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Research Article

Amino Acid and Hormone Content of Plant Growth-Promoting Rhizobacteria Grown in Drought Stress Created by PEG6000

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Abstract

In this study the bacterial strains had been isolated from the rhizosphere and phyllosphere of wild and traditionally cultivated plants growing in the Eastern Anatolia Region of Turkey. The present study used a total of 60 Plant Growth-Promoting Rhizobacterial (PGPR) strains belonging to 9 different genera (including Pantoea, Bacillus, Pseudomonas, Peanibacillus, Agrobacterium, Acinetobacter, Brevibacillus, Cellulomonas and Micrococcus sp.), which are known to increase the tolerance to abiotic stress. The hormone and amino acid contents of PGPR were determined under drought stress by the addition of polyethylene glycol (PEG6000). Our results showed that, drought stress generally increased the amino acid and hormone contents of the bacteria. While significant increases in amino acid contents were found in Pantoea agglomerans (RK-92, KIN-99 and RK-205), Bacillus megaterium (TV-20E and TV-22B), Bacillus subtilis (BA-140 and TV-17C), Pseudomonas flourescens (K-22B and FDG-37), Bacillus pumilus (TV-67C and TV-83A), Brevibacillus brevis (FD-1), Micrococcus luteus (TV-91B), Peanibacillus polymyxa (KIN-37), Pseudomonas chlororaphis (İK-38), Pseudomonas putida (BA-8); hormone contents were significantly increased in Bacillus pumilus RK-103, Bacillus sphaericus FD-48 and Peanibacillus polymyxa KIN-37. These findings suggest that, PGPR may be used to decrease the loss of yield in the drought stress by inducting the systemic tolerance of the plants.

Keywords: PGPR, Drought stress, Polyethylene glycol, Amino acid, Hormone

PEG 6000 Tarafından Oluşturulan Kuraklık Stresinde Büyüyen Bitki Büyümesini Teşvik Eden Rizobakterilerin Amino Asit ve Hormon İçeriği

Öz

Bu çalışmadaki bakteri suşları, Türkiye'nin Doğu Anadolu bölgesinde yetişen yabani ve geleneksel olarak yetiştirilen bitkilerin rizosferinden ve filosferinden izole edilmiştir. Bu çalışmada, abiyotik strese toleransı artıdığı düşünülen 9 farklı cinse (*Pantoea, Bacillus, Pseudomonas, Peanibacillus, Agrobacterium, Acinetobacter, Brevibacillus, Cellulomonas* and *Micrococcus sp.*) ait toplam 60 bitki büyümesini teşvik eden rhizobacterial (PGPR) suşu kullanılmıştır. Bu suşlar polietilen glikol (PEG6000) ile kuraklık stresine maruz bırakıldıktan sonra hormon ve amino asit içerikleri belirlendi. Genel olarak bakterilerin amino asit ve hormon içeriği kuraklık stresine maruz kaldığında artmıştır. Yüksek aminoasit ve hormon seviyesi koruma sağlar ve stres baskısına maruz kalmayı azaltır. Özellikle amino asit içeriğindeki artış *Pantoea agglomerans* (RK-92, KIN-99 and RK-205), *Bacillus megaterium* (TV-20E and TV-22B), *Bacillus subtilis* (BA-140 and TV-17C), *Pseudomonas flourescens* (K-22B and FDG-37), *Bacillus pumilus* (TV-67C and TV-83A), *Brevibacillus brevis* (FD-1), *Micrococcus luteus* (TV-91B), *Peanibacillus polymyxa* (KIN-37), *Pseudomonas chlororaphis* (İK-38), *Pseudomonas putida* (BA-8) bakterilerinde, ve hormon içeriğindeki artış ise *Bacillus pumilus* RK-103, *Bacillus sphaericus* FD-

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48 and *Peanibacillus polymyxa* KIN-37 bakterilerinde gözlemlenmiştir. Çalışmadan, bu bakterilerin bitkinin sistemik toleransını arttırarak kuraklık stresinde verim kaybını azaltmak için kullanılabileceği sonucuna varılabilir.

Anahtar Kelimeler: PGPR, Kuraklık stresi, Polietilen glikol, Amino asit, Hormon

1. Introduction

The lack of water is one of the main constraints on plant growth and crop yield in both humid areas and arid conditions. Drought stress causes limitation to the plant growth and productivity of agricultural crops. The decline of plant growth caused by water insufficiency is considered to be one of the most important ecological factors limiting plant survival and establishment (Henry and Le Hou´erou, 1996).

Plant tolerance to water stress depends on morphological adaptation as well as biochemical and genetic properties. Under water stress, sensitive plants suffer rapid irreversible cell damage due to decomposition of their membranes (Kloepper et al., 2004). In order to obtain the maximum yield and profit in agriculture, efficient utilization of water, is essential since irrigation water sources are becoming scarce due to climate change (Van Loon et al., 1998).

In recent years, plants are constantly exposed to a wide range of environmental stresses which limits the plant productivity during the last decade. Over several centuries, breeding programs have focused on generating crop species with enhanced productivity under suboptimal environmental conditions. Breeding for tolerance to abiotic stress factors in crops has usually been limited by the lack of reliable traits for selection. Multiple genes play role in concert to increase the stress tolerance (Murillo-Amador et al., 2006). Therefore, the developments of methods and strategies to ameliorate the deleterious effects of abiotic stress factors on plants have received significant attention.

Drought tolerance and water use efficiency of the plants growing in arid and semi-arid regions can be improved by inoculation of plants with beneficial plant growth promoting rhizobacteria (PGPR) (Marulanda et al., 2007). PGPR, induced systemic tolerance (IST) has been proposed for physical and chemical changes in plants that result in enhanced tolerance to abiotic stress (Yang et al., 2009). Stress tolerance of plants increases by the presence of various beneficial soil microorganisms found in soil (Ryan et al., 2009). PGPR utilize the metabolites leaked from roots as C and N sources, thus can colonize the plant roots. Colonization of PGPR enhance the plant growth under stress conditions by producing ACC deaminase (Dey et al., 2004), generating plant growth regulators like indole acetic acid (IAA) (Mishra et al., 2010), gibberellic acid (Narula et al., 2006), cytokinins (Ortíz-Castro et al., 2008) and ethylene (Saleem et al., 2007). Moreover,, they fix asymbiotic nitrogen (Ardakani et al., 2010), help solubilization of mineral phosphates and other nutrients (Hayat et al., 2010), control plant disease caused by other bacteria and fungi producing antibiotics, enzymes and siderophores (Pathma et al., 2011). Investigations documented that inoculation with PGPR induces plant tolerance to drought stress (Khalid et al., 2004, Kohler et al., 2009). PGPR can amend the root structure, and promote plant development by increasing levels of phytohormones such as IAA, gibberellic acid and cytokinins (Kloepper et al., 2007). Swain et al. (2007) showed that inoculation of *Bacillus subtilis* on *Dioscorea rotundata* L. improved the IAA production of the plant compared to non-inoculated plants.

Beneficial rhizobacteria can adapt to specific environmental conditions and develop tolerance to stressed enviroments (Samancioglu et al., 2016, Yıldırım et al., 2016, Erdogan et al., 2016, Ipek et al., 2017, Aras et al., 2018, Arıkan et al., 2018, Erdogan et al., 2018, Kitir, et al. 2018)... Therefore, investigation of the stress responsive mechanisms like accumulation of proline, sugars, EPS etc. under stress conditions may aid in selecting more stress tolerant microbial strains. PGPRs have been reported to have the potential for the amelioration of the deleterious effects of drought stress in crops (Mayak et al., 2004; Hayat et al., 2010). Investigating stress markers such as amino acids and/or phytohormone synthesis at PEG created drought in the axenic medium may aid in selecting the more stress-adapted tolerant strains (Marulanda et al., 2009).

Altough the positive effects of PGPR on tolerance of the plants to the abiotic stress are known for a long time, exact mechanism of action is still unclear. The primary aim of the study was to explore the type and amount of the organic acid and hormone content odrought tolerant PGPR isolates from soils of different rhizosphere and phyllosphere of wild and traditionally cultivated plants growing in the Eastern Anatolia Region of Turkey.

2. Material and Method

2.1. Bacterial Strains

In this study, a total of 60 Plant Growth-Promoting Rhizobacterial (PGPR) strains belonging to 9 different genera (including *Pantoea, Bacillus, Pseudomonas, Peanibacillus, Agrobacterium, Acinetobacter, Brevibacillus, Cellulomonas* and *Micrococcus*) and 15 different species (including *Pantoea agglomerans, Bacillus megaterium, Bacillus subtilis, Pseudomonas putida, Pseudomonas flourescens, Bacillus pumilus, Peanibacillus polymyxa, Agrobacterium rubi, Bacillus sphaericus, Pseudomonas chlororaphis, Acinetobacter radioresistens, Brevibacillus brevis, Brevibacillus choshiensis, Cellulomonas turbata* and *Micrococcus luteus strains*) were used (Table 1). The bacterial strains had been isolated from the rhizosphere and phyllosphere of wild and traditionally cultivated plants growing in the eastern Anatolia region of Turkey (Kotan et al., 2005; Kotan et al., 2009; Erman et al., 2010). All the bacterial strains have capacity to grow in nitrogen-free conditions and/or to solubilize phosphate that obtained from the culture collection unit in the Department of Plant Protection, Faculty of Agriculture at Atatürk University, Erzurum, Turkey. The identity of the bacteria had been identified according to fatty acid methyl esters (FAME) analysis by using Sherlock Microbial Identification System (Microbial ID, Newark, DE, USA) (Miller, 1982). The bacteria were previously reported as plant growth promoting characteristic (Kantar et al., 2009; Cakmakcı et al., 2010; Karagoz et al., 2012; Tozlu et al., 2012) and potential bio-control agents against a wide range of bacterial and fungal pathogens that cause economically important crop losses in agriculture (Kotan et al., 2004; Kotan et al., 2005; Kotan and

Sahin, 2006; Kotan et al., 2009). Bacterial cultures were grown on Nutrient Agar (NA) for routine use, and maintained in Nutrient Broth (NB) with 15% glycerol at -80°C for long-term storage.

2.2. Hypersensitivity Tests (HR)

All of the bacterial strains were tested for hypersensitivity on tobacco plants (*Nicotina tabacum* L. var. Samsun) as described by Klement et al. (1964). The bacterial suspensions (10^8 cfu/ml) prepared in sterile distilled water were infiltrated into the inter costal area of the leaves of tobacco plants by using a 3-cc syringe (Becton Dickinson, Franklin Lakes, NJ, USA). The inoculated plants were incubated in a completely randomized design on the greenhouse bench for 24–48 h at 20–28 °C. The presence of rapid tissue necrosis at the inoculation site was recorded within 24–48 h after infiltration. This test was repeated at least three times for each strain. For HR tests sterilized distilled water (sdH_2O) was used as a negative control.

2.3. Bacterial Growth under Water Stress and Laboratory Experiment

The isolates that could grow at the drought stress of -0.73 MPa (25% PEG6000) were selected for plant growth promoting (PGP) properties like production of IAA (Gordon and Weber, 1951), Giberrallic acid (Sandhya et al., 2010), cytokinin (Barbara and Wong, 1989), bacterial cells accumulate small compatible solutes called osmolytes that include amino acids like glutamate, glutamine, proline, alanine etc, quarternary amines like glycine betaine and sugars like sucrose, trehalose and polyglucosyl granules that improve cell growth under adverse osmotic conditions serving as osmoprotectants (Potts, 1994), under no-stress and stress conditions. Bacteria exposed to drought stress applied to -0.73MPa PEG6000 but was not applied to optimum conditions grown in bacteria.

Frozen bacterial cultures were streaked on Nutrient Agar (NA, Oxoid) plates. The cultures were individually incubated at 27 °C for 24 h. After incubation period, a single colony was transferred to 1000-ml flasks containing Nutrient Broth (NB, Oxoid), and grown aerobically in the flasks on a rotating shaker (150 rpm) for 48 h at 27 °C (Merck, Germany) and diluted to a final concentration of 10^8 CFU.ml^{-1} (colony forming units) using sterile distilled water containing 0.025% Tween 20. Sixty bacteria sample of each PGPR were used in the experiment to determine amino acid and hormone.

2.3.1. Amino Acid Analysis

0.1 N HCl added in one-gram fresh sample, homogenized with ultraturraks, and incubated in 4°C at 12 hours. Samples were vortexed. After samples were centrifuged at 1200 rpm for 50 min, supernatants were filtered through 0.22 µm (Millex Millipore). Then supernatants were transferred to vial and vials for amino acid analysis in HPLC as described by Aristoy and Toldra (1991), Antoine et al. (1999) and Henderson et al. (1999). Briefly, Zorbax Eclipse-AAA 4.6 x 150 mm, 3.5 µm columns (Agilent 1200 HPLC) were used and reading was recorded at 254 nm, and the amino acids were identified by comparison with standards. O-phthaldialdehyde (OPA), fluorenylmethyl-chloroformate (FMOC) and 0.4 N Borate. The following were used as the mobile phase in the chromatography system: mobile phase. A: 40 mM NaH_2PO_4 (pH 7.8) and mobile phase B: Acetonitrile/Methanol/Water (45/45/10 v/v/v) solutions. The flow rate of the mobile phase moved through the system at 2 ml/min and the column temperature was 40 °C. Aspartate, glutamate, asparagine, serine, glutamine, histidine, glycine, theonine, arginine, alanine, tyrocine, cystine, valin, methionine, tryptophan, phenylalanine, isoluecine, leucine, lysine, hydroxyproline, sarcosine, proline quantity of lichen samples determined as pmol/µL after 26 minutes derivation process in HPLC.

2.3.2. Hormone Analysis

Extraction and purification processes were executed as described by Kuraishi et al. (1991) and Battal and Tileklioglu (2001). methanole 80% adjusted to -40 °C was added in fresh samples (Davies, 1995). After solution was homojenized for 10 minutes with ultraturraks, it was incubated for 24 hours in dark condition. The samples were filtered through filter (Whatman No:1) and then supernatants were filtered again at 0.45 µm pore (Cutting, 1991). Supernatants were dried in 35 °C by evaporator pumps. Dried supernatants were solved using 0.1 M KH_2PO_4 (pH 8.0). Extracts were centrifugedat 5000 rpm for 1 hour at 4°C for separating fatty acids (Palni et al., 1983). Polvinilpolipirilidon (PVPP), 1 g, was added to supernatant for separating phenolic and color matters (Money and Staden, 1984; Chen, 1991; Qamaruddin, 1996). Supernatant with PVPP was filtered (Whatman No:1) to separate PVPP (Cheikh and Jones, 1994). For further specific separation, Sep-Pak C-18 (Waters) cartridge was used. Hormones adsorbed by cartridge transferred to vials using 80% methanole. The hormone was analyzed by HPLC using a Zorbax Eclipse-AAA C-18 column (Agilent 1200 HPLC) and absorbance of 265 nm in UV detector. Flow speed was set to 1.2 ml/min and at column temperature of 25 °C. Giberallic acid, salisilic acid, indol acetic acid (IAA), absisic acid (ABA) were determined by using 13% acetonitrile (pH 4.98) as mobile phase.

2.4. Statistically Analysis

Data were sorted by PGPR species and differences among species were attained using LSD (Least significant difference) test SAS statistical package program (SAS Inst., 1997). Differences were declared to be significant at $P<0.05$.

Table 1. Bacterial strains used in this study

No	Isolat no	Bacterial species	HR	No	Isolat no	Bacterial species	HR
1	TV-3D	*Bacillus megaterium*	–	31	FD-1	*Brevibacillus brevis*	–
2	TV- 6D	*Bacillus megaterium*	–	32	FD-48	*Bacillus sphaericus*	–
3	TV-6F	*Bacillus subtilis*	–	33	FD-49	*Bacillus sphaericus*	–
4	TV-11D	*Pseudomonas flourescens*	–	34	K-7E	*Pseudomonas flourescens*	–
5	TV-12E	*Bacillus subtilis*	–	35	K-9C	*Pseudomonas putida*	–
6	TV-12H	*Bacillus subtilis*	–	36	K-19B	*Pseudomonas putida*	–
7	TV-13B	*Bacillus subtilis*	–	37	K-19D	*Pseudomonas putida*	–
8	TV-13C	*Bacillus megaterium*	–	38	K-22B	*Pseudomonas flourescens*	–
9	TV-17C	*Bacillus subtilis*	–	39	KBA-2	*Peanibacillus polymyxa*	–
10	TV-20E	*Bacillus megaterium*	–	40	KBA-8	*Pantoea agglomerans*	–
11	TV-22B	*Bacillus megaterium*	–	41	KBA-10	*Bacillus megaterium*	–
12	TV-42A	*Pseudomonas putida*	–	42	KP-63	*Pseudomonas flourescens*	–
13	TV-53D	*Brevibacillus choshiensis*	–	43	KP-81	*Pseudomonas putida*	–
14	TV-54A	*Cellulomonas turbata*	–	44	KIN-21	*Peanibacillus polymyxa*	–
15	TV-60D	*Bacillus megaterium*	–	45	KIN-37	*Peanibacillus polymyxa*	–
16	TV-67C	*Bacillus pumilus*	–	46	KIN-99	*Pantoea agglomerans*	–
17	TV-83A	*Bacillus pumilus*	–	47	RK-77	*Pantoea agglomerans*	–
18	TV-87A	*Bacillus megaterium*	–	48	RK-79	*Pantoea agglomerans*	–
19	TV-91B	*Micrococcus luteus*	–	49	RK-84	*Pantoea agglomerans*	–
20	TV-91C	*Bacillus megaterium*	–	50	RK-85	*Pantoea agglomerans*	–
21	M-3	*Bacillus megaterium*	–	51	RK-92	*Pantoea agglomerans*	–
22	A-1	*Agrobacterium rubi*	–	52	RK-103	*Bacillus pumilus*	–
23	A-16	*Agrobacterium rubi*	–	53	RK-123	*Pantoea agglomerans*	–
24	A-18	*Agrobacterium rubi*	–	54	RK-126	*Pantoea agglomerans*	–
25	BA-140	*Bacillus subtilis*	–	55	RK-134	*Pantoea agglomerans*	–
26	BA-8	*Pseudomonas putida*	–	56	RK-142	*Bacillus subtilis*	–
27	İK-37	*Pseudomonas chlororaphis*	–	57	RK-153	*Pantoea agglomerans*	–
28	İK-38	*Pseudomonas chlororaphis*	–	58	RK-198	*Pantoea agglomerans*	–
29	İK-39	*Bacillus pumilus*	–	59	RK-205	*Pantoea agglomerans*	–
30	FDG-37	*Pseudomonas fluorescens*	–	60	RK-344	*Acinetobacter radioresistens*	–

3. Results

The list of the bacterial strains used in this study and their hypersensitivity test results were given in Table 1. All the bacterial strains were hypersensitivity negative on tobacco plants.

3.1. Amino Acids Content of PGPRs

In this study, the drought tolerance capabilities of PGPR grown in non-stress conditions were investigated by exposing the bacteria to drought stress created by addition of PEG6000 to the growth medium. The hormone and amino acid contents of sixty different PGPRs are given in Tables 2, 3, 4 and 5. When the PGPRs were exposed to drought-stress, amino acid content of BA-8, TV-20E, RK-92, BA-140, A-1, M-3, K-9C, RK-142, RK-79, K-22B, KIN-21, FD-49, TV-12E and A-18 bacterial strains significantly increased with respect to the non-stressed bacteria. Especially, this increase is more prominent in some amino acid values. Compared to non-stress and drought-stress conditions, the highest asparagine amino acid content was obtained from TV-20E, TV- 6D, A-1, TV-42A, RK-126, FD-48, TV-87A, A-18 and İK-39 bacterial strains; serine amino acid in TV-67C, TV-3D, İK-37, TV-83A, KBA-10, FD-49, TV-11D, A-18 and K-9C bacterial strains; glutamine amino acid in BA-140, A-1, KIN-37, FDG-37, KIN-99, K-19D, TV-67C, RK-85 and RK-92 bacterial strains; histidine amino acid in K-22B, K-9C, KBA-2, TV-91B, TV-17C, RK-84, KP-81, TV-6F and RK-85 bacterial strains; glycine amino acid in RK-92, RK-84, M-3, KIN-99, RK-142, RK-79, TV-12E, RK-123 and KBA-8 bacterial strains; theonine amino acid in BA-140, RK-126, KBA-2, RK-92, TV-20E, M-3, A-16 A-1, FDG-37 and TV-91B bacterial strains; alanine amino acid in FDG-37, TV-22B, BA-140, B13, İK-37, İK-38, TV-20E, M-3, A-18 and TV-83A bacterial strains; tyrocine amino acid in TV-83A, KIN-99, TV-17C, K-22B, TV-12E, TV-3D, TV-12H, KIN-21, FD-1 and RK-134 bacterial strains; cystine amino acid in TV-91B, K-19D, M-3, TV-6F, TV-60D, TV-91C, RK-92, FD-49, İK-39 and RK-84 bacterial strains; valin amino acid in TV-20E, A-1, M-3, RK-79, RK-92, TV-12H, KIN-99, KBA-2, TV-17C and TV-67C bacterial strains; phenylalanine amino acid in BA-8, FD-48, TV-17C, TV-12E, RK-142, TV-11D, RK-79, KIN-21, K-7E and RK-205 bacterial strains; aspartate amino acid in BA-8, TV-17C, A-1, KP-81, İK-38, KIN-99, KBA-10, M-3, TV-53D and RK-198 bacterial strains; glutamate amino acid in RK-205, KBA-8, TV-54A, KIN-21, KP-81, TV-91C, RK-77, FD-49, TV-42A and RK-84 bacterial strains; prolin amino acid in RK-92, KBA-2, FDG-37, TV-67C, TV-53D, K-9C, İK-38, KIN-37, RK-84 and K-19B bacterial strains; tryptophan amino acid in TV-22B, KBA-10, TV-87A, RK-126, RK-142, RK-123, TV-54A, İK-38, TV-12E and RK-198 bacterial strains; isoluecine amino acid in KIN-37, BA-140, TV-54A, TV-22B, KP-81, RK-134, B42, RK-123, TV-91B and RK-153 bacterial strains; leucine amino acid in İK-38, KBA-2, TV-67C, RK-84, TV-53D, FDG-37, TV-87A, TV-17C, FD-49 and TV-20E bacterial strains; hydroxyproline amino acid in FD-1, RK-123, BA-140, 19, TV-17C, TV-60D, K-19B, KBA-10, RK-77 and TV-91C bacterial strains; sarcosine amino acid in TV-17C, BA-8, TV-12E, K-22B, TV-11D, RK-79, A-16, RK-153, RK-85 and M-3 bacterial strains; methionine amino acid in BA-8, KIN-99, TV-12H, RK-79, TV-53D, A-1, K-22B, KBA-8, TV-12E and KBA-2 bacterial strains; while the highest total amino acid content was obtained from KIN-99, K-22B, TV-17C and BA-8 bacterial strains.

3.2. Hormone Contents of PGPRs

Gibberellic acid, indoleacetic acid, salicylic acid and abscisic acid level changes of PGPR were examined under non-stress and drought stress conditions.. The highest gibberellic acid contents of the bacteria were found in the RK-153, TV-22B, FD-1, KIN-99, TV-13C, KIN-21, KP-63, RK-92, K-19D and K-9C bacterial strains in drought stress condition, while the salicylic acid and indole acetic acid content in the bacterial strains of KIN-37, TV-22B, RK-153, RK-344, FD-1, TV-11D, TV-87A, K-9C, RK-92 and RK-153; in the bacterial strains of FD-48, TV-60D, TV-11D, KIN-21, RK-142, RK-126, K-7E, KP-63, KIN-99 and TV-42A, respectively (Table 6). Hormone contents of tested PGPR were found significantly higher under drought stress conditions compared to the control treatment.

4. Discussion

4.1. Effects of Stress Condition on Amino Acids Production of PGPRs

During the plant development stage, the direct action mechanism of PGPR on the tolerance of the plants to drought stress was reported to be the production of phytohormones such as IAA and cytokinins (Patten and Glick, 1996). As an indirect mechanism, bacterial cells increase the accumulation of small compatible solutes called osmolytes of the plants that include amino acids like glutamate, glutamine, proline, alanine etc, quaternary amines like glycine betaine and sugars like sucrose, trehalose and polyglucosyl granules. These amino acids and osmolytes (like quarternary amines) were found to increase with the drought stress (Crowe and Crowe, 1992). Thus, they were reported to free the radicals protecting the integrity of the membranes and prevent the corruption of enzymes (Bohnert and Jensen, 1996). The studies highlight that the osmolytes difuse in free radicals and chemical chaperones preventing the corruption of the membranes and proteins. Our study showed that drought stress (-0.73 Mpa) created with PEG6000 agar application increased the amino acid content of PGPR compared to optimum conditions. For example, tyrocine amino acid level was 506693 pmol/µL in TV-83A strain, histidine (21469 pmol/µL) in K-22B , sarcosine (20583 pmol/µL) in TV-17C, methionine (20330 pmol/µL) in BA-8, glutamate (19810 pmol/µL) in BA-140, tryptophan (18037 pmol/µL) in TV-22B, isoleucine (15,478 pmol/µL) in KIN-37, cysteine (13055 pmol/µL) in TV-91B, asparagine (9419 pmol/µL) in TV-20E, hydroxyproline (7039 pmol/µL) in FD-1, alanine (6751 pmol/µL) in FDG-37, phenylalanine (5891 pmol/µL) in BA-8, proline (5599 pmol/µL) in RK-92, valin (4567 pmol/µL) in TV-20E, serine (3239 pmol/µL) in TV-67C, glycine (1734 pmol/µL) in RK-92, glutamine (1553 pmol/µL) in RK-205, theonine (1544 pmol/µL) in BA-140, aspartate (1543 pmol/µL) in BA-8 and leucine (1222 pmol/µL) in İK-38 bacterial strains. An increase in the proline content associated with the stress tolerance mechanism has been reported with *Pseudomonas putida, Pseudomonas* sp. *and Bacillus megaterium,* which are known to increase the plant development in arid environmental conditions (Marulanda et al., 2009). PGPR provide resistance and tolerance to soil salinity resulted from drought stress. The extracellular polysaccharides produced by the plant during drought stress help formation of biofilms (Potts, 1994). Biofilm formation help increasing the accumulation of amino acids which in turn increase the stress tolerance of the plant .In this study, an increase in the amino acid content of PGPR under drought stress was observed in most cases compared to the control. The highest amino acid value was observed by KIN-99 bacterial strains which was higher than 100 pmol/µL.

In our study, proline content was found to have positive effects on drought stress tolerance mechanism. The highest proline value was observed by RK-92 bacterial strains. Sandhya et al. (2010) also showed that the free proline content increased in five *Pseudomonas* spp. strains under stressed conditions compared to the control.

Increase in the tryptophan content was reported to prevent the damage caused in the cell tissues under abiotic stress factors (Glick et al., 2007). Our results showed that there was a very significant increase in the tryptophan contents of some PGPR strains such as TV87-A, TV91B, IK-38, KBA-10, KP-63, RK-103, RK-123, RK-126, RK-153 under stress conditions compared to control. These results are also in accordance with the study of Sandhya et al. (2010), where they showed increased amounts of tryptophan, free amino acids, sugars and exopolysaccharides under drought stress which played an important role in the stress tolerance of *Pseudomonas* spp.

4.2. The Effects of Stress Condition on Hormone Production of PGPRs

PGPRs direct effect can be found on plant growth facilitating by synthesizing plant hormones. PGPRs produce plant growth-promoting compounds such as auxins, cytokinins and gibberellins (Saikia et al., 2006). When plants exposed to drought stress, they have a systemic effect tolerance mechanism of PGPR by means of applied abiotic stress which causes physical and chemical changes in the plant (Yang et al., 2009). These changes, especially increasing the drought stress phytohormone (IAA, GA, ABA) activity, constitute great importance (Glick, 1995). PGPR can improve the roots and promote plant development with the production of different phytohormones such as IAA (Kloepper et al., 2007). In addition, PGPRs can increase the plant growth by creating ways to signal such as salicylic acid, gibberellins and IAA hormones in plants. In response to roots, the bacteria synthesize indole acetic acid (IAA) and plant cells take up some of the IAA that is excreted by the bacteria. Along with the endogenous IAA produced by the plant, IAA synthesized by the bacteria affects plant cell proliferation (Glick et al., 2007). In our study, when PGPRs were grown in drought stress, the amount of the hormones was found to increase compared to the control.

In particular, when PGPRs were grown in drought stress; the highest indole acetic acid hormone of PGPRs was determined in FD-48 strains compared to the control. Similarly, Marulanda et al. (2009) reported an increase in the plant growth and IAA content in relation to the mechanism of the tolerance to stress in *Pseudomonas putida*, *Pseudomonas* sp. and *Bacillus megaterium* under drought conditions Sadeghi et al. (2012) and Cimrin et al., 2020 found that bacteria application reduced stress damage in line with releasing more IAA in drought stress conditions.

One of the changes occur in plants under drought stress, is the stomatal closure to reduce the water loss in leaves (Decoteau, 2000). Plants' internal cytokinin level reduces with the levels of increased ABA hormone. In our study, the highest ABA hormone was observed in TV-53D strain exposed to drought stress.. Especially under abiotic stress conditions such as drought stress, the tolerance mechanism generates oxidative stress protection (Reymond and Farmer, 1998). Salicylic acid (SA) plays a major role in the tolerance mechanism (Gray and Smith, 2005). The highest SA value (3752 ng/µl) was determined in KIN-37 strains under drought stress. Similarly, an increase in plant growth related to the production of SA was found using two isolated PGPRs (*P. fluorescens* Pf4 and P) (Saikia et al., 2006).

The results of the study showed that amino acid and hormone content of the investigated bacteria increased under drought stress. Amino acid increases in bacteria were observed in *Bacillus megaterium* TV-20E, *Bacillus pumilus* TV-67C, *Bacillus subtilis* BA-140, *Pseudomonas flourescens* K-22B, *Pantoea agglomerans* RK-92, *Pseudomonas fluorescens* FDG-37, *Pantoea agglomerans* KIN-99, *Micrococcus luteus* TV-91B, *Pseudomonas putida* BA-8, *Pantoea agglomerans* RK-205, *Bacillus megaterium* TV-22B, *Peanibacillus polymyxa* KIN-37, *Pseudomonas chlororaphis* İK-38, *Brevibacillus brevis* FD-1, *Bacillus subtilis* TV-17C. Hormone content was found to increase in *Bacillus pumilus* RK-103, *Bacillus sphaericus* FD-48 and *Peanibacillus polymyxa* KIN-37.

5. Conclusions and Recommendations

Many studies showed positive effects of PGPRs on the quality of plants and the yield by improving the tolerance mechanism under different abiotic stress conditions including the drought stress without degradation of soil. However, to date, the exact relation between PGPR and the improved plant tolerance has not been elucidated. In our study, a total of 60 PGPR strains belonging to 9 different genera and 15 different species were used to determine the effect of drought stress on the amino acid and hormone levels of PGPRs. The results showed that the hormone and amino acid contents of PGPR increased under drought stress which was induced by PEG6000. This finding suggests that increased stress tolerance of the plants may be resulting from the increase in the metabolite content of PGPR which induces the accumulation of these metabolites in the plant. In conclusion, the isolation and screening of indigenous PGPR traits based on their ability to increase their amino acid and hormone content under drought stress may be useful in the rapid selection of the efficient PGPR strains that could be used as bio-inoculants for plant production under abiotic stress.

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Table 2. Amino acid content of PGPR (pmol/µL) (mean ± standard error. n = 4 each treatment)

Isolates	Asparagine		Serine		Glutamine		Histidine		Glycine	
	NS	DS	NS	DS	NS	DS	NS	DS	NS	DS
TV-3D	7119.1±4	6129.0±5w	1129.1±2f	2989.0±8b	827.6±8h	282.0±2s	2014.1±6c	1875.0±5d	153.7±2a	242.5±8qr
TV- 6D	5473.0±3s	8990.0±4c	1339.3±3s	1430.0±5m	355.8±5k	616.0±3r	4566.3±7s	4013.0±3d	730.7±3j	290.8±5k
TV-6F	5140.0±2h	6448.3±3r	2030.0±2p	1868.3±4w	1348.0±4j	437.3±2a	3092.0±7m	7811.3±2p	279.2±2l	241.9±4qr
TV-11D	8264.3±2k	7130.6±8b	2650.0±5d	2320.6±3j	356.5±3k	81.2±5e	3424.0±8k	2976.6±4q	601.3±5o	202.1±3v
TV-12E	7340.0±3w	5152.0±4g	1560.0±2g	1662.0±8d	1217.0±8o	221.0±2x	2014.0±5c	2716.0±3s	496.5±2v	467.7±8w
TV-12H	5101.4±2f	5108.0±3j	1249.6±6z	1750.0±4b	317.1±4y	511.5±6w	2438.6±4e	4011±5d	504.1±6y	201.4±4v
TV-13B	6570.0±5n	5240.6±2b	767.0±7d	895.6±3t	1406.0±3f	97.1±7c	2219.0±3z	4232.6±6b	328.6±7f	77.4±3lk
TV-13C	5769.6±2i	5889.3±2d	763.6±7e	805.0±2a	937.1±2f	431.8±7c	2259.6±8x	2210.3±3a	801.0±7h	133.5±2c
TV-17C	5589.0±3n	6068.6±5x	1650.0±8e	1318.6±2u	270.2±2t	371.1±8j	12433±4h	9365.6±2j	567.3±8p	243.9±2qr
TV-20E	7352.0±8v	9419.0±2b	2577.6±5f	732.0±3h	445.5±3z	726.1±5m	1816.0±3e	970.3±1n	513.7±5s	134.8±3c
TV-22B	7340.0±4w	5129.6±6i	980.0±4m	1039.6±2j	1219.5±2no	165.1±4a	4433.0±2y	7044.6±5v	298.2±4j	187.2±2x
TV-42A	7682.3±3o	8790.0±7g	1782.3±3y	1340.3±5s	646.8±5q	306.8±3p	5229±2x	4013.3±3d	452.4±3z	201.6±5v
TV-53D	7139.67±4a	7350.0±7v	1119.6±8h	1450.0±2k	1116.6±2t	382.5±8h	7231.7±3u	1545.0±4j	895.7±8e	143.5±2b
TV-54A	8869.0±3g	5490.6±8r	1390.0±4o	898.6±6st	615.0±6r	257.1±4u	4588.4±2e	1783.4±8g	241.3±4r	76.2±6l
TV-60D	6430.3±2s	5470.0±5ts	1220.0±3b	1018.0±7k	948.8±7e	517.0±3v	2413.3±5w	5663.8±7h	302.5±3i	309.0±7h
TV-67C	5857.0±2a	7139.0±4a	1400.0±2n	3239.3±7a	662.3±7p	938.3±2f	6574.0±2r	5616.3±5j	456.9±2yx	1342.9±7d
TV-83A	8139.0±3l	5689.3±3j	1129.6±1f	2569.0±8g	1273.1±8m	615.3±1r	4532.6±3v	7230.3±6u	805.4±1g	165.2±8z
TV-87A	5469.6±2t	7690.0±8n	1349.6±5q	1560.0±5g	1114.6±5t	774.0±5k	4010.6±8d	3694.0±7f	298.2±5j	108.4±5fg
TV-91B	5659.6±5k	6749.0±4l	1399.0±2n	959.0±4o	953.6±4d	288.0±2r	5435.6±4m	11063.0±2i	508.4±2t	20.6±4q
TV-91C	6929.6±2f	5226.4±3c	1511.6±4i	1125.4±3g	511.6±3w	272.3±4t	6508.6±3a	555.3±4k	785.1±4i	187.2±3x
M-3	6030.0±3z	7239.3±2d	860.0±5w	890.0±8u	1217.5±8o	378.0±5i	14032.0±2f	564.0±2u	519.1±5r	802.2±8h
A-1	6539.6±8o	8969.0±2d	939.6±3p	1009.0±4l	1171.6±4q	1368.5±3h	3022.6±2n	875.0±3p	400.9±3c	20.8±4q
A-16	5659.6±4k	5208.0±3d	1119.6±2h	1168.0±3c	1273.1±3m	673.6±2o	2013.6±5c	711.6±2s	301.2±2ji	18.1±3q
A-18	7127.6±3b	7680.3±2o	1777.6±4z	2310.3±2k	375.6±2i	410.8±4f	11459±2w	2232.3±5y	398.9±4c	135.2±2c
BA-140	5946.0±3c	5256.0±5z	2072.9±3o	1340.3±2s	673.5±2o	1553.8±3d	6546.6±6n	913.3±2o	600.3±3o	196.3±2w
BA-8	6570.0±2n	5540.0±4p	1440.0±5l	1940.0±5q	938.0±5f	315.0±5n	8231.6±7w	3645.0±3h	445.6±5a	362.2±5e
İK-37	6712.5±1m	7210.0±3z	1270.7±6x	2670.0±2c	302.4±2q	433.5±6bc	4506.6±7k	6548±8z	365.0±6ed	262.8±2o

İK-38	6034.9±5y	5622.3±8l	1528.3±3h	1142.3±6d	1525.8±6e	217.3±3y	4461.3±8d	1812.3±4f	266.0±3mn	84.6±6j
İK-39	6129.0±2w	7672.0±4p	1229.0±2a	1306.5±7v	1076.0±7v	435.0±2ab	15733.0±3d	4549.0±3t	267.8±2mn	189.5±7x
FDG-37	4550.0±4n	7239.0±3y	1430.0±1m	809.0±7z	1007.5±7a	1066.0±1w	7765.0±2q	535.3±2v	567.4±1p	144.6±7b
FD-1	8900.0±5e	5504.6±2q	1780.6±5yz	1670.6±8c	255.0±8u	77.8±5f	7545±5o	6013.6±2c	723.7±5k	109.8±8fg
FD-48	8340.3±3h	7810.0±2m	1344.3±3r	1860.0±5x	671.3±5o	306.5±3p	1872.3±2d	1476.0±5k	318.2±3g	229.8±5t
FD-49	6751.0±2l	7669.6±5pq	1771.3±4a	2409.6±4i	457.8±4x	206.1±4z	9341.6±3j	4533.6±2v	243.7±4qr	133.8±4c
K-7E	6567.6±4n	7647.7±2r	1427.6±8m	1494.1±3j	454.1±3y	438.0±8a	4566.0±3l	5647.0±6i	801.8±8h	397.9±3c
K-9C	7440.3±3t	5399.0±6v	1009.2±7l	2309.6±8k	859.1±8g	616.1±7r	4544.3±2u	20609.6±7b	815.3±7f	113.1±8ed
K-19B	6508.9±4p	5881.0±7e	896.9±5st	1138.0±4e	1081.4±4u	246.0±5v	1233.9±3M	6869.0±7x	94.5±5i	31.4±4p
K-19D	7299.6±8x	5260.0±7y	1249.6±6y	1889.6±3v	1006.6±3a	977.6±6b	6012.6±2c	5999.8±8d	446.8±6a	444.9±3a
K-22B	6569.6±7n	5980.3±8b	749.6±7f	969.3±2n	1015.6±2z	416.8±7e	4314.6±5a	21469.3±3a	400.9±7c	101.6±2h
KBA-2	5869.6±5f	5489.0±5r	1119.6±2h	929.0±2q	824.6±2h	270.5±2t	2438.6±2V	16053.0±2c	243.2±2qr	100.5±2h
KBA-8	6869.0±6h	6569.0±4n	899.3±4s	2129.0±3m	769.3±3l	327.5±4l	4532.3±6v	2205.2±5b	277.9±4l	454.6±3yz
KBA-10	6770.3±7k	5277.6±3x	1240.0±5z	2418.6±2h	1138.5±2r	305.1±5pq	6013.3±7c	1245.6±2l	670.3±5l	237.8±2s
KP-63	5600.0±2m	6430.0±8s	1300.0±3w	1068.0±5i	1392.5±5g	455.5±3xy	5231.0±7n	7565.0±4r	501.5±3u	57.1±5o
KP-81	5458.2±4u	6331.0±4t	1860.5±2x	2111.0±2n	425.7±2d	523.0±2u	8967.6±8g	7814.0±3p	399.7±2c	133.4±2c
KIN-21	6130.6±5w	6870.6±3h	1900.6±4u	2240.6±3l	1284.1±3l	329.1±4l	4567.6±5s	4668.6±8p	407.8±4b	244.5±3q
KIN-37	6800.6±3j	7139.3±2u	1250.6±3y	786.3±8b	1645.6±8c	1354.0±3i	4018.6±4c	835.3±4q	80.1±3k	116.2±8d
KIN-99	7668.3±4q	6480.0±2q	1238.3±5z	1915.0±4s	936.3±4f	1045.5±5x	1756.8±3h	4598±3q	69.6±5m	723.1±4k
RK-77	6860.0±8i	5202.6±3e	1440.0±6l	740.6±3g	1131.0±3s	83.6±6de	2546.0±8t	5765.6±2f	92.9±6i	201.4±3v
RK-79	6888.0±7g	6179.3±2v	1448.0±3k	1619.3±2f	1919.5±2a	256.8±3u	5541.0±4l	3141.3±2l	630.1±3n	533.7±2q
RK-84	5880.0±5e	5089.0±2l	1780.0±2yz	862.0±2w	1222.5±2n	327.5±2l	4412.0±3z	8684.0±3n	447.1±2a	1500.0±2c
RK-85	7110.3±6d	6130.3±3w	1130.3±1f	1240.3±5z	1728.3±5b	782.3±1j	3015.3±2o	7314.3±2t	106.8±1g	256.6±5p
RK-92	5999.0±7a	5256.3±2l	856.0±5x	763.0±2e	966.5±2c	774.0±5k	1657.0±1i	746.0±5r	1911.1±5a	1734.0±2b
RK-103	9489.8±2a	4119.0±2p	1329.8±3t	969.1±6n	1334.3±6k	228.5±3w	1874.3±5r	5675.0±2g	83.2±3j	64.2±6n
RK-123	6289.3±4u	6979.0±3e	1909.3±4t	1039±7j	693.8±7n	272.5±4t	5007.3±2o	2483.0±3u	110.9±4ef	457.7±7x
RK-126	5837.0±5h	8319.3±2i	2586.4±2e	1929.3±7r	771.6±7kl	319.3±2m	7013.0±4z	1231.3±2m	722.7±2k	189.0±7x
RK-134	7558.0±2s	7401.3±5u	1328.0±3t	1781.3±8y	614.1±8r	457.3±3x	8952.0±5m	3012.3±5op	803.7±3hg	221.9±8u
RK-142	4558.0±3m	5561.0±2o	1118.0±2h	879.0±3v	1213.5±3p	83.0±2de	3010.0±3p	3550.0±2i	268.1±2m	635.8±3m
RK-153	8869.0±2f	8310.3±3j	2129.0±5m	849.3±2y	310.2±2o	547.0±5t	4002.4±2s	6102.3±6b	464.9±5w	57.4±2o
RK-198	5109.6±3j	5399.6±8w	928.6±2q	892.3±5u	553.1±5s	84.8±2d	4568.6±4s	656.3±7t	367.7±2d	110.2±5ef
RK-205	7129.6±2b	5870.3±4f	899.6±6s	771.1±2c	805.0±2i	393.3±6g	3674±3g	5913.3±7e	564.3±6p	265.0±2no
RK-344	5211.1±5d	4527.6±2o	1380.0±7p	910.6±3r	411.5±3f	158.1±7b	3542.7±5y	454.6±8w	268.0±7mn	203.8±3v

*: Numbers with the same letters in the same column are not statistically different ($p < 0.05$), NS: Non-stress conditions (control), DS: Drought stress conditions

Table 3. Amino acid content of PGPR (pmol/µL) (mean ± standard error. n = 4 each treatment)

Isolates	Theonine		Alanine		Tyrocine		Cystine		Valin	
	NS	DS	NS	DS	NS	DS	NS	DS	NS	DS
TV-3D	428.7±6g	7.2±4yx	3332.2±5npo	2094.8±2f	941.1±8o	9670.2±4h	619.5±1r	3903.4±4z	4953.3±2n	1178.9±8k
TV- 6D	95.6±7z	146.8±3qr	1710.4±2m	1469.4±6o	2574.1±5k	271.1±3p	4158.8±t	2995.4±3x	841.1±3p	59.4±5m
TV-6F	1433.0±7c	107.5±2y	7990.5±6c	1857.6±7j	2449.2±4m	1843.0±2q	951.7±2j	6841.5±2f	3714.9 ±2w	795.2±4t
TV-11D	135.3±8tu	15.8±1v	907.3±7c	1397.1±7q	973.4±3m	353.9±1g	3449.80±4n	816.5±2p	108.3±5i	119.3±3g
TV-12E	461.2±5e	131.0±5v	4931.1±7w	670.6±8i	3395.3±8h	15156.1±5d	5795.1±5m	2307.3±3n	1883.7±2v	840.3±8p
TV-12H	61.2±4e	82.1±2b	1048.6±8mno	1778.2±3k	136.9±4f	9011.8±2j	3800.8±3j	3661.3±2h	1179.57±6a	2991.1±4c
TV-13B	1399.0±3d	42.9±4mn	6069.2±5h	586.1±2k	5298.7±3r	2211.2±4o	2744.8±2c	3713.6±5f	4043.4±7t	88.9±3j
TV-13C	1301.4±8f	41.5±5m-p	3886.1±4i	1127.1±5t	5918.5±4o	306.2±5m	2562.1±4q	2725.2±2e	3991.3±7u	149.4±2c
TV-17C	181.6±4o	62.3±3fg	899.3±3d	203.5±2n	14389.0±3e	258333.0±3	3351.1±3p	3457.8±6l	2649.6±8i	2299.8±2l
TV-20E	79.06±3cd	1024.0±2m	633.4±2j	5005.0±3t	3581.6±2e	391.8±2d	2251.7±2o	2138.1±7r	1894.6±5t	4567.4±3q
TV-22B	575.3±2z	41.2±4m-p	4123.0±4d	5964.4±2i	2967.3±4i	2142.2±4p	3351.1±2p	3087.5±7tu	4964.5±4m	127.3±2f
TV-42A	149.2±2q	41.3±3nop	4390.3±b	2501.3±4d	1226.9±3f	1099.3±3j	2883.4±3z	2566.5±8i	799.2±3s	797.2±5ts
TV-53D	433.8±5f	40.9±5nop	4953.8±2v	5835.9±3l	855.3±2r	65.5±5n	5799.4±3l	2814.7±5b	14876.0±8g	1842.3±2x
TV-54A	44.4±2ml	47.2±6jkl	2076.7±1g	3010.4±5w	5133.9±1u	1759.7±6t	4040.6±2s	3817.0±4c	1141.6±4l	155.9±6a
TV-60D	317.5±6i	145.4±3rs	5359.2±5o	2590.7±6c	769.6±4s	1138.5±3h	1617.1±6y	5842.1±3j	3025.9±3z	1179.9±7k
TV-67C	63.6±7f	41.7±2 m-p	3334.2±2mno	6667.0±3j	1253.5±5d	281.1±2o	4040.6±7l	2560.8±8j	1514.8±2c	2266.9±7k
TV-83A	647.0±7x	34.6±1s	3328.4±4q	3965.4±2f	3398.7±3g	506693.0±1w	1108.8±7g	3350.4±4p	2459.5±1k	1862.3±8w
TV-87A	677.0±8w	13.9±5wv	6068.8±5h	1126.0±1e	7119.6±2n	1318.8±5z	2727.3±8ed	3346.4±3q	1117.4±5m	150.0±5cb
TV-91B	1133.5±5i	893.3±3r	4801.6±3x	1117.3±5u	5292.5±4s	370.3±3f	2927.7±3y	13055.0±2a	1510.7±2d	186.6±4y
TV-91C	132.5±4uv	223.7±4k	712.1±2h	2343.3±3e	1213.9±3g	1373.0±4x	3253.7 ± 2r	4859.1±4n	1912.4±4s	1179.2±3k
M-3	1002.9±3n	1001.9±8n	5118.0±4s	4046.1±4e	5912.3±2p	435.0±8a	2201.8±5q	8407.3±3d	3987.2±5v	3490.4±8x
A-1	233.7±8j	984.9±7p	1209.2±3s	834.4±8y	2527.3±2l	256.4±7s	6744.5±2o	1658.1±2x	4570.9±3p	4134.8±4s
A-16	686.1±4v	998.8±5o	3332.1±2po	927.2±7b	886.7±5p	380.9±5e	3350.7±3p	830.5±2o	1179.5±2k	2189.4±3o
A-18	135.6±3t	4.41±6yz	1126.2±2t	3965.6±5f	8114.5±2k	1295.5±6b	2822.7±2a	2566.5±3i	1995.2±4q	1956.4±2r
BA-140	42.6±2mno	1544.9±7a	3950.4±5g	5888.9±6d	1050.9±6k	642.4±7u	1479.5±1d	1523.1±2a	1109.9±3n	2266.9±2m
BA-8	87.1±2a	88.4±2a	2928.7±2y	1400.1±7q	431.7±8a	2661.1±2j	2044.5±5t	2138.5±5r	2608.2±5j	1997.5±5q
İK-37	79.1±3cd	49.4±4ji	1761.7±6l	5278.6±7q	7417.9±5l	353.1±4g	4539.8±3q	3393.1±2o	2893.7±6f	1179.9±2k
İK-38	5.8±2a	25.7±5t	3332.2±7nop	5135.6±5r	1811.6±4s	367.3±5f	2883.4±4y	3090.2±6t	1892.3±3tu	75.8±6l
İK-39	890.0±5s	39.6±3pq	2927.0±7y	1781.0±6k	5062.2±3v	1234.4±3e	3453.5±8m	4082.0±7u	1834.4±2y	1844.3±7x
FDG-37	217.1±2l	979.8±2q	2500.2±8d	6751.3±7e	12112.5±8f	1128.1±2i	6744.5±7g	924.0±7k	1890.6±1u	1883.0±7v
FD-1	57.5±3h	40.1±4n-q	3900.0±5h	2879.0±2a	733.8±4t	5187.1±4t	3729.2±5e	3502.1±8j	797.6±5ts	218.7±8x
FD-48	142.9±8s	49.5±3ji	8461.0±4b	3622.9±4k	4733.8±3w	225.3±3v	3553.5±6i	836.1±5n	19582.5±3d	145.9±5d
FD-49	40.3±4n-q	20.0±5u	4412.7±2a	1780.1±2k	4287.4±4z	1216.4±5g	6224.1±7i	4296.6±4r	1084.6±4o	2152.4±4p
K-7E	125.2±3w	47.9±6ijk	672.1±3i	1369.4±3r	1334.4±3y	1310.9±6a	3085.5±2u	918.7±3l	1860.6±8w	1424.8±3i

K-9C	429.9±2g	4.0±3z	3818.9±8j	1637.7±2t	348.4±2h	266.5±3q	3920.1±4x	775.1±8q	15787.5±7f	129.0±8f
K-19B	76.8±2d	50.2±2i	3018.9±4v	2072.0±5h	347.4±4h	346.1±2h	2231.4±5p	2310.0±4n	24914.8±5b	140.0±4e
K-19D	740.3±5u	88.2±2a	3308.7±3s	3308.7±2s	988.7±3l	878.8±2q	1513.0±3b	10490.0±3c	19143.7±6e	727.6±3v
K-22B	461.4±2e	60.3±3gh	6089.3±2g	275.5±3m	3398.7±2g	21877.5±3c	4022.8±2w	1133.0±2f	4570.9±7p	1580.4±2a
KBA-2	59.7±6gh	1222.3±8g	2918.2±2z	1046.5±8w	397.4±1c	324.7±8k	2636.3±1g	851.8±6m	32709.1±2a	2607.2±2j
KBA-8	1321.0±7e	76.9±4d	4779.3±5y	1467.0±4o	1137.5±4h	252.6±4t	8294.8±5e	1692.9±3w	13002.3±4h	806.3±3r
KBA10	562.4±7b	76.6±3d	3090.4±8u	1210.4±3s	9490.9±5i	278.9±3o	6737.4±3h	2724.6±2e	1187.1±5j	60.0±2m
KP-63	362.9±8h	43.0±2mn	5118.0±5s	1041.7±2x	4286.1±3z	467.0±2y	2491.0±4m	2047.3±1t	8414.5±3k	1956.1±5r
KP-81	133.8±3tuv	46.1±2lk	329.1±4l	3336.3±2m	1670.5±2u	770.3±2s	3835.7±8b	2567.2±5i	1510.5±2d	1450.0±2h
KIN-21	1070.2±2j	37.8±5qr	5338.4±3p	3335.3±5mn	2447.1±4m	5597.7±5q	588.1±7s	3027.4±3w	8384.1±4l	797.6±3ts
KIN-37	465.8±5d	1480.3±2b	3311.9±2r	9252.5±2a	3666.6±3d	3679.9±2c	10697.8±5b	980.6±4i	1504.8±3e	2223.5±8n
KIN-99	85.7±2a	124.0±6w	4957.9±4u	1369.4±7r	402.6±2b	63946.1±6a	1807.8±6v	2570.9±8h	21167.5±5c	2753.1±4h
RK-77	740.6±3u	72.0±7e	3329.5±3pq	962.5±5z	2268.6±2n	245.5±7u	619.7±7r	2642.0±7f	2991.1±6c	108.3±3i
RK-79	568.0±a	169.3±7p	5875.9±2k	767.2±6f	4726.3±5x	138.9±7w	3866.1±2a	1508.0±5c	11548.6±3j	3045.6±2y
RK-84	494.0±2c	20.0±8u	4779.3±1y	1208.0±7s	1672.0±2u	320.0±8l	6222.8±4i	3909.4±6y	4250.4±2r	152.5±2b
RK-85	1031.8±3l	78.2±3d	4775.1±5z	2052.4±2i	1829.3±6r	334.2±3j	5804.8±5k	3031.8±3v	1890.9±1u	614.4±5w
RK-92	112.4±2x	1143.7±2h	6578.4±2f	1420.8±4p	4261.5±2a	1814.3±2s	2493.2±3m	4766.8±2o	11922.2±5i	3012.8±2b
RK-103	81.3±5cb	35.5±5sr	1778.1±4k	956.7±2a	340.0±4i	523.3±5v	4694.1±6p	1615.8±1y	4250.2±3r	114.2±6h
RK-123	980.1±2q	35.8±2s r	5830.5±5m	898.3±3d	7127.1±5m	354.6±2g	2730.0±3d	2034.1±5u	2842.1±4g	183.2±7z
RK-126	33.8±6s	1280.0±2w	2944.4±3x	3332.0±2nop	490.5±3x	1275.3±2c	2556.4±2k	3676.5±3g	1179.5±2k	810.0±7q
RK-134	569.7±7a	42.1±2m-p	4127.6±2c	3414.0±5l	4158.5±2b	4310.9±3y	2141.2±1r	3394.4±4o	2982.4±3e	1188.1±8j
RK-142	568.6±7a	197.2±3m	3307.0±4s	1074.8±2v	3412.7±4f	301.6±2n	2568.9±5ih	3493.1±8k	4627.9±2o	1563.8±3b
RK-153	143.2±8s	8.87±2x	1763.2±3l	1637.7±3n	5596.0±3q	382.6±5e	1000.1±3h	3553.5±7i	1492.8±5g	73.8±2l
RK-198	821.5±5t	596.0±5y	1398.3±2q	718.0±8g	392.9±2d	299.2±2n	3181.5±4s	3087.2±8tu	1565.9±2b	1883.0±5v
RK-205	1037.5±4k	39.7±2opq	5522.8±2n	1779.3±4k	10393.0±2g	262.5±3r	2203.9±2e	1541.9±7z	2987.3±6d	1501.0±2f
RK-344	77.92±3d	189.0±3n	3302.8±3t	2638.8±3b	1234.5±5e	441.9±8z	4040.6±3v	2126.7±5s	784.4±7u	1767.5±3z

*: Numbers with the same letters in the same column are not statistically different ($p < 0.05$), NS: Non-stress conditions (control), DS: Drought stress conditions

Table 4. Amino acid content of PGPR (pmol/µL) (mean ± standard error. n = 4 each treatment)

Isolates	Phenylalanine		Aspartate		Glutamate		Prolin		Tryptophan	
	NS	DS	NS	DS	NS	DS	NS	DS	NS	DS
TV-3D	6198.0±7m	867.0±5j	714.0±1i	686.0±2	11399.0±2m	17199.0±2j	366.0±3az	577.0±4c	4056 .0±0.4v	4893.6±1.0l
TV- 6D	3604.0±7k	226.0±4f	532.0±5f	505.0±4i	17129.0±5kl	15280.0±1k	487.0±5l	376.0±2y	1562.0±0.3m	12348.8±0.0p
TV-6F	8431.0±8f	659.0±2p	755.0±2fe	693.0±3m	15200.0±2l	17348.0±5i	486.0±2l	287.0±6ji	4450.5±0.0p	4202.4±0.8s
TV-11D	811.0±5l	1835.0±8t	980.0±4h	652.0±2sr	18870.0±6r	14000.0±2b	443.0±6r	403.0±7v	8645.2±0.0i	5534.5±0.6f
TV-12E	6828.0±4i	3203.0±3n	551.0±4c	736.0±2g	15300.0±7j	13802.0±4e	310.0±7d	369.0±7z	2282.0±0.5g	14656.6±1.0l
TV-12H	4884.0±3z	6659.0±2k	448.0±3n	650.0±5s	17800.0±7a	14500.0±4s	457.0±8q	204.0±8q	5526.0±6.0g	4894.6±0.0l
TV-13B	8485.0±2d	47.0±5t	899.0±2r	413.0±3o	14700.0±8o	14320.0±3w	257.0±5lk	546.0±3h	9462.0±0.5y	1503.7±0.6o
TV-13C	8755.0±4b	164.0±2k	1238.0±4c	733.0±4g	14399.0±5u	16399.0±2t	219.0±4m	140.0±2t	8601.0±0.3j	8974.8±0.6e
TV-17C	232.0±3e	4084.0±3h	724.0±3h	1248.0±3b	15640.0±4a	15328.0±4i	257.0±3lk	465.0±5p	14178.9±0.0m	8591.1±0.6k
TV-20E	485.0±2y	547.0±2V	705.0±2k	649.0±2s	19022.0±3p	14499.0±3s	456.0±2q	862.0±2s	19698.0±1.1c	2943.5±0.3d
TV-22B	3277.0±1m	904.0±4h	913.0±1q	912.0±1q	14000.0±8b	13999.0±2b	407.0±4u	575.0±3dc	4061.0±0.5u	18037.3±3.0d
TV-42A	549.0±5v	1150.0±3c	758.0±5e	865.0±5v	16002.0±4w	17760.0±1b	474.0±3on	390.0±2w	8317.0±1.4l	6860.3±0.8t
TV-53D	5326.0±2x	1134.0±5d	693.0±2m	952.0±2l	14549.0±3q	14000.0±5b	474.0±2n	1676.0±4e	2817.0±0.3f	4651.9±0.0o
TV-54A	965.0±4g	199.0±6h	558.0±7a	881.0±4t	16760.0±2o	19130.0±4m	559.0±1f	585.0±3b	4735.7±0.0n	16470.6.0±1.0j
TV-60D	3281.0±4l	255.0±3d	546.0±8d	802.0±2z	14000.0±1b	15604.0±5b	258.0±5k	545.0±5h	6994.5±0.3r	4329.7±0.0q
TV-67C	597.0±3u	79.0±2q	370.0±5s	812.0±5y	19080.0±5o	14129.0±3x	257.0±2lk	1732.0±6d	4186.0±1.4t	4807±0.6m
TV-83A	42012.0±2l	676.0±4o	734.0±4g	640.0±2tu	17659.0±2e	17599.0±2g	185.0±4s	515.0±3k	4918.0±0.3k	9570.0±0.6w
TV-87A	6197.0±4m	46.0±8t	545.0±2d	790.0±6a	16539.0±4r	15650.0±4z	218.0±4mn	851.0±2t	3673.0±0.3z	17559.4±0.5f
TV-91B	8476.0±3e	263.0±7c	634.0±3v	654.0±7qr	17879.0±1z	16299.0±3u	402.0±3v	424.0±1t	9451.5±0.8z	12140.0±0.5q
TV-91C	1744.0±2v	531.0±5w	513.0±8h	701.0±7l	19879.0±5e	18129.0±2v	382.0±2x	325.0±5c	9214.1±0.3b	1889.1±1.2h
M-3	4865.0±1a	80.0±6pq	612.0±4w	964.0±8j	19130.0±2m	15399.0±2h	634.0±4yx	555.0±3g	8592.7±0.5k	319.0±0.5z
A-1	5330.0±5w	27.0±7v	692.0±3m	1229.0±5d	14329.0±4v	15499.0±5f	312.0±3d	1046.0±5n	5571.4±0.3a	653.0±0.5w
A-16	7697.0±2h	317.0±7b	498.0±7j	710.0±4j	14499.0±4s	14678.0±2p	118.0±2v	602.0±8a	10176.0±0.3t	3673.3±0.6z
A-18	849.0±4k	617.0±5s	491.0±8k	513.0±2h	23197.0±3a	15000.0±6n	324.0±2c	545.0±7h	8771.5±1.0h	4326.4±2.0r
BA-140	975.0±6f	131.0±6m	723.0±5h	460.0±5l	17129.0±2kl	13990.0±1c	389.0±5w	1181.0±5l	5529.0±0.5g	557.0±0.3x
BA-8	865.0±7j	5891.0±7q	900.0±4r	1543.0±2a	21130.0±4c	16780.0±5n	218.0±2mn	565.0±6e	5354.2±0.0h	1615.2±0.0l
IK-37	511.0±6x	184.0±2i	642.0±3t	912.0±3q	18889.0±3q	15600.0±2c	481.0±6m	487.0±7l	1616.0±0.8y	8593.0±2.8k
IK-38	633.0±8r	682.0±4m	639.0±2u	996.0±2g	12398.0±2kl	17623.0±4f	329.0±7b	1591.0±7g	2965.0±1.2b	16394.0±1.0k
IK-39	4300.0±5	550.0±2v	938.0±4on	657.0±4pq	17039.0±1m	16402.0±6t	573.0±7d	1098.0±5m	9224.0±1.0a	5549.0±1.1c
FDG-37	6153.0±4o	214.0±3g	686.0±3n	754.0±3f	19900.0±5d	14069.0±7z	212.0±8p	1868.0±6c	1490.0±1.1p	1510.0±0.6n
FD-1	847.0±2k	482.0±2z	813.0±2y	877.0±5u	19900.0±2d	16300.0±7u	285.0±5j	387.0±7w	6644.7±0.6u	2961.6±2.0c
FD-48	7899.0±3g	5667.0±5t	924.0±8p	694.0±6M	14540.0±4r	11320.0±7n	289.0±4i	307.0±2e	2892.4±0.8e	1249.2±0.0r
FD-49	677.0±8no	1166.0±2b	953.0±5lk	936.0±3o	17901.0±6y	17999.0±7x	110.0±2w	1007.0±4p	14657.0±0.6l	3740.1±0.3y
K-7E	1829.0±4u	1246.0±3y	405.0±4p	725.0±2h	15537.0±7d	16500.0±8s	365.0±3a	297.0±2g	8819.4±1.0g	1208.7±0.0s

K-9C	3680.0±3i	106.0±8n	967.0±3i	599.0±1x	15505.0±7e	13699.0±5f	212.0±8p	1635.0±3f	5540.0±0.8e	1117.0±0.3u
K-19B	2551.0±2q	82.0±4p	691.0±8m	541.0±8e	12998.0±7i	15461.0±4g	135.0±4u	1267.0±2j	5545.0±0.7d	1173.4±0.5t
K-19D	6231.0±5l	414.0±3a	800.0±4z	453.0±4m	18765.0±7t	15693.0±3y	367.0±2az	487.0±5l	9450.3±0.8z	7334.3±0.8q
K-22B	5631.0±4u	1056.0±2e	1044.0±3f	375.0±3r	17599.0±8g	13800.0±2e	213.0±2po	205.0±2q	2971.0±0.3a	8935.6±0.3f
KBA-2	5830.0±3r	180.0±4j	544.0±4d	775.0±7c	13599.0±5g	13699.0±4f	488.0±2l	2221.0±3b	9460.7±0.3y	984.7±0.5v
KBA-8	5829.0±2r	905.0±5h	554.0±3b	562.0±8z	19849.0±4f	19139.0±3l	524.0±5j	204.0±8q	1474.3±0.6q	1753.3±1.0k
KBA-10	4816.0±4c	97.0±3o	802.0±2z	979.0±5h	16130.0±3v	17568.0±2h	387.0±8w	458.0±4q	1489.5.0±0.8p	17584.0±1.8e
KP-63	4503.0±3e	680.0±4mn	888.0±4s	566.0±4y	19572.0±2i	14100.0±1y	189.0±5r	367.0±3az	5565.0±1.15b	20356.9±0.0b
KP-81	601.0±2t	64.0±3r	966.0±3ji	1214.0±3e	19808.0±4g	18301.0±5u	613.0±4z	1008.0±2p	5533.5±1.0f	7945.6±0.5p
KIN-21	5161.0±1y	1322.0±2x	955.0±2k	766.0±2d	16000.0±3w	19111.0±2n	486.0±3l	685.0±2w	9165.0±0.6c	5534.0±1.2f
KIN-37	2636.0±5p	35.0±1u	811.0±1y	298.0±4u	17685.0±2c	12498.0±5j	305.0±2e	1566.0±5h	6957.0±0.3s	147.0±0.8b
KIN-99	6183.0±2n	8747.0±5c	504.0±4i	982.0±3h	15398.0±1h	15300.0±2j	632.0±4y	292.0±2h	7334.0±0.8q	9068.2±0.0d
RK-77	4203.0±4g	186.0±2i	659.0±5p	713.0±2ji	19880.0±5e	18090.0±3w	117.0±3v	809.0±7v	9529.4±0.5x	10164±0.6u
RK-79	4533.0±5d	1493.0±4w	523.0±3g	912.0±8q	17128.0±2l	13599.0±8g	203.0±2q	481.0±5m	5601.0±1.1z	8228.0±0.3m
RK-84	7699.0±3h	1205.0±6a	402.0±2q	704.0±5lk	19800.0±4h	17669.0±4d	302.0±1f	1533.0±6i	6596.0±0.5w	9744.3±2.0v
RK-85	5823.0±4s	601.0±7t	540.0±4e	779.0±4b	17130.0±5kl	14130.0±3x	433.0±5s	822.0±7u	1473.0±0.3q	5175.5±0.8j
RK-92	5600.0±3v	19.0±7.0±w	832.0±3x	713.0±3ji	15699.0±3x	12001.0±2l	544.0±2h	5599.0±2a	6602.0±0.5v	191.0±0.5a
RK-103	1899.0±2s	50.0±8s	939.0±2n	734.0±8g	14499.0±5s	16549.0±2q	255.0±7l	532.0±4i	1857.8.0±0.5j	20710.9±3.0a
RK-123	8888.0±1a	652.0±5q	833.0±2x	499.0±4j	18799.0±4s	15049.0±5m	285.0±5j	883.0±2r	4892.7±0.6l	16506.3±1.0i
RK-126	654.0±5q	679.0±4mn	754.0±5f	701.0±3l	16559.0±2p	13499.0±2h	471.0±3o	485.0±3l	3917.0±0.3x	16988.8±0.6g
RK-134	6046.0±2p	876.0±2i	363.0±2t	846.0±3w	14498.0±3s	17131.0±7k	216.0±2no	388.0±2w	3922.0±1.1w	12484.0±0.6o
RK-142	4830.0±4b	2832.0±8o	712.0±6ji	766.0±2d	19128.0±8m	14031.0±5a	382.0±4x	636.0±5x	7974..0±1.8o	16588.2±0.5g
RK-153	600.0±6t	138.0±3l	674.0±2o	512.0±8h	19129.0±4m	14400.0±6u	366.0±3az	910.0±2q	5817.0±0.5y	11469.5±0.3r
RK-198	3625.0±7j	184.0±2i	632.0±4v	948.0±5m	13599.0±3g	14459.0±7t	384.0±2x	1014.0±3o	7984.0±0.3n	13658.0±0.3n
RK-205	6751.0±7j	1238.0±5z	768.0±5d	411.0±4o	19299.0±2k	19810.0±2g	304.0±2fe	480.0±8m	6115.5±0.8x	471.0±0.3y
RK-344	658.0±8p	48.0±3ts	405.0±3p	694.0±3m	23140.0±3b	13897.0±5d	289.0±3i	1227.0±4k	5256.9±0.0i	1883.0±1.2i

*: Numbers with the same letters in the same column are not statistically different ($p < 0.05$), NS: Non-stress conditions (control), DS: Drought stress conditions

Table 5. Amino acid content of PGPR (pmol/µL) (mean ± standard error. n = 4 each treatment)

Isolates	Isoluecine		Leucine		Hydroxyproline		Sarcosine		Methionine	
	NS	DS	NS	DS	NS	DS	NS	DS	NS	DS
TV-3D	4561.0±1u	10590.7±1r	452.0±8o	656.0±1w	4398.0±8y	2673.4±1b	6441.0±8n	6985.8±5e	10483.2±5g	1283.4±2i
TV- 6D	6377.9±5z	10745.5±3q	169.0±3s	201.0±4m	2442.0±3h	2589.2±6d	15488.0±3j	8874.8±4p	2522.5±2wx	1049.7±6m
TV-6F	6324.5±2b	9886.6±8u	564.0±6d	353.0±8w	4727.1±7x	1907.5±8s	6444.0±5m	6456.3±8l	8559.1±6q	1246.9±7j
TV-11D	4591.3±4t	2689.8±6o	173.0±0qr	171.0±6rs	1549.9±9a	3542.1±6j	14082.0±6p	14395.4±6n	1427.8±7e	1831.1±7o
TV-12E	4645.4±4r	6258.9±1e	345.0±7x	717.0±1t	5587.6±5u	1582.8±4y	12015.0±7y	15939.1±6h	5941.3±7f	2466.5±8z
TV-12H	7475.7±3s	8124.2±2m	188.0±1n	413.0±2t	3294.8±6po	1595.4±6x	13284.0±9q	6444.8±6m	2881.5±8c	7566.4±3v
TV-13B	6035.6±2f	8914.7±6a	205.0±7l	462.0±6n	7447.0±0.5j	3277.7±6r	9383.6±5o	12362.9±6u	8713.9±5p	1428.5±2e
TV-13C	6008.5±4g	10892.8±6o	212.0±3kj	365.0±6v	3295.6±3o	3443.2±6m	7978.8±3z	1101.7±6z	9484.6±4i	1718.9±5q
TV-17C	8690.5±3e	8113.0±6n	513.0±3i	883.0±6z	1899.2±0t	4263.5±6a	16512.0±8f	20583.8±7d	5251.8±3i	2391.5±2c
TV-20E	8094.2±2o	10225.0±3t	155.0±4v	845.0±3n	3419.1±4n	252.0±3t	11667.0±5d	9817.9±3l	2011.7±2i	1464.7±3b
TV-22B	3458.0±1h	12356.9±3e	564.0±7d	622.0±3z	3290.8±5q	2449.2±3g	9667.0±5m	3338.6±3s	8911.2±4o	1657.2±2t
TV-42A	7857.7±5p	4591.0±8t	789.0±2p	165.0±8t	553.0±2m	2371.5±8j	6757.1±2f	7984.7±8y	2010.4±3ji	2008.4±4j
TV-53D	8845.3±2b	9063.6±2z	911.0±3k	988.0±4i	6017.5±3r	1945.6±4q	10495.0±3k	5486.9±5z	8535.9±2r	3057.8±3q
TV-54A	8114.0±7n	12619.0±1d	540.0±2g	523.0±1h	1909.3±6s	179.0±1v	7984.0±0y	4667.0±1j	2189.0±1h	1511.6±5y
TV-60D	2551.7±8r	10896.0±0n	713.0±3u	435.0±8r	3512.1±3l	4219.3±0b	4958.0±3h	5223.1±8f	6572.4±5a	1681.1±6r
TV-67C	6390.6±5y	9367.0±6w	612.0±7a	1121.0±7d	1554.9±4z	2010.2±6o	6463.6±7j	5670.3±6x	1609.1±2v	2190.0±3h
TV-83A	3438.1±4i	2787.3±6n	412.0±3t	411.0±6t	3037.6±3u	362.0±6p	8708.5±3t	5575.9±6y	8167.6±4t	2008.8±2p
TV-87A	4933.4±2o	10807.9±7p	339.0±3y	884.0±7l	5687.4±3t	2064.2±7m	14344.0±3o	7579.0±5a	11967.1±5d	1734.3±1p
TV-91B	5231.3±3m	11260.6±7l	512.0±8i	207.0±7l	6554.4±8o	4359.9±7z	11739.0±8c	4859.1±7i	6540.8±3b	1736.5±5p
TV-91C	8225.0±8l	6379.4±4z	224.0±3i	543.0±8f	2856.4±3y	3551.1±9i	14524.0±3m	3968.3±6o	3784.9±2o	1432.4±3d
M-3	5286.5±4l	3179.8±7l	412.0±7t	411.0±7t	3292.3±5q	1692.0±7w	9381.0±7o	11955.8±7z	5783.2±4g	888.6±4p
A-1	1181.6±3z	8550.1±7g	150.0±3w	755.0±7r	3083.2±3t	399.±7s	6463.0±3kj	6393.4±5p	9039.6±3l	2747.1±8u
A-16	3642.5±7g	8758.8±6d	339.0±3y	484.0±6l	4214.5±3c	242.±6tu	8718.0±3s	12472.2±6t	9204.2±2k	852.7±7q
A-18	4719.2±8q	5698.9±2i	523.0±1h	713.0±2u	2091.7±1l	1124.1±2h	7979.0±7z	3056.6±2u	4152.5±2k	1940.1±5m
BA-140	11811.0±5h	14066.0±3c	611.0±7a	470.0±3m	1491.8±7d	4854.5±3w	6249.0±5s	8077.5±3w	890.6±5p	1623.8±6u
BA-8	5166.2±4n	9161.88±3y	334.0±3z	353.0±9a	2299.3±5k	2524.6±4e	8517.0±6u	16008.6±5g	1189.9±2k	20330.9±7b
İK-37	6353.0±3a	9181.1±8x	399.0±8u	813.0±8o	1543.3±8b	569.0±8l	6751.0±8g	11763.3±8b	3963.8±6n	1462.9±7f
İK-38	7312.6±2u	9491.5±1v	538.0±1g	1222.0±1a	1332.3±2f	183.0±1v	5065.0±6g	6309.3±6q	2880.1±7s	2188.1±5h
İK-39	4173.0±4y	8626.7±4f	232.0±1g	448.0±5p	7636.9±1i	3172.6±5s	8773.0±2q	6460.0±4k	5956.6±7d	1383.5±6h
FDG-37	2660.3±3p	2540.5±6s	213.0±4kj	960.0±6j	5687.9±5t	1216.9±6g	4104.0±4m	8020.8±6x	7942.9±8u	2328.6±7e

FD-1	5544.9±2k	4134.1±2z	513.0±6i	257.0±2c	2026.0±6n	7039.9±2m	5332.0±6d	5364.2±2c	1052.0±5m	706.4±2r
FD-48	6353.4±8a	2307.7±2u	662.0±8v	136.0±7x	7824.2±8f	2371.1±3j	3408.2±8q	11347.3±7e	3995.4±4l	2326.0±4e
FD-49	8770.7±5c	2550.4±3r	565.0±6d	876.0±3m	1115.4±6i	1580.4±3y	5310.1±6e	6099.3±3t	2304.5±2f	1283.4±2z
K-7E	8112.0±4n	1970.2±5v	211.0±1k	178.0±4op	2933.5±1x	2981.6±9w	14697.0±1l	10978.9±4i	3971.6±3m	2250.5±3g
K-9C	8239.2±3k	5889.0±3h	766.0±8q	104.0±3g	5697.2±8s	164.0±3v	11761.0±8b	3158.4±3t	5781.9±8g	2004.5±2k
K-19B	8246.8±8j	6647.6±7w	1083.0±7f	176.0±7pq	7224.7±7k	3785.3±5f	8738.0±7r	5462.6±5a	2826.9±4t	2406.8±5b
K-19D	6621.0±4x	5544.1±8k	576.0±8c	240.0±8f	6528.9±8p	3026.1±8v	6463.0±8kj	7303.0±8c	8219.7±3s	672.8±2s
K-22B	3905.3±3d	1909.2±3w	544.0±3f	180.0±3o	4054.4±3e	1124.1±3h	15292.0±3k	15895.0±3i	2338.7±2d	2523.5±3w
KBA-2	7404.9±4t	3377.7±7j	1181.0±3b	1136.0±7c	7780.1±3h	1332.3±5f	2360.0±3w	8383.6±4v	2891.2±2r	2447.2±8a
KBA-8	8373.6±3h	4878.6±1p	288.0±6b	189.0±1n	3294.5±6po	1908.3±1s	2681.1±6v	6724.7±7h	7402.7±5w	2518.9±4y
KBA-10	2657.7±2p	1251.3±1y	354.0±8w	310.0±8a	3295.5±8o	3755.8±8g	12033.9±8w	6713.7±8i	9402.1±8j	968.5±3o
KP-63	3204.2±4k	11563.6±3j	2450.0±4e	158.0±5u	4085.7±4d	3531.7±5k	6456.2±4l	8872.2±5p	6572.1±5a	1830.4±2o
KP-81	11780.8±3i	12209.7±7f	341.0±1y	506.0±7j	1441.0±1e	427.0±5n	2229.1±1y	6461.7±5kj	5939.8±4f	890.9±2b
KIN-21	6318.2±2c	3999.9±1b	630.0±6y	346.0±2x	7926.1±6d	2377.1±2i	6438.3±6n	3511.9±3p	5242.7±3j	1605.0±5ji
KIN-37	7479.5±1r	15478.4±8b	653.0±3w	335.0±8z	3295.8±3o	352.0±8q	7979.8±3z	11931.2±8a	5775.9±2h	1560.8±2n
KIN-99	16450.0±4a	4879.9±0p	1089.0±8e	543.0±6f	7808.5±8g	1909.0±5s	10505.5±8j	4526.2±9k	3599.0±4p	11061.1±7f
RK-77	3724.7±5e	1034.1±6a	452.0±7o	249.0±6d	2524.7±7e	3601.6±6h	6435.0±7o	5679.6±6w	7224.1±3z	1143.3±5l
RK-79	7475.0±3s	6651.1±3v	711.0±4u	112.0±3b	6619.4±4n	603.0±3k	3402.1±5r	13283.7±3q	6007.8±2c	7256.0±6y
RK-84	5545.2±2k	2635.4±2q	545.0±7fe	1028.0±2h	7124.5±7l	159.0±2v	2681.8±7v	6303.3±2r	7392.0±1x	1945.2±7l
RK-85	8365.6±4i	8375.0±8h	413.0±3t	513.0±8i	2607.8±3c	2833.5±8z	11159.4±3h	12020.7±88x	5946.5±5e	2008.4±2j
RK-92	4630.8±3s	7589.0±7q	441.0±7q	634.0±7x	7914.0±7e	416.0±7o	4318.5±7l	9641.7±5n	26087.1±2a	564.7±4t
RK-103	3950.3±2c	2880.5±3m	413.0±5t	598.0±3b	1498.3±5c	509.0±3r	17267.2±5e	5762.7±3v	2007.9±4j	1021.0 ±2n
RK-123	4013.1±2a	11493.2±1k	418.0±6s	488.0±1k	8479.1±6a	5180.4±1v	12048.8±6v	4101.2±1n	8964.3±5m	1480.1±3a
RK-126	5548.5±5j	10456.4±6s	543.0±3f	565.0±6d	1719.0±5v	1996.5±6p	5395.3±3b	7332.3±6b	2521.0±3wxy	2007.4±2jk
RK-134	4350.3±2x	11957.4±6g	228.0±5h	514.0±6i	4217.0±5cb	2094.6±6l	12894.6±5s	4100.8±6n	11936.1±2e	1487.8±5w
RK-142	3903.8±6d	6307.3±7d	411.0±8t	215.0±7j	6116.6±8q	662.0±5j	23225.2±8c	2306.5±7x	8945.0±4n	1394.6±2g
RK-153	6353.4±2a	10947.3±3m	765.0±7q	733.0±3s	2512.7±7f	2764.4±3a	5900.7±5u	7221.5±3d	1438.8±3c	1677.2±3s
RK-198	4423.5±4v	3703.0±3f	2380.0±3f	482.0±3l	8227.8±3b	214.0±3u	27612.6±3b	11227.3±3g	2571.8±2v	1489.1±8z
RK-205	4356.4±5w	1693.9±3x	412.0±8t	190.0±3n	6528.8±8p	1863.3±3u	12910.4±8r	37951.2±3a	10157.8±2h	1413.5±4f
RK-344	10745.0±3q	2324.4±4t	548.0±0e	575.0±2c	1932.0±0r	230.0±2tu	12020.4±0x	11257.5±4f	2519.9±3xy	1489.1±3x

*: Numbers with the same letters in the same column are not statistically different ($p < 0.05$), NS: Non-stress conditions (control), DS: Drought stress conditions

Table 6. Hormone content of PGPR (ng/µL) (mean ± standard error. n = 4 each treatment)

Isolates	Giberallinc acid		Indol acetic acid		Salicylic acid		Absisic acid	
	NS	DS	NS	DS	NS	DS	NS	DS
TV-3D	2006.0±6k	3487.0±v	114.5±2e-h	113.30±8g-l	1862.1±5q	2769.6±3z	1.2±0.8yz	6.7±2b-i
TV- 6D	7568.0±7b	6813.0±5m	128.5±3u	141.50±4m	2024.2±3c	2727.4±4c	6.9±2.0b-h	45.2±8k
TV-6F	3597.0±7u	6478.0±3p	111.6±2i-o	137.53±3op	1459.6±8m	1939.3±3h	89.4±7.0d	27.0±7q
TV-11D	5163.0±8f	8113.0±2t	122.4±5x	214.06±2b	1878.0±4o	3395.4±2f	4.7±3.1kq	3.0±2r-v
TV-12E	1443.0±5v	6720.0±4n	103.6±2abz	150.40±2ml	1917.7±3k	2549.7±2k	7.7±4.2b-e	3.0±1.2r-x
TV-12H	991.0±4d	4894.0±3i	108.7±6o-u	152.40±3kl	1598.0±2c	2777.6±3y	5.3±3.7h-n	1.4±0.6xyz
TV-13B	1722.0±3p	4353.0±5n	120.7±7ayz	117.56±2bcd	1405.4±2p	2710.0±2e	1.9±0.6t-z	2.7±1r-y
TV-13C	2079.0±8h	8851.0±6f	107.0±7w-y	137.73±8op	1178.2±3x	2788.1±8x	3.3±1.2r-w	7.1±2b-g
TV-17C	8149.0±4r	7637.0±3a	138.2±8op	127.86±4uv	2258.4±2v	2318.8±4t	4.4±1.8l-r	1.0±0.2y-z
TV-20E	8361.0±3q	6991.0±2k	125.7±5wv	110.16±3o-t	2381.0±5r	991.8±3z	11.2±3.2a	13.8±3xy
TV-22B	1844.0±2n	9575.0±1c	101.4±3b	111.76±2i-n	1688.0±3u	3711.0±2b	2.3±1.0s-z	44.0±8k
TV-42A	7652.0±2z	8632.0±5n	111.6±8i-p	172.33±2g	1873.8±2p	2559.8±2j	4.8±2.1k-q	60.2±7f
TV-53D	3751.0±3t	7003.0±3j	105.7±4w-z	168.00±3h	1655.5±3w	2733.9±3b	7.4±1.8b-f	122.5±6a
TV-54A	3235.0±2x	7967.0±4w	112.7±3g-m	113.0±2g-l	1290.4±2u	2760.6±2a	1.7±0.5xyz	19.3±4tu
TV-60D	2375.0±5d	7482.0±8d	107.06±2w-v	227.0±8b	1340.5±5t	2295.5±2u	4.3±2.0l-r	42.0±8l
TV-67C	5131.0±2g	4814.0±7j	124.5±2w	120.0±5aby	1642.6±3y	2956.4±3q	1.4±0.4xyz	15.1±3wxy
TV-83A	1334.0±3x	7795.0±5y	106.3±3u-y	153.9±4kj	2027.3±8c	2834.4±2u	4.5±0.7k-r	22.9±7r
TV-87A	1257.0±8a	7422.0±6f	110.6±2k-q	112.2±3i-m	1946.2±4g	3373.7±3g	2.3±0.4s-z	22.1±6rs
TV-91B	1607.0±4s	4354.0±7n	104.8±5a-z	113.5±8g-k	2091.0±3a	2456.4±2m	8.1±2.1b	2.2±1s-z
TV-91C	1577.0±3t	6490.0±2o	106.0±7x-z	136.1±4pq	1455.6±2n	2014.2±5d	5.3±2.0i-n	1.6±1 y-z
M-3	1227.0±2b	6268.0±4r	104.4±8ayz	105.3±3x-z	1913.5±2l	2808.3±7w	2.7±1.2r-y	15.1±2wxy
A-1	762.0±2e	8680.0±2l	111.2±5j-p	113.5±2g-k	1518.1±3i	1364.7±8s	1.2±0.3yz	111.0±9b
A-16	4132.0±5p	6009.0±3w	121.1±4yz	108.2±2r-v	1133.1±5y	2650.7±5h	16.0±4.2w	11.5±2a
A-18	8055.0±2v	1975.0±2l	132.6±3ts	131.9±3st	2386.1±2q	2356.2±4s	1.7±0.5xyz	1.8±1 y-z
BA-140	6275.0±6q	8674.0±5m	108.5±8p-v	111.9±2i-n	1507.4±3j	3156.7±3n	1.5±0.2 y-z	14.2±2xy
BA-8	5844.0±7x	6194.0±2u	122.2±4xy	134.6±3qr	2422.0±8o	1701.7±8t	3.4±1.6o-v	1.7±1xyz
İK-37	5597.0±7z	6850.0±3l	118.8±3a-z	139.6±2on	1615.7±4a	2572.7±2i	1.4±0.7xyz	53.4±6g
İK-38	5195.0±8e	7287.0±8g	107.6±2s-v	114.0±5f-i	1976.5±7f	2905.3±5s	5.2±2.0h-n	86.4±7d
İK-39	1310.0±3y	5655.0±4y	105.8±2x-z	147.7±7m	1875.8±7po	1930.5±7j	2.3±1.2s-z	36.0±8n
FDG-37	2952.0±2z	8496.0±3o	102.2±3ab	111.9±8ni-m	1388.2±8r	1505.3±8j	3.5±2.0n-u	15.3±2wx

FD-1	6255.0±5s	9245.0±2d	110.4±2l-q	113.5±5g-j	1833.9±5r	3409.3±5e	1.7±0.8xyz	22.2±6rs
FD-48	2074.0±2i	4402.0±2m	111.9±5i-n	926.1±4a	1703.4±3t	3085.3±4o	21.8±5.7rs	5.9±2e-l
FD-49	4657.0±3k	4959.0±5h	108.5±2p-s	121.3±3y	1893.1±8m	1813.2±2s	1.5±0.3 y-z	21.0±5st
K-7E	3290.0±w	8454.0±2p	113.4±3g-l	186.2±8e	1700.8±4t	2437.2±3n	30.1±6.4p	50.7±8h
K-9C	2824.0±2a	8736.0±6j	120.2±8ayz	112.4±4i-m	1572.7±3e	3290.9±8h	7.3±2.5b-f	17.9±3uv
K-19B	2509.0±3c	6269.0±7r	106.2±4u-z	127.9±3uv	1524.5±2h	2402.9±4p	5.0±1.3i-p	7.8±2bcd
K-19D	2169.0±2f	8760.0±7i	105.1±7a-z	152.8±2kl	1495.9±2k	2940.9±7r	1.0±0.2yz	16.2±3wv
K-22B	2669.0±5b	7451.0±8e	107.3±7t-w	138.0±2op	1236.7±5w	2974.3±7p	1.3±0.6 y-z	6.1±2d-l
KBA-2	3823.0±2s	7639.0±3a	107.7±8r-v	108.3±3q-v	1486.6±7l	2720.4±8d	61.8±8.0f	27.6±5q
KBA-8	2005.0±6k	5295.0±2b	112.1±5i-n	150.6±2l	1402.4±8p	2036.0±2b	4.5±2.0l-q	45.5±7jk
KBA-10	1424.0±7w	7865.0±5x	97.4±3b	133.2±5rs	2249.0±5x	2828.9±5v	3.6±2.0m-s	4.5±2k-r
KP-63	1626.0±7r	8771.0±2h	111.9±8i-n	178.1±2f	1936.2±4i	3227.4±2k	3.7±1.4m-s	1.6±1xyz
KP-81	1122.0±8c	8702.0±4k	116.8±4cde	156.9±3i	1535.2±3g	2870.7±3t	1.2±1.5yz	47.2±9i-j
KIN-21	4041.0±5q	8832.0±3g	105.4±3x-z	207.4±8c	2145.5±3y	2957.1±8q	3.7±1.6m-s	41.8±8l
KIN-37	1626.0±4r	10433.0±8a	115.6±2def	140.4±4n	1571.0±2e	3752.1±4a	6.7±1.3b-i	43.8±7k
KIN-99	4146.0±3o	8867.0±4e	115.4±2d-g	176.1±7g	1604.5±2b	2675.5±7f	97.1±8.0c	2.3±1s-z
RK-77	1426.0±8w	3979.0±3r	107.6±3s-v	112.0±7i-n	1631.6±3z	2499.4±3l	5.1±1.5h-o	34.4±5no
RK-79	1689.0±4q	5497.0±2a	105.1±2a-z	152.9±8k	1398.4±2q	2658.4±2g	7.8±6.2bcd	1.6±1xyz
RK-84	1777.0±3o	7031.0±2i	109.2±5n-r	120.1±5aby	1613.0±5a	2873.6±2t	1.2±0.2yz	17.9±4uv
RK-85	1886.0±2m	7510.0±3c	102.3±7ab	154.1±3kj	1680.7±7v	2246.1±4x	5.7±2.4f-l	1.03±1yz
RK-92	1508.0±1u	8761.0±2i	107.9±8r-v	139.3±8on	1647.2±8x	3267.1±3i	28.5±6.3pq	32.9±7o
RK-103	4131.0±5p	9707.0±5b	119.9±5a-z	112.0±4i-n	1557.0±5f	3237.7±2j	1.3±0.4xyz	34.2±8no
RK-123	1511.0±2u	6849.0±2l	110.7±4k-q	155.2±3j	1271.8±4v	2457.3±2m	4.5±2.0l-q	6.4±2b-j
RK-126	6251.0±4t	8145.0±3s	106.1±3w-z	190.9±2e	1864.5±3q	2674.6±2f	1.6±0.2xyz	11.6±5az
RK-134	2069.0±5j	6072.0±2v	105.7±8w-z	132.3±2ts	1441.0±3o	2111.4±2z	1.5±0.5o-v	3.3±1xyz
RK-142	1296.0±3z	5228.0±5c	106.2±4u-z	192.3±4d	2002.3±8e	3160.0±4m	5.4±1.8g-m	53.0±8g
RK-153	4457.0±2l	7186.0±2h	132.7±8st	113.4±3g-k	1577.5±4d	3508.4±3c	0.9±0.2z	13.5±4xy
RK-198	2112.0±4g	7566.0±6b	118.2±5abc	111.8±2i-n	1885.1±3n	2423.0±2o	47.5±7.0i	13.3±5yz
RK-205	3170.0±3y	5203.0±7d	112.0±4i-n	138.9±2on	1630.4±2z	3198.9±2l	6.3±2.0ck	4.3±2l-r
RK-344	8071.0±5u	2302.0±7e	130.7±3t	125.7±3v	2253.6±2w	3496.1±3d	8.0±2.6bc	38.3±7m

*: Numbers with the same letters in the same column are not statistically different ($p < 0.05$), NS: Non-stress conditions (control), DS: Drought stress conditions