رقم الإيداع لدى مديرية المكتبات والوثائق الوطنية

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رقم الترخيص لدى دائرة المطبوعات والنشر

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الفهرس:

* ما ورد في هذا العدد يعبر عن آراء الكتاب أنفسهم ولا يعكس بالضرورة آراء هيئة التحرير أو سياسة جامعة مؤتة.

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- الأستاذ الدكتور محمد بدر، جامعة الشارقة، الإمارات العربية المتحدة.
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- الأستاذ الدكتور فارمارز دجافانرودي، جامعة الأمير محمد بن فهد، السعودية.
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مؤتة للبحوث والدراسات

سلسلة العلوم الطبيعية والتطبيقية

مجلة علمية محكمة ومفهرسة تصدر عن عمادة البحث العلمي في جامعة مؤتة

كلمة المحرر

تصدر مجلة مؤتة للبحوث والدراسات في سلسلتها **العلوم الطبيعية والتطبيقية** منذ عام 1986، وهي مجلة علمية محكمة ومفهرسة، وتصدر بشكل منتظم وبواقع مجلد واحد في كل عام منذ تأسيسها، يحتوي المجلد على عددين، ويشرف على تحريرها هيئة من الأساتذة المتخصصين والأكاديميين في مختلف التخصصات العلمية والتطبيقية، ورقم تصنيفها الدولي-(ISSN 1022-6812). تقوم المجلة بنشر الأبحاث الأصيلة التي تسهم بنشر العلم والمعرفة في كافة تخصصات **العلوم الطبيعية والتطبيقية**. وتخضع الأبحاث المقدمة للنشر إلى معايير دقيقة تشمل التدقيق الفني والتحكيم العلمي من قبل محكمين اثنين للتحقق من صلاحية البحث للنشر.

وقد حظيت المجلة بسمعة رائدة محلياً وإقليمياً على مدار الثلاث عقود الماضية، فأصبحت مجلة معتمدة لغايات النقل والترقية للباحثين في كافة الجامعات الحكومية والخاصة في الأردن، بشكل خاص، والعالم العربي، بشكل عام، وهذا يبرر العدد الكبير والمتزايد من الأبحاث الذي يرد إلى المجلة من جامعات ومؤسسات ومراكز بحثية محلية وإقليمية ودولية، ولضمان جودة الأبحاث المنشورة في المجلة، فإنها تتبع معايير وضوابط وإجراءات تضمن جودة المنتج البحثي وتتضمن:

1. قواعد النشر
2. المواصفات الفنية
3. إجراءات النشر
4. أخلاقيات النشر

عميد البحث العلمي

رئيس التحرير

أ. د أسامه عيسى مهاوش

1. قواعد النشر.

انسجاماً مع الخطة الاستراتيجية لجامعة مؤتة ورؤيتها للوصول إلى تحقيق معايير التصنيفات العالمية للجامعات، وانطلاقاً من الخطة الاستراتيجية لعمادة البحث العلمي ورؤيتها التي تنص على: **(نحو عمادة حاضنة لبحث علمي متميز يرتقي بتصنيف الجامعة محلياً وإقليمياً وعالمياً)** ورسالتها التي تتضمن: **(تأمين بيئة قادرة على إنتاج بحوث علمية تسهم في تعزيز دور الجامعة في البحث والابتكار محلياً وإقليمياً وعالمياً)**. فقد ارتأت عمادة البحث العلمي تطوير مجلة مؤتة للبحوث والدراسات للوصول إلى قواعد البيانات العالمية، مثل: SCOPUS, ISI, PubMed والارتقاء بعامل التأثير (Impact Factor) للمجلة، لوصول الانتاج البحثي للمؤلفين إلى العالمية.

وبناء عليه، وعند تقديم أبحاثكم للنشر في المجلة، يراعى الآتي:

1. اعتماد نظام جمعية علماء النفس الأمريكية (APA)، للاطلاع على الدليل المختصر لطريقة التوثيق، ولمزيد من الأمثلة، يرجي زيارة الموقع التالي: http://www.apastyle.org/ وموقع المجلة على الرابط: https://ejournal.mutah.edu.jo
2. تكتب جميع المراجع العربية باللغة الإنجليزية في المتن وفي قائمة المراجع.
3. ترجمة كافة المراجع غير الإنجليزية (بما في ذلك المراجع العربية) إلى اللغة الإنجليزية، مع ضرورة ابقاء القائمة العربية موجودة.
4. اذا كان للمراجع العربية ترجمة إنجليزية معتمدة فيجب اعتماد ذلك، أما المراجع التي ليس لها ترجمة إنجليزية معتمدة (مثل: فقه السنه) فيتم عمل Transliteration أي كتابة المرجع بالأحرف الإنجليزية كتابة حرفية، (Fiqih Alsunah) .
5. إعادة ترتيب كافة المراجع (والتي يفترض أنها قد أصبحت باللغة الإنجليزية) حسب ترتيب الأحرف الإنجليزية (Alphabets) بما يتناسب مع نظام APA.
6. يجب الالتزام بالمواصفات الفنية لتحرير المخطوط المبينة على موقع المجلة، علماً بأن البحث يخضع للتدقيق الفني عند استلامه. وفي حال عدم الالتزام بهذه المواصفات الفنية يُعاد البحث.
7. يتم تسـليم البحث والملفات المطلوبة والنماذج الخاصة بهـا الكترونيـاً على الموقع https://ejournal.mutah.edu.jo/ والمبينة في الجدول التالي.
8. عدم الالتزام بأي من النقاط السابقة يعفي المجلة من السير في إجراءات التحكيم

الرقم	اسم الملف	ملاحظات
.1	رسالة تغطية **Cover Letter**	توجه الى رئيس التحرير
.2	صفحة الغلاف **Title Page**	يكتب التالي باللغتين العربية والإنجليزية في صفحة الغلاف وحسب الترتيب التالي: 1. عنوان البحث 2. اسم الباحث (الباحثين) من ثلاثة مقاطع. 3. العنوان البريدي 4. الرتبة العلمية 5. البريد الإلكتروني 6. رقم الهاتف
.3	ملخص البحث **Abstract**	يكتب الملخص باللغتين العربية والإنجليزية بحيث لا يزيد الملخص عن (150) كلمة والكلمات المفتاحية **(keywords)** عن خمس كلمات.
.4	البحث **Research Document**	يجب أن تلتزم وثيقة البحث بالمتطلبات التالية: 1. عدم وجود اسم الباحث (الباحثين). 2. أن لا يحتوي البحث على أي معلومات تشير إلى الباحث (الباحثين). 3. أن يكون التوثيق للمراجع في المتن **(In-text Citation)** باللغة الإنجليزية. 4. اعتماد نظام جمعية علماء النفس الأمريكية **(APA)**. 5. الالتزام بالمواصفات الفنية لطباعة البحث. 6. تخضع البحوث للتدقيق الفني قبل السير في إجراءات التحكيم.
.5	قائمة المراجع **References**	يجب أن تلتزم قائمة المراجع بالمتطلبات التالية وترسل في نفس الملف: 1. تكتب المراجع (الواردة في البحث باللغة الإنجليزية) في القائمة النهائية مرتبة حسب الحروف الهجائية **(Alphabets)**. 2. إذا كان للمراجع العربية ترجمة إنجليزية معتمدة فيجب اعتماد ذلك، أما المراجع التي ليس لها ترجمة إنجليزية معتمدة (مثل: فقه السنة) فيتم عمل **Transliteration** أي كتابة المرجع بالأحرف الإنجليزية كتابة حرفية (**Fiqih Alsunah**). 3. إعادة ترتيب كافة المراجع (والتي يفترض أنها قد أصبحت باللغة الإنجليزية) حسب ترتيب الأحرف الإنجليزية **(Alphabets)** بما يتناسب مع نظام **APA**. 4. الإبقاء على قائمة المراجع العربية وإدراجها في نهاية الملف بعد المراجع المترجمة.
.6	التعهد Pledge	يلتزم الباحث بتعبئة التعهد

2. المواصفات الفنية.

يجب الالـــتزام بالمواصفات الفنيـــة لتحريـــر المخطوط والموجـــودة على الرابـــط: https://ejournal.mutah.edu.jo ، حيث يخضع البحث للتدقيق الفني عند استلامه، وفي حال عدم الالتزام بهذه المواصفات الفنية يُعاد البحث.

3. إجراءات النشر.

1. يُقدم البحث للنشر إلى عمادة البحث العلمي في جامعة مؤتة الكترونياً على موقع المجلة https://ejournal.mutah.edu.jo.
2. يوقع الباحث على تعهد النشر وفق نموذج خاص تعتمده المجلة.
3. يعرض البحث على هيئة تحرير المجلة، ويسجل في السجلات المعتمدة.
4. يخضع البحث المرسل إلى المجلة إلى التدقيق الفني والتحكيم الأولي من هيئة التحرير؛ لتقرير أهليته للتحكيم الخارجي، ويحق للهيئة أن تعتذر عن السير في إجراءات التحكيم الخارجي أو عن قبول البحث للنشر في أي مرحلة دون إبداء الأسباب.
5. يرسل البحث إلى محكمين اثنين على أن يقوم كلاً منهما بالرد في مدة أقصاها شهر، وفي حال عدم الرد ضمن الموعد المحدد يتم ارسال البحث إلى محكم آخر، وبناء عليه يكون قرار هيئة التحرير على النحو الآتي:
   أ. يُقبل البحث للنشر في حالة ورود تقارير إيجابية من المحكمين الإثنين، وبعد أن يقوم الباحث بإجراء التعديلات المطلوبة، إن وجدت.
   ب. في حال ورود تقارير سلبية من كلا المحكمين يرفض البحث.
   ج. في حالة ورود رد سلبي من أحد المحكمين ورد إيجابي من المحكم الثاني يرسل البحث إلى محكم ثالث للبت في أمر صلاحيته للنشر.
6. إذا كان الباحث من جامعة ما فلا يجوز أن يُحكَّم البحث من قبل زميل يعمل في الجامعة نفسها.
7. يجب على الباحث بعد إبلاغه بإجراء التعديلات أن يقوم بذلك وفق ملاحظات المحكمين في مدة أقصاها أسبوعين من تاريخه، وفي حال عدم استجابة الباحث ضمن المدة المحددة يتم وقف إجراءات السير في نشر البحث.
8. إذا أفاد المحكم (مراجع التعديلات) أن الباحث لم يقم بالالتزام بإجراء التعديلات المطلوبة، يُعطى الباحث فرصة ثانية وأخيرة مدتها أسبوعين للقيام بالتعديلات المطلوبة، وإلاّ يرفض البحث ولا ينشر في المجلة.
9. تمنح رسالة القبول بعد إجراء التدقيق الفني المترتب على البحث بعد التعديل.
10. ترتب البحوث المقبولة في المجلة وفقا لسياسة المجلة.
11. ما ينشر في المجلة يعبر عن وجهة نظر الباحث ولا يعبر بالضرورة عن وجهة نظر جامعة مؤتة، أو هيئة التحرير، أو القائمين عليها.

4. أخلاقيات النشر.

تلتزم هيئة التحرير والمحكمون والباحثون بأخلاقيات النشر التالية:

أولاً: واجبات هيئة التحرير

1. العدالة والاستقلالية: يقوم المحررون بتقييم المخطوطات المقدمة للنَّشر على أساس الأهمية والأصالة وصحة الدراسة ووضوحها وأهميتها لنطاق المجلة، بغض النظر عن جنس المؤلفين أو جنسيتهم أو معتقدهم الديني بحيث يتمتع رئيس التحرير بسلطة كاملة على كامل المحتوى التحريري للمجلة وتوقيت نشره.
2. السرية: هيئة التحرير وموظفو التحرير مسؤولون عن سرية أية معلومات حول البحث المقدم وعدم إفشاء هذه المعلومات إلى أي شخص آخر غير المؤلف والمحكمين والهيئة الاستشارية كلٌ وفقاً لاختصاصه.
3. الإفصاح وتضارب المصالح: هيئة التحرير مسؤولة عن عدم استخدام معلومات غير منشورة موجودة في البحث المقدم لأغراض النشر دون موافقة خطية صريحة من المؤلفين، ويجب على عضو هيئة التحرير الإفصاح عن وجود أي تضارب في المصالح مع أي من المؤلفين. مثل علاقات تنافسية أو تعاونية أو علاقات أخرى مع أي من المؤلفين؛ بدلاً من ذلك، سوف يطلبون عضو خارجي للتعامل مع المخطوطة.
4. قرارات النشر: تحرص هيئة التحرير على أن تخضع جميع الابحاث المقدمة للتحكيم من قبل اثنين على الأقل من المحكمين الذين هم خبراء في مجال البحث. وتعتبر الهيئة مسؤولة عن تحديد أي من الابحاث المقدمة إلى المجلة التي سيتم نشرها، بعد التحقق من أهميتها للباحثين والقراء.

ثانياً: واجبات المحكمين.

1. المساهمة في صنع قرارات هيئة التحرير.
2. السرعة والدقة في الوقت: أي محكم يشعر بعدم قدرته على مراجعة البحث لأي سبب كان يجب عليه إخطار هيئة التحرير على الفور ورفض الدعوة للتحكيم بحيث يمكن الاتصال بالمحكمين البدلاء.
3. السرية: أي أبحاث وردت للمجلة للتحكيم والنشر هي وثائق سرية؛ لذا يجب ألا تظهر أو تناقش مع الآخرين إلا إذا أذن بها رئيس التحرير وينطبق هذا أيضا على المحكمين المدعوين الذين رفضوا الدعوة للتحكيم.
4. معايير الموضوعية: يجب مراجعة وتحكيم الأبحاث بموضوعية وأن تُصاغ الملاحظات بوضوح مع الحجج الداعمة، بحيث يمكن للمؤلفين استخدامها لتحسين أبحاثهم بعيداً عن النقد الشخصي للمؤلفين.

5. الإفصاح وتضارب المصالح: يجب على أي محكم مدعو للتحكيم أن يُخَطِّرْ هيئة التحرير على الفور بأن لديه تضارب في المصالح ناجم عن علاقات تنافسية أو تعاونية أو علاقات أخرى مع أي من المؤلفين بحيث يمكن الاتصال بالمحكمين البدلاء.
6. المحافظة على سرية المعلومات أو الأفكار المتميزة غير المنشورة والتي تم الكشف عنها في الأبحاث المقدمة للتحكيم وعدم استخدامها دون موافقة كتابية صريحة من المؤلفين وينطبق هذا أيضاً على المحكمين المدعوين الذين يرفضون دعوة التحكيم.

ثالثا: واجبات المؤلفين.

1. معايير إعداد البحث: يجب على المؤلفين الالتزام بالقواعد والإجراءات والمواصفات الفنية وأخلاقيات النشر الموجودة على موقع المجلة.
2. السرقة الأدبية: لا يجوز بأي حال من الأحوال الاعتداء على حق أي مؤلف آخر بأي صورة من الصور فالقيام بهذا العمل يعتبر سرقة أدبية ويتحمل من قام بهذا العمل كامل المسؤولية القانونية والأدبية عن ذلك.
3. الأصالة: يجب على المؤلفين التأكد من تقديم أعمال أصيلة تماما، وتوثيق أعمال أو كلمات الباحثين الآخرين التي تم الرجوع اليها في بحثهم. وينبغي أيضا الاستشهاد بالمنشورات المؤثرة في مجال البحث المقدم. فأخذ المعلومة دون توثيق المصدر بجميع أشكاله يُشكل سلوكاً غير أخلاقي للنشر ويأخذ أشكالاً عديدة، مثل اعتماد بحث على أنه للمؤلف نفسه، نسخ أو إعادة صياغة أجزاء كبيرة من بحث أخر (دون الإسناد).
4. عدم إرسال البحث إلى مجلات مختلفة وبشكل مُتزامِن: يجب على المؤلف عدم إرسال أو نشر نفس البحث في أكثر من مجلة واحدة. وبالتالي، لا ينبغي للمؤلفين أن يُقدِموا مخطوطة سبق نشرها في مجلة أُخرى وذلك لأن تقديم بحث بالتزامُن مع أكثر من مجلة واحدة هو سلوك غير أخلاقي وغير مقبول.
5. تأليف المخطوطة: يجب أن يتم إدراج الأشخاص الذين يستوفون معايير التأليف التالية كمؤلفين في البحث بحيث يكونوا قادرين على تحمل المسؤولية العامة عن المحتوى: (1) تقديم مساهمات كبيرة في تصميم أو تنفيذ أو الحصول على البيانات أو تحليل أو تفسير الدراسة؛ (2) المســاهمة في صياغــة وكتابة محتوى البحــث أو مراجعته. (3) مراجعة النسخة النهائية من البحث والموافقة عليها وعلى تقديمها للنشر. إضافة إلى ذلك هناك أشخاص لا يستوفون معايير التأليف فيجب ألا يُدْرَجوا كمؤلفين، ولكن يجب ذكرهم في قسم "شكر وتقدير" بعد الحصول على إذن كتابي منهم.
6. الإفصاح وتضارب المصالح: يجب على المؤلفين الإبلاغ عن أي تضارُب في المصالح مع جهات لا تعلمها هيئة التحرير يمكن أن يكون له تأثير على البحث. ومن أمثلة التضارب المحتمل في المصالح التي ينبغي الإفصاح عنها مثل العلاقات الشخصية أو المهنية، والانتماءات، والمعرفة في الموضوع أو المواد التي نوقِشَتْ في البحث.
7. المخاطر والمواد البشرية أو الحيوانية: إذا كان العمل ينطوي على استخدام مواد كيميائية أو إجراءات أو معدات لها أي مخاطر غير عادية، فيجب على المؤلفين تحديدها بوضوح في البحث. وكذلك إذا كان العمل ينطوي على استخدام أو إجراء تجارب على البشر أو الحيوانات في بحثهم، فيجب على المؤلفين التأكد من أن جميع الإجراءات تم تنفيذها وفقاً للقوانين والتعليمات ذات الصلة وأن المؤلفين قد حصلوا على موافقة مسبقة بهذا الخصوص. وكذلك ويجب مراعاة حقوق الخصوصية الخاصة بالمشاركين من البشر.
8. التعاون: يجب على المؤلفين التعاون بشكل كامل والاستجابة الفورية لطلبات المُحررين بشأن البيانات الأولية والتوضيحات وإثبات الموافقات الأخلاقية وموافقات المرضى وأذونات حقوق الطبع والنشر. وفي حالة اتخاذ قرار أولي بشأن إجراء التعديلات الضرورية على البحث، يجب على المؤلفين الاستجابة لملاحظات المحكمين بشكل منهجي ويقوموا بإجراء التعديلات المطلوبة وإعادة تقديمها إلى المجلة بحلول الموعد النهائي المحدد.
9. الأخطاء الأساسية في الأعمال المنشورة: عندما يكتشف المؤلفون أخطاء كبيرة أو عدم دقة في أعمالهم المنشورة، فإن عليهم الالتزام بإخطار محرري المجلة أو الناشر فوراً والتعاون معهم إما لتصحيح البحث أو سحبه.

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جامعة مؤتة

قسيمة اشتراك

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ج– للطلبة: (5) دنانير سنوياً

د – تضاف أجرة البريد لهذه الأسعار.

تُملأ هذه القسيمة، وترسل مع قيمة الاشتراك إلى العنوان التالي:

رئيس هيئة تحرير مجلة مؤتة للبحوث والدراسات

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المحتويات

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Efficiency Improvement of the Condensation Pipes in the Soil for a Basin Type Solar Desalination Unit

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Mohammed A. Al-Dabbas**

Abstract

A solar desalination unit consisting of a set of conventional basin-type solar stills, and a set of condensation pipes buried in the soil was investigated in this study. The effects of soil moisture and condensation pipes length, depth, diameter and material of the pipes in improving the efficiency of the solar still was studied. Compared to the traditional condensers used in conventional basin type solar stills, it was found that using buried metallic pipes as condensers led to an increase in the freshwater production rate by up to 136%.

Additionally, increasing the soil moisture led to improvements in the effectiveness of the buried condensation pipes in condensing more freshwater.

Compared to conventional solar stills the freshwater production rate in this study increased by about 54% for a soil moisture level of 30%. Furthermore, metallic pipes produced more freshwater compared to plastic pipes of the same heat transfer surface area. Compared to the plastic pipes, fresh water production rate increased by 98% when metallic pipes were used.

Keywords: Solar Desalination; Condensation Rate; Solar Still; condensation pipes; Freshwater production

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Efficiency Improvement of the Condensation Pipes in the Soil for A basin Type Solar Desalination unit

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تحسين كفاءة أنابيب التكثيف داخل التربة لوحدة التحلية بالطاقة الشمسية

عامر "محمد علي" أحمد مامكغ

صقر محمد حمدان حرزالله

محمد عواد الدباس

ملخص

بهدف انتاج المياه العذبة تم عمل نظام لتحلية المياه تألف من مجموعة من المقطرات الشمسية التي تم داخلها تسخين الماء المالح بواسطة اشعة الشمس المباشرة وانتاج الهواء الرطب الذي نقل مباشرة بواسطة مراوح إلى انابيب مدفونة تحت التربة عملت كمكثفات. لتحسين كفاءة النظام وبالتالي انتاج كميات أكبر من الماء العذب تمت دراسة تأثير اطوال، اقطار واعماق الأنابيب الموجودة تحت التربة وكذلك رطوبة التربة على معدل التكثيف داخل تلك الأنابيب.

لقد تبين من هذه الدراسة أن زيادة اقطار، اطوال واعماق الأنابيب وكذلك زيادة رطوبة التربة قد قامت بتحسين كفاءة نظام التحلية مما زاد في كمية المياه العذبة الناتجة، حيث كانت الزيادة بمقدار 136% عندما استخدمت الأنابيب المدفونة تحت التربة كمكثفات للهواء الرطب مقارنة بالمكثفات التي تستخدم عادةً في المقطرات الشمسية التقليدية. كما كان لمادة الأنبوب تأثير على معدل التكثيف داخل الأنابيب حيث كان المعدل اعلى عند استخدام الأنابيب المعدنية مقارنة بالأنابيب البلاستيكية.

الكلمات الدالة: تحلية شمسية، معدل التكثيف، مقطرات شمسية، أنابيب تكثيف، انتاج ماء عذب.

Introduction

With the dramatic growth in population and increase in living standards, freshwater supplies are deteriorating (Kuylenstierna , Björklund, & Najlis, 2009., Fritzmann., Löwenberg., Wintgens, & Melin, 2007., El-Kady & El-Shibini, 2001). Solar desalination of brackish and impure water, as well as seawater, seems to be a promising solution to this problem. It has been used for many years to provide freshwater and represents the most attractive and simple technique among existing desalination processes. It is suitable for small-scale units at locations where solar energy is abundant. It has been studied as a preferred process because of its energy efficiency and low environmental impact. In the Middle East, Jordan has one of the highest solar intensities; the mean value of the radiation density can reach 200W/m2 (Abdallah, Abu-Khader, & Badran, 2009, Etier, Al Tarabsheh & Ababneh, 2010). Moreover, Jordan is considered the fourth poorest country in the world in terms of water resources (Denny, Donnelly, & McKay, 2008) The use of solar desalination and improvements in the efficiency of solar devices could be a suitable solution for desalinating water in remote areas with poor water quality and a lack of other treatment options. Basin type solar stills are an option that can be used for water desalination and are considered one of the cheapest solutions for purifying brackish water. They are suitable for the Middle East and Africa due to their low cost and ease of maintenance (Salah, Omar, & Abu-Khader, 2008, Shanmugasundaram, 2016). The main drawback of the conventional basin type solar still is its low productivity, which is about 4 l/m2/d. This low level of productivity makes it impractical for many uses. Many basin type solar still designs have been developed and constructed (Akash, Mohsen, & Nayfeh,2000, Al-Hayek & Badran, 2004; Kabeel & El-Agouz, 2011; *et al.*, 2013; Malik, Kumar & Sodha, 1982) while others evaluated the performance Hanson, Zachritz, Stevens, Mimbela, & Cisneros, 2004, Maalej, 1991, Sharma, & Mullick, 1993; Tiwari, Minocha , Sharma, & Khan,1997). Efficiency improvements by cooling of the solar still condenser was also reported (Abu-Hijleh, 1996, Abu-Arabi, Zurigat, Al-Hinai, & Al-Hiddabi, 2002, Mamkagh and Anderson, 2018).

The efficiency of the conventional solar still can be improved by using buried metallic pipes that are connected to the still, and using these pipes as a condenser to produce more freshwater. Lindblom & Nordell (2007) and Lindblom & Nordell (2006), studied two types of condensation systems for drinking water production and for subsurface irrigation. The systems were theoretically analyzed by numerical simulations of the mass and heat transfer in the soil and pipe system for 90 days. It was found that the freshwater production rate was improved by decreasing the surrounding air temperature and increasing the humidity and velocity of the air. Bagher et al. (2012) also studied condensation systems for subsurface irrigation and drinking water production. Their systems produce approximately 0.5 l/m2/h. Hexigeduleng & Yixin (2010) used perforated pipes placed inside the soil to irrigate greenhouse tomatoes. The effect of the pipe depth on desalinated water production was studied by Lindblom (2012) and found that it had a negative effect on condensation rate.

The main objective of the present study was to connect the buried condensation pipes to the conventional basin type solar stills to serve as a condenser for enhancing the still productivity. The effects of soil moisture and the buried piping parameters (length, depth, diameter, and material of the pipes) on improving the condensation effectiveness are also investigated.

Materials and Methods

Experimental Site

The field experiment was carried out in a region with soil consisting of sandy clay loam in the southern part of Jordan at Agricultural Research Station, Faculty of Agriculture, Mutah University (31°16′N, 35°44′E, and 962 m above mean sea level). The site was chosen in the center of the field where the solar stills would be exposed to sunlight most of the time without obstacles. The solar radiation levels and number of sunny hours per day for the 5 month duration of the experiment were measured and are presented in Table1.

Table (1) Average monthly solar radiation and sunny hours per day for the 5 months of the experiment

	May	June	July	August	September
kWh/m^2	223	249	248	226	177
Average daily Sunny hours	13:47	14:12	13:59	13:15	12:20

Design and construction

A solar desalination system (Figure 1) designed and constructed and consisted of two main sections, the first section was a set of simple solar stills and the second section was a set of condensation pipes buried in the soil.

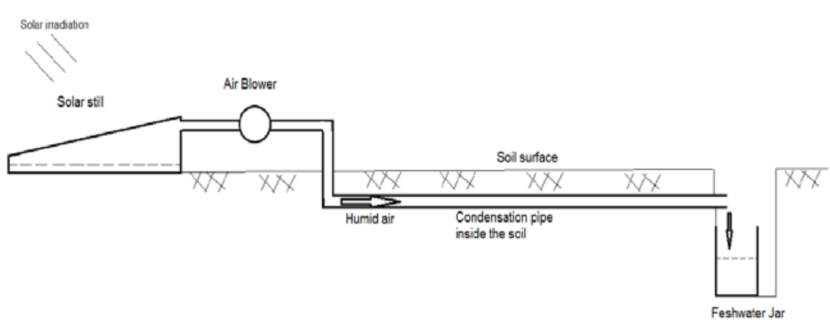


Figure (1) Profile of the solar desalination system

The solar desalination unit consisted of 13 conventional single slope basin-type solar stills. Each still consisted of the following sections: a wooden framework, a transparent cover, a float, an inlet from the brackish water tank, and an outlet to the air blowers. Figure 2 show the schematic diagram of one solar still where the framework of the still was made of wood for ease of construction and good isolation from the external environment. It was fabricated in a box type shape of 80 cm x 80 cm and 1 cm in thickness. The height of the front side was 10 cm and the back side was 20cm high. One conventional basin type solar still was used separately as the reference case for experimental control. It was tested separately under the same conditions as the proposed solar still unit and its daily freshwater production rate was found to be 4 l/m^2.

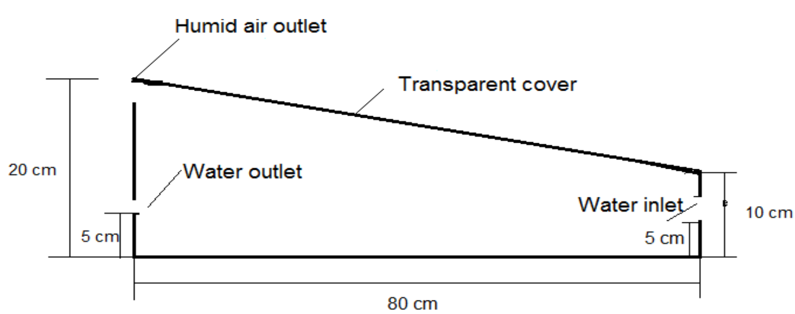


Figure (2) Schematic diagram of the solar still.

As shown in Figure 3, brackish water flows from the water tank to the solar stills by gravity. To ensure that the depth of the water remained around 5 cm, small floats were installed inside the solar stills.

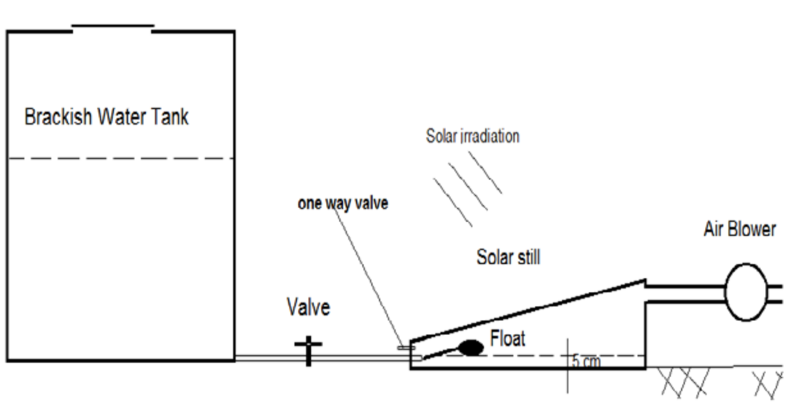


Figure (3) Solar still with brackish water tank and air blower

The water depth used was based on previous studies showing that this depth increases the evaporation rate inside the solar still (Wasil & Altamush, 2012; Tiwari & Tiwari, 2007; Bilal, Akash, Mohsen, & Nayfeh, 2000). One-way valves were used to vent the solar still so air can enter the still but vapor cannot exit. The air blowers then transfer the vapor formed from the stills through plastic pipes to the condensation pipes that are buried in the soil.

The condensation pipes

The condensation pipes were chosen based on what was locally used for water distribution. To determine the effect of length, depth, diameter, and material of the pipes affected on condensation rate, metallic and plastic pipes with different diameters and lengths were buried in the soil at different depths. The condensation areas of the pipes were calculated from the pipe lengths and diameters. The lengths of the condensation pipes used in this experiment were 2m, 4m, and 6m. The diameters were 0.5" and 1" for the metallic pipes and 1" for the plastic pipes.

The productivity of conventional basin type solar stills (Kalogirou, 1997). needed to be referred to because each square meter of pipe condensation area requires at least one solar still to produce the required quantity of vapor. Because pipes have different condensation areas, valves were used to connect each pipe to an adequate number of stills.

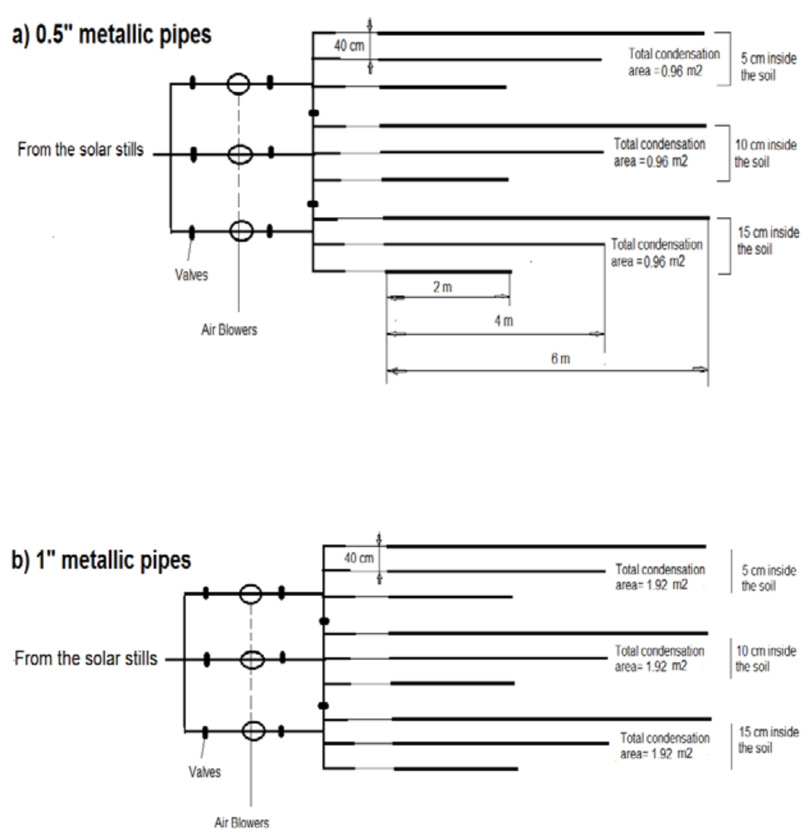
Because the condensation rate decreases with the pipe depth (Bagher, Boroomandnasab & Thameur, 2012, Mikielewicz & Mikielewicz, 2010) in this study the pipes were not buried very deep in the soil. The depths of these pipes for the experiment were 5cm, 10cm, and 15cm.

Evaporation in solar stills is the process of turning brackish water into vapor by applying heat from sunlight. The reverse process is condensation, which takes place in the pipes and converts vapor into liquid water. The necessary condition for this process to occur is that the temperature of the condensation pipes should be lower than the vapor temperature (Tromp-van, & McDonnell, 2006). For the experiment, the soil temperature at the pipes was about 23^{o}C, the temperature of the condensation pipes was 30^{o}C, and the vapor temperature was 60^{o}C, so the proper condition for condensation to occur on the inner surface of the pipes was established.

The solar stills were tightly sealed to prevent heat and vapor leakage. Air blowers were used to transmit the vapor from the solar stills to the metallic and plastic pipes in the soil. The daily freshwater that was produced could then be collected at the pipes outlets.

Thermocouple probes were used to measure the temperature of the soil around the pipes, the temperature of the pipes, and the temperature of the vapor. The solar radiation levels and exposure times were also measured.

To control the direction of the vapor flow from the solar stills to the condensation pipes, several valves were used. This enabled the delivery of the vapor to any condensation pipe or group of pipes as needed.



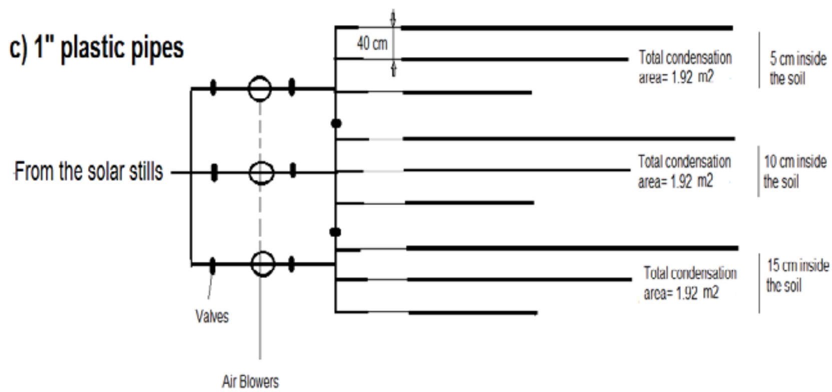


Figure (4) Design of the experiment with: a) 0.5" metallic pipes, b) 1"metallic pipes and c) 1"plastic pipes.

Figure 4 shows the final design of the experimental setup. The design was divided into three groups with different parameters. The first group contained nine metallic pipes with diameters of 0.5"and lengths of 2 m, 4 m, and 6 m. The first three pipes of this group were buried at a depth of 5 cm, the second three pipes at 10 cm, and the other three pipes at 15 cm. The second group contained nine metallic pipes with diameters of 1", which also had lengths of 2m, 4m, and 6 m. These pipes were divided similarly and buried at the same depths as the first group. The third group contained nine plastic pipes with diameters of 1" and lengths of 2m, 4m, and 6 m. This group of pipes were also divided similarly and buried at the same depths as the first and second groups. A pipe spacing of 40 cm was used in this study because it was considered optimum spacing for peak condensation rate production (Lindblom, 2012).

Soil moisture around the condensation pipes

Increases in soil moisture around the condensation pipes can improve the pipe efficiency because it increases the temperature difference between the soil and the pipes. The moisture level was brought to the desired level at the end of September by adding a known quantity of water.

Soil moisture sensors were used to measure the moisture level. Three levels of soil moisture, 10%, 20%, and 30%, were established around the condensation pipes. For each level of soil moisture, the condensation rate was also measured by collecting the freshwater at the pipe outlets.

Results and Discussion

Factors influencing the condensation rate

Figure 5 shows the relationship between the time of the experiment and the freshwater production rate of the solar desalination system. It shows no significant differences in the freshwater production rates between May, June, July, and August. A significant decrease to 5.01 l/m2/d occurred in September constituting over 20% relative to June. This was because September had lower solar radiation levels and fewer sunny hours than the other months, as shown in Table 1. Compared to the reference case of 4 l/m^2/d) for the conventional solar still, the amount of freshwater production rate in any of these months was much higher. This demonstrates the superiority of the solar desalination system used in this study. This increase was obtained because buried pipes were used as the condenser for the solar stills instead of the traditional solar still condenser consisting of the transparent cover.

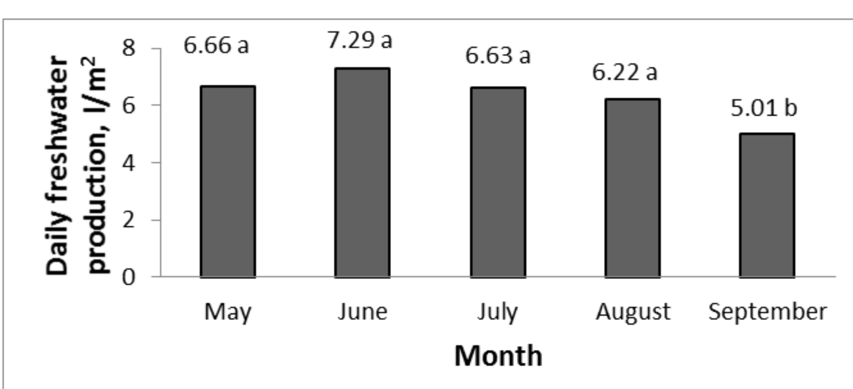


Figure (5) Monthly freshwater productivity of solar desalination unit by months

Means marked by the same letters are not significantly different at the 0.05 level.

Figure 6 shows the effect of pipe material and diameter on the freshwater production rate. Compared to the plastic pipes the fresh water production rate increased by 98% when metallic pipes were used. The metallic pipe with a diameter of 1"produced about 9.46 $l/m^2/d$ while the plastic pipe with a diameter of 1"produced about 4.76 $l/m^2/d$. This indicates that there is a significant difference in the freshwater production rate due to the pipe material. The difference in production rate could be caused by the thermal conductivity difference between the plastic pipe (PVC), which has a thermal conductivity of 0.19 W/(mK), and the steel pipe, which has a about 54 W/(mK) thermal conductivity (John & Ronald, 2010). The higher thermal conductivity of the steel pipe allows it to transfer heat to the surrounding soil more effectively, enabling faster cooling.

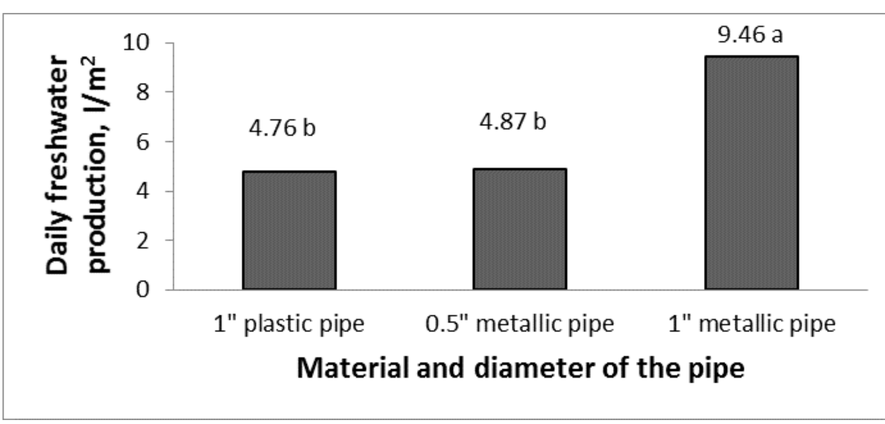


Figure (6) The effect of the pipes material and diameter on their freshwater production rate. Means marked by the same letters are not significantly different at the 0.05 level.

The metallic pipe with a 1" diameter produced significantly more freshwater compared to the pipe with a 0.5" diameter. It produced 9.46 $l/m^2/d$ compared to 4.87 $l/m^2/d$ for the 0.5" diameter pipe. This is because the larger diameter increases the pipe's ability to cool more rapidly. Compared to the reference case the freshwater production rate increased by about 136% when the 1" diameter metallic pipe was used.

Figure 7 shows a linear proportional relationship between the length of the pipe and the condensation rate due to larger heat transfer/condensation area. It produces more freshwater when there is a sufficient amount of vapor available. The condensation rate in longer pipes cannot be predicted because the humid air becomes colder and drier while passing through the pipe, thus negatively affecting the freshwater production rate (Lindblom & Nordell, 2006). Because the pipes used in this study are not very long, there is a need for additional studies focusing on longer pipes and their effects on condensation rate.

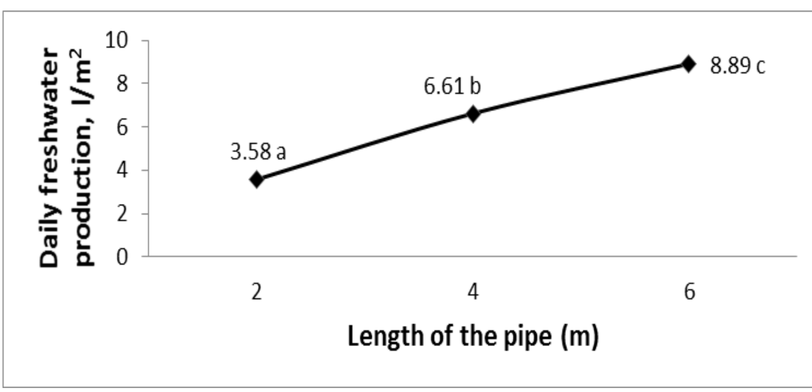


Figure (7) The effect of the pipe length on its freshwater production rate.

Means marked by the same letters are not significantly different at the 0.05 level.

The pipe with a 2m length produced freshwater at a rate of about 3.58 $l/m^2/d$. The production rate for the 4 m length of pipe was about 6.61 $l/m^2/d$, while the rate for the 6 m long pipe was about 8.89 $l/m^2/d$. These levels of freshwater production rates were considered significant improvements. Compared to the reference case of 4 $l/m^2/d$, the freshwater production rate increased by about 65% and 122% for the 4 m and 6 m pipes, respectively.

Figure 8 shows the effect of the pipe depth on freshwater production rate. When the pipe was buried at 5 cm, 10 cm, and 15 cm, the freshwater production rates were 5.91 $l/m^2/d$, 6.39 $l/m^2/d$, and 6.79 $l/m^2/d$, respectively.

The figure shows a significant increase in production rate when the pipe was buried at a depth of 15 cm. Compared to the reference case, the freshwater production rate increased about 59% and 69% for buried depths of 10 cm and 15 cm, respectively. Referring to Tromp-van Meerveld and McDonnell [30], this is because the soil near the surface dries faster than the deeper soil, which results in less soil thermal conductivity and a decrease in the pipe condensation rate.

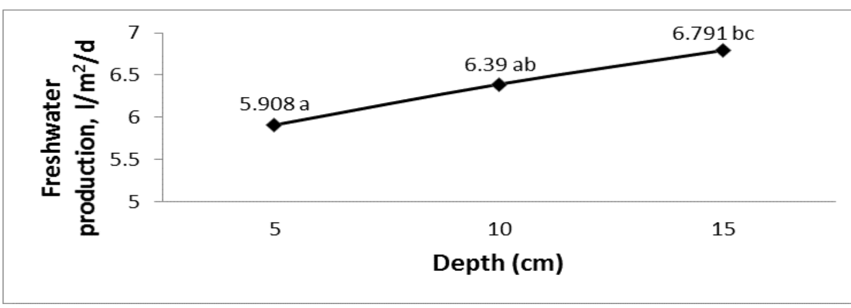


Figure (8) The effect of the pipe depth inside the soil on its freshwater production rate.

Means marked by the same letters are not significantly different at the 0.05 level.

Condensation pipes efficiency

As shown in Figure 9, when the soil moisture around the condensation pipes was 10%, the freshwater production rate was 3.46 $l/m^2/d$, but by increasing the soil moisture to 20% the freshwater production rate increased to 5.02 $l/m^2/d$. A significant increase in the freshwater production rate occurred when the soil moisture around the condensation pipes was 30%. The production rate for the 30%moisture level was 6.16 $l/m^2/d$, which was an increase of about 54% compared to the reference case.

The main reason for this could be due to an increase in the soil thermal conductivity (Nidal, & Randall, 2000, Venkat, Jackson & Zehrfuhs, 2003).The water in the soil enabled a quicker removal of heat, which results in an increase in temperature difference between the soil and the condensation pipes, thus improving the pipe condensation rate.

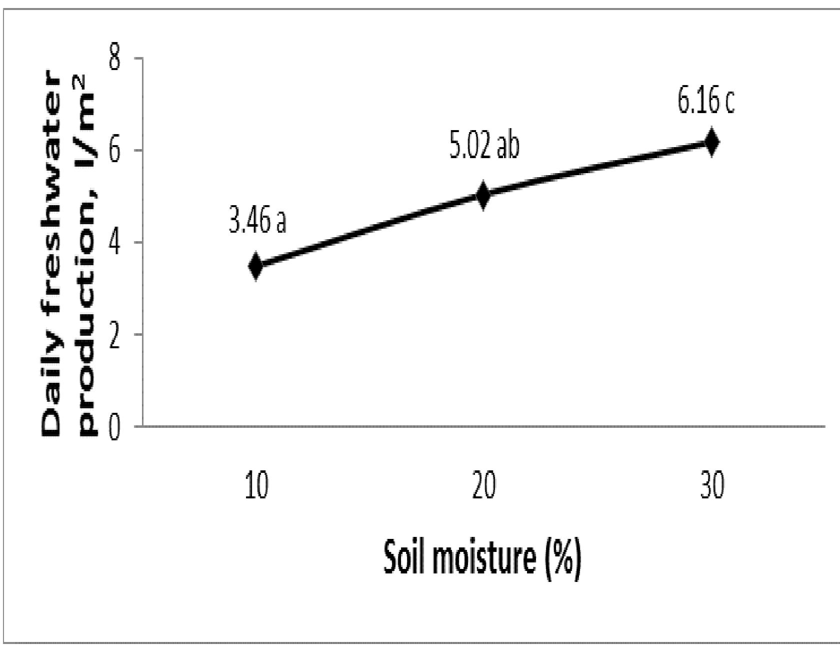


Figure (9) Effect of soil moisture on the pipe freshwater production rate

Means marked by the same letters are not significantly different at the 0.05 level.

Conclusion

The use of buried metallic pipes as condensers instead of the traditional solar still condensers led to an increase in freshwater production rates up to 136%. This shows the superiority of the solar desalination system used in this study over the conventional solar still.

The solar desalination system produced more freshwater than the conventional basin type solar still when the length, diameter, and depth of the pipe were increased. The improved production was due to the greater efficiency of the buried condensation pipes.

The metallic pipes produced more freshwater compared to the plastic pipes even when they had the same condensation area. Compared to the plastic pipes, the fresh water production rate increased by 98% when metallic pipes were used.

Seasonality also affects the freshwater production rates due to the variability in solar radiation intensity and the number of sunny hours per day.

Increasing soil moisture around buried pipes led to efficiency improvements in the buried condensation pipes and was a good way to condense more freshwater on the inner surface of the pipes. This effect was because water in the soil helped to transfer heat from the pipes to the surrounding soil, leading to more rapid cooling of the pipes. Compared to the conventional still, freshwater production rate increased about 54% when the soil moisture was 30%.

Acknowledgment

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Effect of NaCl Saline Irrigation Water on Soil Salinity

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Abstract

Water scarcity and soil salinization are the two main common problems that affect the agricultural production in Jordan Valley, which is considered the main agricultural region in Jordan, where most areas are irrigated with saline irrigation water, particularly in the center and south region of the valley. This study was conducted to evaluate the impact of NaCl irrigation water on soil salinity in a short-term experiment. Durum wheat was planted in a field with nearly half dunum area in the central region of the valley on 29th of December 2017 and harvested on the second of April 2018. Three salinity levels (S) (S1 2 (the control), S2 4, and S3 8 dS/m) with three irrigation amounts (R) of readily available water (RAW) (R1 120%RAW (control), R2 100%RAW, and R3 70% RAW) were used in the field experiment. Calcium, magnesium, and sodium concentration were measured once before planting and once after harvesting, soil electrical conductivity of saturated paste extract (ECe) and pH were measured every three weeks during the growing season. The results showed that the soil salinity in terms of (ECe) has increased gradually during the growing season, the final ECe has increased from an average of 0.96 ± 0.02 dS/m in the control to an average of 7.91 ± 0.48 dS/m in the most stressed treatment (S3R3) at 10 cm depth of the study area. Sodium adsorption ratio (SAR) has increased from 0.83 ± 0.03 in the control to 21.87 ± 2.41 in the most stressed treatment (S3R3), calcium, magnesium, and pH has decreased slightly when compared with the control.

Keywords: Jordan Valley, saline-sodic irrigation water, soil salinity and sodicity.

*قسم الأراضي والمياه والبيئة، كلية الزراعة، الجامعة الأردنية، الأردن.

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أثر استخدام مياه الري القلوية على ملوحة التربة

لمـــى حمدي

أيمن ســليمان

ملخص

تعد مشكلة توفر المياه و ملوحة التربة من أكثر المشاكل شيوعا في الأردن خاصة منطقة وادي الأردن الذي يعد عصب الأردن الزراعي، حيث تستخدم مياه مالحة نسبياً في الري خاصة في وسط وجنوب وادي الأردن، هذه الدراسة نفذت بهدف تقييم التغيرات في الملوحة لتربة حقل بمساحة نصف دونم تقريبا تقع في منطقة الأغوار الوسطى في وادي الأردن عند ري التربة بمياه مالحة نسبياً باستخدام كلوريد الصوديوم لمدة موسم واحد من زراعة القمح الصلب، ثلاثة مستويات من الملوحة مع ثلاثة مستويات من كمية مياه الري تم استخدامها في البحث، مستويات الملوحة كانت (2،4،8 ديسمينز/م) أما مستويات الري كانت (70%، 100%، 120%) من السعة الحقلية، تم قياس الملوحة ودرجة الحموضة كل ثلاثة أسابيع خلال الموسم، أما تراكيز بعض العناصر كالصوديوم والكالسيوم والمغنيسيوم فتم قياسها مرتين واحدة قبل الزراعة و الثانية بعد الحصاد، أظهرت الدراسة زيادة في الملوحة كمية الصوديوم عند معامل الري الأكثر ملوحة والأقل كمية ري، كما أثبتت الدراسة أن نوعية مياه الري الرديئة قد تؤدي لتراجع في خصائص التربة الكيميائية حتى لو تم استخدامها لموسم واحد فقط في منطقة غور الأردن.

1. Introduction

The process of increasing salt content in the soil to a limit that decreases crop productivity, causes environmental damage and lowers its economic value is known as soil salinization (Machado & Serralheiro, 2017). In irrigated areas, the formation of salt-affected soils is the most important process of land degradation. The extent to which salts accumulate in the soils is mainly related to irrigation water quality, type of irrigation system, different management practices, depth of groundwater if available, and the presence of drainage system (Läuchli & Grattan, 2007). Approximately 20% of cultivated land in the world, and 33% of irrigated land are salt-affected and currently are under degradation (Shrivastava and Kumar, 2014).

Soil salinity changes considerably with time and space because salinization results from both primary (natural) occurrence and secondary human-induced behaviour (Ammari et al., 2013). The primary cause comes from parent soil material, salt deposits, insufficient precipitation and other climate conditions that limit leaching ions from soil profile. Salinization is more frequent in arid and semi-arid regions where the high rate of water evaporation extremely exceeds precipitation rate, as it facilitates salts to accumulate, especially in the soil surface (Ekmekci et al., 2005). The secondary cause results from human activities, in particular inadequate irrigation practices and using low quality of irrigation water (Webber et al. 2010). In regions that suffer from water scarcity, treated wastewater is used as an alternative source of irrigation water. The use of low-quality water may lead to the accumulation of salts in the soil, since the leaching fraction is reduced and the salts in the irrigation water are not leached enough. Accumulation of salts also can occur as a result of prolonged use of fertilisers.

Soil texture also influences soil salinization. High concentration of sodium ions in the soil causes soil dispersion which adversely affects soil physical properties such as soil drainage and aeration. Many of the countries in the Middle East have salinity and drought problems that affect their agricultural production such as Jordan, Syria and Lebanon. Jordan is considered among the most water stressed countries, and expected to have a long-term water crises (Hadadin et al., 2010). Agricultural sector in Jordan has the highest water consumption ratio that is used as irrigation water. More than 60% of Jordan agricultural products are grown in the Jordan Valley. The valley exhibits a very unique climate that allows growing crops in the winter season, mostly in the north of the Dead sea (AbuAisha, 2001), and it has a considerable contribution in national food requirements and international balance of payments in Jordan (Shammout et al., 2017).

Salinity of irrigated soils along the Jordan Valley is dramatically increasing since the natural floods are no longer available to wash the irrigated land and leach salts. In addition, high evaporative conditions, the lack of adequate drainage system and insufficient amount of rainfall for sufficient leaching contribute to additional salt accumulation (Miyamoto et al. 2005). The highest soil sodium content and Sodium Adsorption Ratio are found in the central region of the valley. About 75% of the top-soils are saline in the central valley because 96% of the farms in the valley use drip irrigation which causes a further accumulation of salts especially at the top soil layer as drip irrigation usually uses limited amount of water (Al-Zu'bi & Al-Kharabsheh, 2003). Using low irrigation water quality is common in the central valley and showed a pronounced increase in soil salinity at the central region from 2007 to 2013 ranged from 51%-63% (Ammari et al., 2013).

Many studies have been conducted to investigate the effect of irrigation water on soil quality, that include different aspects, either by comparing some soil quality parameters before and after irrigation, or by studying the difference between irrigated and non-irrigated fields. A four years study was conducted in Bari, Italy did not show any significant effect of saline and sodic irrigation water on soil chemical and physical properties when leaching requirement is considered. (Rietz & Hayness, 2003) indicated that a small increase in soil salinity has a high detrimental effect on microbial community. As demonstrated by numerous researchers a deterioration in soil quality would occur when soil is irrigated frequently with saline and sodic water, it will contain large amounts of sodium and salts (Thompson, 1991; Amézketa 1999; Tedeschi & Dell’Aquila 2005; Al-Zu’bi Y 2007; Huang et al., 2011; Askri et al., 2014).

In Jordan, the threat of water scarcity and soil salinization is expected to increase in the near future, thus more studies are needed to help farmers and decision makers to choose the best management practices. The objective of this study was to evaluate the impact of NaCl saline irrigation water on soil salinity during one growing season of durum wheat in the central Jordan Valley.

Materials and methods:

The experiment was conducted at the Agricultural Research Station in the central Jordan Valley (Damea) (32.08N, 35.58E), with a height of 218 below sea level (Fig. 1). Soil salinity has shown a pronounced increase from 2007 to 2013in this area ranged from 51%-63% (Al-Rjoub & Al-Samarrai, 2006). The soil type is Entisol with a fine loamy sand texture. The soil depth in the study area was 1.5 m with no drainage system. The experimental design was split plot randomised complete block design where three levels of salinity (S1 (2 dS/m), S2 (4 dS/m) and S3 (8 dS/m)) with three levels of water supply (R1 (120 % of RAW), R2 (100 % of RAW) and R3 (70 % of RAW)) based on Readily Available Water (RAW). RAW is the soil moisture held between field capacity and a nominated refill point for unrestricted growth, at which water can be easily absorbed by plant from the soil.

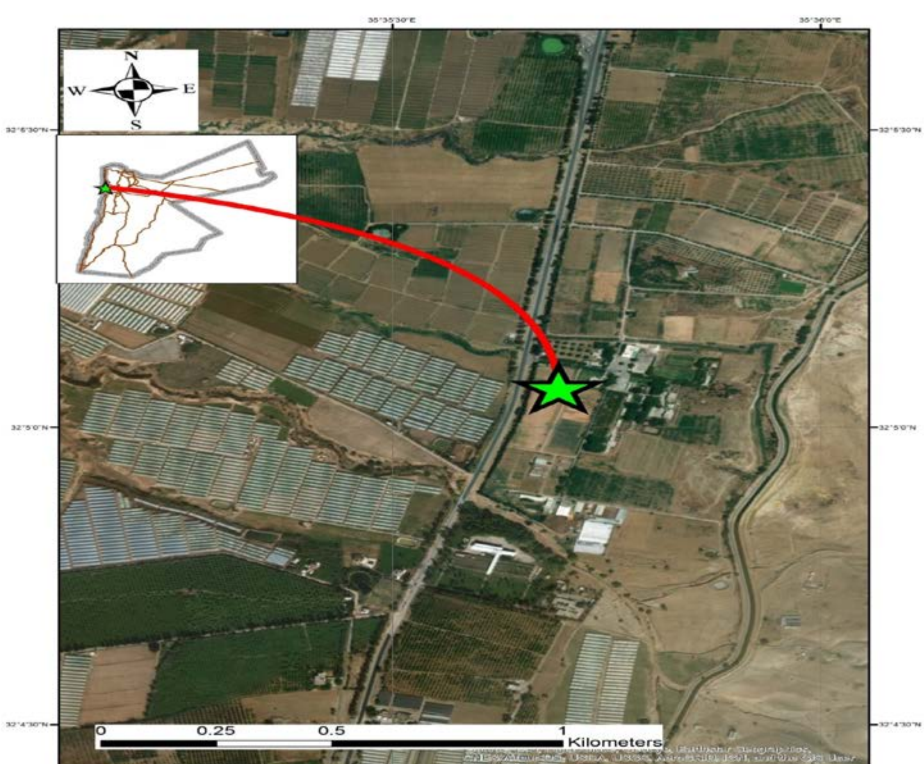


Figure 1. Map of the study area

Um Qais durum wheat cultivar was planted on 29/12/2017 using drip irrigation system. Each plot has an area of 9 m^2, the area was divided into four blocks, in each block a factorial combinations of the two factors: three salinity levels with three water amounts levels were made to form the nine treatments (S1R1, S1R2, S1R3, S2R1, S2R2, S2R3, S3R1, S3R2 and S3R3) in one block (Fig. 2). In this paper those nine treatments are given the letters (A, B, C, D, E, F, G, .H, and I), respectively. Each treatment was replicated four times with a total number of 36 plots (3x3m) in an area of 456.5 m^2.

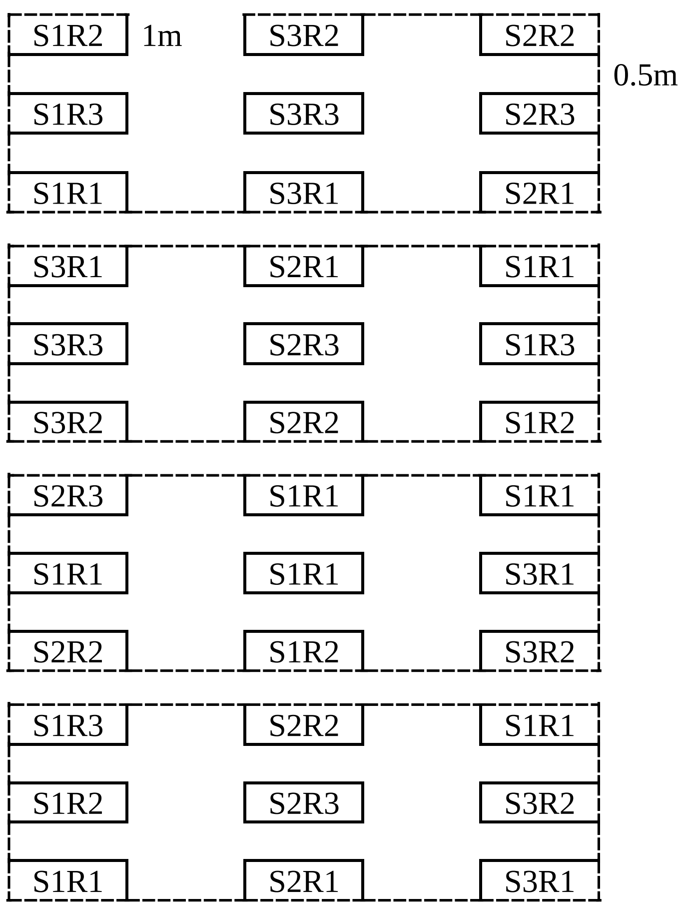


Figure 2: Field experiment layout

The RAW was applied when the measured soil moisture reached the critical soil moisture which is defined as the fraction of total available soil water between field capacity and wilting point that is readily available for crop transpiration. The management allowable depletion (MAD) was assumed to be 0.5 based on Allen et al. recommendation for durum wheat (1998). RAW was calculated using the following formula:

$$RAW = MAD\ (FC - PWP)z \qquad (1)$$

Where (FC) is field capacity, (PWP) is permanent wilting point, and z is root depth in mm. When soil water content reaches the critical level then irrigation water should be applied to reach the field capacity. The critical soil water content can be found as follows:

$$The\ Critical\ soil\ moisture = FC - MAD(FC - PWP) \qquad (2)$$

The irrigation scheduling for the nine treatments of field experiment is illustrated in Table 1, regarding that the rainfall during the growing season was 77 mm and the average temperature was nearly 23ºC.

Table 1. Irrigation scheduling for the field experiment.

Date **R3 (70 %)**	**R1 (120 %)**	**R2 (100 %)**	
15-Feb	70	57	40
03-Mar	70	57	40
14-Mar	70	57	40
24-Mar	70	57	40
01-Apr	70	57	40
Total (mm)	350	285	200

Soil chemical and physical properties were first determined on 20/12/ 2017 after dividing the area into four blocks. Samples for initial conditions were taken once at two depths (10 and 30 cm) from each block. Soil texture was measured using the pipette method (Gardner, 1965). The bulk density was measured using the core method (Blake, 1965). The field capacity and permanent welting point were determined using the ceramic plate method (Gardner, 1965).

Soil soluble potassium and sodium were measured by flame photometer (Jenway Research PFP7/C). The cation exchange capacity was determined by sodium acetate method (Chapman, 1965). Other ions (chloride, calcium, magnesium and bicarbonate) were measured by titration according to the methods illustrated by (Rhoades et al., 1999). Phosphorus was determined by Olsen method (Olsen, 1965), total nitrogen by Kjeldahl method (Bremner, 1965). It was found that the electrical conductivity of the saturated soil extract (ECe) and pH are the two valuable measures to assess soil chemical conditions (Smith and Doran, 1996), therefore soil salinity and pH were measured frequently by taking samples from the two central blocks, nine locations were determined for the soil samples to represent the nine plots of each block, the total locations number was eighteen, four depths were taken from each location (10,30,50 and 70 cm) every three weeks during the growing season of the durum wheat, the method used to determine soil salinity was the saturated soil extract (Rhoades et al., 1999).
A pH and EC meters of type BP3001 were used each time.

Sodium adsorption ratio (SAR) is a preferred measure of sodicity (Marchuk & Rengasamy, 2011), and known as a good index of structural stability (Oliver et al., 2013). It is defined as the ratio between the amount of sodium ions in soil solution considering its dispersion effect with the amount of calcium and magnesium ions considering their flocculation effect on soil. Measurements were taken from the soil water extract and calculated as follows:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}} \quad (3)$$

Soil chemical and physical properties are shown in Table 2.

Table (2) Soil chemical and physical properties in the Jordan Valley experiments (initial conditions before planting). (CEC) is the cation exchange capacity of the soil.

a. Soil chemical properties	
Cl (ppm)	0.33 ± 0.05
Na (ppm)	41.98 ± 6.52
K (ppm)	54.55 ± 0.04
Ca (ppm)	120 ± 0.65
P (ppm)	42 ± 4.10
Mg (ppm)	105.6 ± 1.24
Organic C (%)	0.23 ± 0.01
N (%)	0.5 ± 0.05
CEC (cmol/kg)	18.6 ± 0.48
SAR	0.83 ± 0.02
ECe (dS/m)	4 ± 0.23
pH	8 ± 0.09
b. Soil Physical properties	
Clay (%)	16 ± 0.48
Sand (%)	73 ± 0.65
Silt (%)	10 ± 0.55
Field capacity (FC) (cm^3/cm^3)	0.186 ± 0.01
Permanent welting point (PWP) (cm^3/cm^3)	0.09 ± 0.01
Saturated water content(cm^3/cm^3)	0.38 ± 0.02
Bulk density (g/cm^3)	1.58 ± 0.11

Soil soluble amounts of magnesium, calcium and sodium were measured again at the end of the growing season with SAR, with ECe and pH to compare the soil initial and final chemical conditions. The durum wheat was harvested on 2/4/2018, the total amount of the applied irrigation water for the whole field experiment was 90.18 m^3 and was distributed as 37.8, 30.78 and 21.6 m^3 for R1, R2 and R3, respectively. 1.6 and 3.5 kg/m^3 NaCl was added to each tank for S2 and S3 treatments, respectively. The electrical conductivity was measured frequently before and after irrigation. The weight of NaCl was estimated in both experiments according to Rani and Sharma (2015) methods. Some chemical properties of the irrigation water are shown in Table 3.

Table (3) Some chemical properties of irrigation water for the treatments of field (a) and greenhouse experiment,

	Ca meq/l	Mg meq/l	Na meq/l	SAR	pH	EC_{iw} (dS/m)
(A, B, C)	6.52 ± 2.30	4.11 ± 0.48	12.03 ± 0.910	5.22± 0.050	7.81 ± 1.50	2.01 ± 0.32
(D, E, F)	5.35 ± 2.11	4.31 ± 0.47	71.29 ± 2.230	32.44 ± 1.13	7.79 ± 0.41	4.01 ± 0.64
(G, H, I)	5.33 ± 2.10	4.23 ± 0.47	162.95 ± 3.71	74.53 ± 3.10	7.77 ± 0.45	7.98 ± 1.52

ANOVA was calculated using the general linear model (GLM) procedure of the Statistical Analysis System (NCSS), version 12 (NCSS Statistical Software, Kaysville). Differences were considered significant at $\alpha = 0.05$. The analysis was used in the results was one-way ANOVA except for Table 5. Two-way ANOVA was used to study the interaction between salinity and deficit irrigation. The two samples t-test for unequal variances was used to determine the significant changes in the results with the control treatment $\alpha = 0.05$.

3. Results

The relationship between salinity levels and irrigation amounts is illustrated in Table 4. The relative high soil salinity was observed in R3 (70% RAW) for the three salinity treatments S1, S2 and S3. There was a significant increase of ECe in S1 (the control) from an average of 1.41 ± 0.15 dS/m when the irrigation level was R1 (120% RAW) to an average of 2.23 ± 0.30 dS/m (S1) when irrigation level was R3 (70% raw). The soil salinity in S2 treatments increased gradually from 2.18 ± 0.31 dS/m, then 2.9 ±0.36 dS/m to a statistically significant increase of 3.15 ±0.42 dS/m, in R1 (120% RAW), R2 (100% RAW) and R3 (70% RAW) respectively. The increase in soil salinity was most noticeable in S3, where the average soil salinity changed from 3.77 ± 0.54 dS/m, 4.41 ± 0.83 dS/m, and 4.52 ± 0.77 dS/m for R1, R2 and R3 respectively, although statistically there was insignificant among S3 when compared to the control of R1 (120%). The two samples t-test of unequal variances was used to compare the mean of the treatments with the mean of the control ($\alpha = 0.05$).

Table (4) The mean electrical conductivity of the three salinity levels in field (S1, S2 and S3) with respect to the three irrigation levels (R1, R2 and R3).†

Treatments	R1 120%	R2 100%	R3 70%
S1 (2 dS/m)	1.41 ± 0.15 (A)	1.58 ± 0.23 (B)	2.23 ± 0.30 (C)*
S2 (4 dS/m)	2.18 ± 0.31 (D)	2.9 ±0.36 (E)	3.15 ±0.42 (F)*
S3 (8 dS/m)	3.77 ± 0.54 (G)	4.41 ± 0.83 (H)	4.52 ± 0.77 (I)

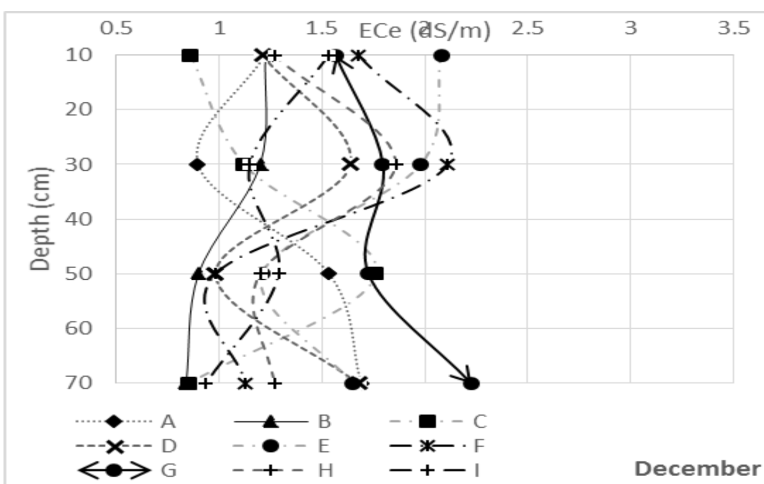
† The letter next to each value represents the treatment symbol in the field experiment. The star symbol * means that the treatment showed a significant result compared with the control using two samples t-test of unequal variances.

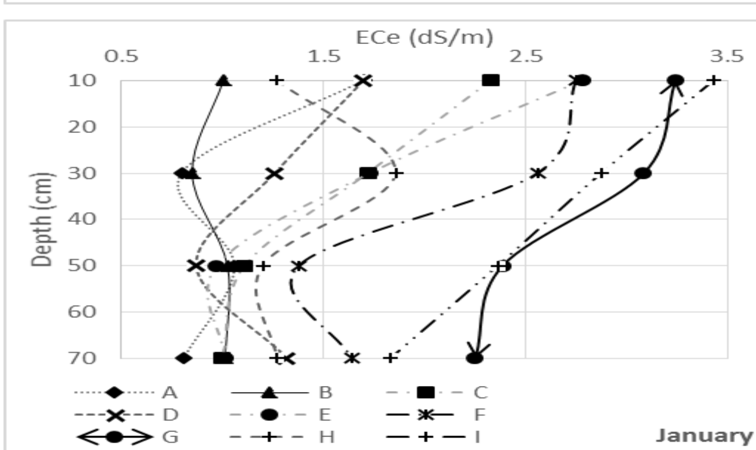
Analysis of variance (ANOVA) was calculated considering the two independent factors, salinity levels (S1, S2, and S3), and irrigation water treatments (R1, R2, and R3). The significance of the two factors on soil salinity are illustrated by Fisher test (F) and probability value (P). The irrigation water salinity (R) showed a significant impact on soil salinity while irrigation levels were insignificant, and the interaction between the two factors in the field experiment was weak (Table 5).

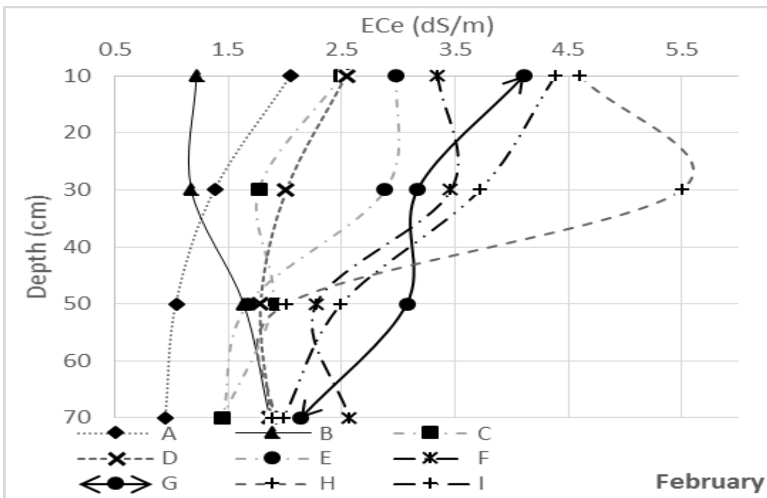
Table (5) Two-way ANOVA considering the three salinity levels with the three irrigation levels in field experiment

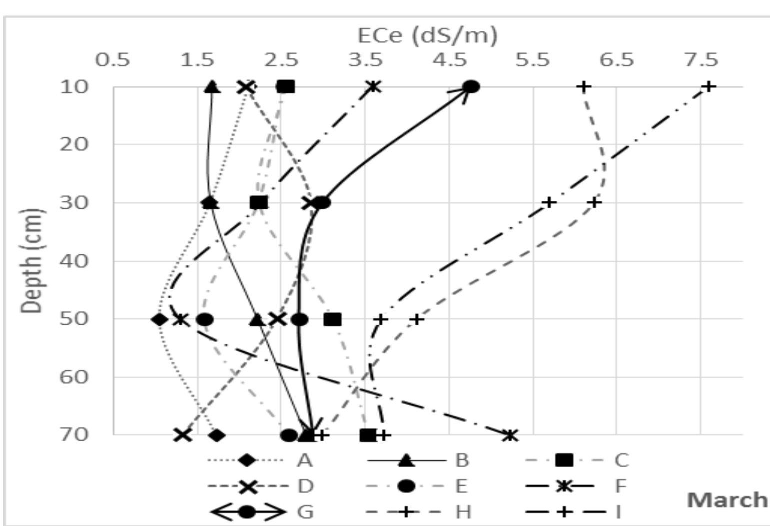
Source of Variation	SS	df	MS	F	P-value	F crit
Sample	94.59	2	47.296954	19.82709	9.8E-08	3.109311
Columns	10.92	2	5.4590419	2.288454	0.107945	3.109311
Interaction	1.21	4	0.3031328	0.127075	0.972231	2.484441
Within	193.22	81	2.385471			

The changes in soil salinity in the four depths (10, 30, 50, and 70 cm) each month during the growing season for the nine treatments are illustrated in Fig. 3. In December, the soil salinity values showed an insignificant changes within the different layers and between the treatments using one way ANOVA analysis the p-value was more than 0.05. On 25/12/2017, soil salinity at 10 cm for A (the control) was very close to other treatments with values of 1.22, 0.89, 1.53 and 1.69 dS/m for the depths 10, 30, 50, and 70 cm, respectively. In January, all the values were less than 3 dS/m except in (G) treatment, ECe was 3.24 and 3.1 dS/m for the depths 10 and 30 cm, respectively, although the ANOVA analysis showed that the significant changes within the four layers in soil salinity starts in January ($P<0.05$). In February, the increase in soil salinity was obvious at two depths (10 and 30 cm) for treatments F, G, H and I. In March, there was a dramatic increase in soil salinity for the most stressed treatments (H) and (I) near the surface, ECe was 3.59, 4.76, 6.1, and 7.6 dS/m at 10 cm for F, G, H and I treatments, respectively. The deepest layers (50 and 70 cm) didn't record any values higher than 4 dS/m except the treatment H, at which the ECe was 4.11 dS/m at 50 cm depth, ANOVA showed that in March the significant value was the highest with p = 0.00084, The accumulation of salts continued in April. The salinity concentrated in the first 40 cm depth, soil salinity was 6.49, 6.23, 7.65, and 7.9 dS/m for the treatments F, G, H, and I, respectively at 10 cm depth, ANOVA showed a significant difference in soil salinity between soil layers P-value = 0.01413. The control (A) in April didn't show any soil salinity higher than 2 dS/m in the four depths.






ECe (dS/m)
0.5
1.5
2.5
3.5
4.5
5.5
Depth (cm)
10
20
30
40
50
60
70
A
B
C
D
E
F
G
H
I
February


ECe (dS/m)
0.5
1.5
2.5
3.5
4.5
5.5
6.5
7.5
Depth (cm)
10
20
30
40
50
60
70
A
B
C
D
E
F
G
H
I
March

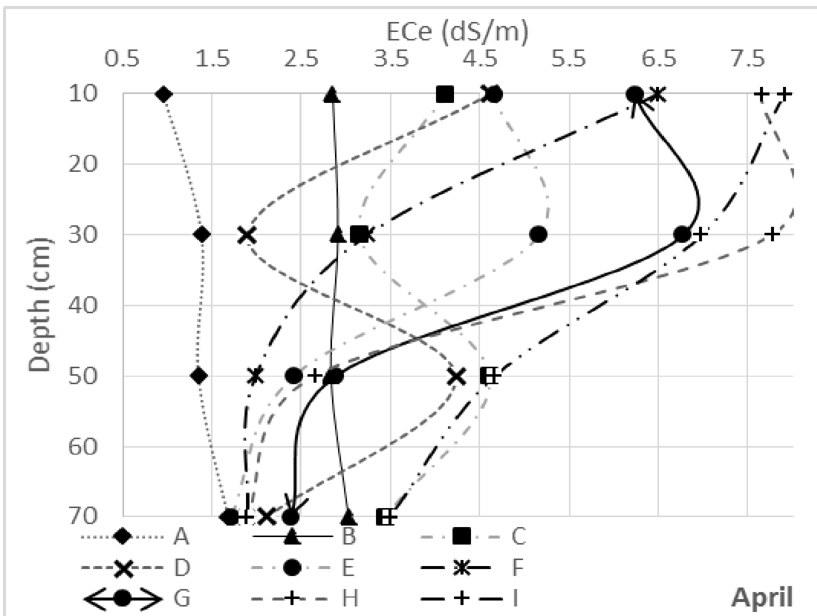


Figure 3. The changes in soil salinity at each month of the growing season, considering the depths (10, 30, 50, and 70 cm) for the nine treatments of field experiment (A, B, C, D, E, F, G, H, and I).

The final soil chemical properties were taken on 7/4/2018 (Table 6). The concentration of magnesium and calcium ions decreased gradually from the control (A) with 6.1 ± 0.76 meq/l to 5.55 ± 0.12 in (I), using ANOVA showed that both has significant changes between the nine treatments (P-value < 0.05). The significance difference in calcium was in all treatments compared to the control when using two samples t-test of unequal variances (α = 0.05). The sodium ions concentration increased considerably among the nine treatments. It was 2.05 ± 0.05, 10.3 ± 0.31 and 12.22 ± 0.78 meq/l for A, B and C respectively, while it was 10.23 ± 0.73, 40.9 ± 2.73 and 51.53 ± 5.21 meq/l for G, H and I treatments, respectively, the P-value in ANOVA was very small for sodium concentration (P-value = 5.43017E-27), the highly significant changes was also shown in SAR, with very small P- value (1.09407E-29) using one way ANOVA. SAR increased from 0.83 ± 0.03 in A (control) to 17.28 ± 1.82 and 21.87 ± 2.41 for treatments H and I, respectively. There was no significant change in pH, while the ECe changed significantly from 0.96 ± 0.02 dS/m at control (A) to 7.65 ± 0.28 and 7.91 ± 0.48 dS/m for treatments H and I, respectively.

Table (6) The final soil chemical properties in field (a) and greenhouse (b) experiments.

Treatment	Ca meq/l	Mg meq/l	Na meq/l	SAR	ECe	pH
A	6.1 ± 0.76	6.1 ± 0.75	2.05 ± 0.05	0.83 ± 0.03	0.96 ± 0.02	8.01 ± 0.03
B	6.25 ± 0.73*	6.25 ± 0.70	10.3 ± 0.31*	4.12 ± 0.03*	2.85 ± 0.03*	8.05 ± 0.03
C	6.34 ± 0.45*	5.98 ± 0.43	12.22 ± 0.78*	4.92 ± 0.12*	4.11 ± 0.03*	8.00 ± 0.01
D	5.51 ± 0.32*	5.4 ± 0.32*	14.21 ± 0.87*	6.08 ± 0.12*	4.61 ± .06*	7.89 ± 0.02
E	5.56 ± 0.37*	5.5 ± 0.31*	20.49 ± 1.20*	8.74 ± 0.75*	4.65 ± 0.04*	8.00 ± 0.01
F	5.6 ± 0.22*	5.6 ± 0.21*	11.36 ± 0.77*	4.80 ± 0.35 *	6.49 ± 0.05*	7.81 ± 0.05
G	5.59 ± 0.12*	5.57 ± 0.13*	10.23 ± 0.73*	4.33 ± 0.08*	6.23 ± 0.15*	7.89 ± 0.05
H	5.6 ± 0.11*	5.6 ± 0.12*	40.9 ± 2.73*	17.28 ± 1.82*	7.65 ± 0.28*	8.01 ± 0.02
I	5.55 ± 0.12*	5.54 ± 0.12*	51.53 ± 5.21*	21.87 ± 2.41*	7.91 ± 0.48*	7.86 ± 0.05

* The star symbol * means that the treatment showed a significant result compared with the control using two samples t-test of unequal variances.

4. Discussion

The accumulation of salts in the soil in this experiment may be explained by several reasons, such as low quality irrigation water, inadequate management practices and climate conditions, in addition of the insufficient amount of irrigation that reduces the ability of the soil to leach salts and causes further accumulation of salts. This could explain results of Table 4 where the accumulation of salts was significant in R3 treatments (the lowest irrigation amount).

According to the Two-way ANOVA (Table 5), three hypothesis can be discussed, the impact of salinity levels on soil salinity, the impact of irrigation water amounts on soil salinity, and the impact of the interaction between salinity levels and irrigation amounts on soil salinity. The results showed that the water salinity level has the highest impact on soil salinity, particularly when irrigated with 8 dS/m saline water, while irrigation water has insignificant effect, and the interaction between the two factors was insignificant too.

The accumulation of salts in the field during the growing season didn't exceed the average of 4.51 dS/m for the 80 cm depth, even in the most stressed treatment (I). This can be explained by the short growing season in the field due to the hot climate in Jordan Valley. Such a short growing season limited the effect of the irrigation water on salinizing the soil. Also, the type of soil texture affects the rate of salinization. Loamy sand, the soil texture of the study area has a high proportion of sand particles that do not allow for much accumulation of salts unlike clay particles (Singh & Chatrath, 2001).

The accumulation of salts was noticed to be near the surface. In the field, most of the layers with 50 and 70 cm depth stayed non-saline, this was mostly noticed in April. The climate condition at Jordan Valley is expected to play the major role in this, where the rainfall was less than 80 mm for the whole season. The temperature started a rapid increase from the mid of February, the salt is expected to be near the surface as the rate of evaporation exceeds the rate of rainfall. According to Fig. 3 the difference between the treatments in soil salinity started to be obvious in March, and recorded as statistically significant from February. This can be explained by two reasons, the frequent irrigation in March and the high evaporative condition due to the increase in temperature, this was in a good agreement with (Bajwa et al., 1992), (Hamam & Negim 2014), & (Bedbabis et al., 2014).

Even though the experiment was conducted in a short term for one growing season of durum wheat but there was a deterioration in the soil chemical properties, sodium concentration, SAR, and ECe increased significantly, while the magnesium and calcium concentration decreased. There was no significant change in pH. The significant decrease in calcium and magnesium was noticed at the end of the growing season mainly because of the plant uptake and the effect of sodium accumulation (Munns, 2002). The high increase in sodium concentration in soil from the applied irrigation water increased the SAR for (H and I) treatments to be above 13, the high SAR indicated that the soil became sodic according to the increase of sodium in relative with calcium and magnesium in soil. The soil salinity was above 4 dS/m in H and I treatments, accordingly a saline sodic soil was formed in the most stressed treatments H and I after one wheat growing season of NaCl irrigation water in Jordan Valley. The increase in soil salinity and sodicity when a sodic irrigation water is used was also observed by Ashraf et al. (2017) in a short-term experiment.

5. Conclusion

Saline irrigation water concentration has a great effect on soil salinity and sodicity. Also, the unique climate condition of Jordan Valley is assumed to play an essential role in affecting the level of deterioration of soil salinity and sodicity when irrigated with NaCl saline water even for one season. A 70% RAW (R3) can still be suitable to be used with a moderate saline irrigation water as this treatment did not increase soil salinity and pH significantly during the growing season for S1 and S2. The impact of saline and sodic irrigation water on soil salinity should be conducted in other locations at the valley to establish a long- and short-term management plan to limit the increase in salt affected soil in Jordan, and keep sufficient agricultural productivity for the valley in the future.

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Effect of stratification and sulphuric acid scarification for breaking seed dormancy on different genotypes of Arecaceae family; Phoenix dactylifera and Washingtonia robusta.

Muwaya Alasasfa*

Abstract

This study aims at examining the effect of stratification and sulphuric acid scarification treatments on Medjool, wild date palm (Phoenix dactylifera) and Washingtonia robusta seeds. The results showed that the highest germination percentage was obtained from wild date palm genotype. The results also showed that the highest plumule length was obtained from Washingtonia robusta seed after 30 days of planting. Furthermore, the study showed that the employment of different pre sowing treatments induced significant increase in germination percentage, radicle length and plumule length of seeds after 20 and 30 days of planting. The highest germination percentage was reported when the seeds were immersed in cold water(8 °C) for 12 hours followed by hot water (80 °C) for 8 hours. Additionally, it was found that the type of water source during germination process (whether tap or distilled water) had no significant effect on germination percentage or radicle and plumule lengths.

Keywords: Germination percentage; Radicle length; Plumule length; Scarification; Stratification.

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تأثير معاملات التنضيد والتخديش باستخدام حمض الكبريتيك لكسر سكون البذور على طرز جينية مختلفة من العائلة النخيلية

Phoenix dactylifera and Washingtonia robusta

معاوية عايد العساسفة

ملخص

تهدف هذه الدراسة إلى دراسة تأثير التنضيد والتخديش باستخدام حمض الكبريتيك على طرز جينية مختلفة من العائلة النخيلية مثل: صنف المجهول ونخيل التمر البري Phoenix dactylifera وبذور Washingtonust robusta. أظهرت النتائج أن أعلى نسبة إنبات كانت للطرز الجينية من نخيل التمر البري. وأظهرت النتائج أيضًا أنه تم الحصول على أعلى طول رويشة في بذور Washingtonia robusta بعد 30 يومًا من الزراعة. علاوة على ذلك ، أوضحت الدراسة أن استخدام المعاملات المختلفة قبل الزراعة لكسر السكون تساهم في زيادة كبيرة في نسبة الإنبات ، وفي أطوال الرويشة والجذير بعد 20 و 30 يومًا من الزراعة.ومن الجدير بالذكر أن أعلى نسبة إنبات للطرز الجينية المختلفة كانت عند غمر البذور في الماء البارد (8 درجات مئوية) لمدة 12 ساعة متبوعة بالماء الساخن (80 درجة مئوية) لمدة 8 ساعات. بالإضافة إلى ذلك ، لم يكن لمصدر المياه أثناء عملية الإنبات (سواء كان من الصنبور أو باستخدام الماء المقطر) أي تأثير معنوي على نسبة الإنبات أو أطوال الرويشة والجذير.

1. Introduction

The Arecaceae (Palmae) family varies in propagation methods and each genus has at least one propagation method that is successful and effective (Zaid & De Wet, 2002). For example, date palm (Phoenix dacylifera L.) could be propagated by different methods including seeds, offshoots or tissue culture, while Washingtonia genus is propagate only by seeds. Trees propagated by seeds have high genetic variation and have a longer juvenile stage than those propagated by other methods (Zaid & De Wet, 2002). It was also noticed that the seed propagation (sexual propagation) is not a preferred method of date palm propagation. However, it might be useful for breeding purposes, ornamental and feeding. Seed propagation is also considered the easiest and fastest method for propagation. Planting date seeds is the most economical way to select clones that have desirable characters such as pest and salt tolerance (Meerow,1990).

Dormancy is a condition where seeds will not germinate even when the environmental conditions such as water availability and temperature are favorable for germination. It is determined by genetics, environmental influence and plant hormones (Mayer & Poljakoff-Mayber, 1989). In physiological dormancy, the tissues surrounding the embryo can affect germination by inhibiting water uptake, providing mechanical resistance to embryo expansion and radicle emergence, limiting oxygen gas exchange of the embryo, or by regulating embryo inhibitor supply. However, it is an efficient mechanism to help seeds' survival and spread. It is also evident that physical dormancy is caused by impermeability of water and gas to embryo by the cell layers of seed coat (Baskin & Baskin, 2004). Generally, germination of untreated palm seeds with hard, solid and inflexible seed coat will be slow (Meerow, 1990).

Germination percentage can be improved through some pre-sowing techniques (Azad et al., 2006a, 2006b, 2011). Many pre-sowing treatments of seed germination were tested to break seed dormancy and increase the germination rate. Scarification of seed coat may overcome seed dormancy (Catalan & Macchiavelli, 1991). Acid treatment and hot water treatment (Mafatlal & Nataraj, 2015; Airi et al., 2009; Kobmoo and Hellum, 1984) are used to break seed dormancy as well.

Many studies have shown that weakening the seed coat either by mechanical, chemical scarification or soaking in cold/hot water might enhance the permeability of water and gases to the embryo (Vleeshouwers et al., 1995). Okunlola et al., (2011) noticed that the cold/hot water treatment of some forest trees seeds (Parkia biglobosa) increases germination rate and seedling height. Meerow (1990), on the other hand, argued that pre-sowing treatment of palm seeds by immersing the seeds in water can also improve the germination percentage. He also noticed that the water temperature (30–35°C) can play a significant role in increasing seed germination percentages. (Habila et al., 2016) indicated that the boiling water had the most effective method of breaking date palm seed dormancy. (Muhammad et al., 2017) & (Kheloufi et al., 2017) showed that acid treatments had the highest effect on germination rate and seedling growth of P. dactylifera and three other species of Acacia respectively. A significantly high germination percentage for Grewia damine Gaertn seeds was recorded in the treatment of scarification with a sand paper (De Mel & Yakandawala, 2016).

Phoenix dactylifera and Washingtonia. sp are important trees species for agroforestry, social forestry, home garden, rapid growth and tolerance for infertile and dry seasons. Those special traits make them very useful species for rehabilitation of degraded lands. Therefore, these species are considered a fertile ground for researchers especially when it comes to studying the appropriate seed germination techniques.

The current study examined the effect of pretreatment methods of breaking seed dormancy on two genera of Arecaceae (Phoenix dactylifera and Washingtonia sp). Medjool cultivar, wild date palm from Phoenix dactylifera and Washingtonia robusta (from Washingtonia genus) are wild date palm that distributed in dry Middle Eastern regions as well as north Arabian deserts. It is closely related to the cultivated date palms. Moreover, it shows morphological similarities, climatic requirements and production of the basal suckers therefore botanists place it under P. dactylifera L. (Jaradat, 2011). It is characterized by having small fruits containing relatively little edible flesh and dark brown to dark grey bark. It also occurs in a dense stand that does not grow much more than cultivars in height and the leaves are roughly scarred (Alasasfa et al., 2015).

Only very scarce studies examined the breaking of seed dormancy of Arecaceae family in Jordan. The current study attempts to examine the effect of different dormancy breaking pretreatment on three genotypes: Wild date palm, Medjool and Washingtonia robusta. The study also attempts to investigate the effect of such breaking pretreatment on the seed response, seed germination and early seeding growth of the three genotypes under investigation.

2. Materials and Methods

2.1. Experimental site

The experiment was carried out in the Department of Plant production, Faculty of agriculture, Mutah University, Jordan.

2.2. Source of materials

Three genotypes were comprised in this study (wild, Medjool and Washingtonia genus). The wild date palm seeds were collected from Wadi Ibn Hammad, Karak governorate, Jordan; Medjool seeds were collected from Ghour Alsafi, Karak governorate, Jordan and Washingtonia seeds were collected from Faculty of Agriculture in Mutah University. The collected seeds were washed with fresh water three times to remove the remaining fruit pieces. The seeds were dried for 6 to 8 days in aerated and shaded area. Then, the seeds were kept in a dry place for ten days to reduce the moisture after collection. Only healthy dried seeds were used for the experiment (Figure 1). The seeds were exposed to seven pre-planting treatments and control, with two water sources for planting: tap water (W1) and distilled water (W2) for each treatment. The treatments used for seeds are given as follows:

2.3. Treatment keys

Treatment 1 (T1): Control; seeds were planted without any pre planting treatments.

Treatment 2 (T2): Immersion in normal water at room temperature (20–22°C) for 12 hours.

Treatment 3 (T3): Immersion in warm water (25–35°C) for 12 hours.

Treatment 4 (T4): Immersion in hot water (80°C) for 8 hours.

Treatment 5 (T5): Immersion in cold water (8°C) for 12 hours.

Treatment 6 (T6): Immersion in hot then in cold water (80 °C \ 8 °C) for 8 and 12 hour ss(respectively).

Treatment 7 (T7): Immersion in cold then in hot water (8 °C \ 80 °C) for 12 and 8 hours (respectively).

Treatment 8 (T8): Immersion in concentrated H2SO4 for 4 minutes.

2.4. Treatment application and planting of seeds

The germination test was conducted in December 2017 by sowing 256 seeds from each source on cotton in paper cups (12 Oz). The seeds were distributed in eight treatments. Each treatment had 32 seeds. Half of them were irrigated with tap water and the rest were irrigated with distilled water (two seeds in a paper cup with eight replications with the two source of watering, for eight treatments; 2*8*2*8). They were covered by poly bags. Poly bag paper cups were kept in growth chamber throughout the experiment at 27 °C under dark conditions. Measurements were recorded twice during the experiment (i.e. after 20 and 30 days of planting). Data were analyzed using variance test (ANOVA), SAS version 9.0 (Statistical analysis System) (2002) software. The means were separated with the least significant difference (LSD) for comparison of means, under 0.05 % probability level.

2.5. Data Collection and analysis

2.5.1. Germination percentage (%)

The germination percentage was calculated as the ratio of germinated seeds to the total number of seeds planted (Okunlola et al., 2011) at 20 and 30 days after planting (DAP).

$$\text{Germination percentage (\%)} = \frac{\text{Number of germinated seeds}}{\text{Number of planted seeds}} \times 100$$

2.5.2 Radicle and plumule length

The radicle and Plumule lengths of the seedling sampled were measured using measuring ruler.

Fig(1) Seed genotypes of Arecaceae family: A. Medjool seeds (P. dactylifera). B. Wild date palm seeds (P. dactylifera) and C. (W. robusta) seeds.

3. Results

3.1 Seed genotype effects

3.1.1 Seed germination

Seed germination started when radicle formed (Figure 2). Results showed that seed type has a key role in germination percentage either after 20 or 30 days of seeding.

Fig(2) The germination begins as soon as the radicle appears: A. Medjool date palm. B. Wild date palm and C. (W. robusta).

Results showed that the highest germination percentages (79.56% and 86.65 % after 20 and 30 days of seeding respectively) were obtained by wild date palm seed while the lowest percentages (23.12% and 26.25% after 20 and 30 day of planting, respectively) were obtained by Washingtonia seeds. With regards to ‘Medjool seeds’, the germination percentage were 59.29% and 65.62% after 20 and 30 days of planting. The percentage was not significant from wild date palm but significant from Washingtonia seeds as shown in Table (1). The germination of seeds treated with immersion in cold water for 12 h and hot water for 8 h (87.5%) was significantly compared to the control.

Table (1) Effect of seed genotypes on germination percentage, radicle length and plumule length after 20 and 30 days of planting.

	Germination percentage		**Radicle length (cm)**		**Plumule length (cm)**	
	20 days	**30 days**	**20 days**	**30 days**	**20 days**	**30 days**
Wild date palm	79.56 a	86.65 a	2.59 a	5.1 a	0 b	0.37 b
Medjool	59.29 a	65.62 a	1.23 b	3.08 b	0 b	0.09 b
Washingtonia sp.	23.12 b	26.25 b	0.84 b	1.18 b	0.7 a	1.25 a

*** Values within same column that have different letters are significantly different at 0.05 level of probability according to LSD.**

3.1.2. Radicle length

Results in Table (1) clearly show that radicle length was significantly affected by seed type. The highest radicle length was obtained from wild date palm (2.59 and 5.1cm after 20 and 30 days of planting, respectively) and the lowest one was reported from Washingtonia seeds. Results showed that radicle length had significant differences between wild date palm and other seeds. However, no significant differences were reported between Medjool and Washingtonia seeds as shown in Table (1).

3.1.3. Plumule length

Plumule length was also significantly affected by seed type as shown in Table (1). The highest plumule lengths (0.69 cm and 1.25 cm after 20 and 30 days of planting, respectively) were obtained by washingtonia seeds and the lowest one (0.09 cm) was obtained from Medjool seeds. The statistical analysis, however, showed that there was no significant difference in plumule length of ‘wild date palm and ‘Medjool’ seeds.

3.2. Treatment effects

3.2.1. Germination percentage

Germination started significantly earlier in all pretreatment compared to the control (T1). Seed treated with cold / hot water (T7) germinated significantly higher (87.5%) than that of T1 (0%) and T2 (51%). Germination percentage was also significantly higher (75%) in cold water (T5) after 30 days of planting than that of T1 (Table 2). Least significant differences showed significant difference on seed germination in T7 with control and immersion in water at room temperature (T2). Also, T5 has significant differences with T1, but there was no significant difference with T2, T3, T4, T6, T7 and T8 (See Table 2).

3.2.2. Radicle length

Results showed that there were significant differences among the treatments related to radicle length after 20 and 30 days of planting (Table 2). The highest radicle length (6.33 cm) was obtained by hot temperature (T4). But the lowest radicle length (0.02 cm) was obtained by control treatment (T1).

3.2.3. Plumule length

The results in Table (2) clearly show that the plumule length was also affected by the pretreatments. The highest mean plumule length (1.92 cm) was obtained from hot temperature treatment (T4) after 30 days of planting.

The lowest mean length (0 cm) was obtained by T1, T2 and T3 pretreatments, which could be related to the delayed seeds germination process. There were significant differences in plumule length between (T4) treatment with T1, T2, T3, T5 and T8, while the other treatments have no significant differences among them.

Table (2) Effect of different pretreatments on germination percentage, radicle length and plumule length after 20 and 30 days of planting.

	Germination percentage		**Radicle length (cm)**		**Plumule length (cm)**	
Pretreatment	**20 days**	**30 days**	**20 days**	**30 days**	**20 days**	**30 days**
T1	0 c	10 c	0 d	0.02 d	0 b	0 b
T2	50.83 bc	55 bc	0.6 cd	2.26 cd	0 b	0 b
T3	54.2 ab	58.33 ab	0.07 d	1.72 cd	0 b	0 b
T4	74.17 a	74.17 ab	4.1 a	6.33 a	1.12 a	1.92 a
T5	61.11ab	75 ab	2.01 bc	4.39 abc	0 b	0.4 b
T6	70.83 ab	70.83 ab	1.82 bc	3.49 abc	0.25 b	0.75 ab
T7	87.5 a	87.5 a	2.92 ab	5.2 abc	0.42 ab	1.34 ab
T8	53.99 ab	59.51 ab	1.56 cd	3.12 bcd	0.22 b	0.57 b

* Values within same column that have different letters are significantly different at 0.05 level of probability according to LSD.

3.3. Water source effects

In all water sources, germination started after 20 days of planting (Table 3). LSD showed no significance difference ($P>0.05$) in germination.

Results in Table (3) indicated that water source has not effect on germination percentage, radicle length and plumule length. It is worth noting that high germination percentage (59.6 %, Table 3) was recorded in distilled water treatment after 30 days of planting.

Table (3) Effect of water source on germination percentage, radicle and plumule length after 20 and 30 days of planting.

	Germination percentage		**Radicle length (cm)**		**Plumule length (cm)**	
Water source	20 days	30 days	20 days	30 days	20 days	30 days
Tap water	52.65 a	59.42 a	1.64 a	3.13 a	0.15 a	0.55 a
Distilled water	55.33 a	59.6 a	1.47 a	3.11 a	0.29 a	0.58 a

* Values within same column that have different letters are significantly different at 0.05 level of probability according to LSD.

4. Discussion

The study showed differences in the response of palm seeds to the pretreatments of breaking dormancy. Despite the fact that wild, Medjool, and Washingtonia seeds responded positively to the pretreatments, the wild date seeds performed better. This may be due to adaptation to environmental conditions, high vitality embryo, and that the seed coat of wild date is thinner than its counterparts. The current results of the study are consistent with many other studies in the literature. For instance, the results reported in Kitzke (1958) study showed that the germination percentage of presoaking seed palm can be improved and therefore responded positively. However, this was not true for all species in the same pattern. Also, the current results are hand in hand with the results of Green et al., (2013). In his study, Green et. al. indicated that there were differences in germination percentage and period within six oil palm cultivars. This may be due to the genetic role in the process of breaking seed dormancy.

The results also indicated that Washingtonia seeds showed a greater ability to grow the plumule faster than Phoenix sp. I argue that the reason for this may be due to genetic makeup or to the small size of seeds compared to the others. I further argue that the increase in germination percentage, radicle and plumule length of palm seeds with different pretreatments could be attributed to the weakened seed coat. Consequently, the results were quite similar to those reported in Von Fintel et al., (2004). In this study, Fintel et al. investigated the effect of seed germination and breaking dormancy methods on wild date palm. It was reported that the pretreatment by soaking or acid scarification had no positively significant effect on wild dates while the application of boiling water was reported to be extremely negative for seed germination process. Kitzke (1958) reported that the duration of the presoak period on seeds of the same species could be varying. He has found that the concentrated H_2SO_4 for 4 minutes will record significantly high germination speed compared to control. Okunlola et al., (2011), however, reported that immersion of seeds of Parkia biglobosa in H_2SO_4 for 5 minutes could damage the embryo and lead to insufficient break dormancy.

In the present study, the influence of water source on seed germination, radicle and plumule length was also tested. The results showed that that there was no significant effect of water source on the study parameters during the experiment period. Perhaps different water sources could be important only in the advanced seedling stages because of the presence of salt water. This may be due to the fact that the need of seeds for nutrients during early germination stage is very little.

5. Conclusion

Presoaking treatments for “Phoenix dactylifera” and “Washingtonia robusta” are quite simple and inexpensive for the small-scale farmers and nurseries. In addition, seed dormancy can vary from species to species, stage of maturity of seed and degree of drought. Therefore, pretreatment should be adjusted accordingly. However, further research is needed to investigate the effect of nitric oxide, X-ray and other treatment of breaking seed dormancy in date palm planting.

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Assessment of Height Models Covering Jordan valley Area

Khaldoun Said Qtaishat *

Abstract

The production of Digital Elevation Models (DEMs) is expensive, but now the height models which can be generated from high resolution satellites are available free of charge with good and reasonable accuracy. The 90-metre TanDEM-X Digital Elevation Model has been released for scientific use and is now available free of charge as a global dataset. By providing this data, the German Aerospace Center (DLR) encourages free access to satellite data.

This paper provides an independent investigation into the quality, performance of Elevation Models (DEMs) which generated from TanDEM-X with 90m spacing (3 arcsec) for Jordan valley. The accuracy of DEM is assessed through the comparison of accuracy against an independent data from aerial LiDAR, and against DEM created from AW3D30 with one arc second free of charge. The root mean square differences (m) is 2.40 m against LiDAR, and AW3D30 with one arc second for areas with slope < 20%.

Keywords: DEM, satellites, TanDEM-X, AW3D30, accuracy.

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تقييم نماذج الارتفاع الرقمية التي تغطي منطقة وادي الأردن

خلدون سعيد محمد قطيشات

ملخص

يعد إنتاج نماذج الارتفاع الرقمية (DEMs) مكلفًا، ولكن في الوقت الحاضر تعتبر نماذج الارتفاع التي يمكن إنشاؤها من أقمار صناعية عالية الدقة متاحة مجانًا وبدقة جيدة ومعقولة. يعد (TanDEM-X DEM) متاح لجميع المواقع الأرضية بما في ذلك القارة القطبية الجنوبية وجميع خطوط العرض فوق 60 درجة شمالًا. تم إصدار الارتفاع الرقمي TanDEM-X بطول 90 مترًا للاستخدام العلمي وهو متاح الآن مجانًا لاستخدام البيانات العلمية كمجموعة بيانات عالمية، من خلال توفير هذه البيانات يشجع المركز الألماني للفضاء (DLR) الوصول الحر والمفتوح إلى بيانات الأقمار الصناعية.

تقدم هذه الورقة دراسة مستقلة عن الجودة والأداء والموثوقية لنماذج الارتقاء (DEMs) التي تم إنشاؤها من TanDEM-X بمسافات 90 متر (3 arcsec) لوادي الأردن. يتم تقييم دقة DEM من خلال مقارنة الدقة مع بيانات مستقلة من LiDAR ، وDEM التي تم إنشاؤها من AW3D30 المجانية. يبلغ متوسط الخطا 2.40 مترمربع مقابل LiDAR و AW3D30 للمناطق ذات الميل <20٪.

Introduction

Digital Elevation Models (DEMs) are a basic component for geographic information systems (GIS) and basic requirement for several applications. The digital elevation models can be used to create topographic maps, also to monitor land use and vegetation, collect hydrological information such as drainage paths or soil moisture, and observe polar ice caps or glaciers. This was been investigated by Jacobsen (2004).

The Sources of DEMs from space are (Jacobsen, 2010):

- Radar – Interferometric Synthetic Aperture Radar (InSAR) (covering large areas).
- optical images – stereo satellites (covering large areas), flexible satellites.
- LiDAR – up to now not from space - ICESAT not satisfying point spacing.

The production of Digital Elevation Models (DEMs) is expensive (Höhle, 2009), but now the height models which can be generated from high resolution satellites are available free of charge or commercially with good and reasonable accuracy as shown in Table 1 (Jacobsen, 2013).

Table (1) Height Models Covering large Area (Free of Charge and Commercial Height Models)

Height model	Organization	Source	Range	Spacing
Free of charge and commercial Height Models				
GMTED2010	USGS and NGA	various	global	7.5 arcsec
SRTM (C-band)	NGA and NASA	Shuttle InSAR	Latitude 56° S to 60° N	1 arcsec
SRTM X-band	DLR	Shuttle InSAR (X-band)	Latitude 56° S to 60° N partially	1 arcsec
ACE2	ESA ESRIN and	SRTM and altimeter	Latitude 56° S to 60° N,	3 arcsec

Height model	**Organization**	**Source**	**Range**	**Spacing**
Free of charge and commercial Height Models				
	Montfort University	and other data	remaining area other data sets	
ASTER GDEM-2	METI (Japan) and NASA	ASTER optical stereo satellite	Latitude 83° S to 83° N	1 arcsec
AW3D30	JAXA (Japan)	ALOS PRISM optical stereo satellite	Latitude 82° S to 82° N	1 arcsec
Commercial Height Models				
Elevation 30 (Reference 3D)	Airbus Defense and Space	SPOT 5 HRS	~46% of Earth land mass	30m
EuroMaps 3D	GAF and DLR	Cartosat-1 optical stereo satellite	Some European and Near East countries and on request	5 m
NextMap	Intermap	Airborne InSAR	USA, European countries	5 m
WorldDEM	Airbus Defense and Space and DLR	TanDEM-X InSAR	global	10 m
ALOS World 3D Topographic Data (AW3D)	NTT Data / RESTEC	ALOS PRISM optical stereo satellite	Latitude 82° S to 82° N	5 m

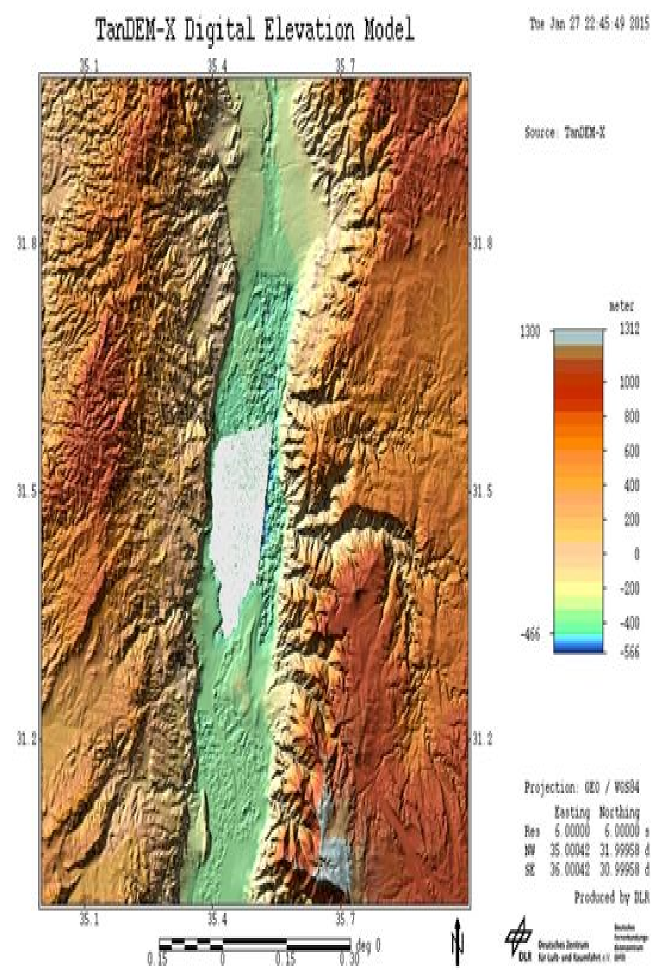
The TanDEM-X digital elevation model with 90-m spacing (3 arcsec) horizontal sampling is now available for download for scientific applications and is concidered now to be afree of charge Degital Height Model. The global data set can be easily downloaded after a simple registration – without science proposal submission. The 90-m TanDEM-X DEMs are multi-looked versions of the 12-m TanDEM-X DEMs with considerably improved relative height accuracy. The accuracies are the absolute accuracies and relative accuracies (RMSE, SZ, and NMAD), but the morphologic details are dominated by point spacing and relative accuracy.

The TanDEM-X DEM covers all of Earth's land surfaces, totaling over 148 million square kilometers. The absolute height accuracy is one metre. This 3D image of the Earth was completed in September 2016 and is approximately 30 times more accurate than any other global dataset. The elevation models generated with TanDEM-X and TerraSAR-X also have the advantage of being the first to capture the Earth with uniform accuracy and no gaps.

The two satellites continue to fly in close formation and acquire images of Earth to detect topographic changes that have occurred as a result of earthquakes or in glaciers, permafrost regions, agricultural areas or urban zones. Also, the generated digital elevation models (commercial or free of charge) can be used to create topographic maps, to monitor land use and vegetation, collect hydrological information such as drainage paths or soil moisture, and observe polar ice caps or glaciers (Jacobsen, 2019).

The Test Site

TanDEM-X Digital Elevation Models (DEMs) with 90-m spacing (3 arcsec) are analysed over the established Jordan valley site. Figure 1 shows the DEMs layed over the area.

1: 

Figure

TanDEM-X Digital Elevation with 90-m spacing (3 arcsec) horizontal sampling Model for Jordan valley area

One of the most difficult issues that require addressing is how to assess the quality of the of Digital Elevation Models (DEMs). In general, a way to check the quality of any measurement is by comparing results with a measurement from significantly higher quality generated from aerial LiDAR sensors and against DEMs created from larg scale aerial photogrammetry (Höhle, 2009). This would then provide a benchmark or reference measurement to compare against. In the past this has been very difficult to achieve as far there has been little equipment available to compare against the high quality.

Digital Elevation Models (DEMs) are a basic component for geo information systems (GIS), so the quality of DEM is assessed through the accuracy parameters and morphologic details (external assesment). The accuracies are the absolute accuracies and relative accuracies (RMSE, SZ), but the morphologic details are dominated by point spacing, contours and relative accuracy.

Results and Discussions

Figure 2 and Table 2 show the color coded height differences of TanDEM-X Digital Elevation Models with 90-m spacing (3 arcsec) WorldDEM for Jordan valley area against LiDAR, for the same area, which was used as a benshmark. Open area including not dense urban area filtered to DTM with vegetation filter for LiDAR reference. The Jordan test area was analyzed by removing the poor points in the water by performing water mask and was added to the digital elevation model, as shown in Figure 3 and Figure 4. So the output generated from the Digital elivation model with used water mask as shown in Figure 5.

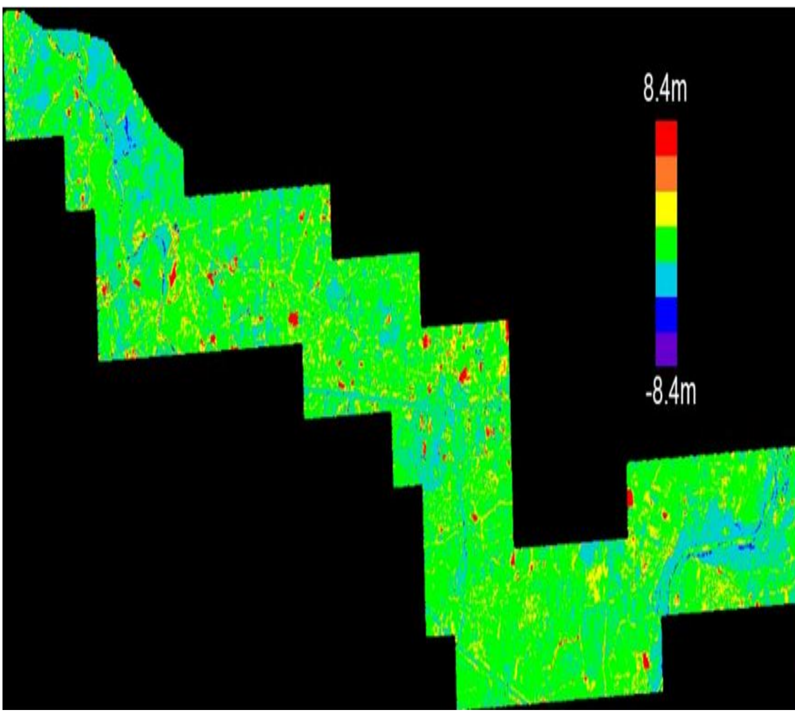


Figure 2: Color Coded Height Differences Free TANDEM-X WorldD Against LiDAR, Jordan Valley –Open Area Including Not Dense Urban Area Filtered to DTM.

Table (2) Free TANDEM-X WorldDEM against LiDAR

	Whole area	slope < 20%
SZ	1.96m	1.59m
NMAD	1.48m	0.99m

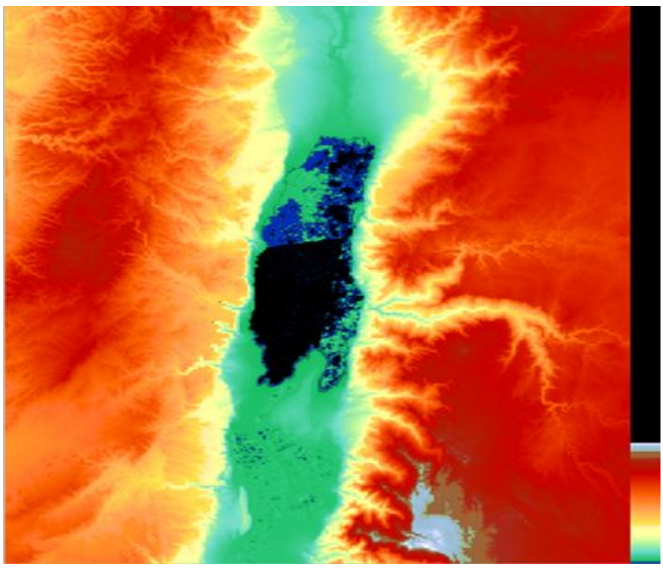


Figure 3: Input DEM with Poor Points on Water (Image of TDM90 Height Model)

Figure 4: Water Mask (TDM90)

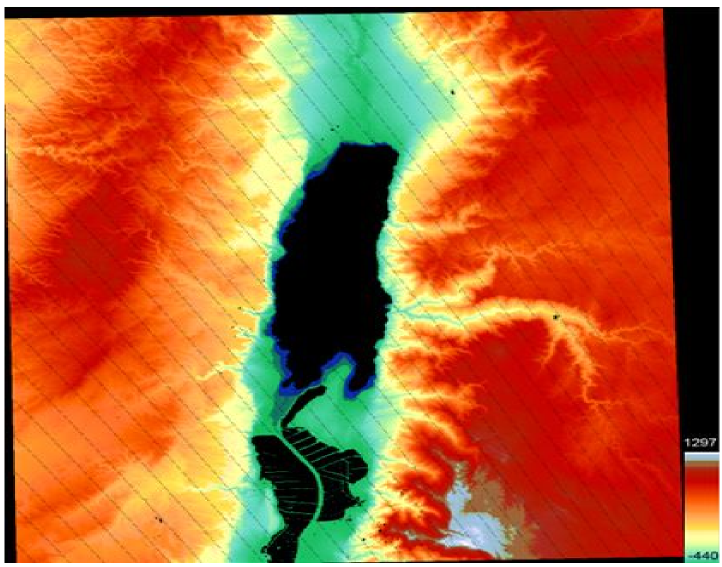


Figure 5: Output with Used Water Mask (Image of Height Model Generated with ASCIMA Software)

Figures 6, 7, and 8 show the morphologic details of the contour lines. The LiDAR contour lines is shown in figure 8 which based on a DSM with 50 m contour intervals. The TanDEM-X Digital Elevation Models (DEMs) with 90-m spacing (3 arcsec) WorldDEM contour lines are very close to it, It is nearly identical to the contour lines based on The LiDAR. Whereas the AW3D30 contour lines for the same area do not show so many details as the contour lines of TanDEM-X Digital Elevation Models, So the contours and morphologic quality of TanDEM-X Digital Elevation Models (DEMs) matches and agrees to the sequence of accuracy (Table 3) and the point spacing.

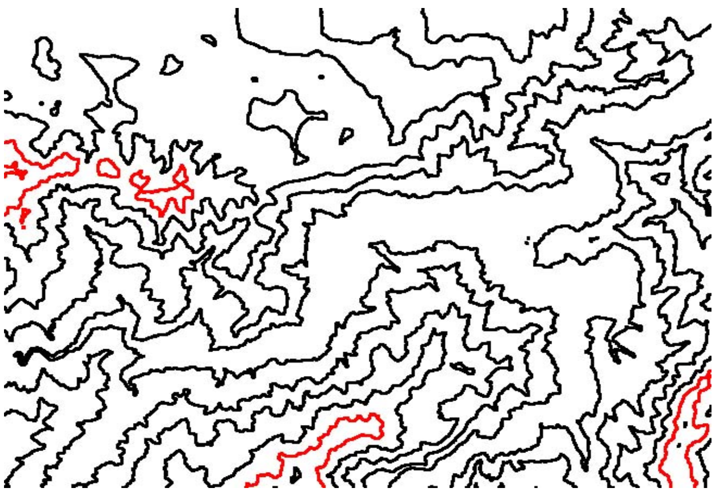


Figure 6: Contour Lines Created from Aerial LiDAR, Contour Interval 50m

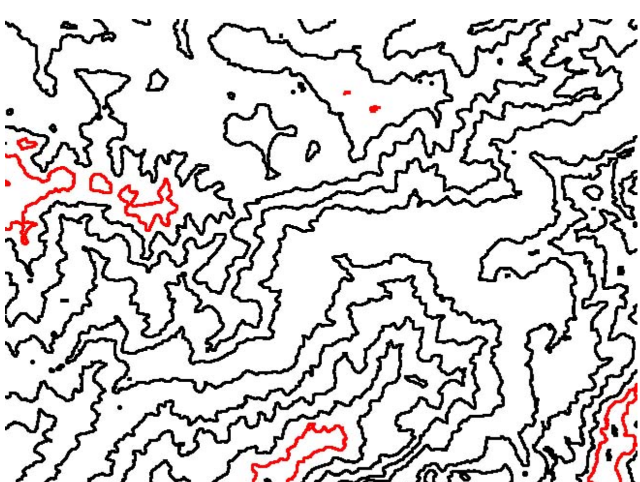


Figure 7: Contour Lines Created from Aerial TanDEM-X WorldDEM, Contour Interval 50m

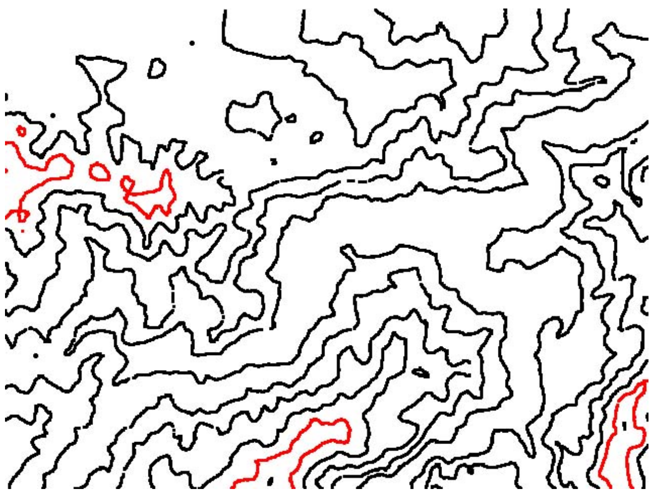


Figure (8) Contour Lines Created from AW3D30, Contour Interval 50m

Table (3) Accuracy Numbers of the Investigated DEM [m]

Compared DEM	**Whole area**		**Slope < 20%**	
	SZ	NMAD	SZ	NMAD
TanDEM-X - LiDAR	3.60	3.09	2.32	1.33
AW3D30 - LiDAR	3.96	3.23	2.49	2.16

Also FreeTanDEM-X WorldDEM, GDEM2, and SRTM have been analyzed for Jordan test area (Figure 9). FreeTanDEM-X WorldDEM has a higher accuracy and again is more accurate than GDEM2 and SRTM. As known, the height model accuracy depends on the terrain slope. If the DEM's accuracy shall be compared for different sites, this has to be done in areas which have inclination less 20%.

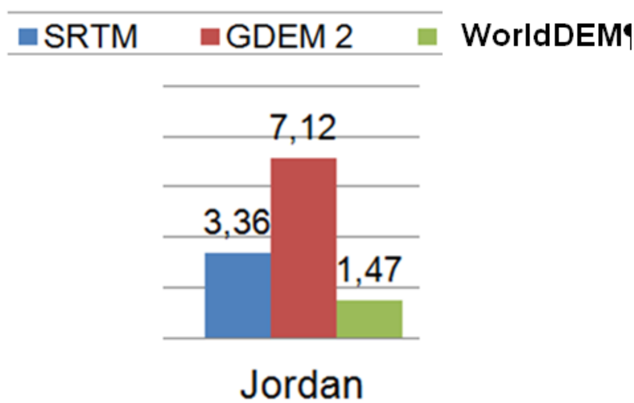


Figure (9) DEM Root Mean Square Differences (m) for Free TanDEM-X WorldDEM against SRTM, and GDEM2 with Slope < 20%

Conclusions

The free of charge available Digital Elevation Models have reached a good level of accuracy and morphologic information. Some height models covering large area are accessible free of charge or commercially in case of more information and higher accuracy. From the free of charge available height models, new TanDEM-X Digital Elevation with 90-m spacing (3 arcsec) is dominating up to now. The new TanDEM-X Digital Elevation with 3 arcsec point spacing, named with a nominal higher accuracy as AW3D30, has the advantage of more actual DSM information and shows more morphologic details. The accuracy of DEM is assessed through the comparison of accuracy against an independent data from aerial LiDAR, and against DEM created from AW3D30 with one arc second (30m spacing) free of charge. The root mean square differences (m) is 2.40 m against LiDAR, and AW3D30 with one arc second for areas with slope < 20%.

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Hamiltonian-Jacobi Treatment of Damped Harmonic Oscillator Based on Employing the Method of Dual Coordinates

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Abstract

In this paper, we provide the canonical approach for studying the damped harmonic oscillator based on the doubling of degrees of freedom approach. Explicit expressions for Lagrangians of the elementary modes of the problem and characterising both forward and backward time propagations are given. A Hamiltonian analysis showing the equivalence with the Lagrangian approach is also done. To this end, the techniques of separation of variables were applied.

Keywords: Doubling of degrees of freedom; Dissipated harmonic oscillator; Hamilton-Jacobi; Time-independent Lagrangians.

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معالجة الهزاز التوافقي المتخامد باستخدام طريقة هاميلتون- جاكوبي بعد مضاعفة درجات الحرية

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ملخص

في هذا العمل قمنا بدراسة الهزاز التوافقي المتخامد باستخدام طريقة هاميلتون- جاكوبي بعد مضاعفة درجات الحرية. لقد تم تقديم تعابير صريحة لدالة لاغرانج لوصف هذا النظام. تتضمن هذه الأنظمة صورة أساسية وصورة زمنية معكوسة. هذا يعني دائماً أن يتم وصف الأنظمة في نظام ثنائي الأبعاد. نظام فرعي واحد يبدد الطاقة والآخر يمتص الطاقة المنقولة من النظام الأول. تم تطبيق تقنيات الفصل بين المتغيرات وطريقة التحولات الفيصلية من أجل حل معادلة هاملتون جاكوبي لهذه الأنظمة.

Introduction

The Hamilton-Jacobi theory is the principal of classical mechanics. This theory principally helpful in identifying conserved quantities for mechanical systems, which may be likely even when the mechanical problem itself cannot be solved totally.

The Hamilton-Jacobi Equation is an important example of how new information about mechanics can come out of the action. It is an important step to formulate the equation of motion for simple harmonic oscillator of nth-dimensional (Goldstein, 2000).

The inverse problem of variational calculus is to construct the Lagrangian from the equations of motion. Different Lagrangian representations are obtained from the direct and indirect approaches (Santilli, 1984). In the direct representation as many variables are introduced as there are in the equations of motion. The equation of motion corresponding to a coordinate q is related with the variational derivative of the action with respect to the same coordinate. Whereas, in the indirect representation, the equation of motion is supplemented by its time - reversed image. The equation of motion with respect to the original variable then corresponds to the variational derivative of the action with respect to the image coordinate and viceversa (Bateman, 1931; Feshbach and Tikochinsky, 1977).

However, Serhan et al. obtained the action function for a suitable Hamiltonian that describes the damped harmonic oscillator, and then the system is quantized using the WKB approximation and the canonical quantization (Serhan et al., 2018). In addition, Wang and Ru Wang formulated the least action principle for classical mechanical dissipative systems. They considered a whole conservative system composed of a damped moving body and its environment receiving the dissipated energy (Qiuping Wang & Ru Wang, 2018).

Bateman showed that a procedure of doubling of degrees of freedom is required in order to use the usual canonical quantization methods (Bateman, 1931). Applying this idea to damped harmonic oscillator one obtains a pair of damped oscillations (Blasone & Jizba, 2004).This system includes a primary one and its time reversed image.

The aim of this paper is to extend the Hamilton-Jacobi formulation for doubling of degrees of freedom of the Time-Independent Mechanical systems. Furthermore, we will apply the technique of separation of variables and canonical transformations to solve the Hamilton-Jacobi partial differential equations for these systems. This leads to another approach for solving mechanical problems for doubling of degrees of freedom systems on equal footing as for regular systems.

The paper is organized as follows. In section 2, a review of the Hamilton-Jacobi Equation is introduced. In section 3, Doubling of Degrees of Freedom is discussed.Then in section 4 we present Hamilton-Jacobi Treatment of Damped harmonic Oscillator. The paper closes with some concluding remarks in section 5.

Review of the Hamilton-Jacobi Equation

We can reach the Hamilton Jacobi equation by using the action function as follows (Goldstein, 1980):

Consider the action for N particles, with 3N configuration space coordinates x_i .

$$S(x_i, t) = \int_{t_0}^{t} L(x_i, \dot{x}_i, t)dt \qquad (1)$$

The action S is defined as the integral of the Lagrangian L between two times t_0 and t.

Taking the first variation of the action integral (1) gives

$$\delta S = \sum_i \left(\left[\frac{\partial \mathcal{L}}{\partial x_i} \delta x_i \right]_{t_0}^{t} + \int_{t_0}^{t} \left(\frac{\partial \mathcal{L}}{d x_i} - \frac{d}{dt} \frac{\partial \mathcal{L}}{\partial \dot{x}_i} \right) \delta x_i \, dt \right) \qquad (2)$$

The expression inside the integral that multiplies the variation δx_i must vanish for each i (Euler- Lagrange equations)

$$\delta S = \sum_i \frac{\partial \mathcal{L}}{\partial \dot{x}_i} \delta x_i(t) = \sum_i p_i \, \delta x_i(t) \qquad (3)$$

Where we have used the assumption, that, although the particles could have started from any point x_i at the initial time, the variation of that initial point is zero : $\delta x_i(t_0) = 0$. We have also used the fact that $\frac{\partial \mathcal{L}}{\partial \dot{x}_i}$ is the momentum p_i conjugate to the coordinate x_i .

But considering the action to be a function of the final positions x_i(t) and final time t, we also have for the first variation

$$\delta S = \sum_i \frac{\partial S}{\partial \dot{x}_i}\ \delta x_i(t) \qquad (4)$$

Comparing the two expressions (3) and (4) for the first variation of the action we have

$$p_i = \frac{\partial S}{\partial x_i} \qquad (5)$$

Differentiating the action with respect to time, we obtain

$$L = \frac{\partial S}{\partial t} + \sum_i \frac{\partial S}{\partial x_i}\dot{x}_i \qquad (6)$$

Substituting equation (5) into equation (6), we obtain

$$\frac{\partial S}{\partial t} + \left(\sum_i p_i \dot{x}_i - L\right) = 0 \qquad (7)$$

The expression in brackets is recognized as the Hamiltonian $H(x_i, P_i, t)$.

Using

$$H(q_i, p_i, t) = p_i \dot{q}_i - L(q_i, \dot{q}_i, t)$$

we can write equation (7) as

$$\frac{\partial S}{\partial t} + H\left(x_i, \frac{\partial S}{\partial x_i}, t\right) = 0 \qquad (8)$$

Which is the Hamilton-Jacobi equation in terms of the action function S .

Using the canonical transformations, we may determine the coordinates x_i by differentiate the function S (x_i, t) with respect to α_i and then put the results of these differentiations to new constants β_i. In this way we obtain

$$\beta_i = \frac{\partial S}{\partial \alpha_i} \qquad (9)$$

Doubling of Degrees of Freedom

A doubling of degrees of freedom is a doubling from one field configuration to another. In dissipative systems, the energy of the damped subsystem of the whole system must be dissipated away and transferred to another subsystem. This invariably means that the damped oscillator is described by a two-dimensional system; one subsystem of which dissipates the energy and the other of which gets amplified by the transferred energy. The simplest model for dissipation is damped oscillators with one or two degrees of freedom. This kind of model has been suggested long ago by Bateman (Bateman, 1931; Hasse, 1975) and later by Morse and Feshbach (Morse and Feshbach, 1953) and Feshbach and Tikochinsky (Feshbach and Tikochinsky, 1977).

The paradigm of the dissipative dynamics is the damped harmonic oscillator model. In a one-dimensional configuration space, its equation of motion is

$$m\ddot{x} + \gamma\dot{x} + kx = 0 \qquad (10)$$

Where γ is the damping constant or friction. Physically, this equation describes a classical dissipative system losing energy at a constant rate γ as time increases. This equation cannot be derived from any Lagrangian, since there is no stationary solution. In order to find out a suitable Lagrangian, one can assume that the energy lost by the system goes into another system, namely reversed–image system, which absorbs it (Morse and Feshbach, 1953).

$$m\ddot{y} - \gamma\dot{y} + ky = 0 \qquad (11)$$

That is, if the energy of the oscillator described by equation (10) is lost at a rate γ, it will be gained at the same rate (with negative friction, $-\gamma$) by the reversed–image system equation (11).

This implies a zero total energy balance and, more importantly, that stationary (external) solutions for the larger system can be found.

Hamilton-Jacobi Treatment of Damped harmonic Oscillator

Homogeneous Dissipative Harmonic Oscillator

The equation of motion of the one dimensional damped harmonic oscillator is

$$m\ddot{x}+\gamma\dot{x} + kx = 0 \qquad (12)$$

where the parametersm, γ, k are time independent. However, since the system in equation (12) is dissipative, a straight forward Lagrangian description leading to a consistent canonical quantization is not available (Banerjee and Mukhejee, 2002).

In order to develop a canonical formalism, one requires equation (16) alongside its reversed image counterpart (Banerjee and Mukhejee, 2002; Ikot et al., 2010):

$$m\ddot{y} - \gamma\dot{y} + ky = 0 \qquad (13)$$

And write the variation of the action S as

$$\delta S=\int_{t_1}^{t_2} dt\ [(\frac{d}{dt}(m\dot{x}+ \gamma ɤ x) + kx)\delta y + (\frac{d}{dt}(m\dot{y}\ - ɤ\gamma\ y) + ky)\delta x \qquad (14)$$

From equation(14), equation (12) is obtained by varying S with respect to y whereas equation (13) follows from varying S with respect to x. Then the equations of motion for x and y follow as Euler – Lagrange equations for y and x respectively.

Now, starting from equation (14) we can deduce

$$\delta S = -\delta\int_{t_1}^{t_2} dt\ [\ m\dot{x}\dot{y}\ +\ \frac{\gamma}{2}(x\dot{y} - \dot{x}y) - kxy\ ] \qquad (15)$$

It is then possible to identify

$$L = m\dot{x}\dot{y} + \frac{\gamma}{2}(x\dot{y} - \dot{x}y) - kxy \qquad (16)$$

The Lagrangian (16) can be written in a suggestive form by the substitution of the hyperbolic coordinates ξ and η defined by

$$x = \frac{1}{\sqrt{2}}(\xi + \eta) \tag{17}$$

$$y = \frac{1}{\sqrt{2}}(\xi - \eta) \tag{18}$$

So that

$$L = \frac{m}{2}(\dot{\xi}^2 - \dot{\eta}^2) + \frac{\gamma}{2}(\eta\dot{\xi} - \xi\dot{\eta}) - \frac{k}{2}(\xi^2 - \eta^2) \tag{19}$$

Then the Hamiltonian reads

$$H = \frac{1}{2m}p_\xi^2 + \frac{k}{2}\xi^2 - \frac{1}{2m}p_\eta^2 - \frac{k}{2}\eta^2 \tag{20}$$

If we use the equations of transformation

$$p_\xi = \frac{\partial S}{\partial \xi} \tag{21}$$

$$p_\eta = \frac{\partial S}{\partial \eta} \tag{22}$$

We obtain the differential form of the Hamiltonian

$$H = \frac{1}{2m}\left(\frac{\partial S}{\partial \xi}\right)^2 + \frac{k}{2}\xi^2 - \frac{1}{2m}\left(\frac{\partial S}{\partial \eta}\right)^2 - \frac{k}{2}\eta^2 \tag{23}$$

The standard Hamilton-Jacobi equation for this Hamiltonian is given by

$$H + \frac{\partial S}{\partial t} = 0 \tag{24}$$

By substituting of equation (23) into equation (24), we obtain

$$\frac{1}{2m}\left(\frac{\partial S}{\partial \xi}\right)^2 + \frac{k}{2}\xi^2 - \frac{1}{2m}\left(\frac{\partial S}{\partial \eta}\right)^2 - \frac{k}{2}\eta^2 + \frac{\partial S}{\partial t} = 0 \tag{25}$$

Now we can expand the variables in the usual way of separation used in the Hamilton-Jacobi equation by assuming that S is the sum of three terms:

$$S(\xi,\eta,t) = W_\xi + W_\eta - \alpha_3 t \quad (26)$$

Substituting equation (26) into equation (25), we obtain the following differential equation for W_ξ and W_η:

$$\left[\frac{1}{2m}\left(\frac{\partial W_\xi}{\partial \xi}\right)^2 + \frac{k}{2}\xi^2\right] - \left[\frac{1}{2m}\left(\frac{\partial W_\eta}{\partial \eta}\right)^2 + \frac{k}{2}\eta^2\right] - \alpha_3 = 0 \quad (27)$$

This equation can be correct if both of the terms in the left hand side is equal to a constant, since they are functions of different variables

$$\frac{1}{2m}\left(\frac{\partial W_\xi}{\partial \xi}\right)^2 + \frac{k}{2}\xi^2 = \alpha_1 \quad (28)$$

$$\frac{1}{2m}\left(\frac{\partial W_\eta}{\partial \eta}\right)^2 + \frac{k}{2}\eta^2 = \alpha_2 \quad (29)$$

where α_1, α_2 and α_3 are constants such that

$$\alpha_1 - \alpha_2 = \alpha_3 \quad (30)$$

By integrating the equations (28) and (29), we obtain

$$W_\xi = \frac{\sqrt{2m\alpha_1}}{2}\xi\sqrt{1 - \frac{m\omega^2}{2\alpha_1}\xi^2} + \frac{\alpha_1}{|\omega|}sin^{-1}\sqrt{\frac{m\omega^2}{2\alpha_1}}\xi \quad (31)$$

and

$$W_\eta = \frac{\sqrt{2m\alpha_2}}{2}\eta\sqrt{1 - \frac{m\omega^2}{2\alpha_2}\eta^2} + \frac{\alpha_2}{|\omega|}sin^{-1}\sqrt{\frac{m\omega^2}{2\alpha_2}}\eta \quad (32)$$

Therefore,

$$S(\xi,\eta,t) = \frac{\sqrt{2m\alpha_1}}{2}\xi\sqrt{1-\frac{m\omega^2}{2\alpha_1}\xi^2} + \frac{\alpha_1}{|\omega|}sin^{-1}\sqrt{\frac{m\omega^2}{2\alpha_1}}\ \xi + \frac{\sqrt{2m\alpha_2}}{2}\eta\sqrt{1-\frac{m\omega^2}{2\alpha_2}\eta^2} + \frac{\alpha_2}{|\omega|}sin^{-1}\sqrt{\frac{m\omega^2}{2\alpha_2}}\ \eta - (\alpha_1-\alpha_2)t \qquad (33)$$

Using the canonical transformations, we may determine the coordinates ξ and η by differentiating the function $S(\xi,\eta,t)$ with respect to α_1 and α_2 and then put the results of these differentiations to new constants β_1 and β_2 respectively. In this way we obtain

$$\beta_1 = \frac{\partial S}{\partial\alpha_1} = \frac{1}{|\omega|}sin^{-1}\sqrt{\frac{m\omega^2}{2\alpha_1}}\xi - t \qquad (34)$$

$$\beta_2 = \frac{\partial S}{\partial\alpha_2} = \frac{1}{|\omega|}sin^{-1}\sqrt{\frac{m\omega^2}{2\alpha_2}}\eta + t \qquad (35)$$

equations (34) and (35) can be solved to give

$$\xi = \sqrt{\frac{2\alpha_1}{m\omega^2}}\sin(\omega\beta_1+\omega t) \qquad (36)$$

$$\eta = \sqrt{\frac{2\alpha_2}{m\omega^2}}\sin(\omega\beta_2-\omega t) \qquad (37)$$

To determine the momenta p_ξ and p_η, we may differentiate the function $S(\xi,\eta,t)$ with respect to $\xi$and η. In this way we obtain

$$p_\xi = \frac{\partial S}{\partial\xi} = \sqrt{2m\alpha_1 - m^2\omega^2\xi^2} \qquad (38)$$

$$p_\eta = \frac{\partial S}{\partial x_2} = \sqrt{2m\alpha_2 - m^2\omega^2\eta^2} \qquad (39)$$

Substituting equations (36) and (37) into equations (38) and (39); respectively, we obtain

$$p_\xi = \sqrt{2m\alpha_1}\cos(\omega\beta_1+\omega t) \qquad (40)$$

$$p_{\eta}=\sqrt{2m\alpha_2}\cos(\omega\beta_2-\omega t) \quad (41)$$

Substituting the equations (36) and (37) into equations (17) and (18), we get the final results of the equations of motion in terms of time:

$$x=\frac{1}{\sqrt{2}}(\xi+\eta)=\frac{1}{\sqrt{2}}\left[\sqrt{\frac{2\alpha_1}{m\omega^2}}\,sin(\omega\beta_1+\omega t)+\sqrt{\frac{2\alpha_2}{m\omega^2}}\,sin(\omega\beta_2-\omega t)\right] \quad (42)$$

$$y=\frac{1}{\sqrt{2}}(\xi-\eta)=\frac{1}{\sqrt{2}}\left[\sqrt{\frac{2\alpha_1}{m\omega^2}}\,sin(\omega\beta_1+\omega t)-\sqrt{\frac{2\alpha_2}{m\omega^2}}\,sin(\omega\beta_2-\omega t)\right] \quad (43)$$

One can notice that the damping factor γ is no longer exist through all the results obtained.

Non-Homogeneous Dissipative Harmonic Oscillator

The equation of motion of the one dimensional damped harmonic oscillator is

$$\ddot{x}-2\Upsilon\,\gamma\,\dot{x}+\omega^2x=\mathcal{E}y \quad (44)$$

where the parameters γ, ω, $\mathcal{E}$ are time independent. However, since the system in equation (44) is dissipative, a straight forward Lagrangian description leading to a consistent canonical quantization is not available (Banerjee and Mukhejee, 2002).

In order to develop a canonical formalism, one requires equation (44) alongside its reversed image counterpart (Banerjee and Mukhejee, 2002; Banerjee andMukherjee, 2015):

$$\ddot{y}+2\,\gamma\Upsilon\dot{y}+\omega^2y=\mathcal{E}x \quad (45)$$

The first oscillator is represented by x whereas the second oscillator is represented by y.

The special case $\mathcal{E}=0$ is the uncoupled motion of the two oscillators that corresponds to Bateman’s doublet consisting of a damped harmonic oscillator and its time reversed image (Bateman, 1931; Caldirola, 1941; Kanai, 1948).

The Lagrangian of the system can be constructed by the inverse Lagrangian method. First, we write the variation of the action as

$$\delta S= \int_{t_1}^{t_2} dt\ [(\frac{d}{dt}(\dot{x} - 2\Upsilon\, \gamma x) + \omega^2 x - \mathcal{E} y)\delta y + (\frac{d}{dt}\ (\ \dot{y}\ + 2\,\gamma\Upsilon y) + \omega^2 y - \mathcal{E} x)\delta x \qquad (46)$$

From equation (46), equation(44) is obtained by varying S with respect to y whereas equation (45) follows from varying S with respect to x. Then the equations of motion for x and y follow as Euler – Lagrange equations for y and x respectively.

Now, starting from equation (46) we can deduce that

$$\delta S = -\delta\int_{t_1}^{t_2} dt\ [\ \dot{x}\dot{y} - \gamma\, \Upsilon(x\dot{y} - \dot{x}y) - \omega^2 xy\ + \frac{\mathcal{E}}{2}(x^2 + y^2)] \qquad (47)$$

It is then possible to identify

$$L = \dot{x}\dot{y} - \Upsilon\gamma\ (x\dot{y} - \dot{x}y) - \omega^2\ x\ y + \frac{\mathcal{E}}{2}(x^2 +\ y^2) \qquad (48)$$

The Lagrangian (48) can be written in a suggestive form by the substitution of the hyperbolic coordinates ξ and η defined by

$$x = \frac{1}{\sqrt{2}}(\ \xi + \eta) \qquad (49)$$

$$y = \frac{1}{\sqrt{2}}(\ \xi - \eta) \qquad (50)$$

The Lagrangianis then

$$L= \frac{1}{2}(\ \dot{\xi}^2 - \dot{\eta}^2) -\ \Upsilon(\ \eta\dot{\xi} - \xi\dot{\eta})\ - \frac{\omega^2}{2}(\ \xi^2 - \eta^2) + \frac{\mathcal{E}}{2}(\xi^2 + \eta^2) \qquad (51)$$

we find that the Hamiltonian H reeds

$$H = \frac{1}{2}p_\xi^2 - \frac{1}{2}p_\eta^2 + \frac{1}{2}(\omega^2 -\ \mathcal{E})\ \xi^2 -\ \frac{1}{2}(\omega^2 +\ \mathcal{E})\eta^2 \qquad (52)$$

If we use the equations of transformation

$$p_\xi = \frac{\partial S}{\partial \xi} \qquad (53)$$

$$p_\eta = \frac{\partial S}{\partial \eta} \qquad (54)$$

We obtain the differential form of the Hamiltonian

$$\mathrm{H} = \frac{1}{2}\left(\frac{\partial S}{\partial \xi}\right)^2 + \frac{1}{2}(\omega^2 - \mathcal{E})\,\xi^2 - \frac{1}{2}\left(\frac{\partial S}{\partial \eta}\right)^2 - \frac{1}{2}(\omega^2 + \mathcal{E})\eta^2 \qquad (55)$$

The standard Hamilton-Jacobi equation for this Hamiltonian is given by

$$\mathrm{H} + \frac{\partial S}{\partial t} = 0 \qquad (56)$$

By substituting of (55) in (56), we obtain

$$\frac{1}{2}\left(\frac{\partial S}{\partial \xi}\right)^2 + \frac{1}{2}(\omega^2 - \mathcal{E})\,\xi^2 - \frac{1}{2}\left(\frac{\partial S}{\partial \eta}\right)^2 - \frac{1}{2}(\omega^2 + \mathcal{E})\eta^2 + \frac{\partial S}{\partial t} = 0 \qquad (57)$$

Now we can expand the variables in the usual way of separation used in the Hamilton-Jacobi equation by assuming that S is the sum of three terms:

$$\mathrm{S}\,(\xi\,, \eta\,, t) = W_\xi + W_\eta - \alpha_3 t \qquad (58)$$

By substituting of equation (58) into equation (57) we obtain the following differential equation for W_ξ and W_η

$$\left[\frac{1}{2}\left(\frac{\partial W_{\mathcal{E}}}{\partial \xi}\right)^2 + \frac{1}{2}(\omega^2 - \mathcal{E})\,\xi^2\right] - \left[\frac{1}{2}\left(\frac{\partial W_\eta}{\partial \eta}\right)^2 + \frac{1}{2}(\omega^2 + \mathcal{E})\eta^2\right] - \alpha_3 = 0 \qquad (59)$$

This equation must be correct if both of the terms in the left hand side are equal to a constant, since they are functions of different variables

$$\frac{1}{2}\left(\frac{\partial W_{\mathcal{E}}}{\partial \xi}\right)^2 + \frac{1}{2}(\omega^2 - \mathcal{E})\,\xi^2 = \alpha_1 \qquad (60)$$

$$\frac{1}{2}\left(\frac{\partial W_\eta}{\partial \eta}\right)^2 + \frac{1}{2}(\omega^2 + \mathcal{E})\eta^2 = \alpha_2 \qquad (61)$$

Where α_1 , α_2 and α_3 are the constants such that

$$\alpha_1 - \alpha_2 = \alpha_3 \qquad (62)$$

By integrating the equations (60) and (61), we obtain

$$W_\xi = \frac{\sqrt{2\alpha_1}}{2}\,\xi\sqrt{1 - \left(\frac{\omega^2 - \mathcal{E}}{2\alpha_1}\right)\ \xi^2} + \frac{\alpha_1}{\sqrt{(\omega^2 - \mathcal{E})}}\ \sin^{-1}\sqrt{\frac{\omega^2 - \mathcal{E}}{2\alpha_1}}\ \xi \qquad (63)$$

And

$$W_\eta = \frac{\sqrt{2\alpha_2}}{2}\eta\sqrt{1-\frac{(\omega^2+\varepsilon)}{2\alpha_2}\eta^2} + \frac{\alpha_2}{\sqrt{\omega^2+\varepsilon}}\ \sin^{-1}\sqrt{\frac{\omega^2+\varepsilon}{2\alpha_2}}\eta \qquad (64)$$

Therefore,

$$S(\xi,\eta,t) = \frac{\sqrt{2\alpha_1}}{2}\xi\sqrt{1-\frac{(\omega^2-\varepsilon)}{2\alpha_1}\xi^2} + \frac{\alpha_1}{\sqrt{(\omega^2-\varepsilon)}}\ \sin^{-1}\sqrt{\frac{(\omega^2-\varepsilon)}{2\alpha_1}}\ \xi\ + \frac{\sqrt{2\alpha_2}}{2}\eta\sqrt{1-\frac{(\omega^2+\varepsilon)}{2\alpha_2}\eta^2} + \frac{\alpha_2}{\sqrt{(\omega^2+\varepsilon)}}\ \sin^{-1}\sqrt{\frac{(\omega^2+\varepsilon)}{2\alpha_2}}\eta - (\alpha_1-\alpha_2)t \qquad (65)$$

Using the canonical transformations, we may determine the coordinates ξ and η by differentiating the function S(ξ ,η ,t) with α_1 and α_2 and then put the results of these differentiations to new constants $\beta_1$and β_2, respectively. In this way we obtain

$$\beta_1 = \frac{\partial S}{\partial \alpha_1} = \frac{1}{\sqrt{(\omega^2-\varepsilon)}}\ \sin^{-1}\sqrt{\frac{\omega^2-\varepsilon}{2\alpha_1}}\ \xi - t \qquad (66)$$

$$\beta_2 = \frac{\partial S}{\partial \alpha_2} = \frac{1}{\sqrt{(\omega^2+\varepsilon)}}\ \sin^{-1}\sqrt{\frac{\omega^2+\varepsilon}{2\alpha_2}}\eta + t \qquad (67)$$

Equations (66) and (67) can be solved to give

$$\xi = \sqrt{\frac{2\alpha_1}{(\omega^2-\varepsilon)}}\sin\sqrt{(\omega^2-\varepsilon)}\ (\beta_1 + t) \qquad (68)$$

$$\eta = \sqrt{\frac{2\alpha_2}{(\omega^2+\varepsilon)}}\sin\sqrt{(\omega^2+\varepsilon)}\ (\beta_2 - t) \qquad (69)$$

To determine the momenta p_ξ and p_η we may differentiate the function S(ξ,η,t) with respect to ξ and η. In this way we obtain

$$p_\xi = \frac{\partial S}{\partial \xi} = \sqrt{2\alpha_1 - (\omega^2-\varepsilon)\,\xi^2} \qquad (70)$$

$$p_\eta = \frac{\partial S}{\partial \eta} = \sqrt{2\alpha_2 - (\omega^2+\varepsilon)\eta^2} \qquad (71)$$

Substituting equations (68) and (69) into equations (70) and (71); respectively, we obtain

$$p_\xi = \sqrt{2\alpha_1}\cos(\sqrt{(\omega^2 - \varepsilon)}(\beta_1 + t)) \quad (72)$$

$$p_\eta = \sqrt{2\alpha_2}\cos(\sqrt{(\omega^2 + \varepsilon)}(\beta_2 - t)) \quad (73)$$

Substituting the equations (68) and (69) into equations (49) and (50), we get the final results of the equations of motion in terms of time:

$$x = \frac{1}{\sqrt{2}}\left[\sqrt{\frac{2\alpha_1}{\omega^2 - \varepsilon}}\, sin\,(\sqrt{(\omega^2 - \varepsilon)}(\beta_1 + t)) + \sqrt{\frac{2\alpha_2}{\omega^2 + \varepsilon}}\, sin\,(\sqrt{(\omega^2 + \varepsilon)}(\beta_2 - t))\right] \quad (74)$$

$$y = \frac{1}{\sqrt{2}}\left[\sqrt{\frac{2\alpha_1}{\omega^2 - \varepsilon}}\, sin(\sqrt{(\omega^2 - \varepsilon)}(\beta_1 + t) - \sqrt{\frac{2\alpha_2}{\omega^2 + \varepsilon}}\, \sin\,(\sqrt{(\omega^2 + \varepsilon)}(\beta_2 - t))\right] \quad (75)$$

One can notice that the damping factor γ is no longer exist through all the results obtained.

Figures (1) and (2) show that the system described by the variable x releases its energy (dissipation) while the system described by the variable y absorbs the energy from the system described by the x variable (Majima and Suzuki, 2011).

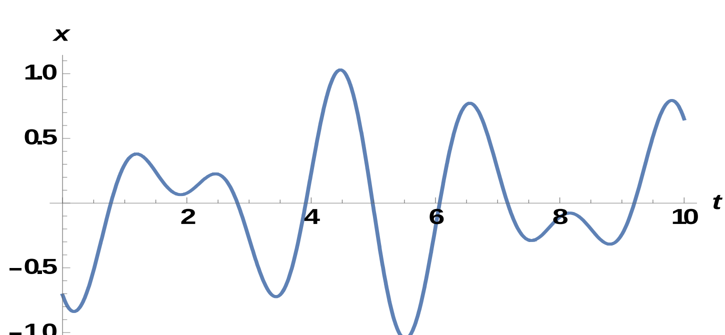

Fig.1: The coordinate x as a function of time t

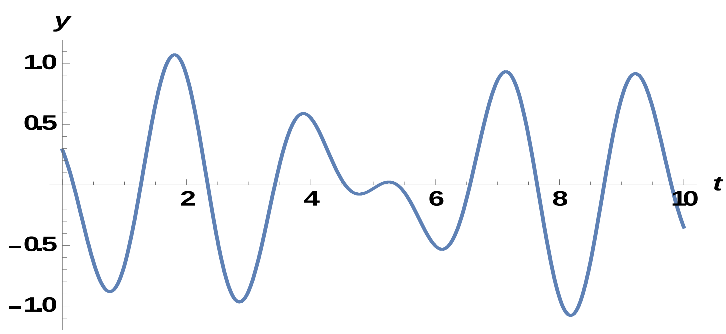

Fig.2: The coordinate y as a function of time t

Conclusion

This work has aimed to study Hamiltonian-Jacobi Method of Time-Independent Mechanical Systems Based on the Doubling of Degrees of Freedom. One can double the degrees of freedom in order to use the usual canonical transformation methods. Applying this idea to three examples of harmonic oscillator, one obtains a pair of damped oscillations a primary one and its time reversed image ($t \to -t$).

Any formulation of the harmonic oscillator is based on the direct or indirect representation. The direct representation leads to lagrangians having an explicit time dependence; hence these are not very popular. The indirect representation avoids this problem by a doubling of the degrees of freedom. It is called indirect because, taking the composite Lagrangian and varying one degree of freedom yields the equation of motion for the other degree. The usual composite Lagrangian, by construction, is two dimensional. It incorporates both forward and backward time propagations.

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