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Mitigation of salinity induced impact on the growth of tomato plants under saline condition through plant growth promoting rhizobacteria

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Abstract
Abiotic stress is one of the most important problems currently faced by agriculture. Plants respond and adapt to a variety of environmental stresses in order to survive. Among these Salinity is one major limiting factor to plant growth and crop productivity. The aim of the study reported here to evaluate the effect of PGPR inoculation in a saline environmental conditions and on enhancement of the growth and yield of tomato under saline field condition. To determine the effect of PGPR two consecutive field experiment was conducted. Tomato seeds were inoculated with the five pre-isolated strains of PGPR (Bacillus subtelis, Pseudomonas fluorescens, Azospirullus, Azotobacter Pseudomonas putida) sown and irrigated at different saline (NaCl) concentration (50mM, 100mM, 150mM, 200mM).the results showed that among these PGPR Pseudomonas putida containing ACC deaminase activity and exhibited the best ability to enhance the plant height no of leaves, no of branches, leaf area index compare to control (non-treated). Bacillus subtelis had significant effect on improving chlorophyll and carotenoid content under 150mM concentration of saline. Higher the dose of saline stress which is 200mM exhibited the suppress growth indices compare the control as well as the inoculated treatments. Moreover the root length, shoot length had significantly improved by the inoculation of Pseudomonas putida under different saline concentration. So that our study had suggested that Pseudomonas putida are consider the most capable PGPR strain which are suited for applied as alleviation tools under saline condition. This PGPR had promote growth indices and stress tolerance to the selected tomato plants which may be gives further varying growth indices under different stress condition as well as in different environmental condition.

Keywords: Plant growth-promoting rhizobacteria, bacillus subtelis, azotobacter pseudomonas *putida*, *Pseudomonas fluorescens, Azospirullus,* salt stress, growth

1. Introduction
Tomato is an important source of minerals and antioxidants such as carotenoids, vitamins C, E and phenolic compounds, which have a key role in human nutrition to prevent certain cancer and cardiovascular diseases [1]. Abiotic stress is one of the most important problems currently faced by agriculture. It causes serious losses in crop production worldwide and reduces planted acreage. Tomato Plants growing in saline soils experience osmotic stress due to increases in the concentration of Na+ and Cl), leading to ionic imbalance in tissues and resulting inhibition of nutrient uptake [2]. Around 6.727 million ha area in India which is around 2.$_1$% of geographical area of the country is salt affected, out of which 2.956 million ha is saline and the rest 3.771 million ha is sodic [3]. The urgency of feeding the world's growing population while combating soil pollution, salinization, and desertification has given plant and soil productivity research vital importance under such circumstances, it requires suitable biotechnology not only to improve crop productivity but also to improve soil health through interactions of plant roots and soil microorganisms. The use of plant growth-promoting bacteria (PGPB) These beneficial microorganisms colonize the rhizosphere of plants and promote growth of the plants through various direct and indirect mechanisms [4, 5]. Some plant growth-promoting rhizobacteria (PGPR) may exert a direct stimulation on plant growth and development by providing plants with fixed nitrogen, phytohormones, iron that has been sequestered by bacterial siderophores, and soluble phosphate [6] Apart from ACC deaminase activity, mechanisms such as production of cytokinin and auxin, antioxidant enzymes such as catalase and volatile substances were also reported to have been exhibited by PGPR strains in alleviation of abiotic stress in plants [7]. Production of phytohormones alters the physiology of the plants to cope with the salinity stress. Today much of the agricultural land has become saline due to faulty irrigation practices and excessive irrigation.

Reckless usage of different pesticides and agrochemicals has worsened the problem further. Under stress conditions, the plant hormone ethylene endogenously regulates plant homeostasis and results in reduced root and shoot growth However, degradation of the ethylene precursor ACC by bacterial ACC deaminase releases plant stress and rescues normal plant growth whereas production of volatile substance by PGPR regulates genes involved in Na+ ion homeostasis and protects plants from salinity stress, these bacteria are capable of lowering ethylene production in their host plants, they should also render the plants more tolerant to salt-induced stress. It has also been observed that PGPR can protect plants from the deleterious effects of environmental stresses including salinity. Hence, this study is conducted to reveal the behavior of the selected PGPR under salinity stress condition and their role in enhancing growth of tomato.

Thus the aim of this study were

1. To determine the effect of PGPR on different morphological characters of tomato under different saline condition.
2. To determine the effect of PGPR on yield and biochemical content of tomato under various mille mole concentration of saline stress.

2. Materials and Methods

2.1 Experimental Site Topography and Climate: The experiment was conducted during Rabi 2019-2020 at Department of Biological Sciences, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS) Prayagraj (Allahabad).The Prayagraj (Allahabad) district is situated at 25.280 N and 81.540 E with an altitude of 98m above sea level. Prayagraj is located in the South-Eastern of Uttar Pradesh and has a sub-tropical climate with extremes of summer and winter. During winter season, temperature drops down to as low as 1-2 oC, while during summer the temperature reaches up to 43-48 oC.

2.2 Plant Materials and Source of Plant growth Promoting Rhizobacteria: Tomato (*Lycopersicon esculentum* (Mill.) variety Kashi Aman were taken as a plant material and procured by the Indian Institute of Vegetable Research IIVR Varanasi. The strain of PGPR were obtained by the Department of Biological Sciences, SHUATS, Prayagraj (Allahabad) UP. The strains were maintained onto LB Agar media.

2.3 Bacterial inoculums and Mode of inoculation of PGPR: Each PGPR strains namely *Bacillus subtilis* (Bs), *Pseudomonas fluorescens* (PF), *Azospirullus* (A1), *Azotobacter* (A2,) *Pseudomonas Putida* (PP) were grown in respective broth on shaking incubator (180 rpm) at 28±2 ℃ for 24 h. For seed treatment healthy seeds were surface sterilized with 0.1% HgCl2 for 2 min and rinsed six times with sterile distilled water. The surface sterilized seeds of tomato were inoculated in broth culture of the PGPR strain cultures for 30 min including normal water (C) as control. Six inoculated seeds of each treatment were placed in separate petri-plate containing soaked (with distilled water) filter papers the petri-plates were incubated at 25±2 oC for 6 days. Seed germination were recorded regularly starting from the 2nd day on the basis of number of the germinated seed out of total germination.

2.4 Greenhouse Experiment, Nursery Preparation and Transplantation: The sterilized seeds for control and sequentially the PGPR strain inoculated seeds were sown to create nuesery. After 20 days of sowing (DAS) seedling were subsequently transplanted to the plastic pots filled with sterilized silty loam soil and farmyard manure (6:1) and tomato seedlings were transferred in these pots. Irrigation were done by normal water at the requriment of plantlets. after 15 days of transplantation the seedling were supplied to the mili mole concentration of NaCl solution that is 50mM(LS), 100mM(A1+LS), 150mM(M2S), 200mM(HS) for 4 to 6 days to develop the required amount of salinity after that the plants were irrigated to the normal tap water. each treatment were replicated three times with three plants each time. Randomly five leaf samples were taken from tomato plantlet after every 15 days against each treatment of PGPR and data was recorded.

2.5 Experimental Setup: for the investigation of effect of PGPR under salinity stress condition the experiment were conducted to the period between Octobers to January 20_19-2020. the experimental design consisted of three completely randomized blocks design each of which contain twenty nine main treatments including control treatments are as follows ($_1$) T_0 control plants without PGPR and saline stress (2) T_1 plants inoculated with PGPR strain *Bacillus subtelis* (3) T_2 plants inoculated with PGPR strain *Pseudomonas fluorescens* (4) T_3 plants inoculated with PGPR strain *Azospirullus* (5) T_4 plants inoculated with PGPR strain *Azotobacter* (6) T_5 plants inoculated with PGPR strain *Pseudomonas putida* (7) T_6 plants without PGPR irrigated with 50mM concentration of NaCl (8) T_7 plants without PGPR irrigated with 100mM concentration of NaCl (9) T_8 plants without PGPR irrigated with 150mM concentration of NaCl (10) T_9 plants without PGPR irrigated with 200mM concentration of NaCl (11) T_{10} plants inoculated with PGPR strain *Bacillus subtelis* irrigated with 50mM concentration of NaCl (12) T_{11} plants inoculated with PGPR strain *Pseudomonas fluorescens* irrigated with 50mM concentration of NaCl (13) T_{12} plants inoculated with PGPR strain *Azospirullus* irrigated with 50mM concentration of NaCl (14) T_{13} plants inoculated with PGPR strain *Azotobacter* irrigated with 50mM concentration of NaCl (15) T_14 plants inoculated with PGPR strain *Pseudomonas putida* irrigated with 50mM concentration of NaCl (16) T_{15} plants inoculated with PGPR strain *Bacillus subtelis* irrigated with 100mM concentration of NaCl (17) T_{16} plants inoculated with PGPR strain *Pseudomonas fluorescens* irrigated with 100mM concentration of NaCl (18) T_{17} plants inoculated with PGPR strain *Azospirullus* irrigated with 100mM concentration of NaCl (19) T_{18} plants inoculated with PGPR strain *Azotobacter* irrigated with 100mM concentration of NaCl (20) T_{19} plants inoculated with PGPR strain *Pseudomonas putida* irrigated with 100mM concentration of NaCl (21) T_{20} plants inoculated with PGPR strain *Bacillus subtelis* irrigated with 150mM concentration of NaCl (22) T_{21}plants inoculated with PGPR strain *Pseudomonas fluorescens* irrigated with 150mM concentration of NaCl (23) T_{22} plants inoculated with PGPR strain *Azospirullus* irrigated with 150mM concentration of NaCl (24) T_{23} plants inoculated with PGPR strain *Azotobacter* irrigated with 150mM concentration of NaCl (25) T_{24} plants inoculated with PGPR strain *Pseudomonas putida* irrigated with 150mM concentration of NaCl (26) T_{25} plants inoculated with PGPR strain *Bacillus subtelis* irrigated with 200mM concentration of NaCl (27) T_{26} plants inoculated with PGPR strain *Pseudomonas fluorescens* irrigated with 200mM concentration of NaCl (28) T_{27} plants inoculated with PGPR strain *Azospirullus* irrigated with 200mM concentration of

NaCl (29) T_{28} plants inoculated with PGPR strain *Azotobacter* irrigated with 200mM concentration of NaCl (30) T_{29} plants inoculated with PGPR strain *Pseudomonas putida* irrigated with 200mM concentration of NaCl. After the two months of growth randomly three plants were chosen within the three replicates in each treatment in order to estimate the desired observations which are described in detail below.

2.6 Growth Parameters

Morphological parameters and biochemical parameters, plant height, Leaf area index were determined by the methods of [8] no. of branches and no. of leaves, root length, shoot length were considered to analyze the effect of PGPR on tomato plants in saline environment. However chlorophyll and carotenoids content were quantified by [9]. 1 gram leaves sample was weighed and crushed with 80% acetone made the volume to 10 ml with 80% acetone, centrifuged at 800 ppm for 5 minutes. The supernatant was read under 663, 645 nanometre. The readings were fed in the following formula and results were determined under spectrophotometer.

Chlorophyll content was calculated by using the following formula and expressed in mg/g fresh weight-$_1$:

$$\text{Chlorophyll 'a'} = {}_12.7 \times (A663) - 2.69 \times (A645) \times \frac{V}{{}_1000 \times w \times a}$$

(Mg g-$_1$ fr.wt.)

$$\text{Chlorophyll 'b'} = 22.9 \times (A645) - 4.68 \times (A663) \times \frac{V}{{}_1000 \times w \times a}$$

(Mg g-$_1$ fr.wt.)

For determination of carotenoid content 0.5 gm of leaf sample and homogenized in $_1$0 ml of acetone (80% acetone). Next to the centrifuged at 3000 rpm at $_1$0 min. The absorbance was recorded at 470 nm.

Total carotenoids = [$_1$000A470-(3.27 Chl-a+$_1$04 Chlb)]/22

Where,
A645 = Absorbance of the extract at 645 nm.
A663 = Absorbance of the extract at 663 nm.
a = Path length of cuvette (1 cm).
V = final volume of the chlorophyll extract (10 ml).
W = Fresh weight of the sample (0.10 g).

2.7 Statistical Analysis

The recorded data were subjected to statistical analysis following Randomized Block Design (RBD), the mean sum of squares due to treatments showed significant difference for all combination of treatment studied under at 1% and 5% level of significance. The analysis of variance were worked out to test the significant differences among treatments by F-Test. It were carried out according to the procedure of complete block design for each character as per methodology suggested by Fisher $_1$936.

3. Results and Discussion

3.1 PGPR Improve morphological qualities in subjected tomato plants: Visual observations of experimental plants were made regarding overall growth of the plants under salt stress concentrations 50 mM, 100mM 150 mM and 200mM. Morphological parameters; plant height, no. of leaves, no. of branches shoot length, leaf area index, and root length were compared in tomato plants treated with PGPRs *Bacillus subtelis (Bs)*, *Pseudomonas fluorescens (PF)*, *Azospirullus (A_1)*, *Azotobacter (A_2) Pseudomonas putida* (PP) strains. A biplot (Figure 1) depicted that plants treated with *Pseudomonas putida* (Pp) strain exhibited significant increase in plant height. The plant height were significantly increased under salinity stress condition in T_{14} (LS+Pp). However under salinity stress condition the minimum plant height were exhibited by T_9 (HS). Control, non-treated plants and *Pseudomonas fluorescens (PF)* treated plants have no significant improvement in morphological parameters.

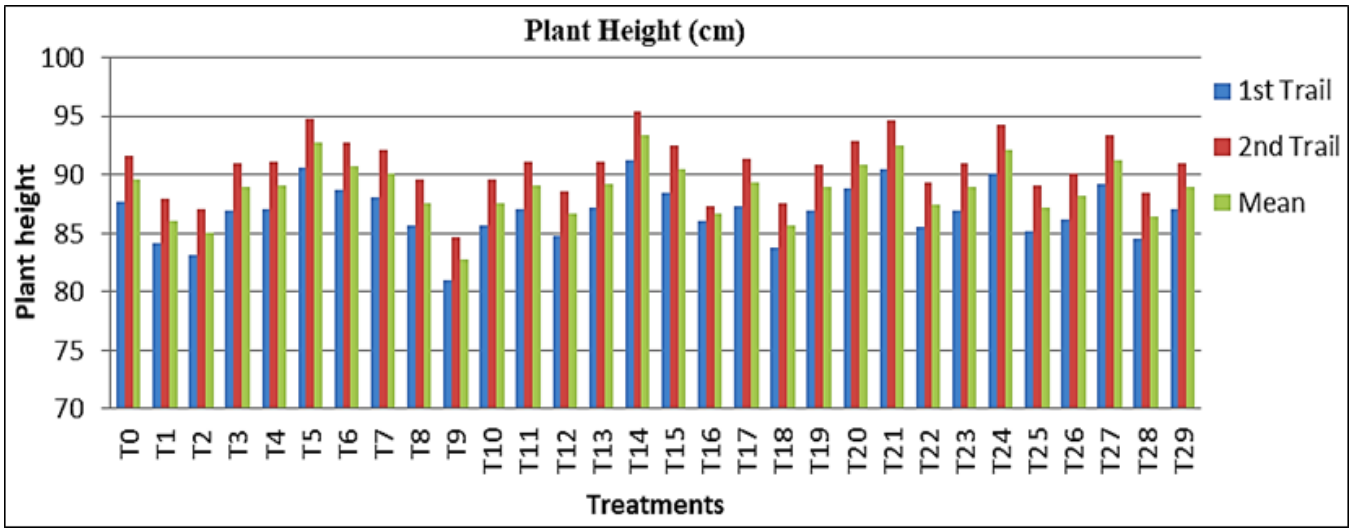

Fig 1: Histogram depicting Effect of PGPR on treated tomato plants, control and non-treated plants regarding plant height under salinity stress T_0(C), T_1(Bs), T_2(Pf), T_3(A_1), T_4(A2), T_5(Pp), T_6(LS), T_7(A1+LS), T_8(M2S), T_9(HS), T_{10}(Bs+LS), T_{11}(Pf+LS), T_{12}(A1+LS), T_{13}(A2+LS), T_{14}(Pp+LS), T_{15}(Bs+A1+LS), T_{16}(Pf+A1+LS), T_{17}(A_1+A1+LS), T_{18}(A2+A1+LS), T_{19}(Pp+A1+LS), T_{20}(Bs+M2S), T_{21}(Pf+M2S), T_{22}(A_1+M2S), T_{23}(A2+M2S), T_{24}(Pp+M2S), T_{25}(Bs+HS), T_{26}(Pf+HS), T_{27}(A_1+HS), T_{28}(A2+HS), T_29(Pp+HS)

Figure 2, 3, 4 showed the status of morphological parameters of maturity by PGPR-treatment. Significant improvement in no. of leaves, no. of branches, leaf area index was observed in plants treated with *Pseudomonas putida* (Pp) strains of PGPR. Consequently the No. of branches and no. of leaves were also enhanced by the inoculation of *Pseudomonas fluorescens (Pf)* in T_{21} (Pf+M2S) combination of treatments as compared to control, non-treated plants. Overall, growth of the PGPR-treated plants was significantly improved after application of PGPR when compared with control, non-treated plants.

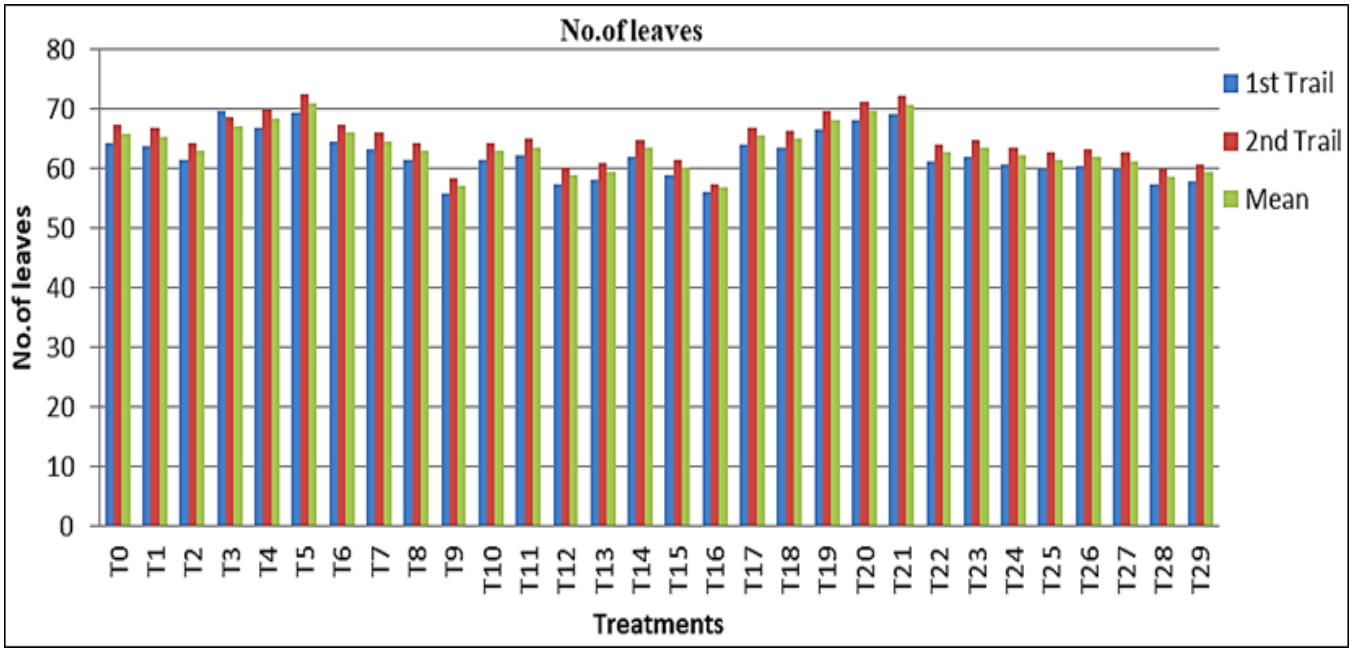

Fig 2: Histogram depicting Effect of PGPR on treated tomato plants, control and non-treated plants regarding no. of leaves under salinity stress T_0(C), T_1(Bs), T_2(Pf), T3(A_1), T_4(A2), T_5(Pp), T_6(LS), T_7(A1+LS), T_8(M2S), T_9(HS), T_{10}(Bs+LS), T_{11}(Pf+LS), T_{12}(A1+LS), T_1(A2+LS), T_{14}(Pp+LS), T_{15}(Bs+A1+LS), T_{16}(Pf+A1+LS), T_{17}(A_1+A1+LS), T_{18}(A2+A1+LS), T_{19}(Pp+A1+LS), T_{20}(Bs+M2S), T_{21}(Pf+M2S), T_{22}(A_1+M2S), T_{23}(A2+M2S), T_{24}(Pp+M2S), T_{25}(Bs+HS), T_{26}(Pf+HS), T_{27}(A_1+HS), T_{28}(A2+HS), T_{29}(Pp+HS)

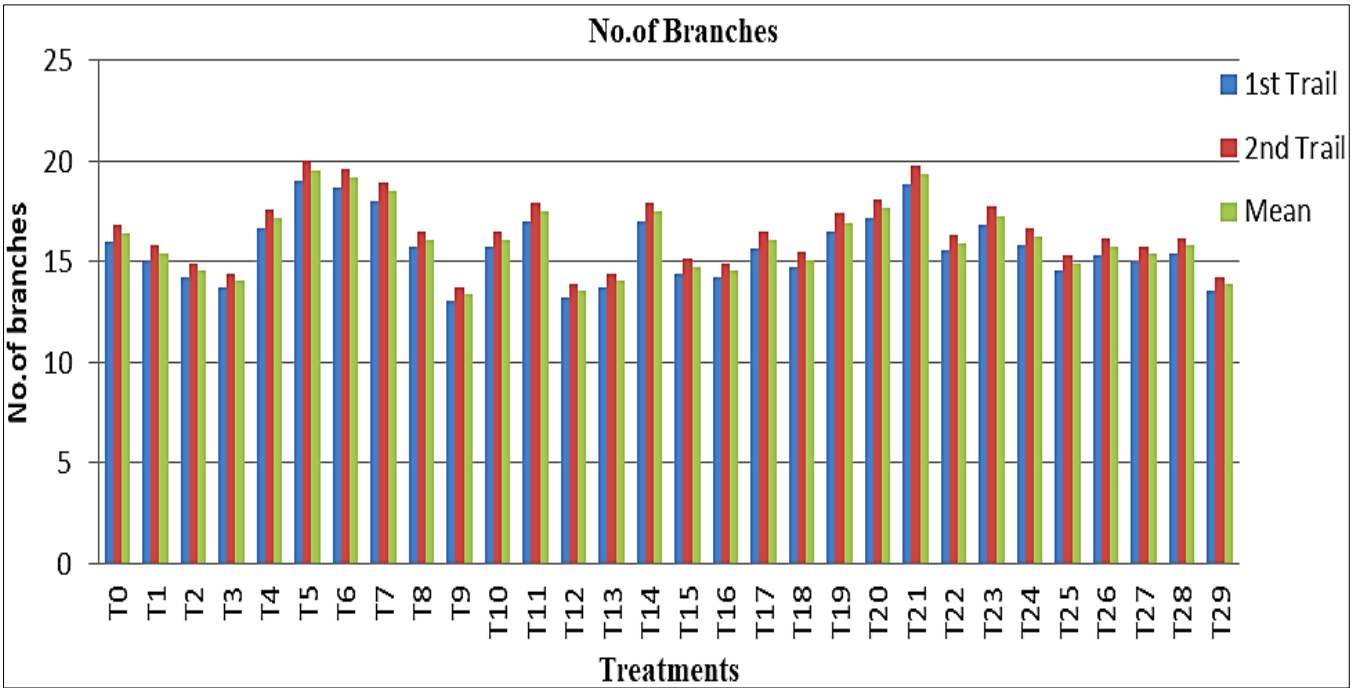

Fig 3: Histogram depicting Effect of PGPR on treated tomato plants, control and non-treated plants regarding no. of branches under salinity stress T_0(C), T_1(Bs), T_2(Pf), T3(A_1), T_4(A2), T_5(Pp), T_6(LS), T_7(A1+LS), T_8(M2S), T_9(HS), T_{10}(Bs+LS), T_{11}(Pf+LS), T_{12}(A_1+LS), T_{13}(A2+LS), T_{14}(Pp+LS), T_{15}(Bs+A1+LS), T_{16}(Pf+A1+LS), T_{17}(A_1+A1+LS), T_{18}(A2+A1+LS), T_{19}(Pp+A1+LS), $T_2$0(Bs+M2S), T_{21}(Pf+M2S), $T_2$2(A1+M2S), T_{23}(A2+M2S), T_{24}(Pp+M2S), T_{25}(Bs+HS), $T_2$6(Pf+HS), T_{27}(A_1+HS), $T_2$8(A2+HS), $T_2$9(Pp+HS)

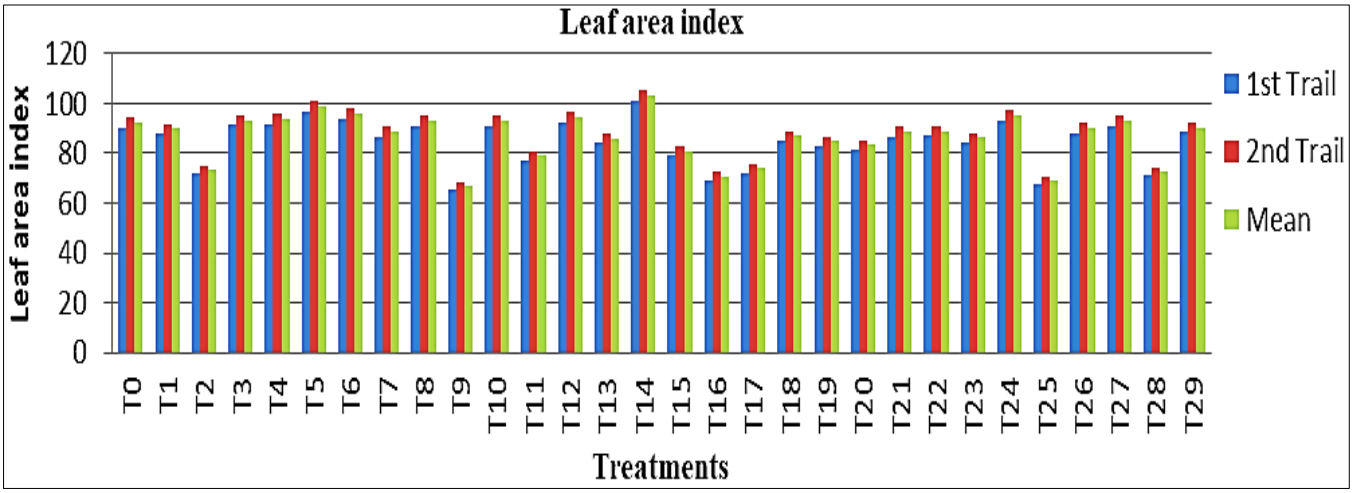

Fig 4: Histogram depicting Effect of PGPR on treated tomato plants, control and non-treated plants regarding leaf area index under salinity stress T_0(C), T_1(Bs), T_2(Pf), T3(A_1), T_4(A2), T_5(Pp), T_6(LS), T_7(A1+LS), T_8(M2S), T_9(HS), T_{10}(Bs+LS), T_{11}(Pf+LS), T_{12}(A_1+LS), T_{13}(A2+LS), T_{14}(Pp+LS), T_{15}(Bs+A1+LS), T_{16}(Pf+A1+LS), T_{17}(A_1+A1+LS), T_{18}(A2+A1+LS), T_{19}(Pp+A1+LS), T_{20}(Bs+M2S), T_{21}(Pf+M2S), T_{22}(A_1+M2S), T_{23}(A2+M2S), T_{24}(Pp+M2S), T_{25}(Bs+HS), T_{26}(Pf+HS), T_{27}(A_1+HS), T_{28}(A2+HS), T_{29}(Pp+HS)

Similarly, *Pseudomonas putida* (Pp) strains of PGPR treated tomato plants showed significant improvement in shoot length, root length of the subjected plants at maturity as depicted in figure no. 5 and 6. Although the *Azospirullus* (A_1) was able to improve shoot length of the subjected plant but was unable to improve other investigated parameters. Similarly, *Bacillus subtelis* (BS) and *Azotobacter* (A_2) didn't exhibited any improvement in the overall growth of shoot and root length of the plant when assessed PGPR inoculation. *Pseudomonas putida* (PP) strain enhanced the overall growth of the tomato plants grown in saline stress. However, control plants didn't show any significant improvement among all studied parameters Conclusively, *Pseudomonas putida* (PP) at different concentration of saline stress showed significant improvement in morphological characters of the treated plants as compared to *Bacillus subtelis (BS)* and *Azotobacter* (A_2). Thus, best response for morphological trait improvement was given by *Pseudomonas putida* (PP) strain.

3.2 PGPR improve biochemical content of subjected treated plants under saline stressed conditions: Under salt stress condition, the content of chlorophyll a, b and level of carotenoids was enhanced by *Pseudomonas putida* (PP) strain when applied onto tomato plants in comparison with control, untreated plants. The data was recorded and It was found that carotenoid level and content of chlorophyll a, b ware increased in *Pseudomonas putida* (PP) treated plants while *Pseudomonas fluorescens* (PF) treated plants showed enhanced level of and chlorophyll a and b (Figure 7,8). However, control, untreated plants didn't exhibited any increase in above said biochemical parameters. *Pseudomonas putida* (PP) significantly enhanced levels of chlorophyll a and carotenoid; *Pseudomonas fluorescens* (PF) increased carotenoids content (Figure. 9) as compared to control, untreated plants where no significant improvement was found of these biochemical parameters as depicted in (Figure 7).

In most saline soils, sodium chloride is the predominant salt species, and its effect can be observed by decreased productivity or plant death [10].

Soil salinity causes plant stress in two ways:

1. Making water uptake by the roots more difficult.
2. Causing plant toxicity via accumulation of high salt concentrations in the plant.

Plants growing in saline soils experience osmotic stress due to increases in the concentration of Na+ and Cl), leading to ionic imbalance in tissues and resulting inhibition of nutrient uptake. A salt resistant crop or variety possesses its resistance characters by avoiding absorption and accumulation of harmful salts and/or by tolerating these salts in the plant tissue. This could be achieved by manipulating the fertility status of the soil, which will help the sensitive plant to avoid accumulation of excessive Na and/or Cl and to maintain a proper ionic balance it is well known that crops suffer reduction in vegetative growth and yield when grown on a saline medium. Salt tolerance of any plant can be measured by increase or decrease in the yield of subjected plant [11] and it is reported that the vegetative growth of the plant is more sensitive to salt stress as compared to the reproductive growth [12] Plants absorb essential nutrients in the form of soluble salts, but excessive accumulation strongly suppresses the plant growth. Several strategies have been developed in order to decrease the toxic effects caused by high salinity on plant growth, including plant genetic engineering [13], it is reported that the vegetative growth of the plant is more sensitive to salt stress as compared to the reproductive growth. In the present study, overall growth of the control, untreated tomato plants that were exposed to salt treatment showed retarded growth in perspective of morphological parameters measured. Perspective of morphological parameters measured. Specifically, they showed decreased growth in shoot length, root length, mass of the shoot, total weight, weight of the root, leaf surface area and number of leaves. The use of plant growth-promoting bacteria (PGPB) [14]. These beneficial microorganisms colonize the rhizosphere/endorhizosphere of plants and promote growth of the plants through various direct and indirect mechanisms. The term Induced Systemic Tolerance (IST) has been proposed for PGPR-induced physical and chemical changes that result in enhanced tolerance to abiotic stress. Plant growth-promoting bacteria are free-living soil bacteria that can either directly or indirectly facilitate rooting [15] and growth of plants [16]. Indirect stimulation of plant growth includes a variety of mechanisms by which the bacteria prevent phytopathogens from inhibiting plant growth and development [17, 18]. Direct stimulation may include providing plants with: fixed nitrogen, phytohormones, iron that has been sequestered by bacterial

siderophores, and soluble phosphate. Many PGPRs also produce the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase and metabolize ACC, a precursor to plant ethylene levels [19, 20]. In current findings, when tomato plants were irrigated with saline water, overall growth of the plants was affected regarding decline in physical traits (plant height, no of branches, leaf number etc.). Overall, chlorophyll content, carotenoid content of the PGPR-treated salt-stressed plants was increased as compared to the untreated, salt stressed tomato plants. In similar studies [21], used *Pseudomonas* sp. PS in Greengram (*Vigna radiata*) plant and found significant increase in plant dry weight, nodule numbers, total chlorophyll content, leghaemoglobin, root nitrogen, shoot nitrogen, root phosphorus, shoot phosphorus, seed yield and seed protein [22]. Was conducted pot study on tomato plants under 2% NaCl stress proved that C4 and T_{15} were the best growth promoters. C4 showed 50% enhancement in root and shoot length as compared to NaCl added untreated plants as well as in absence of NaCl [23]. Inoculate (*Bacillus megaterium*) for enhancing growth of tomato plants under salt stress conditions has been investigated Significant improvement in shoot length, root length, leaf surface area, number of leaves, total weight of the shoot and root was observed in tomato plants inoculated with zm7 strain post 15 and 30 days of its application. Chlorophyll content a, chlorophyll content b, anthocyanin and carotenoid content was increased in tomato plants subjected to Zm7, Zm6 and Zm4 strains. A number of studies have been carried out in order to standardize the process of salinity stress with the combination of PGPR on tomato [24-28].

4. Conclusion

The *Pseudomonas putida* has potential to improve plant growth by elevating various morphological and biochemical parameters in salt-stressed environment. If this strain applied as PGPR, it has the potential to induce salt tolerance to a significant extent in any particular plant. The results from the present investigation it is concluded that seeds treated with five different strains of PGPR, these five strains exhibited varying degrees of growth promotion. Among these strains the strain *Pseudomonas putida* (PP) has potential to improve morphology of tomato plants when compared with control (untreated) under salinity stressed condition. Whereas, the results also indicates there was gradually decrease in all parameters with the increase in salinity stress condition in treatment combination T_9. If this strain applied as PGPR, it has ability to induce salt tolerance to a significant extent in any plant. Moreover, it has also been observed that PGPR can protect plants from the deleterious effects of environmental stresses including salinity by absorption of water and nutrients, improving root development and increasing plant enzymatic activity.

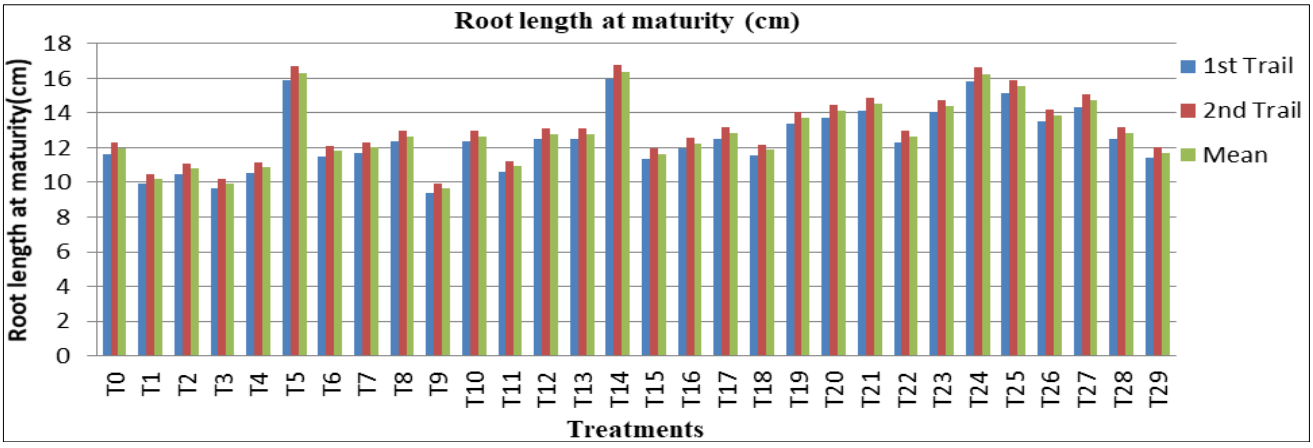

Fig 5: Histogram depicting Effect of PGPR on treated tomato plants, control and non-treated plants regarding root length, T_5(Pp), T_6(LS), T_7(A1+LS), T_8(M2S), T_9(HS), T_{10}(Bs+LS), T_{11}(Pf+LS), T_{12}(A_1+LS), T_{13}(A2+LS), T_{14}(Pp+LS), T_{15}(Bs+A1+LS), T_{16}(Pf+A1+LS), T_{17}(A_1+A1+LS), T_{18}(A2+A1+LS), T_{19}(Pp+A1+LS), T_{20}(Bs+M2S), T_{21}(Pf+M2S), T_{22}(A_1+M2S), T_{23}(A2+M2S), T_{24}(Pp+M2S), T_{25}(Bs+HS), T_{26}(Pf+HS), T_{27}(A_1+HS), T_{28}(A2+HS), T_{29}(Pp+HS)

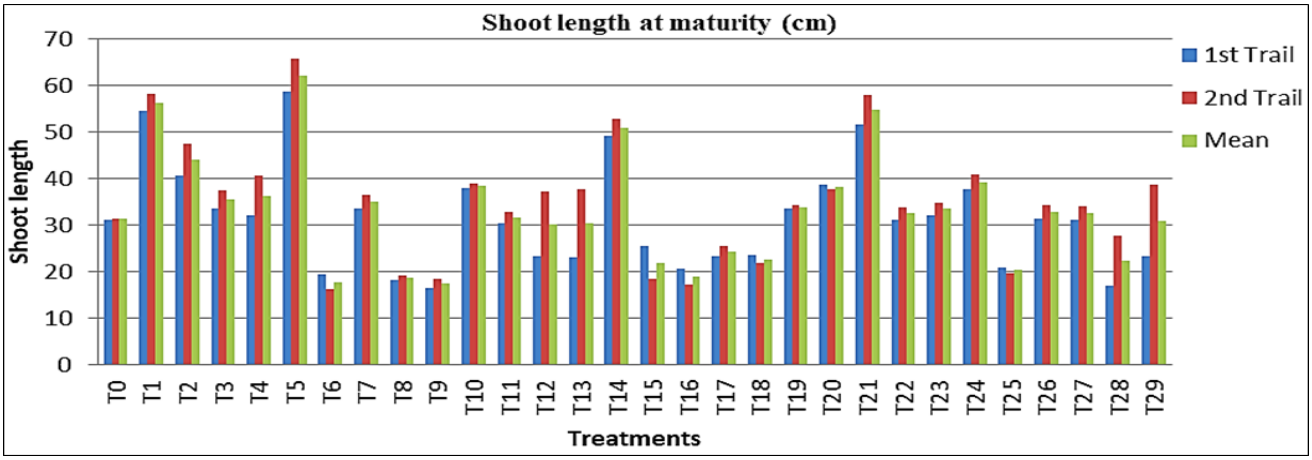

Fig 6: Histogram depicting Effect of PGPR on treated tomato plants, control and non-treated plants regarding shoot length, T_5(Pp), T6(LS), T_7(A1+LS), T_8(M2S), T_9(HS), T_{10}(Bs+LS), T_{11}(Pf+LS), T_{12}(A_1+LS), T_{13}(A2+LS), T_{14}(Pp+LS), T_{15}(Bs+A1+LS), T_{16}(Pf+A1+LS), T_{17}(A_1+A1+LS), T_{18}(A2+A1+LS), T_{19}(Pp+A1+LS), T_{20}(Bs+M2S), T_{21}(Pf+M2S), T_{22}(A_1+M2S), T_{23}(A2+M2S), T_{24}(Pp+M2S), T_{25}(Bs+HS), T_{26}(Pf+HS), T_{27}(A_1+HS), T_{28}(A2+HS), T_{29}(Pp+HS)

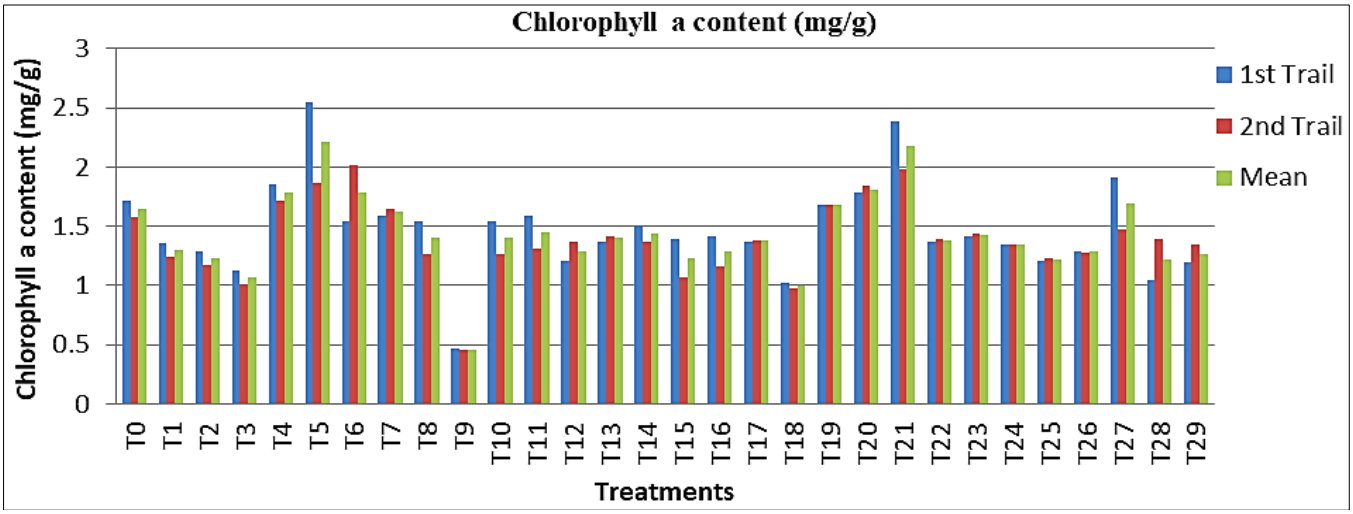

Fig 7: Histogram depicting Effect of PGPR on treated tomato plants, control and non-treated plants regarding chlorophyll a content, T_5(Pp), T_6(LS), T_7(A1+LS), T_8(M2S), T_9(HS), T_{10}(Bs+LS), T_{11}(Pf+LS), T_{12}(A_1+LS), T_{13}(A2+LS), T_{14}(Pp+LS), T_{15}(Bs+A1+LS), T_{16} (+A1+LS), T_{17}(A_1+A1+LS), T_{18}(A2+A1+LS), T_{19}(Pp+A1+LS), T_{20}(Bs+M2S), T_{21}(Pf+M2S), T_{22}(A_1+M2S), T_{23}(A2+M2S), T_{24}(Pp+M2S), T_{25}(Bs+HS), T_{26}(Pf+HS), T_{27}(A_1+HS), T_{28}(A2+HS), T_{29}(Pp+HS)

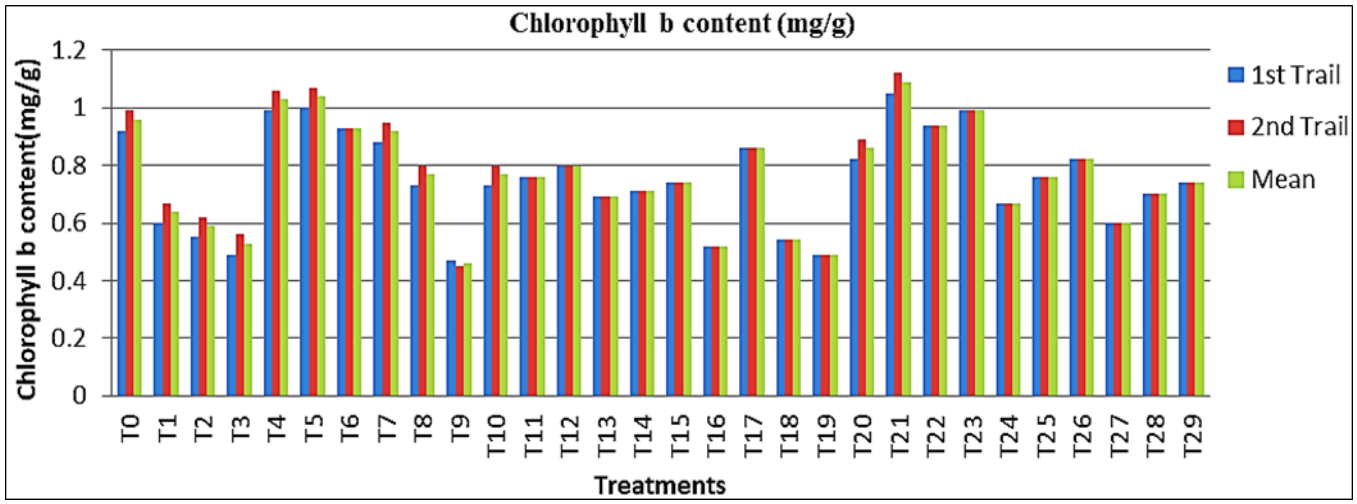

Fig 8: Histogram depicting Effect of PGPR on treated tomato plants, control and non-treated plants regarding chlorophyll b content, T_5(Pp), T_6(LS), T_7(A1+LS), T_8(M2S), T_9(HS), T_{10}(Bs+LS), T_{11}(Pf+LS), T_{12}(A_1+LS), T_{13}(A2+LS), T_{14}(Pp+LS), T_{15}(Bs+A1+LS), T_{16}(+A1+LS), T_{17}(A_1+A1+LS), T_{18}(A2+A1+LS), T_{19}(Pp+A1+LS), T_{20}(Bs+M2S), T_{21}(Pf+M2S), T_{22}(A_1+M2S), T_{23}(A2+M2S), T_{24}(Pp+M2S), T_{25}(Bs+HS), T_{26}(Pf+HS), T_{27}(A_1+HS), T_{28}(A2+HS), T_{29}(Pp+HS)

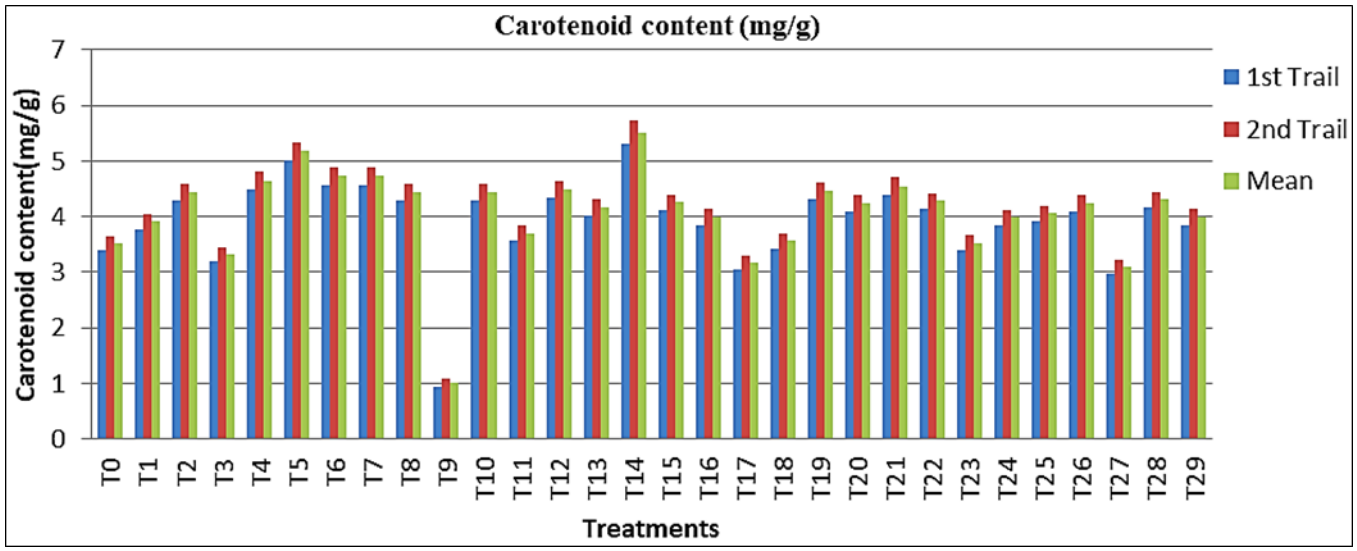

Fig 9: Histogram depicting Effect of PGPR on treated tomato plants, control and non-treated plants regarding chlorophyll carotenoid content, T_5(Pp), T_6(LS), T_7(A1+LS), T_8(M2S), T_9(HS), T_{10}(Bs+LS), T_{11}(Pf+LS), T_{12}(A_1+LS), T_{13}(A2+LS), T_{14}(Pp+LS), T_{15}(Bs+A1+LS), T_{16}(+A1+LS), T_{17}(A_1+A1+LS), T_{18}(A2+A1+LS), T_{19}(Pp+A1+LS), T_{20}(Bs+M2S), T_{21}(Pf+M2S), T_{22}(A_1+M2S), T_{23}(A2+M2S), T_{24}(Pp+M2S), T_{25}(Bs+HS), T_{26}(Pf+HS), T_{27}(A_1+HS), T_{28}(A2+HS), T_{29}(Pp+HS)

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