



الجمهورية الجزائرية الديمقراطية الشعبية

PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

وزارة التعليم العالي والبحث العلمي

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

NATIONAL HIGHER AGRONOMIC SCHOOL-EL Harrach-Algeria

المدرسة الوطنية العليا للفلاحة

Department: Plant Production

القسم : الإنتاج النباتي

Specialty : Plant Production And Breeding

التخصص : إنتاج وتحسين النبات

Graduation project thesis

To obtain the Master's degree in agronomic sciences

TITLE

Study of the effect of plant growth-promoting rhizobacteria (PGPR) during the germination phase of barley (*Hordeum vulgare* L.) under saline conditions

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Defended on: 19/10/2025

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ABSTRACT

Barley, the fourth most cultivated cereal worldwide and a strategic crop in Algeria, is particularly vulnerable to salt stress, a major limiting factor in arid and semi-arid regions. This study adopts a sustainable approach aimed at exploring the potential of plant growth-promoting rhizobacteria (PGPR) as a biological solution to enhance barley tolerance to salinity during the germination stage. Twelve bacterial strains, isolated from Saharan soils exposed to extreme environmental conditions, were previously characterized for their phosphate-solubilizing ability, auxin production, and tolerance to abiotic stresses. Their biostimulant effect was then evaluated under controlled conditions through germination and seedling growth tests conducted at different NaCl salinity levels (50, 100, 200, 300, 400, and 500 mM NaCl). The results showed that salinity exerts a strong inhibitory effect on germination and seedling growth, reflected by reduced germination percentage and speed, as well as slower epicotyl and coleorhiza elongation. However, inoculation with some strains, particularly H3, H5, H9, and H14, significantly mitigated these negative effects by stimulating germination and promoting early growth even under severe saline conditions. This study highlights the agronomic potential of PGPR as natural biostimulants capable of enhancing barley tolerance to NaCl-induced salt stress during germination, offering promising perspectives for the development of PGPR-based biofertilizers and their integration into sustainable crop management strategies in saline-affected environments.

Keywords: Barley, Salt stress, Germination, Seedlings, Biostimulants, PGPR.

RÉSUMÉ

L'orge, quatrième céréale cultivée au monde et culture stratégique en Algérie, est particulièrement vulnérable au stress salin, un facteur limitant majeur dans les zones arides et semi-arides. La présente étude s'inscrit dans une approche durable visant à explorer le potentiel des rhizobactéries promotrices de croissance (PGPR) comme solution biologique pour améliorer la tolérance de l'orge à la salinité au stade germination. Douze souches bactériennes, isolées de sols sahariens soumis à des conditions extrêmes, ont été préalablement caractérisées pour leurs propriétés de solubilisation du phosphate, de production d'auxines et de tolérance aux stress abiotiques. Leur effet biostimulant ensuite été évalué en conditions contrôlées, à travers des tests de germination et de croissance de l'orge soumis à différents niveaux de salinité induits par le NaCl (50, 100, 200, 300, 400 et 500 mM NaCl). Les résultats obtenus ont montré que la salinité exerce un effet inhibiteur marqué sur la germination et la croissance des plantules, traduisant une diminution du pourcentage et de la vitesse de germination ainsi qu'un ralentissement de l'allongement de l'épicotyle et de la coléorhize. Cependant, l'inoculation par certaines souches, notamment H3, H5, H9 et H14, a significativement atténué ces effets négatifs, en stimulant la germination et en favorisant la croissance initiale même sous des concentrations salines sévères. Cette étude met en évidence le potentiel agronomique des PGPR comme biostimulants naturels capables de renforcer la tolérance de l'orge au stress salin au stade germination. Ouvrant des perspectives prometteuses pour le développement de biofertilisants à base de PGPR et leur intégration dans des stratégies de gestion durable des cultures en milieux contraints par la salinité.

Mots clés: Orge, PGPR, Stress salin, Germination, Plantules, Biostimulants.

ملخص

يُعدّ الشعير رابع أهمّ الحبوب المزروعة في العالم ومحصولاً استراتيجياً في الجزائر، غير أنّه يُظهر حساسية عالية للإجهاد الملحي الذي يُعدّ أحد العوامل الرئيسية المقيدة للإنتاج في المناطق الجافة وشبه الجافة. تندرج هذه الدراسة ضمن مقاربة مستدامة تهدف إلى استكشاف إمكانات البكتيريا الجذرية المحفزة للنمو النباتي (PGPR) كحلّ حيوي لتحسين قدرة الشعير على تحمل الملوحة خلال مرحلة الإنبات. تمّ استخدام اثنتي عشرة سلالة بكتيرية معزولة من تربة صحراوية خاضعة لظروف قاسية، سبق توصيفها من حيث قدرتها على إذابة الفوسفات، وإنتاج الأوكسينات، وتحمل الإجهادات اللاأحيائية. بعد ذلك، جرى تقييم تأثيرها المحفّز للنمو في ظروف مضبوطة من خلال اختبارات الإنبات ونمو بادرات الشعير تحت ظروف ملوحة مختلفة ناتجة عن كلوريد الصوديوم (50، 100، 200، 300، 400، و500 ملليمول). أظهرت النتائج أنّ الملوحة تؤثر سلباً وبشكل واضح على الإنبات ونمو البادرات، حيث سُجّل انخفاض في نسبة وسرعة الإنبات، بالإضافة إلى تباطؤ في استطالة كلٍّ من الفلقة

العلوية والجنر الجنيني. ومع ذلك، فإن تلقيح البذور ببعض السلالات، خصوصاً H3، H5، H9 وH14، قد خفّف بشكل ملحوظ من هذه التأثيرات السلبية، إذ حفّز الإنبات وعزّز النمو الأولي حتى في ظلّ تركيزات عالية من الملوحة. تُبرز هذه الدراسة الإمكانيات الزراعية للبكتيريا الجذرية المحفزة للنمو النباتي (PGPR) بوصفها منشطات حيوية طبيعية قادرة على تعزيز تحمل الشعير للإجهاد الملحي خلال مرحلة الإنبات، مما يفتح آفاقاً واعدة لتطوير أسمدة حيوية قائمة على هذه البكتيريا ودمجها ضمن استراتيجيات الإدارة المستدامة للمحاصيل في البيئات المتأثرة بالملوحة.

الكلمات المفتاحية: الشعير، البكتيريا المحفزة للنمو، الإجهاد الملحي، الإنبات، البادرات، المنشطات الحيوية.