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Sho‘rlangan tuproqlarda *pseudomonas* turkumi bakteriyalarining o‘rni va sho‘r stressga chidamliligi

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Anotatsiya: Ushbu maqolada pseudomonas turkumi bakteriyalarining tuproq sho‘rlanishiga va sho‘r tuproqlarga qanday ta’sir ko‘rsatishi haqida ma’lumot berilgan. Ayniqsa pseudomonas turkumi vakillaridan *P. fluorescens, P. putida, P. stutzeri, P. aeruginosa* va ayniqsa *P. chlororaphis* turlari sho‘r stressga chidamliligi ko‘rsatilgan[1].

Kalit so‘zlar: *P. fluorescens, P. putida, P. stutzeri, P. aeruginosa, P. chlororaphis,* Katalaza, Lipopolisaxarid, sho‘r stress, galotolerant, rizosfera

Abstract: This article provides information on the effects of Pseudomonas bacteria on soil salinity and saline soils. In particular, representatives of the Pseudomonas genus P. fluorescens, P. putida, P. stutzeri, P. aeruginosa, and especially P. chlororaphis have been shown to be resistant to salt stress[1].

Key words: P. fluorescens, P. putida, P. stutzeri, P. aeruginosa, P. chlororaphis, Catalase, Lipopolysaccharide, salt stress, halotolerant, rhizosphere

Аннотация: В данной статье представлена информация о влиянии бактерий рода Pseudomonas на засоление почвы и засоленные почвы. В частности, было показано, что представители рода Pseudomonas P. fluorescens, P. putida, P. stutzeri, P. aeruginosa и особенно P. chlororaphis устойчивы к солевому стрессу[1].

Ключевые слова: P. fluorescens, P. putida, P. stutzeri, P. aeruginosa, P. chlororaphis, каталаза, липополисахарид, солевой стресс, галотолерантность, ризосфера

Sho‘rlanish - tuproq eritmasida eruvchan tuzlar, asosan NaCl, shuningdek Na_2SO_4, $MgCl_2$, $CaCl_2$, konsentratsiyasining me’yordan ortib ketishi - global miqyosda qishloq xo‘jaligi yerlarining barqaror degradatsiyasiga olib keluvchi yetakchi abiotik omillardan biridir [2]. Xalqaro tuproqshunoslik ma’lumotlariga ko‘ra, dunyo bo‘yicha 800 million gektardan ortiq yer umumiy quruqlikning 6% dan ortig‘i, turli darajadagi sho‘rlanish ta’sirida bo‘lib, bu ko‘rsatkich har yili iqlim o‘zgarishi, noto‘g‘ri sug‘orish amaliyotlari va drenaj tizimlarining yetarli emasligi tufayli ortib bormoqda [3,4]. Sho‘rlangan muhitda o‘simliklarning o‘sishi ikkilamchi ta’sirlar - osmotik stress, ion toksikligi va oziq moddalar muvozanatining buzilishi - tufayli sezilarli darajada susayadi [5]. Biroq sho‘rlanish nafaqat o‘simliklarga, balki tuproq mikrobiotasining tarkibi, xilma-xilligi va funksional faolligiga ham jiddiy ta’sir ko‘rsatadi [6,7]. Shu nuqtai nazardan, sho‘rlangan tuproqlarda yashashga moslashgan mikroorganizmlarni, xususan *Pseudomonas* turkumi vakillarini o‘rganish ham ekologik, ham amaliy jihatdan katta ahamiyat kasb etadi [8].

Pseudomonas turkumining sho‘rlangan ekotoplarda tarqalishi va ekologik roli juda katta hisoblanadi. *Pseudomonas* turiga mansub bakteriyalar gram-manfiy, qat’iy aerob, qutbli flagellalar yordamida harakatlanuvchi, keng metabolik plastiklikka ega mikroorganizmlardir[9]. Ushbu turkum vakillari turli xil tuproq tiplarida, shu jumladan sho‘rlangan va hatto gipergalin muhitlarda masalan, sho‘r tuproqlar, tuzli botqoqliklar, ko‘l tubi cho‘kindilarida ham muvaffaqiyatli yashay oladi [10]. Sho‘rlangan tuproqlarda *Pseudomonas* turkumining turli turlari - *P. fluorescens, P. putida, P. stutzeri, P. aeruginosa* va ayniqsa *P. chlororaphis* - aniqlangan [11]. Ularning mavjudligi

tuproqning biologik faolligini saqlab qolishda, organik moddalar mineralizatsiyasida va oziq moddalar aylanishining davom etishida muhim rol o‘ynaydi [12]. *Pseudomonas* bakteriyalarining sho‘rlangan muhitlarda tarqalishining ekologik ahamiyati quyidagilarda namoyon bo‘ladi [13]. Ular tuproqda degradatsiyaga uchragan organik moddalarning o‘simlik qoldiqlari, mikrobial biomassa parchalanishini ta’minlaydi [14,15]. Rizosferada o‘simliklar bilan o‘zaro manfaatli aloqalar o‘rnatib, ularning sho‘r stressiga chidamliligini oshiradi [16]. Boshqa galotolerant va galofil mikroorganizmlar bilan birgalikda sho‘rlangan tuproqlarning funksional mikrobiom tarmog‘ini shakllantiradi[17].

Pseudomonas bakteriyalarining sho‘r stressga qarshi hujayraviy adaptiv mexanizmlari. Sho‘rlangan muhitda *Pseudomonas* bakteriyalari ikki asosiy qiyinchilikka duch keladi: 1. muhitning suv potensialining pasayishi osmotik stress va ionlarning ayniqsa Na^+ va Cl^- hujayra ichiga haddan tashqari to‘planishi natijasida yuzaga keladigan ion toksikligi [18]. Ushbu stress omillariga qarshi *Pseudomonas* turkumi bir qancha molekulyar fiziologik adaptiv mexanizmlarni ishlab chiqqan [19]. Osmoprotektantlarning (kompatibil eritmalar) to‘planishi. Sho‘r stress sharoitida *Pseudomonas* hujayralari hujayra ichida sitoplazmatik osmotik bosimni oshirish va fermentativ tizimlarni stabilizatsiya qilish maqsadida kompatibil eritmalar osmolitlarni to‘playdi [20]. Asosiy osmolitlarga quyidagilar kiradi:

- Prolin: *P. fluorescens* va *P. putida* da prolin sintezi proB, proA genlari orqali ortadi [21]. Prolin nafaqat osmoprotektor, balki ROS neytrallovchi sifatida ham ishlaydi. --Glyain betain- Ayrim *Pseudomonas* shtammlari glyain betainni atrof muhitdan faol transport orqali o‘zlashtiradi (BetL, BetS tashuvchi oqsillari) yoki xolin oksidlanish yo‘li bilan sintez qiladi (betAB genlari) [22].

-Trehaloza - *P. aeruginosa* da trehaloza sintezi (otsAB genlari) sho‘r stressga javoban induktsiyalanadi. Trehaloza membrana lipidlarining fazaviy o‘tish haroratini barqarorlashtiradi [23].

- Ektoin: Ba’zi halotolerant *Pseudomonas* shtammlari ektoin sintez qiladi, bu birikma yuqori tuz konsentratsiyasida ham hujayra strukturalarini saqlaydi [24].

Ion gomeostazi va natriy chiqarish nasoslari. Pseudomonas bakteriyalarida Na^+ ionlarining hujayradan chiqarilishi bir necha mexanizmlar orqali amalga oshiriladi [25]:

- Na^+/H^+ antiporterlar NhaA, NhaB tipidagi oqsillar: Protonga qarshi gradient energiyasidan foydalanib, Na^+ ni hujayra tashqarisiga chiqaradi [26].

- Mrp tizimi(multiple resistance and pH regulation: Ko‘p komponentli Na^+/H^+ antiporter bo‘lib, yuqori sho‘r sharoitida samarali ishlaydi[27].

- ATP-gidrolazali natriy nasoslari (Na^+-ATPaza): Ayrim galotolerant shtammlarda aniqlangan [28]. Ushbu mexanizmlar sitoplazmadagi Na^+ konsentratsiyasini toksik darajadan past (odatda 100–200 mM) ushlab turadi [29]. Hujayra devori va membrana tarkibining modifikatsiyasi. Sho‘r stressga uzoq muddatli moslashishda *Pseudomonas* hujayra devori va membrana tarkibida o‘zgarishlar ro‘y beradi [30]. Membranadagi qo‘shilmagan yog‘ kislotalarining nisbati oshadi, bu esa membrananing suyuqligini va ionlarning passiv kirishiga to‘siqni yaxshilaydi [31]. Lipopolisaxarid (LPS) molekulalarining tarkibi o‘zgaradi: fosfat guruhlari soni kamayadi, bu esa hujayra sirtining manfiy zaryadini pasaytirib, Na^+ ionlarining elektrostatik tortilishini kamaytiradi.

Oksidlovchi stressga qarshi himoya tizimlari. Sho‘r muhitda hujayra ichida reaktiv kislorod shakllari (ROS) - superoksid (O_2^-), vodorod peroksid (H_2O_2) va gidroksil radikali (·OH) - hosil bo‘lishi keskin ortadi. Ushbu ROS oqsillarni denaturatsiyalaydi, membranalarning lipid peroksidatsiyasini keltirib chiqaradi va DNKni shikastlaydi. *Pseudomonas* turkumi kuchli antioksidant himoya tizimiga ega [32].

- Superoksid dismutaza (O_2^- ni H_2O_2 va O_2 ga dismutatsiyalaydi. *Pseudomonas* da Fe-SOD (sodB) va Mn-SOD (sodA) izoformlari mavjud.

- Katalaza (CAT, EC 1.11.1.6): H_2O_2ni suv va kislorodga parchalaydi. *P. chlororaphis* da katA va katB genlari tomonidan kodlangan katalazalar aniqlangan. - Alkalgidroperoksid reduktaza (AhpC/AhpF): Organik gidroperoksidlarni neytrallaydi.

- Glutation-S-transferaza (GST): Ksenobiotiklar va lipid peroksidlarini konjugatsiyalaydi.Ushbu fermentlarning faolligi sho‘r stress sharoitida induktsiyalanadi va Pseudomonas ning yashovchanligini ta’minlaydi. Biofilm shakllanishi va ekzopolisaxaridlarning himoya roli. Sho‘rlangan muhitda *Pseudomonas* bakteriyalari ko‘pincha biofilm tuzilmalarini hosil qiladi. - Suvni ushlab turish: EPS yuqori suv saqlash qobiliyatiga ega bo‘lib, biofilmdagi mikro muhitning nisbiy namligini oshiradi [33].

- Fizik xususiyati: Biofilm hujayralarni to‘g‘ridan to‘g‘ri tuz kristallari bilan aloqadan himoya qiladi [34].Sho‘rlangan tuproqlarda *Pseudomonas* rizobakteriyalari (PGPR) o‘simliklar bilan o‘zaro manfaatli aloqalar o‘rnatib, ularning sho‘r stressiga chidamliligini bir qator mexanizmlar orqali oshira[35].

1. ACC deaminaza faolligi- Sho‘r stress o‘simliklarda stress gormoni - etilen - sintezini kuchaytiradi, bu esa ildiz o‘sishini inhibe qiladi. *Pseudomonas* shtammlari tomonidan ishlab chiqariladigan ACC deaminaza (EC 4.1.99.4) etilen prekursori bo‘lgan 1-aminotsiklopropan-1-karboksilatni parchalab, etilen darajasini pasaytiradi. Natijada o‘simliklarning ildiz o‘sishi va suv hamda oziq moddalarni o‘zlashtirishi yaxshilanadi.

2. Indol-3-sirka kislotasi (IAA) sintezi: *Pseudomonas* tomonidan ishlab chiqarilgan IAA ildiz tizimining rivojlanishini rag‘batlantiradi, bu esa sho‘r stress sharoitida o‘simliklarning suv va minerallarni yanada samarali o‘zlashtirishiga imkon beradi.

3. Siderofor ishlab chiqarish: Sho‘rlangan muhitda temirning o‘zlashtirilishi qiyinlashadi. *Pseudomonas* sideroforlari (poverdin) temirni eruvchan kompleks shaklida o‘simlik ildizlariga yetkazib beradi, shu bilan birga patogenlarni temirdan mahrum qiladi.

4. Induktsiyalangan sistemik rezistentlik (ISR): *Pseudomonas* ildizlarda ISR ni faollashtirib, o‘simlikning umumiy stressga chidamlilik potensialini oshiradi. Bu jarayonda jasmonat va etilen signal yo‘llari ishtirok etadi[36].

Galotolerant *Pseudomonas* shtammlarining biotexnologik potensiali. Sho‘rlangan tuproqlardan ajratilgan *Pseudomonas* shtammlari ko‘pincha yuqori darajada galotolerant (0,5-1,5 M NaCl gacha o‘sish qobiliyati) yoki ba’zi hollarda galofil (o‘sish uchun 0,5-2,5 M NaCl talab qiladi) xususiyatlarga ega. Bunday shtammlar quyidagi biotexnologik yo‘nalishlarda qo‘llaniladi.Biopestitsidlar: Sho‘rlangan sharoitda ham samarali antagonistik metabolitlar (fenazinlar, pirrolnitrin) ishlab chiqarish qobiliyati ularni sho‘r stressiga chidamli fitopatogenlarga qarshi qo‘llash imkonini beradi.

Xulosa qilib aytganda sho‘rlangan va neft mahsulotlari bilan ifloslangan tuproqlarda Pseudomonas turlari masalan, *P. stutzeri*, *P. putida* uglevodorodlarni parchalashi mumkin. Enzim ishlab chiqarish: Galotolerant *Pseudomonas* lardan olingan proteazalar, lipazalar va sellyulazalar sanoat jarayonlarida masalan, teri oshlash, oziq-ovqat sanoatida yuqori sho‘r sharoitda ishlatilishi mumkin. Shtammlararo o‘zgaruvchanlik va genetik asoslar. *Pseudomonas* turkumi ichida sho‘r stressga chidamlilik darajasi sezilarli farq qiladi. *P. chlororaphis* odatda o‘rtacha galotolerant (200-400 mM NaCl) bo‘lsa, *P. stutzeri* va *P. putida* ning ba’zi shtammlari 500-800 mM NaCl da o‘sishi mumkin.

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