.918        | 1.875        | 1.861        |
| <b>V<sub>6</sub>T<sub>4</sub></b> | 1.037        | 1.058        | 1.082        | 0.996        | 0.956        | 0.983        | 1.912        | 1.939        |
| <b>V<sub>6</sub>T<sub>5</sub></b> | 0.921        | 0.943        | 0.935        | 0.830        | 0.742        | 0.819        | 1.782        | 1.771        |
| <b>SE.d</b>                       | <b>0.100</b> | <b>0.066</b> | <b>0.075</b> | <b>0.064</b> | <b>0.081</b> | <b>0.060</b> | <b>0.093</b> | <b>0.098</b> |
| <b>CD<br/>5%</b>                  | <b>0.199</b> | <b>0.132</b> | <b>0.150</b> | <b>0.128</b> | <b>0.161</b> | <b>0.120</b> | <b>0.185</b> | <b>0.196</b> |

For flood treatments, significantly higher chlorophyll 'a' content, chlorophyll 'b' content and total chlorophyll content was noticed in the treatment T<sub>4</sub> at all the three stages viz., before flooding (1.028 mg/g, 0.942 mg/g and 1.899 mg/g), at the time of flooding (1.054 mg/g, 0.942 mg/g and 1.889 mg/g) and 15 days after flooding (1.045 mg/g, 0.942 mg/g and 1.911 mg/g). It was closely followed by T<sub>3</sub> (Table. 2), whereas, the lowest chlorophyll 'a' content, chlorophyll 'b' content and total chlorophyll content was noticed in optimum water requirement (T<sub>1</sub>).

The interaction effect also showed significant influence on chlorophyll 'a' content, chlorophyll 'b' content and total chlorophyll content. The highest chlorophyll 'a' content, chlorophyll 'b' content and total chlorophyll content was recorded in V<sub>5</sub>T<sub>4</sub> at before flooding (1.039 mg/g, 0.998 mg/g and 1.933 mg/g), at the time of flooding (1.075 mg/g, 1.000 mg/g and 1.910) and 15 days after flooding (1.131 mg/g, 0.998 mg/g and 1.947 mg/g). It was followed by V<sub>6</sub>T<sub>4</sub> which recorded a chlorophyll 'a' content, chlorophyll 'b' content and total chlorophyll content of before flooding (1.037 mg/g, 0.996 mg/g and 1.912 mg/g), at the time of flooding (1.058 mg/g, 0.956 mg/g and 1.894 mg/g) and 15 days after flooding (1.082 mg/g, 0.983 mg/g and 1.939 mg/g) (Table.2 and Fig. 3). However, V<sub>1</sub>T<sub>1</sub> recorded lowest chlorophyll 'a' content (0.518 mg/g, 0.527 mg/g and 0.524 mg/g), chlorophyll 'b' content (0.562 mg/g, 0.562 mg/g and 0.553 mg/g) and total chlorophyll content (1.080 mg/g, 1.058 mg/g and 1.142 mg/g) at before flooding, at the time of flooding and 15 days after flooding.

**Fig. 3. Interaction effect for flooding stress on total chlorophyll content (mg/g) at the time of flooding in banana at 5<sup>th</sup> MAP**



#### **Chlorophyll stability index**

Chlorophyll stability index remains as a plant stress tolerance indicator, that denote how well chlorophyll pigments resist breakdown under stress conditions. The results pertaining to chlorophyll stability index were presented in the Table.3. From the table, it was observed that the traits chlorophyll stability index significantly differed for genotypes, flood treatments and their interactions. Among the six genotypes screened, the genotype V<sub>5</sub> recorded higher chlorophyll stability index at before flooding (64.77), at the time of flooding (59.34) and 15 days after flooding (69.55). It was closely followed by the genotype V<sub>6</sub> (Table. 3), whereas, significantly the lowest chlorophyll stability index values were recorded by the genotype V<sub>1</sub> at all three stages viz., before flooding (59.49), at the time of flooding (50.09) and 15 days after flooding (60.78).

Regarding the flood treatments, significantly higher chlorophyll stability index was noticed in T<sub>4</sub> at the three stages viz., before flooding (73.93), at the time of flooding (77.22) and 15 days after flooding (83.31). It was closely followed by T<sub>3</sub> (Table. 3) whereas, the lowest stability index was noticed in optimum water requirement (T<sub>1</sub>).

Similarly, the interaction effect also showed significant influence on chlorophyll stability index. The highest stability index was recorded in V<sub>5</sub>T<sub>4</sub> at before flooding (81.25), at the time of flooding (87.29) and 15 days after flooding (85.86). It was followed by V<sub>6</sub>T<sub>4</sub> which recorded a chlorophyll stability index of before flooding (74.90), at the time of flooding (81.20) and 15 days after flooding (84.50) Table 3 and Fig. 2). However, V<sub>1</sub>T<sub>1</sub> recorded lowest chlorophyll stability index (40.69, 30.49 and 38.90) at before flooding, at the time of flooding and 15 days after flooding.

**Table. 3. Effect of flooding stress on chlorophyll stability index, relative water content (%) and proline content (µg/mg) before flooding, at the time of flooding and 15 days after flooding in banana at 5<sup>th</sup> MAP**

|                                   | Chlorophyll stability index |                       | Relative water content (%) |                       | Proline content (µg/mg) |                       |
|-----------------------------------|-----------------------------|-----------------------|----------------------------|-----------------------|-------------------------|-----------------------|
|                                   | Before flooding             | 15days after flooding | Before flooding            | 15days after flooding | Before flooding         | 15days after flooding |
| <b>V<sub>1</sub></b>              | 59.49                       | 60.78                 | 75.37                      | 72.52                 | 81.0                    | 90.1                  |
| <b>V<sub>2</sub></b>              | 62.56                       | 62.84                 | 75.97                      | 74.53                 | 85.0                    | 111.3                 |
| <b>V<sub>3</sub></b>              | 62.28                       | 62.14                 | 75.91                      | 74.23                 | 82.6                    | 94.9                  |
| <b>V<sub>4</sub></b>              | 63.12                       | 66.12                 | 76.25                      | 74.91                 | 87.2                    | 114.7                 |
| <b>V<sub>5</sub></b>              | 64.77                       | 69.55                 | 74.62                      | 75.21                 | 102.2                   | 127.6                 |
| <b>V<sub>6</sub></b>              | 63.12                       | 68.64                 | 76.60                      | 76.01                 | 96.2                    | 118.0                 |
| <b>SE.d</b>                       | <b>3.83</b>                 | <b>5.46</b>           | <b>1.82</b>                | <b>1.93</b>           | <b>10.47</b>            | <b>11.80</b>          |
| <b>CD 5%</b>                      | <b>7.66</b>                 | <b>10.93</b>          | <b>3.64</b>                | <b>3.85</b>           | <b>20.95</b>            | <b>23.60</b>          |
| <b>T<sub>1</sub></b>              | 45.62                       | 55.50                 | 69.07                      | 72.32                 | 57.4                    | 65.9                  |
| <b>T<sub>2</sub></b>              | 64.82                       | 64.27                 | 75.59                      | 74.79                 | 75.8                    | 79.5                  |
| <b>T<sub>3</sub></b>              | 68.29                       | 75.79                 | 77.88                      | 76.53                 | 88.8                    | 95.7                  |
| <b>T<sub>4</sub></b>              | 73.93                       | 83.31                 | 82.33                      | 79.62                 | 101.3                   | 114.6                 |
| <b>T<sub>5</sub></b>              | 60.12                       | 46.19                 | 74.06                      | 69.60                 | 121.9                   | 191.5                 |
| <b>SE.d</b>                       | <b>3.50</b>                 | <b>4.99</b>           | <b>1.66</b>                | <b>1.76</b>           | <b>8.23</b>             | <b>8.89</b>           |
| <b>CD 5%</b>                      | <b>6.99</b>                 | <b>9.97</b>           | <b>3.33</b>                | <b>3.52</b>           | <b>16.46</b>            | <b>17.78</b>          |
| <b>V<sub>1</sub>T<sub>1</sub></b> | 40.69                       | 38.90                 | 63.81                      | 62.82                 | 50.4                    | 57.0                  |
| <b>V<sub>1</sub>T<sub>2</sub></b> | 66.92                       | 59.79                 | 74.65                      | 74.36                 | 68.7                    | 75.8                  |
| <b>V<sub>1</sub>T<sub>3</sub></b> | 69.04                       | 70.57                 | 77.32                      | 75.70                 | 82.7                    | 83.1                  |
| <b>V<sub>1</sub>T<sub>4</sub></b> | 71.67                       | 81.29                 | 80.19                      | 78.22                 | 98.8                    | 108.7                 |
| <b>V<sub>1</sub>T<sub>5</sub></b> | 63.08                       | 53.36                 | 80.88                      | 71.52                 | 104.5                   | 125.7                 |
| <b>V<sub>2</sub>T<sub>1</sub></b> | 44.12                       | 43.89                 | 68.74                      | 70.79                 | 55.6                    | 67.3                  |
| <b>V<sub>2</sub>T<sub>2</sub></b> | 64.37                       | 61.26                 | 75.37                      | 74.81                 | 74.0                    | 79.1                  |
| <b>V<sub>2</sub>T<sub>3</sub></b> | 68.57                       | 71.63                 | 77.78                      | 76.09                 | 87.4                    | 94.8                  |
| <b>V<sub>2</sub>T<sub>4</sub></b> | 73.33                       | 82.67                 | 82.02                      | 78.83                 | 99.3                    | 115.5                 |
| <b>V<sub>2</sub>T<sub>5</sub></b> | 65.22                       | 54.78                 | 75.94                      | 72.13                 | 108.9                   | 199.5                 |
| <b>V<sub>3</sub>T<sub>1</sub></b> | 43.55                       | 43.22                 | 68.42                      | 69.91                 | 52.3                    | 58.8                  |
| <b>V<sub>3</sub>T<sub>2</sub></b> | 64.14                       | 60.58                 | 74.71                      | 74.61                 | 72.5                    | 77.8                  |
| <b>V<sub>3</sub>T<sub>3</sub></b> | 67.67                       | 71.24                 | 77.75                      | 75.96                 | 82.9                    | 92.3                  |
| <b>V<sub>3</sub>T<sub>4</sub></b> | 71.67                       | 82.28                 | 80.88                      | 78.58                 | 99.3                    | 114.6                 |
| <b>V<sub>3</sub>T<sub>5</sub></b> | 68.57                       | 53.40                 | 77.78                      | 72.11                 | 105.9                   | 131.2                 |
| <b>V<sub>4</sub>T<sub>1</sub></b> | 44.53                       | 56.13                 | 70.65                      | 72.14                 | 58.5                    | 68.9                  |
| <b>V<sub>4</sub>T<sub>2</sub></b> | 65.22                       | 64.42                 | 75.94                      | 74.86                 | 76.5                    | 79.2                  |
| <b>V<sub>4</sub>T<sub>3</sub></b> | 68.76                       | 79.28                 | 77.92                      | 76.41                 | 90.0                    | 96.4                  |
| <b>V<sub>4</sub>T<sub>4</sub></b> | 73.42                       | 83.27                 | 82.46                      | 79.88                 | 101.4                   | 115.6                 |
| <b>V<sub>4</sub>T<sub>5</sub></b> | 60.89                       | 47.52                 | 74.30                      | 71.24                 | 109.7                   | 213.6                 |
| <b>V<sub>5</sub>T<sub>1</sub></b> | 53.70                       | 52.81                 | 71.10                      | 71.32                 | 65.1                    | 73.6                  |
| <b>V<sub>5</sub>T<sub>2</sub></b> | 66.25                       | 69.92                 | 76.42                      | 74.93                 | 82.7                    | 82.7                  |
| <b>V<sub>5</sub>T<sub>3</sub></b> | 68.96                       | 81.09                 | 78.23                      | 76.95                 | 98.3                    | 104.4                 |

|                                   |              |              |             |             |              |              |
|-----------------------------------|--------------|--------------|-------------|-------------|--------------|--------------|
| <b>V<sub>5</sub>T<sub>4</sub></b> | 81.25        | 85.86        | 83.53       | 79.91       | 104.5        | 117.1        |
| <b>V<sub>5</sub>T<sub>5</sub></b> | 53.70        | 58.09        | 63.81       | 72.96       | 160.3        | 260.4        |
| <b>V<sub>6</sub>T<sub>1</sub></b> | 47.15        | 50.82        | 71.69       | 71.50       | 62.7         | 69.9         |
| <b>V<sub>6</sub>T<sub>2</sub></b> | 65.85        | 69.67        | 76.46       | 75.17       | 80.6         | 82.1         |
| <b>V<sub>6</sub>T<sub>3</sub></b> | 68.88        | 80.96        | 78.29       | 78.05       | 91.5         | 103.2        |
| <b>V<sub>6</sub>T<sub>4</sub></b> | 74.90        | 84.50        | 84.89       | 82.29       | 104.4        | 116.4        |
| <b>V<sub>6</sub>T<sub>5</sub></b> | 40.69        | 57.26        | 71.69       | 73.06       | 142.0        | 218.4        |
| <b>SE.d</b>                       | <b>8.56</b>  | <b>12.21</b> | <b>4.07</b> | <b>4.31</b> | <b>21.70</b> | <b>24.69</b> |
| <b>CD 5%</b>                      | <b>17.13</b> | <b>24.43</b> | <b>8.15</b> | <b>8.62</b> | <b>37.41</b> | <b>41.38</b> |

### **Relative water content (%)**

Relative water content is crucial for assessing stress and overall plant health, impacting vital functions like photosynthesis growth and survival. The results pertaining to relative water content (%) are presented in the Table.3. From the table it was observed that the traits relative water content (%) were significantly differed for genotypes, flood treatments and their interactions. Among the six genotypes screened, the genotype V<sub>6</sub> recorded higher relative water content at before flooding (76.25%), at the time of flooding (78.02%) and 15 days after flooding (76.01%). It was closely followed by the genotype V<sub>5</sub> (Table. 3). Whereas, significantly the lowest relative water content values were recorded by the genotype V<sub>1</sub> at all three stages viz., before flooding (75.37%), at the time of flooding (73.28%) and 15 days after flooding (72.52%).

Regarding the flood treatments, significantly higher the relative water content (%) was noticed in T<sub>4</sub> at three stages viz., before flooding (82.33%), at the time of flooding (81.34%) and 15 days after flooding (79.62%). It was closely followed by T<sub>3</sub> (Table. 3). Whereas, the lowest relative water content (%) was noticed in optimum water requirement (T<sub>1</sub>).

Similarly, the interaction effect also showed significant influence on relative water content (%). The highest relative water content (%) was recorded in V<sub>6</sub>T<sub>4</sub> at before flooding (84.86%), at the time of flooding (89.52%) and 15 days after flooding (82.29%). It was followed by V<sub>5</sub>T<sub>4</sub> which recorded a relative water content of before flooding (83.53%), at the time of flooding (80.56%) and 15 days after flooding (79.91%) (Table. 3 and Fig.2). However, V<sub>1</sub>T<sub>1</sub> recorded lowest relative water content (63.81%, 62.82% and 62.82%) at before flooding, at the time of flooding and 15 days after flooding.

### **Proline content (µg/mg)**

Proline act as a crucial osmo-protectant, anti-oxidant and signalling molecule helping to maintain cell turgor, stabilizing proteins and scavenging ROS under stress conditions. The results pertaining to proline content (µg/mg) were presented in Table.3. From the table, it was observed that the traits proline content (µg/mg) significantly differed for genotypes, flood treatments and their interactions. Among the six genotypes screened, the genotype V<sub>5</sub> recorded higher proline content at before flooding (102.2µg/mg) (Table.4), at the time of flooding (130.9µg/mg) (Fig.4) and 15 days after flooding (127.6µg/mg) (Table.3). It was closely followed by the genotype V<sub>6</sub> (Fig. 4), whereas significantly the lowest proline content values were recorded by the genotype V<sub>1</sub> at all three stages viz., before flooding (81.00µg/mg), at the time of flooding (88.00µg/mg) and 15 days after flooding (90.1µg/mg).

Regarding the flood treatments, significantly higher proline content (µg/mg) was noticed in T<sub>5</sub> at three stages viz., before flooding (121.9µg/mg) (Table.4), at the time of flooding (190.7µg/mg) (Fig. 5) and 15 days after flooding (191.5µg/mg) (Table.4). It was

closely followed by T<sub>4</sub>, whereas the lowest proline content (57.4µg/mg, 60.00µg/mg and 65.9µg/mg) was noticed in all the three stages of control/optimum water requirement (T<sub>1</sub>).

**Fig. 4. Genotypic effect of proline content (µg/mg) at the time of flooding in banana genotypes at 5<sup>th</sup> MAP**

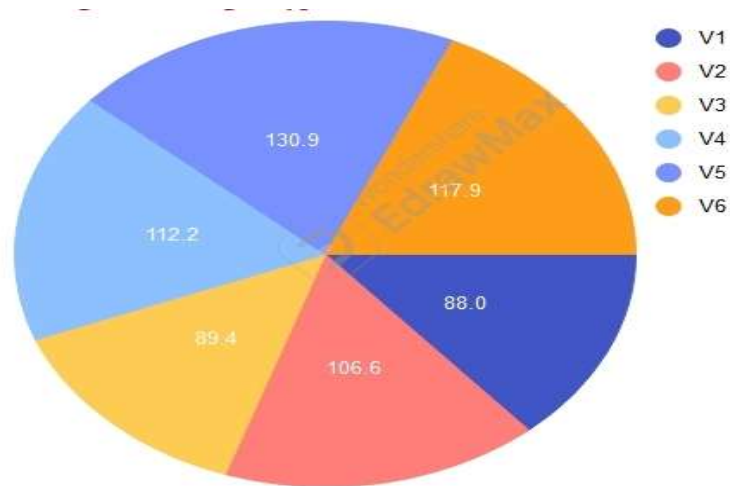
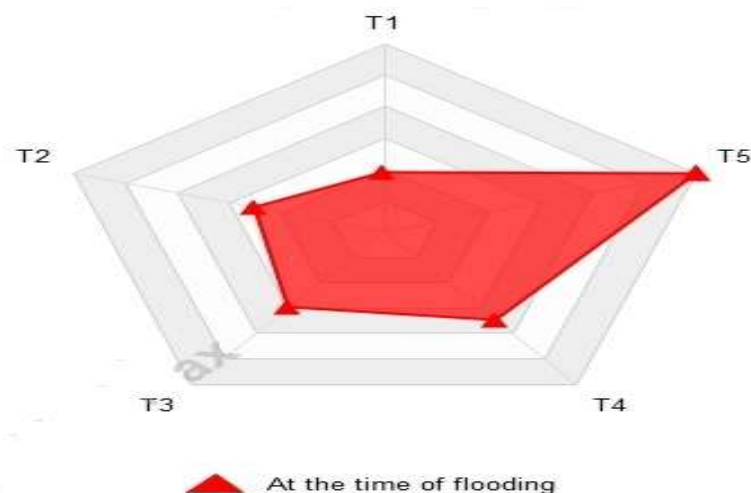


**Fig. 5. Flood treatment effect of proline content (µg/mg) at the time of flooding in banana genotypes at 5<sup>th</sup> MAP**



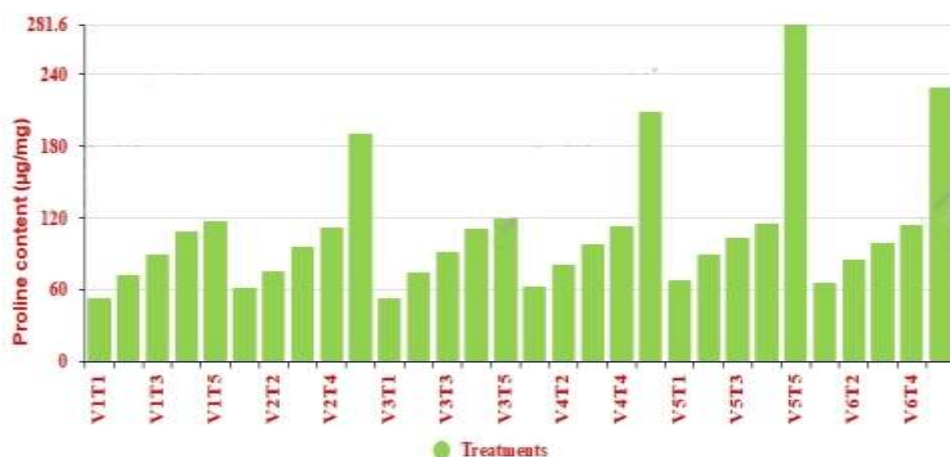
Similarly, the interaction effect also showed significant influence on proline content. The highest proline content was recorded in V<sub>5</sub>T<sub>5</sub> at before flooding (160.33µg/mg) (Table.4), at the time of flooding (281.6µg/mg) (Fig. 6) and 15 days after flooding (260.36µg/mg) (Table.4). It was followed by V<sub>6</sub>T<sub>5</sub> which recorded a proline content of before flooding (142.0µg/mg), at the time of flooding (228.2µg/mg) and 15 days after flooding (218.4µg/mg). However, V<sub>1</sub>T<sub>1</sub> recorded lowest proline content (50.4µg/mg, 52.7µg/mg and 57.00µg/mg) at before flooding, at the time of flooding and 15 days after flooding.

### Discussion

From the results, it was revealed that the genotype Karpooravalli (V<sub>5</sub>) and Monthan (V<sub>6</sub>) showed higher physiological activity up to 72 hours of flooding after that there is a decline

by recording higher leaf area, leaf area index, photosynthetic pigments like chlorophyll 'a', chlorophyll 'b' and total chlorophyll, chlorophyll stability index, relative water content and proline when compared to other genotypes. The results indicated that the genotypes V<sub>5</sub> and V<sub>6</sub> are tolerant to flood stress even upto 3 days of flooding. In this experiment, increased level of photosynthetic pigments viz., chlorophyll 'a', chlorophyll 'b' and total chlorophyll was also observed after the removal of flooding at 96 hours after flooding and 15 days after flooding (Fig. 3). Increased level of photosynthetic pigments leads to higher photosynthetic activity thus resulted in higher leaf area and leaf area index (Fig. 2 & 3). From this study, it was also observed that the genotype V<sub>5</sub> and V<sub>6</sub> were categorized under the banana genomic group of ABB, whereas, others of AA (V<sub>1</sub>-Matti), AAA (V<sub>3</sub>-Red Banana), AB (V<sub>2</sub>-Ney Poovan) and AAB (V<sub>4</sub>-Poovan) indicated bulbisiana genome impacted tolerance mechanism to crop under flood in those genotypes than acuminate genome group. This was evident that the genotypes V<sub>5</sub> and V<sub>6</sub> recorded higher chlorophyll stability index, relative water content and proline content then other genotypes at 72 hours flooding in all the three stages of the study (Fig. 2 and 6). Higher chlorophyll stability index, relative water content and proline content observed by those genotypes V<sub>5</sub> and V<sub>6</sub> have the ability of speedy recovery from the flooding stress.

**Fig. 6. Interaction effect of proline content ( $\mu\text{g}/\text{mg}$ ) at the time of flooding in banana genotypes at 5<sup>th</sup> MAP**



This result was in accordance with Ahamed et al. (2002) who reported that the photosynthetic rate was declined rapidly by progressive flooding in mung bean at vegetative stage. Cho and Yamakawa (2006) reported when the flooding got removed, the photosynthesis activity remains increased to a control level in 8 days at vegetative stage. As longer flooding period, it was decreased in all physiological parameters like leaf area, leaf area index, chlorophyll 'a', chlorophyll 'b' and total chlorophyll, chlorophyll stability index, relative water content and proline content even after removal of flood indicating that prolonged flooding (96hours) was detrimental factor to their growth irrespective of genotypes. However, even under prolonged flooding the genotypes V<sub>5</sub> and V<sub>6</sub> recorded higher physiological parameters then other genotypes of the present study showed the flood tolerant nature of the genotypes.

### Conclusion

In the present investigation, among the total experimentation in banana for flood stresses, the genotype Karpooravalli under 72 hours of flood treatment (V<sub>5</sub>T<sub>4</sub>) expressed positivity

for majority of physiological parameters at all the three stages of flood intervals i.e., before flooded condition, 96hrs after flooded condition/at the time of flooded condition and 15 days after flooded condition.

### **References**

1. Ahmed, S., Nawata, E., Hosokawa, M., Domae, Y. and Sakuratani, T. (2002). Alterations in photosynthesis and some antioxidant enzymatic activities of mungbean subjected to flooding. *Pl. Sci.*, 163: 117–123.
2. Arnon, D.I. (1949). Copper enzymes in isolated chloroplast: polyphenol oxidase in *Beta vulgaris*. *Pl. Physiol.*, 24:1–15
3. Barrs, H.D. and Weatherley, P.E. (1962). A re-examination of the relative turgidity technique for estimating water deficits in leaves. *Australian J. Biol. Sci.*, 24:519-570.
4. Bates, L.S., Waldren, R.P. and Teare I.D. (1973). Rapid determination of free proline for waterstress studies. *Pl. Soil.* 39:205.
5. Cho, J.W. and Yamakawa, T. (2006). Effects on growth and seed yield of small seed soybean cultivars of flooding conditions in paddy field. *J. Fac. Agr., Kyushu Univ.*, 51 (2): 189–193.
6. Crop Production Guide Horticulture Crops. (2020). Directorate of Horticulture and Plantation Crops, Chepauk, Chennai - 600 005 and Tamil Nadu Agricultural University, Coimbatore - 641 003. pp. 7-13.
7. Davies, B.H. (1976). Carotenoids In: Chemistry and biochemistry of plant pigments. Goodwin, T W. (Ed.) Academic Press, London, p. 38-165.
8. DHPC, (2019). Department of Horticulture and Plantation Crops report, Government of Tamil Nadu.
9. Herzog, M., Striker, G.G., Colmer, T.D. and Pedersen, O. (2016). Mechanisms of flooding tolerance in wheat A review of root and shoot physiology. *Pl. Cell and Environ.*, 39 (5): 1068-1086. <https://doi.org/10.1111/pce.12676>
10. Kuo, C.G. and Chen, B.W. (1980). Physiological responses of tomato cultivars to flooding. *J. Amer. Soc. Hort. Sci.*, 105(5):751-755.
11. Liu, P., Sun, F., Gao, R. and Dong, H. (2012). RAP2,6L overexpression delays flooding induced premature senescence by increasing stomatal closure more than antioxidant enzyme activity. *Pl. Mol. Biol.*, 79(6): 609–622. DOI 10.1007/s11103-012-9936-8.
12. Murray, D.B. (1960). The effect of deficiencies of the major nutrients on growth and leaf analysis of the banana. *Trop. Agric. Trinidad*, 37: 97-106.
13. NDMA, (2023). National Disaster Management Authority. Annual Report (2022-2023), Government of India, New Delhi.
14. Ploschuk, R. A., Miralles, D.J., Colmer, T.D., Ploschuk, E.L. and Striker, G.G. (2018). Flooding of winter crops at early and late stages: Impacts on leaf physiology, growth and yield. *Frontiers in Pl. Sci.*, 9:1863. <https://doi.org/10.3389/fpls.2018.01863>
15. Popat, R., Patel, H. and Popat, P. (2024). Agri Analyze [Online tool]. [www.agrianalyze.com](http://www.agrianalyze.com)
16. Rangaswamy, R. (1995). A Text Book of Agricultural Statistics. p.486. New Age International (P) Ltd Publishers, New Delhi.
17. Romina, P., Abeledo, L.G. and Miralles, D.J. (2014). Identifying the critical period for flooding on yield and its components in wheat and barley. *Pant and Soil.* 378: 265–277. DOI10.1007/s11104-014-2028-6.
18. Setter, T.L. and I. Waters. (2003). Review of prospects for germplasm improvement for flooding tolerance in wheat, barley and oats. *Pl. & Soil.* 253:1–34. <https://doi.org/10.1023/A:1024573305997>

19. Shao, G.C., Lan, J.J., Yu, S.E., Liu, N., Guo, R.Q. and She, D.L. (2013). Photosynthesis and growth of winter wheat in response to flooding at different growth stages. *Photosynthetica*. 51(3): 429–437. DOI 10.1007/s11099-013-0039-9.
20. Sharma, S., Sharma, J., Soni, V., Kalaji, H.M. and Elsheery N.I. (2021). Flooding tolerance: A review on regulative morpho-physiological homeostasis of crop plants. *J. Water and Land Develop.*, 49 (IV-VI): 16-28. <https://doi.org/10.24425/jwld.2021.137092>
21. Shaw, R. E., Meyer, W.S., McNeill, A. and Tyerman, S.D. (2013). Flooding in Australian agricultural landscapes: A review of plant responses and crop models. *Crop and Pasture Sci.*, 64 (6): 549-562. <<https://doi.org/10.1071/CP13080>>
22. Sivasubramaniawn, K. (1992). Chlorophyll stability index: methods for determining drought hardness of Acacia species. *Nitrogen Fixing Tree Research Reports*, 10:111-11.
23. Stover, R.H. and Simmonds, N.W. (1987). *Bananas*. 3<sup>rd</sup> ed., Longman Scientific and Technical, London.
24. Tong, C., Hill, C.B., Zhou, G., Zhang, X.Q., Jia, Y. and Li, C. (2021). Opportunities for improving flooding tolerance in cereal crops–physiological traits and genetic mechanisms. *Plants*. 10 (8): 1560. <https://doi.org/10.3390/plants10081560>
25. Voesenek L.A. and Bailey-Serres, J. (2013). Flooding tolerance: O<sub>2</sub> sensing and survival strategies. *Current Opinion in Pl. Biol.*, 16(5): 647–653. DOI 10.1016/j.pbi.2013.06.008.
26. Voesenek, L. A. and Bailey-Serres, J. (2015). Flood adaptive traits and processes: An overview. *New Phytologist*. 206 (1): 57-73. <https://doi.org/10.1111/nph.13209>
27. Williams, R.F. (1946). The physiology of plant growth with special reference to the concept of net assimilation rate. *Ann. Bot.* 10: 41-71.
28. Wu, X., Tang, Y., Li, C., Mchugh, A.D., Li, Z. and Wu, C. (2018). Individual and combined effects of soil flooding and compaction on physiological characteristics of wheat in south-western China. *Field Crops Res.*, 215:163–172. DOI10.1016/j.fcr.2017.10.016.
29. [www.nhb.gov.in](http://www.nhb.gov.in)
30. [www.agrianaiyze.com](http://www.agrianaiyze.com)
31. [www.ndma.gov.in](http://www.ndma.gov.in)
32. [www.nrsc.gov.in/nrscnew/](http://www.nrsc.gov.in/nrscnew/)
33. Xu, X., Ji, J., Xu, Q., Qi, X. and Chen, X. (2017). Inheritance and quantitative trait loci mapping of adventitious root numbers in cucumber seedlings under flooding conditions. *Mol. Gene. Genomics*. 292(2): 353–364. DOI10.1007/s00438-016-1280-2.
34. Zhou, M.Z. (2010). Improvement of plant flooding tolerance. In: *Flooding signalling and tolerance in plants*. Mancuso, S, Heidelberg, S.S, editors. Berlin: Springer-Verlag. p.267–85.