STUDY OF THE EFFECT OF STORAGE TEMPERATURE ON MICROBIAL STORED DATES UNDER VACUUM

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The Sixth International Date Palm Conference (SIDPC)
Abu Dhabi -UAE: 19 – 21 March, 2018.

Abstract:

This research study the effects of different storage temperatures on the microbial load of Khalas cv dates produced in Al Hassa, Saudi Arabia and packed under vacuum at room temperature (25 ºC) and under the refrigerator cooling temperature (5 ºC) for 12 months. The results showed a fast developed of microbial florae on dates as mixture of bacteria and yeasts and fungus while the aerobic bacteria in samples stored at 5 °C for 12 months significantly decreased, compared with dates stored at 25 °C which showed a small decline.

Also, yeast and fungi significantly decreased in storage at 5 °C compared with those stored at 25 °C. It was observed that a more positive effect cooling to control the level of microbes, concludes that refrigeration is the best way to control microbes. Results showed that the cooling is the best way to control microbes in dates stored and bottled under vacuum and proved that the source of microbial development result mostly from bad post-harvest operation in the field and from washing dates lines in the factories.

Keywords: Saudi Arabia, Palm, packing under vacuum, storage, refrigeration, water activity, microbial load

دراسة تأثير درجات حرارة التخزين على الحمل الميكروبي للتمور المعبأة تحت التفريغ

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المؤتمر السادس حول نخيل التمر- أبوظبي من 19 الى 21 مارس 2018

الملخص :

تم من خلال هذا البحث دراسة تأثير درجات حرارة التخزين المختلفة على الحمل الميكروبي لتمور صنف خلاص منتجة بمنطقة الاحساء بالمملكة العربية السعودية ومعبأة تحت التفريغ على درجة حرارة الغرفة (25ºم) وتحت درجة حرارة تبريد الثلاجة (5ºم) لمدة 12 شهر. وأظهرت النتائج وجود حمل ميكروبي على التمور يتمثل في خليط من البكتيريا والخمائر والفطريات في حين أن البكتيريا الهوائية في العينات المخزنة في 5°م لمدة 12 أشهر انخفضت بشكل ملحوظ، مقارنة بالتمور المخزنة في 25°م والتي أظهرت انخفاضا ضئيلا في حملها الميكروبي. كما ان الخمائر والفطريات انخفضت بشكل ملحوظ في التخزين علي 5°م مقارنة مع تلك المخزنة في 25°م. ولوحظ أن للتبريد تأثير أكثر إيجابية للتحكم في مستوى الميكروبات، ويستنتج أن التبريد هو أفضل طريقة للسيطرة على الميكروبات في التمور المخزنة والمعبأة تحت التفريغ كما أثبت أن مصدر الحمل الميكروبي ناتج في أغلبه من معاملات ما بعد الحصاد في الحقل ومن خطوط الغسيل مما يحتم العناية بمعاملة التمور بداية من الحقل بعد الجني لحين تخزينها.

الكلمات المفتاحية: السعودية، التمر، التعبئة تحت تفريغ، التخزين، التبريد، الحمل الميكروبي، النشاط المائي

المقدمة :

يقدر الإنتاج العالمي من التمور بحوالي 7.75 مليون طن بقيمة 3.82 مليار دولار في عام 2010 **(FAO, 2012)**. تحتل المملكة العربية السعودية ثاني أكبر دول العالم إنتاجا للتمور بعد مصر، حيث يبلغ الإنتاج السنوي للملكة في عام 2011 حوالي 108105 طن و بمساحة 156023 هكتار ومنتجة من أكثر من 24 مليون شجرة نخيل للتمر، فهي أكثر الفواكه التي تزرع على نطاق واسع في المملكة العربية السعودية **(وزارة الزراعة، 2012 ; FAO, 2012)**.

يوجد العديد من أصناف التمور التي يتم توجيهها للصناعة في المملكة إلا أنها تتركز في أصناف (رزيز، خلاص، صفري، سكري، صقعي، نبوت سيف، شيشي وأخري). وبلغ عدد مصانع التمور 145 مصنعا بطاقة إنتاجية تقدر بحوالي 290 ألف طن وهو ما يمثل حوالي 29% من إجمالي إنتاج المملكة من التمور، ومعظم الكميات المصنعة من التمور عبارة عن تمور معبأة وتشكل ما نسبته 89 % وحوالي 1 % منها عجينة تمر من إجمالي الكميات المنتجة من مصانع التمور والبقية تصنع بأشكال أخرى (مثل المربيات ومرملاد ودبس وأعلاف) **(حسن، 2012)**.

لا توجد دراسات شاملة على مؤشرات الجودة ومواصفات ثمار التمور الأكثر وفرة ومهمة تجاريا في المملكة العربية السعودية مثل السكري، خلاص، صقعي، عنبرة **(Aleid *et al.*, 2014b)**.

وهناك طلب كبير على التمور السعودية في السوق الدولية. وعلى ذلك، فتخزين التمور في مرحلة النضج الكامل لزيادة مدة صلاحيتها له أهمية كبيرة **(Al-Redhaiman, 2005)**. وعند تخزين التمور تحت ظروف محددة، يمكن أن تتعرض لظواهر تدهور نوعية مثل تبلور السكر على سطح التمور، جفاف الماء بالتمور اللينة، التخمير أو تغيير لون السطح وتغيرات بيولوجية نتيجة لتطور نمو الكائنات الحية **(Aleid *et al.*, 2014a)**. لذا فدرجة الحرارة هي واحدة من أهم العوامل التي تؤثر على العمر الافتراضي وجودة التمور. وحظي التخزين بالتبريد للتمور المزيد من الاهتمام في السنوات الأخيرة في البلدان الرئيسية المنتجة للتمور، ويجري استخدامه في جميع أنحاء العالم لإطالة عمر المنتج ، والحفاظ على المنتجات بجودة عالية وقيمة مضافة من أجل تعزيز القدرة التنافسية في السوق والقيمة الاقتصادية للمنتج **(Al-Yahayai and Al-Kharusi, 2012)**. و في صناعة التمور عادة تخزن على 3^{a}م لمدة تصل إلى سنة **(Aleid, 2013)**.

هناك العديد من المواصفات للتمور تستعمل على الصعيدين المحلي والدولي، مثل مواصفات الولايات المتحدة لتصنيف التمور **(United States standards for grades of dates, 1955)**، مواصفات الدستور الغذائي للتمور **(Codex, 1985)**، ومواصفات اللجنة الاقتصادية الأوروبية للتسويق ومراقبة الجودة التجارية للتمور، مواصفات المملكة العربية للتمور المعبئة رقم 543 عام 1989م، مواصفات دول الخليج رقم 656 عام 1997م، والمواصفات القياسية الخليجية أو لائحة منظمة **(GSO)** الفنية للتمور المعبأة 656 عام **2010م**. ولقد وضعت المواصفات الحالية للتمور لتحديد المواصفات المميزة لبعض أصناف من التمور لضمان سهولة التجارة العالمية للتمور.

تتعرض التمورمثلها مثل المنتجات الزراعية للتلوث الميكروبي في المزارع وأثناء التعامل والتصنيع. وأظهرت الدراسات التي أجريت حتى الآن أن الثمار في مرحلة الرطب تكون ملوثة بأنواع عديدة من الكائنات الحية الدقيقة. والكائنات الحية الدقيقة المحتملة التي تلوث التمور تشمل الأعفان والخمائر وبكتيريا حمض اللاكتيك، في حين تشمل مسببات الأمراض مثل بكتيريا مثل *Staphylococcus aureus* والخمائر مثل *Candida pelliculosa*. ويمكن أن يؤدي التلوث الميكروبي إلى خسائر كبيرة في المحصول وخاصة في مرحلة الرطب. وتعتمد المعاملات التي تهدف إلى الحد التلوث الميكروبي في مصانع التمور في المملكة العربية السعودية على غسيل بالماء النقي أو المعالجة بالكلور. وأظهر مسوحات أجريت في مصانع التمور التي تعتمد على الغسل

بالماء النقي والمعالجة بالكلور أن هذه المعاملات لم تكن فعالة تماما. وفي بعض الحالات كانت التمور المصنعة المعالجة أعلى في المحتوى الميكروبي من التمور الطازجة **(Atia, 2011)**.

ويعتبر الماء أهم مكون في التمور وله دور حاسم في الخواص الفيزيائية والكيميائية والميكروبية والتحلل البيوكيميائي لمكونات الغذاء.

ويوجد الماء في التمور مثلها مثل الأغذية الأخري تحت شكلين: الماء الحر والماء المرتبط, ويؤثر الماء الى جانب السكر على المراحل الأخيرة لنضج التم. وتتغير نسبة الماء في التمرتبعا للتجفيف والترطيب وكذلك باختلاف الأصناف وفترة الجني وإيصالها إلى مصانع التعبئة والتغليف والكبس. ولذلك يؤخذ بالاعتبار نسب الماء في التمر لمنع نشاط الفطريات وبالتالي منع ظاهرة التخمرات والتحميض و تحتاج التمور في مصانع التعبئة والتغليف إلى عملية تجفيف للسيطرة على عامل النشاط المائي. وبذلك تتحدد مجموعات الأحياء المجهريه ونشاطها في التمر مثلر(بكتيريا 0.90 ، خمائر 0.88، فطريات 0.80، بكتريا مقاومة للملح 0.75، بكتريا مقاومة للسكر 0.62) (**العكيدي، 2010**).

درجة الحرارة والأكسجين ونسبة الرطوبة هي أهم العوامل التي تؤثر على نوع و حمل الميكروبات و منه التلف أثناء التخزين. يمكن أن يكون سبب التلوث الميكروبي للتمور من الخمائر مثل *Zygo saccharomyces* هي أكثر تحملا لنسب السكر العالية حيث يحدث التدهور فى التمور عن طريق زيادة التخمير مع زيادة محتوى الماء، والفطريات والبكتيريا وبالتالي فإن درجة حرارة التخزين والمحتوى المائي هي من العوامل الرئيسية التي تؤثر على العمر الافتراضي للتمور أثناء التخزين **(Rygg، 1956)**.

ثمار التمر بصفة عامة مقاومة للتلوث الميكروبي بمختلف أنواع الملوثات الفطرية والبكتيرية بسبب محتواها المرتفع في نسبة السكر **(Siddig, 2012)**.

بينما الطعم الحامضي ومدة حفظ التمور تتأثر ببكتيريا حمض اللاكتيك وبكتريا حمض الخليك التي توجد بأعداد كبيرة. والتلوث الفطري له علاقة مباشرة بالحالة الفيزيائية للتمور والظروف البيئية المحيطة بما في ذلك درجة حرارة التخزين والرطوبة والذي يؤثر علي الصفات الحسية للتمور، وبالتالي يقلل من القيمة التسويقية **(Ragava *et al.*, 2016)**.

درجة الحرارة المثلى لحفظ ثمار التمر هي 0.0°م لمدة 6-12 شهرا، حسب الصنف (تمور شبه لينة، مثل "دجلة نور"، لها فترة تخزين أطول من التمور اللينة، مثل"مدجول" و "برحي"). ولفترات تخزين أطول نستخدم أعلى درجة حرارة تجمد للتمور حوالي -15.7°م , 20٪ رطوبة نسبية، ويمكن أن تبقى التمور على -18°م لمدة أكثر من سنة واحدة، أو في 0.0°م لمدة أقل من العام، أو عند 4°م لمدة 8 أشهر، أو عند 20°م لمدة شهر واحد (يجب أن تبقى الرطوبة النسبية بين 65 و 75٪ في كل الحالات). التخزين والنقل في درجات حرارة منخفضة هو الأداة الأكثر أهمية للحفاظ على جودة التمور لأنه يقلل من (فقدان اللون والنكهة، ونوعيته التكوينية، تأخر تطور عملية التسكر، الإصابة بالأعفان والخمائر، الإصابة الحشرية). يمنع تطور و حدوث ما يسمي بـ syrupiness (نتيجة تحول السكروز إلى السكريات المختزلة) واكتساب التمور الرطبة الطعم الحامضي. وفقدان الماء بالتمور يتناسب طرديا مع فرق الضغط البخاري بين التمور والبيئة المحيطة، وهي تتناسب عكسيا مع الرطوبة النسبية لوسط التخزين. ومن ثم التأثير على حدوث بعض الاضطرابات الفسيولوجية، ونمو الفطريات. تكاثف الرطوبة على التمور (التعرق) بعد فترات طويلة من الزمن ربما أكثر أهمية في تعزيز التدهور و العفن من الرطوبة النسبية والوسط الهوائي والرطوبة النسبية المناسبة للتمور هى 65-75٪، وتمتص التمور الرطوبة من جو الغرفة ما لم يتم تعبئتها في حاويات مقاومة للرطوبة. والنشاط المائي يتراوح من 0.65 إلى 0.85 يتوافق مع محتوي رطوبى من 15 إالى 35٪ في التمور. وانخفاض النشاط المائي يؤدي إلى زيادة المقاومة للأعفان، الخمائر والبكتيريا التي تهاجم ثمار التمر **(Adel and Hussein, 2009)**.

يمكن أن يؤدي تعدد الكائنات الحية الدقيقة المسببة لتلف التمور الطازجة إلى عملية تخزين تمنع تدهور التمور **(Al-Jasser, 2010)**.

وتعتبر الفطريات من أكبر العوامل المسببة لتلف التمور، تليها البكتيريا والخمائر في جميع مراحل النضج على الأشجار، وكذلك أثناء التخزين والتصنيع **(Amal *et al.*, 2014 & Anjili *et al.*, 2015)**
الحمل الميكروبي لثمار تمر النخيل هو خليط من البكتيريا والخمائر والفطريات. حيث وجد أن درجة الحرارة والرطوبة من أهم العوامل في تطور تعفن ثمار التمر التي تسببها الفطريات المحمولة عليها **(Omamor and Hamza, 2004)**.
أعداد الخمائر، الفطريات والبكتيريا على ثمار التمور انخفضت بشكل ملحوظ عند التخزين على -19ºم مقارنة مع تلك المخزنة على 26 و 4ºم **(Al-Jasser, 2010)**. علاوة على ذلك، ذكرت **Benjamin *et al.*, (1976)** أن نوعية التمور المخزنة في درجة حرارة الغرفة كانت سيئة للغاية وغير مقبولة للاستهلاك البشري، وتراوحت درجة الحرارة المناسبة للتخزين من-3 إلى 5ºم.

وفي ظل عدم وجود دراسات متعمقة للربط بين فترة صلاحية التمور وظروف التخزين وخصوصا ارتباط حدوث تغيرات في الحمل الميكروبي للتمور بظروف التعبئة والتخزين فان الهدف من البحث الحالي هو التعرف على درجات الحرارة المناسبة لتخزين التمور المعبأة تحت التفريغ تحت ظروف المملكة.

المواد والطرق:

أجريت هذه الدراسة في مختبرات قسم الهندسة والتصنيع الغذائي بمركز النخيل والتمورالإحساء بالتعاون مع مصنع تعبئة التمور التابع لهيئة الري والصرف بالإحساء. تم تطبيق الدراسة على عبوات التمور المعبأة تحت التفريغ ومخزنة على 5°م مقارنة بدرجة حرارة الغرفة 25°م لمدة 12 شهر.

وتمت تجربة التخزين على تمر صنف خلاص الذي يمثل النسبة الاكبر من نخيل الإحساء. وتم تجميع عينات عشوائية من خطوط التعبئة معبأة تحت التفريغ في أكياس البولي ايثيلين المعقمة وزنها 1 كجم. وتم تصميم المعاملات طبقا للتصميم كامل العشوائية. تم جمع العينات التي تشمل 5 عينات بعد الغسيل مباشرة وقبل التعبئة ومثلها بعد التعبئة في حاويات معقمة ونقلها إلى المختبر لتحليلها وإتمام معاملات التخزين. تم اختبار الجزء الأول من العينات فور جمع العينات. تم تخزين الجزء الثاني من العينات على درجتي حرارة مختلفة 5 و 25°م (درجة حرارة الغرفة) لمدة 12 شهر. وأجريت التحاليل التالية كل 3 شهور متتالية. لتقدير العدد الكلي للميكروبات الحية، تم أخذ 10 جم من التمور من العينات المجمعة وخلطها جيدا في 90 مل من محلول كلويد الصوديوم ذو التركيز 0.9% المعقم وتجنيس المخلوط جيدا في أكياس الهضم المعقمة لمدة دقيقة باستخدام وحدة الهضم لجهاز Masticator Stomacher (IUL Instruments, Barcelona, Spain)". ثم تم عمل تخفيف متدرج للعينات يصل إلى 10^{-7} التخفيفات في الماء المقطر المعقم. يتم تحليل مخلوط العينات والتخفيفات المتدرجة لها كما تم وصفة من قبل العالمان **(Katase and Tsumura, 2011)**.

تم اختيار سلالات ميكروبية نموذجية معرفة من بنك العزلات الميكروبية كمرجعية لتعريف الميكروبات الملوثة المراد الكشف عنا بالعينات. وقد استخدم *Bacillus subtilis* NBRC3023 لاختبار التحقق من تلوث العينات بمجموعة البكتيريا الهوائية. واستخدمت *Escherichia coli* NBRC3301، *Citrobacter freundii* NBRC12681 و *Klebsiella oxytoca* ATCC700324 لاختبار التحقق من تلوث العينات بمجموعة بكتريا القولون. استخدمت *Escherichia coli* NCTC9001 و *Enterobacter aerogenes* NCTC10006 لاختبار التحقق من تلوث العينات بمجموعة البكتريا المعوية.

وتم استخدام *Saccharomyces cerevisiae* S288C و *Aspergillus niger* (BioBall HighDose 10K; bioMerieux, Marcy l'Etoile, France) لاختبار التحقق من تلوث العينات بمجموعة بالخمائر والأعفان. وقد استخدم بكتيريا من نوع *Staphylococcus aureus* ATCC29213 لاختبار التحقق من تلوث العينات بمجموعة البكتريا العنقودية الذهبية *Staph. aureus*.

تم إعداد بيئات من جميع السلالات البكتيرية على أطباق العد القياسية وحضنت في 35º م لمدة 18 ساعة. وقد حضنت خميرة *Saccharomyces cerevisiae* S288C على أطباق أجار البطاطس و سكر الدكستروز في 30º م لمدة 18 ساعة. ثم تلى ذلك، أخذت مستعمرة صغيرة واحدة من أطباق العزلات القياسية وتم تلقيحها في 90 مل من محلول كلويد الصوديوم ذو التركيز 0.9%، بعد التجانس، تم إعداد التخفيف التسلسلي لمعلق العينة في نطاقات التلوث المختلفة. حيث تم تلقيح البكتيريا في مدي واسع ($\log CFU\ g^{-1} = 1.0 – 5.0$ or 1.0 – 6.0) في اختبارات التلوث الصناعي، وتم تلقيح الخميرة والعفن، والتي هي أقل خطورة في التلوث بشكل عام في مدى صغير ($\log CFU\ g^{-1} = 1.0 – 3.0$ or 1.0 – 4.0). تم تقدير اعداد الميكروبات النامية بهذة المخاليط البيئية المتجانسة باستخدام نظام TEMPO حيث تم استخدام نظام TEMPO (BIOMERIEUX). ويعبر عن النتائج بعدد الوحدات المكونة للمستعمرة لكل 1 جرام من العينة ($cfu\ g^{-1}$) واعتمادا على عدد وحجم المستعمرات ذات التفاعل الايجابي، فان نظام TEMPO بحسب عدد الكائنات الحية الدقيقة في العينة في مدي من 10 - 49000 $cfu\ g^{-1}$ للتخفيف 10/1 من العينة أو 100 - 490000 $cfu\ g^{-1}$ لتخفيف 100/1 من العينة أو 1000 - 4900000 $cfu\ g^{-1}$ لتخفيف 1000/1 من العينة.

- تم استخدام مجموعة TEMPO-TVC للعد الكلي للبكتيريا الهوائية، تم تحضين البطاقة في 35º م لمدة 40-48 ساعة.
- واستخدام مجموعة TEMPO-CC و TEMPO-EB على التوالي لحصر التعداد الكلي لمجموعتي بكتريا القولون والبكتريا المعوية وتم تحضين البطاقات في 35º م لمدة 22-27 ساعة.
- وتم استخدام مجموعة TEMPO-YM للعد الكلي للخمائر والأعفان، مع تحضين البطاقات في 25 º م لمدة 72-76 ساعة.
- وأخيرا تم استخدام مجموعة TEMPO-STA للعد الكلي للبكتريا العنقودية وتم تحضين البطاقات في 35º م لمدة 24-27 ساعة.

لكل تخفيف يتم عمل ثلاثة مكررات وبعد التحضين المناسب، تم عد المستعمرات على جهاز عد المستعمرات وتحليلها إحصائيا **(Umar *et al*., 2014)** كما تم قياس النشاط المائي كما هو متبع بواسطة طريقة **(Ahmed and Ramaswamy, 2006).**

وتم التعبير عن النتائج في صورة متوسطات (كل قيمة متوسط لعدد 3 مكررات لكل معاملة)، تم تحويل القيم التي تم الحصول عليها ($cfu\ g^{-1}$) لأرقام لوغاريتمية. في هذه الدراسة تم تحليل نتائج قيم ومتوسطات المكررات إحصائيا بطريقة التصميم المتعدد العوامل كامل العشوائية، وطبقت لاختبار تحليل التباين للحصول علي قيمة أقل فرق معنوي (LSD) بين قيم المتوسطات للمتغير تحت تأثير نفس العامل المؤثر (الزمن) تحت نفس درجة حرارة التخزين. تم استخدام نطاقات متعددة Duncan عند مستوى معنوية 5٪ (مستوى ثقة 95%) والفروق المعنوية تقاس عند مستوي احتماليه $P \leq 0.05$ **(Snedecor and Cochran, 1980).**

النتائج والمناقشة:

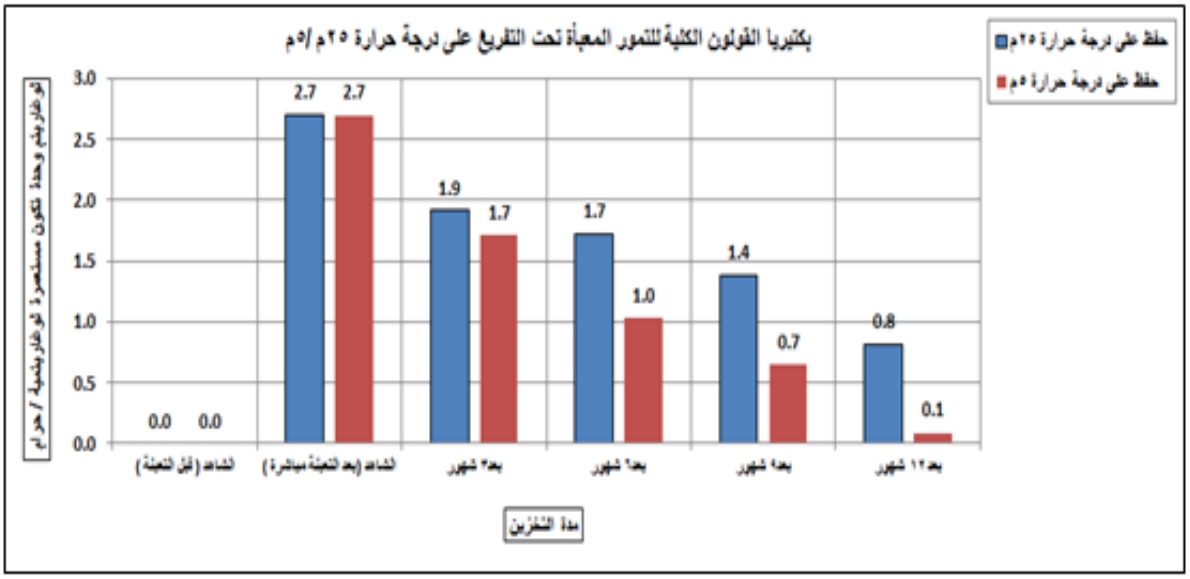
أوضحت الدراسة تأثير درجة حرارة التخزين على جودة التمور المخزنة بعد تعبئتها تحت التفريغ خلال سنة من بداية التخزين، وذلك بالمقارنة بالمواصفات الخليجية لجودة التمور GSO 656/2010. وبصفة عامة عند خفض درجة حرارة التخزين يمكننا زيادة مدة التخزين وتحسين خصائص الجودة للتمور.

تظهر النتائج (جدول 1) أن تغيرات الحمل الميكروبي مقترنة بالنشاط المائي للتمر. ويتضح أن القيم اللوغاريتمية لأعداد مجموعة بكتريا القولون ***Escherichia coli*** ومجموعة البكتريا المعوية الممرضة *Enterobacteriaceae* سجلت القيمة صفر عند تخزين تمور صنف الخلاص المعبأة تحت التفريغ علي

درجة حرارة الغرفة (25º م / 5º م) بكل العينات المأخوذة عشوائيا. وذلك لعدم ملائمة ظروف التخزين لنمو الخلايا البكتيرية خاصة التعبئة تحت التفريغ (ظروف لاهوائية).

وهي بذلك متطابقة مع قيم المواصفات الخليجية للتمور GSO 656 لعام 2010 (0.0 – 1.0 لوغاريتم وحدة تكون المستعمرة الميكروبية/جم تمر) خلال 12 شهر.

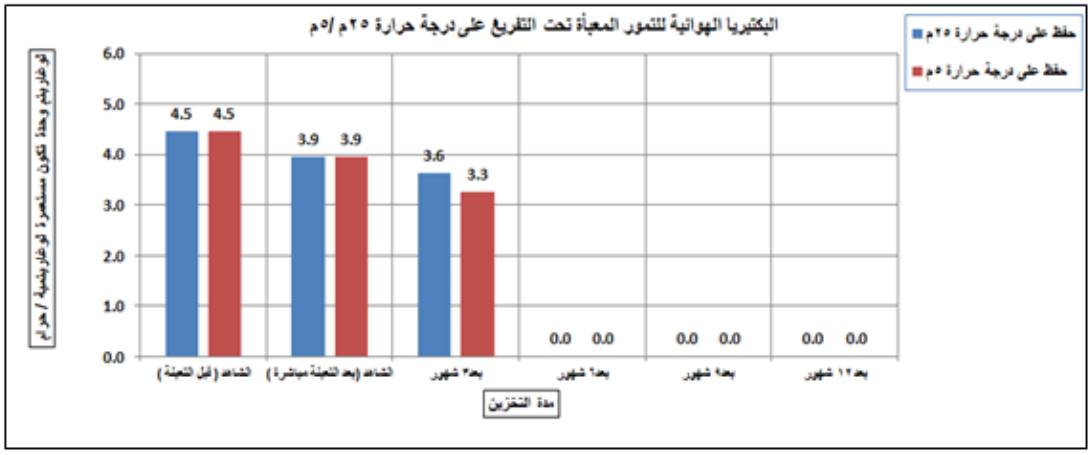
ويتضح من خلال الشكل 1 أن قيم أعداد مجموعة بكتريا القولون الكلية Total coliform لم تسجل فروقا معنوية في العينات المخزنة على درجات الحرارة (25º م / 5º م) خلال الستة اشهر الاولى من التعبئة ، بينما سجلت فروق معنوية في حالة العينات المخزنة على درجة حرارة (25º م / 5º م) بعد الستة اشهر الاولى من التخزين. والاتجاه العام للقيم اللوغاريتمة لعدد وحدات المستعمرات الميكروبية المتكونة / جم عينة يأخذ في الانخفاض أثناء فترة التخزين وفي حدود المواصفة المسوح بها من قبل المواصفات الخليجية للتمور المعبأة GSO 656 (2010). كما يلاحظ أن هناك ارتفاع ملحوظ بعد التعبئة مباشرة من المستوي صفر قبل التعبئة إلى 2. 7 لوغاريتم (وحدة تكون المستعمرة الميكروبية/جم تمر) بعد التعبئة مباشرة. مما يدل علي حدوث تلوث للتمور الخام ويفسر الزيادة بعد التعبئة مباشرة عن قيمتها في المصدر إلى تلوث المياه المستخدمة في الغسيل. كذلك يلاحظ انخفاض كبير في أعداد بكتريا القولون الكلية والمخزنة على درجة حرارة 5º م مقارنة بتلك المخزنة على درجة حرارة 25º م . وعموما يلاحظ الانخفاض في العدد الكلي لبكتيريا القولون الكلية في التمور المعبأة تحت التفريغ وذلك لعدم ملائمة ظروف التخزين لنمو الخلايا البكتيرية خاصة التعبئة تحت التفريغ (ظروف لاهوائية).



شكل (1): تأثير درجة حرارة التخزين في (25º م / 5º م) لمدة 12 شهر على العدد الكلي ["لوغاريتم وحدة تكون المستعمرة الميكروبية/جم" ($Log\ cfu\ g^{-1}$)] لبكتريا القولون الكلية (TC) Total coliform على ثمار تمر الخلاص المعبأة تحت التفريغ.

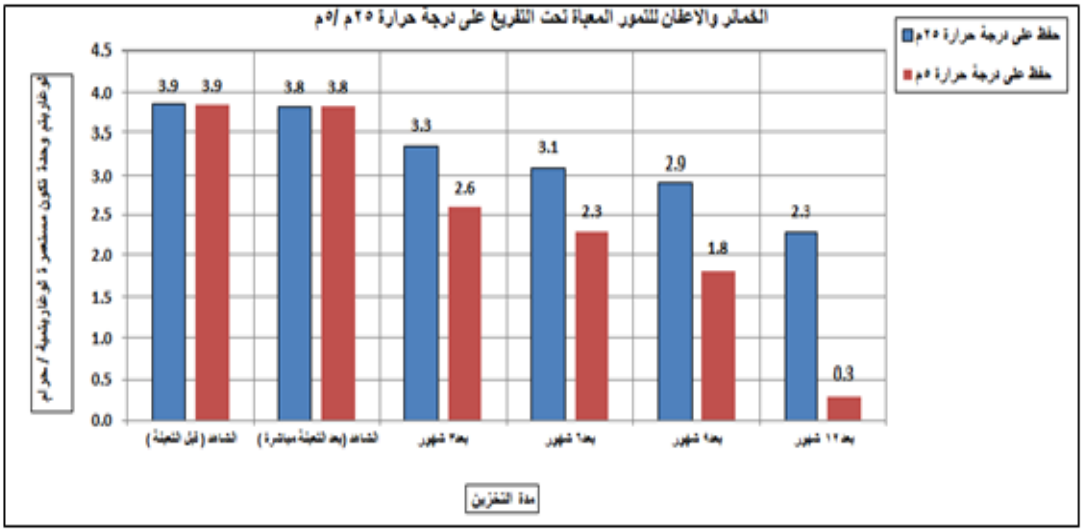
كما يوضح الشكل 2 أن قيم أعداد مجموعة البكتريا الهوائية الكلية Total count لم تسجل فروقا معنوية مرتفعة في حالة العينات الخاصة والمخزنة على درجات حرارة (25º م / 5º م) وكانت القيم اقل من الحدود

المسموح بها طبقا للمواصفات الخليجية للتمور المعبأة GSO 656 (2010). يلاحظ أن الاتجاه العام للقيم اللوغاريتمة لعدد وحدات المستعمرات الميكروبية المتكونة / جم عينة , يأخذ في الانخفاض أثناء فترة التخزين (12 شهر) وفي حدود المواصفة المسوح بها من قبل المواصفات الخليجية للتمور المعبأة. كما يلاحظ أن هناك انعدام تام للوغاريتم (وحدة تكون المستعمرة الميكروبية/جم تمر) بعد مرور 3 شهور من التخزين على درجات حرارة (25º م / 5º م). ويفسر ذلك لعدم ملائمة ظروف التخزين لنمو الخلايا البكتيرية خاصة التعبئة تحت التفريغ (ظروف لاهوائية) ولانخفاض المحتوى من الماء المرتبط بالثمار.



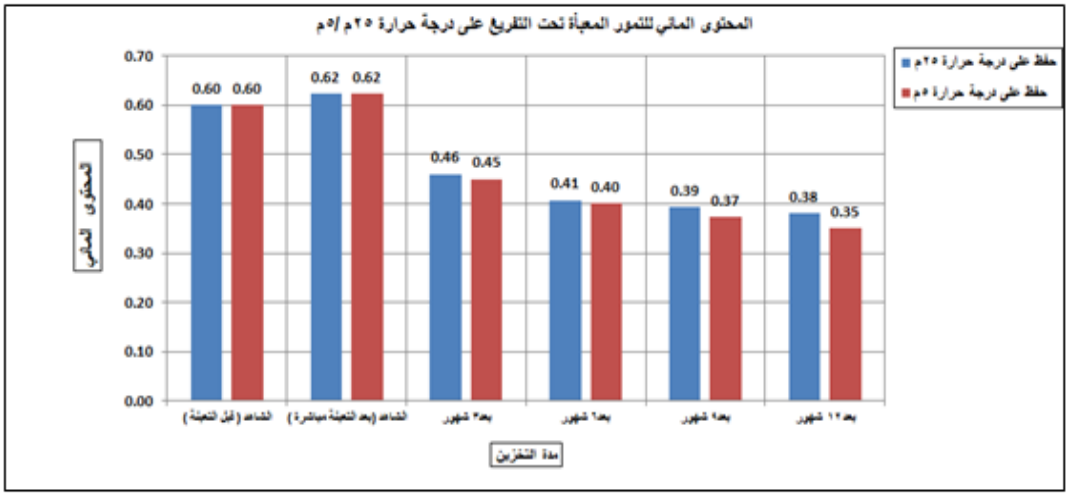
شكل (2): تأثير درجة حرارة التخزين في (25º م / 5º م) لمدة 12 شهر على العدد الكلي للبكتريا الهوائية ["لوغاريتم وحدة تكون المستعمرة الميكروبية/جم" ($Log\ cfu\ g^{-1}$)] على ثمار تمر الخلاص المعبأة تحت التفريغ .

كذلك بملاحظة النتائج بالجدول (1) والموثقة بالشكل رقم (3) قيم أعداد مجموعة الخمائر والأعفان Yeast and Mold و التي سجلت فروقا معنوية في حالة العينات المخزنة على درجة حرارة (5º م). كما يلاحظ أن الاتجاه العام للقيم اللوغاريتمة لعدد وحدات المستعمرات الميكروبية المتكونة / جم عينة يأخذ في الانخفاض السريع أثناء فترة التخزين على درجة حرارة (5º م) مقارنة بتلك المخزنة على درجة حرارة (25º م) . ويفسر ذلك لعدم ملائمة ظروف التخزين لنمو خلايا الفطريات و الخمائر خاصة التعبئة تحت التفريغ (ظروف لاهوائية) ولانخفاض المحتوي من الماء المرتبط بالثمار مع استمرار مقاومة خلايا الفطريات والخمائر نتيجة لقيامها بعمل تحلل لبعض مكونات التمور من سكريات في صورة تخمرات تتضح بطعم تخمر خفيف كلما زادت مدة التخزين.



شكل (3): تأثير درجة حرارة التخزين في (25º م / 5º م) لمدة 12 شهر على العدد الكلي للخمائر و الأعفان ["لوغاريتم وحدة تكون المستعمرة الميكروبية/جم" ($Log\ cfu\ g^{-1}$)] على ثمار تمر الخلاص المعبأة تحت التفريغ .

توضح النتائج بالجدول (1) و الموثقة بالشكل رقم (4) قيم المحتوي المائي لثمار تمر الخلاص المعبأة تحت التفريغ والمخزنة لمدة 12 شهر علي درجة حرارة (25º م / 5º م) ، والتي لم تسجل فروقا معنوية بين التمور المعبأة والمخزنة على درجة حرارة (25º م / 5º م) خلال نفس الفترة . كما يلاحظ أن الاتجاه العام لقيم المتوسطات للمحتوي المائي يأخذ في الانخفاض أثناء فترة التخزين (12 شهر) .



شكل (4): تأثير درجة حرارة التخزين في (25º م / 5º م) لمدة 12 شهر على المحتوي المائي بثمار تمر الخلاص المعبأة تحت التفريغ.

من ما سبق يتضح أنه نتيجة لعدم وجود دراسات شاملة على مؤشرات الجودة ومواصفات ثمار التمور الأكثر

وفرة واهمية تجارية في المملكة العربية السعودية تمر الخلاص يلزمنا بالالتزام بالمواصفات الخليجية للتمور المعبأة (2010) GSO 656. وأن تخزين التمور لفترات زمنية تحت ظروف محددة يجعلها تتعرض لتغيرات في جودتها من جفاف الماء النشط بالتمور اللينة، و حدوث تخمرات وتغيرات بيولوجية نتيجة لتطور نمو الكائنات الحية وبالتالي التأثير على العمر الافتراضي وجودة التمور وهذا يتوافق مع ما أقره **(Aleid *et al.*, 2014b)**.

يأخذ بالاعتبار الاهتمام بنسب الماء النشط في التمر لمنع نشاط الفطريات وبالتالي منع ظاهرة التخمرات والتحميض. لذا تحتاج التمور في مصانع التعبئة والتغليف إلى عملية تجفيف للسيطرة على عامل النشاط المائي. من ثم فإن درجة حرارة التخزين والمحتوى المائي هي العوامل الرئيسية التي تؤثر على العمر الافتراضي للتمور أثناء التخزين، فانخفاض النشاط المائي يؤدي إلى زيادة المقاومة للأعفان، الخمائر والبكتيريا التي تهاجم ثمار التمر وهذا يتوافق مع ما أقره **(Rygg، 1956)** و**(Adel and Hussein, 2009)** و **(Atia, 2011)**.

الخاتمة

وعليه لوحظ أن التبريد له تأثير أكثر إيجابية للتحكم في مستوى الميكروبات، ويستنتج أن التبريد هو أفضل طريقة للسيطرة على الميكروبات في التمور المخزنة والمعبأة تحت التفريغ كما أثبت أن مصدر الالحمل الميكروبي ناتج في أغلبه من معاملات ما بعد الحصاد في الحقل ومن خطوط الغسيل.

حفظ التمور على درجة حرارة 5°م يساعد إطالة مدة التخزين و الحفاظ علي جودة التمور.

التمور المخزنة على درجة حرارة 25م غير مطابقة للمواصفات الخليجية حيث لوحظ نشاط بكتيريا الخمائر والاعفان بأكثر من الحدود المسموح بها في المواصفة .

التأكيد على اهمية عملية الحصاد والنقل والتداول للثمار بالطرق العلمية الصحيحة

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FINGERPRINTING OF SOME OMANI DATE PALM CULTIVARS USING SSR MARKERS

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The Sixth International Date Palm Conference (SIDPC)
Abu Dhabi -UAE: 19 – 21 March, 2018.

Abstract: The numbers of known date palm cultivars that are distributed all over the world are approximately 5,000, out of which about 250 are found only in Oman. It is a dioecious, perennial, monocot plant, and its heterozygous form makes its progeny strongly heterogeneous. Most of these cultivars were described using morphological markers such as fruit and vegetative traits, but these are greatly affected by the environment and are also complex. In general, the identification and evaluation of genetic diversity between the cultivars on the basis of morphological markers is difficult. Recently DNA markers have been used to provide the information on the relatedness of date palm cultivars that are difficult to distinguish morphologically. Microsatellites (SSR) have been used widely in date palm genetic diversity among GCC countries. In this study, the genetic diversity of twelve of Omani date palm cultivars was studied by using 10 microsatellite markers which is same markers used in GCC countries date palm cultivars. Mature leaves samples of all cultivars, five replicates per cultivar, were collected from five governorates of Oman from north and south Al-Batinah (Sohar and Barka), Al-Dahirah (Ibri), Al-Dakhilia (Wadi Quriate, Nizwa), Al-Sharqiya (Samad Al-Shan, Al-Kamel & Al-Alwafi) and Al-Burymi (Mahadah, Al-Buraymi). A total of 113 alleles were scored with average of 11.3 alleles per locus. It was ranged from 5 alleles/locus for SSR (PDCAT 17) to 17 alleles/locus SSR (mPdCIR 10). The polymorphic information content (PIC) average 0.668. There was genetic diversity within and among the selected cultivars and were assessed by using microsatellite markers.

INTRODUCTION

Microsatellite or simple sequence repeat (SSR) molecular markers have been proven to be very powerful in plant diversity analysis because they are locus specific, co-dominant, highly polymorphic and highly reproducible. Genetic variation in the date palm germplasm has been traditionally characterized using morphological descriptors. However, such morphological markers are often unreliable and ambiguous because of the influence of environmental factors and confounding effects of developmental stage of the plant) Barrow, 1998). The aim of this investigation was to study the genetic variation (polymorphisms) among different Omani date palm cultivars using SSR markers. Date palm (*Phoenix dactylifera* L.) is a dioecious perennial monocotyledon plant with long generation times (a period of 4 to 5 years is necessary to reach the

first flowering) that belongs to *Arecaceae* family (Elhoumaizi, 2002). It is important to study the genetic diversity of the Omani date palm cultivars, because it helps to find the identity of DNA that will helps in documenting the Omani cultivars in order to preserve them. Also, to determine the strains within species, make sure and check conventional seedlings before being placed in the tissue propagation, definition promising new cultivars for farmers, to make sure the genetic stability of the output of agriculture and textile version genetic compatibility with the original certification and to ensure product quality.

The most common characteristics that are used to identify different cultivars of date palm are the morphology of leaves, spines, and fruit, which are mainly based on the characterization of introduced date palm cultivars in California (Nixon, 1950). Over the years, many date palm cultivars have been transplanted to areas other than the area of their origin, and they may have been given different names. As a result, a variety may have different names in different areas, or two genetically different varieties may have the same name. This may reduce the genetic diversity of the cultivars, making them vulnerable to biotic and abiotic stresses. In general, the identification and evaluation of genetic diversity between cultivars on the basis of morphological markers is difficult. The identification of trees is usually not possible until the onset of fruiting, which takes 3 to 5 years. Further, characterizing varieties requires a large set of phenotypic data that are difficult to access statistically and are variable because of environmental effects (Sedra *et. al.*, 1993, 1996, 1998). Biochemical markers (isozymes and proteins) are effective in varietal identification (Bennaceur *et. al.*, 1991; Fakir et al., 1992; Bendiab *et. al.*, 1993). However, they give limited information and are an indirect approach for detecting genomic variation (Elmeer, 2015).

In this study, we aimed to investigate the genetic diversity of date palms in Oman to improve production and reveal the genetic relationships among 10 date palm cultivars using 12 nuclear microsatellite markers. These cultivars have names that were given by farmers after continuous selection.

MATERIAL AND METHODS

Collection of material

Date palm material was collected 5 replicates of 12 cultivars from the different region on Oman (North and South Al-Batinah governorate, Al-Dahrah, Al-Dakhliah, Al-Sharqeah, Al-Buraimi) as shown in Table 1 and Fig. 1. These cultivars represent the diversity of date palm genotypes in the Omani date palm plantation. Young leaves from mature, randomly sampled trees, were collected and stored at -80°C, until DNA extraction.

Molecular analysis

DNA was extracted by using (Maxi: kit Qiagen Cat # 68163 DNeasy plant). It was measured DNA concentration using a 1% of Agarose gel and then detected using UV light and was used the device (Nanodrope) to ensure the purity of DNA by absorption measurement at a wavelength between 260 and 280 nm to enter it in the next stage figure2. The microsatellite amplification reaction was performed by using Applied Biosystems (2720 thermo cycler, Singapore) with 10 primers combinations. Table 2 shows the microsatellite combination and its allelic ranges (Peakall 2012). The PCR program had initial denaturation at 95 ^{0}C for 5 minutes, then 35 cycles of 95 ^{0}C for 30 minutes, 52/55 ^{0}C for 1 min, and 72 ^{0}C for 1 minute and final elongation step at 72 ^{0}C for 7 minutes. Amplification products were separated using 2% agarose gel electrophoresis shown figure3. The

microsatellite alleles were detected using Beckman coulter CEQTM 8000 automated DNA sequencer machine. Control sample in replication was used in this experiment along with the samples to be analyzed, to ensure the repeatability and accuracy of results.

RESULTS AND DISCUSSION

The targeted fragments and allele scoring were performed by fragment analysis. For each marker, the average number of alleles per locus, the expected heterozygosity (He) and the observed heterozygosity (Ho) were calculated by Gene Alex 6.3 software. The genetic similarity and the analysis of molecular variance (AMOVA) and principal coordinates analysis (PCoA) were also calculated using Gene Alex 6.3 software. DARwin 6.0 software was used to make dendrogram which showed the distribution of different individuals.

A total of 113 alleles were scored with average of 11.3 alleles per locus. It was ranged from 5 alleles/locus for SSR (mPdCIR 57) to 20 for locuse SSR (mPdCIR 10). The polymorphic information content (PIC) average .6650 and it was range between 0.4818 (PDCAT21) and 0.9125 (mPdCIR 10) (Table 3). The average of expected heterozygosity (He) ranged between 0.227 (mPdCIR 85) and 0.718 (mPdCIR 10) and the average of observed heterozygosity (Ho) ranged between 0.150 (mPdCIR 85) and 0.700 (mPdCIR 16) (**Table 3**). Most of markers, the observed heterozygosity value was higher than the expected one. The percentage of polymorphic loci per cultivar varied between 60% and 100% with an average of 85% (**Table 4**). Molecular variance analysis showed that 70 % of the variation was due to differences within populations, while 30 % was due to differences between populations in Omani cultivars (Fig. 4).

The Dendrogram shown in figure 5, illustrates the divergence between the studied Omani date palm cultivars and suggests their tree brunching, Dendrogram divided into four main groups, Group A has the following cultivars (Lolo, Menaz, Kash Qantrah, Shahel, Hilali Makran). While Group B has the following cultivars (Selani, Hasas, Manhe) and group C has the following cultivars (Nasho Al-khashba, Hilali Asfer, Merzaban, Hilali A-Hasa) and group D has combination with different following cultivars: Hilali Alhasa, Shahel, Merzaban (Fig. 6). The principal coordinates analysis (PCoA) of the 12 Omani cultivars showed that the majority of cultivars were grouped in cluster and also dispersed among different sub-clusters. DNA SSR markers are powerful tool to provide information on the relatedness of varieties that are difficult to distinguish morphologically, thus helping in the management of plant accessions and in breeding programs. In this study, SSR markers have been used to assess the molecular characterization and the phylogenic relationships of Omani date palm cultivars. Present results provide evidence of a genetic diversity.

CONCLUSION

This study showed the distribution of Omani date palm cultivars from different region in Oman and analysis based on SSR markers. In future s this technique will help our study and provide a useful tool for research on genetic diversity, gene mapping, and marker-assisted selection in date palm. Therefore, while allowing studies on genetic variation, SSR markers also provides information on gene function related to possible phenotypic differences between the date palm cultivars.

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Tables

Table 1. Samples used in fingerprint study

No	Sample Name	Code	Location	No. replicate
1	Selani	SL	Batinah,Al-Dahrah,Al-Dakhliah,al-sharqeah,Buraimi	5
2	Hasas	HSS		
3	Merzaban	MR		
4	Shahel	SHL		
5	Menaz	MNZ		
6	Manhe	MNH		
7	Lolo	LO		
8	Hilali Makran	HM		
9	Hilali Alhasa	HH		
10	Hilali Asfer	HA		
11	Nasho alkhashba	NK		
12	Khash Qantrah	KK		

Table 2. List of microsatellite primers designed for date palm by Billotte el al. (2004) and Akkak et al. (2009), marker name, annealing temperature Tm (^{0}), motif repeat, observed allelic size range (bp) and status of amplification.

No	Locus Name	Sequences (5 '-3')	Annealing T_m (^{0}).	Motif repeat	Expected Allelic range(bp)	Observed Allelic range(bp)
1	PDCAT10	F: CACTGCTCCTGTTGCCCTGT R: TGTAGAAGGGCAGAGGACGG	55°C	$(TC)_{16}$	107-127	114-128
2	PDCAT14	F: TGCTGCAAATCTAGGTCACGA R: GTTTACCCCTCGGCCAAATGTAA	55°C	$(TC)_{19}(TC)_{16}$	101-155	135-168
3	PDCAT17	F: CAGCGGAGGGTGGGCCTC R: GTTTCTCCATCTCCCTTTTTCTGCTACTC	55°C	$(GA)_{21}$	116-145	143-165
4	PDCAT20	F: TTTCAGACACATCAAGTAACGATGA R: GTTTACGTCCACCCCAAGTTACGA	55°C	$(GA)_{29}$	294-353	343-361
5	PDCAT21	F: GTGTTTGAAGATTGATTTTGTGTTATGAG R: GTTTCGAACTATGCACAATAGTATATTG	55°C	$(GA)_5T(GA)_2TA(GA)_2$ $GC(GA)_5(GT)_7$	144-150	143-163
6	mPdCIR 10	F: ACC CCG GAC GTG AGG TG R: CGT CGA TCT CCT CCT TTG TCT C	52°C	$(GA)_{22}$	118-161	130-152
7	mPdCIR 15	F: AGC TGG CTC CTC CCT TCT TA R: GCT CGG TTG GAC TTG TTC T	52°C	$(GA)_{15}$	120-156	140-157
8	mPdCIR 16	F: AGC GGG AAA TGA AAA GGT AT R: ATG AAA ACG TGC CAA ATG TC	52°C	$(GA)_{14}$	130-138	143-157
9	mPdCIR 85	F: GAG AGA GGG TGG TGT TAT T R: TTC ATC CAG AAC CAC AGT A	52°C	$(GA)_{29}$	152-183	174-200
10	mPdCIR 93	F: CCA TTT ATC ATT CCC TCT CTT G R: CTT GGT AGC TGC GTT TCT TG	52°C	$(GA)_{16}$	153-184	160-181

Table 3. The PIC values and alleles/loci of 17 microsatellite primer combination and Heterozygoty of Omani cultivars calculated with GenAlex 6.3 software He: average of expected heterozygosity; Ho: average of observed heterozygosity.

Locus Name	Alleles/loci	PIC Value	He	Ho
PDCAT10	10	0.639	0.627	0.683
PDCAT14	10	0.705	0.262	0.167
PDCAT17	5	0.573	0.375	0.483

PDCAT20	9	0.555	0.427	0.483
PDCAT21	7	0.548	0.420	0.517
mPdCIR 10	17	0.916	0.718	0.450
mPdCIR 15	15	0.879	0.672	0.683
mPdCIR 16	13	0.779	0.610	0.700
mPdCIR 85	11	0.570	0.227	0.150
mPdCIR 93	16	0.798	0.682	0.650
Total	113	-		
Average	11.3	0.668		

Table 4. Percentage of polymorphic loci of Omani cultivars

Population	Percentage (%)
Selani	80
Hasas	70
Merzaban	90
Shahel	100
Menaz	90
Manhe	100
Lolo	60
Hilali Makran	90
Hilali Alhasa	80
Hilali Asfer	90
Nasho alkhashba	80
Kash Qantrah	90
mean	85

Figures

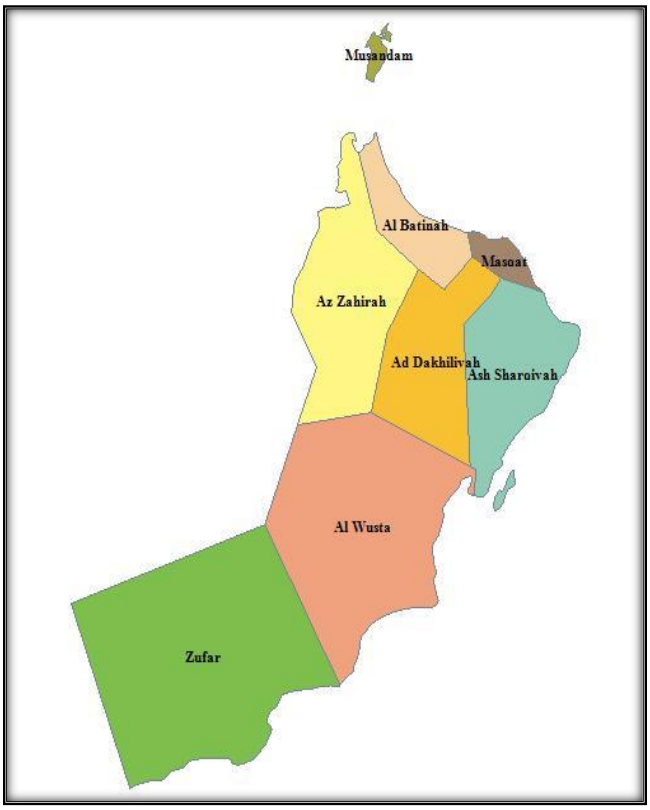

Fig. 1. Locations of Date palm collected

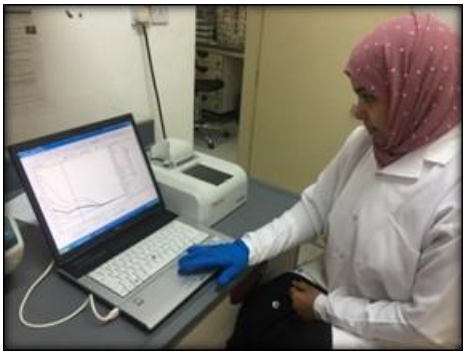

Fig. 2. Measuring the purity of the DNA using a device (Nanodrop).

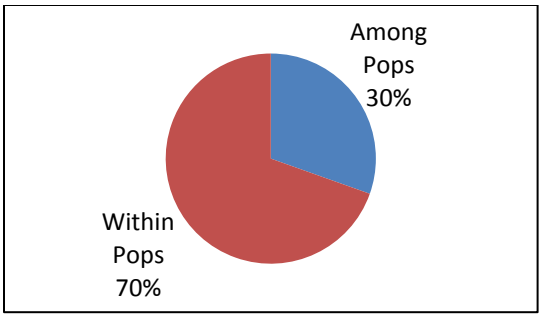

Fig. 3. Analysis of molecular variance between Oman cultivars.

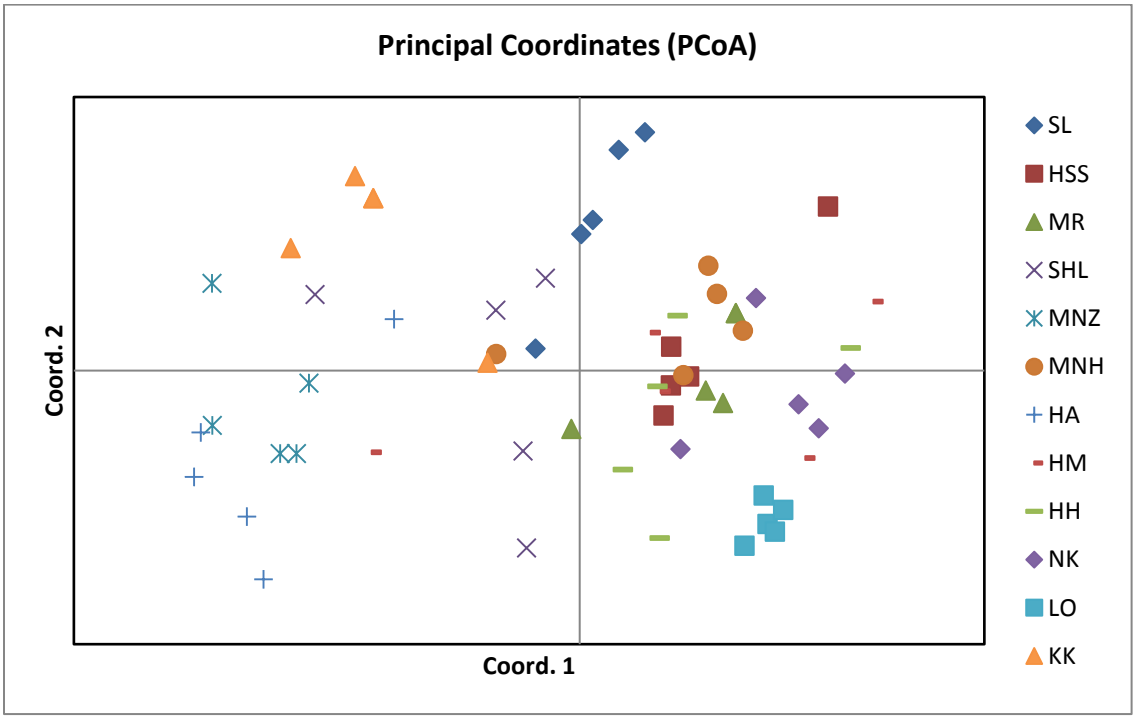

Fig. 4. principal coordinates analysis of Omani date palm cultivars

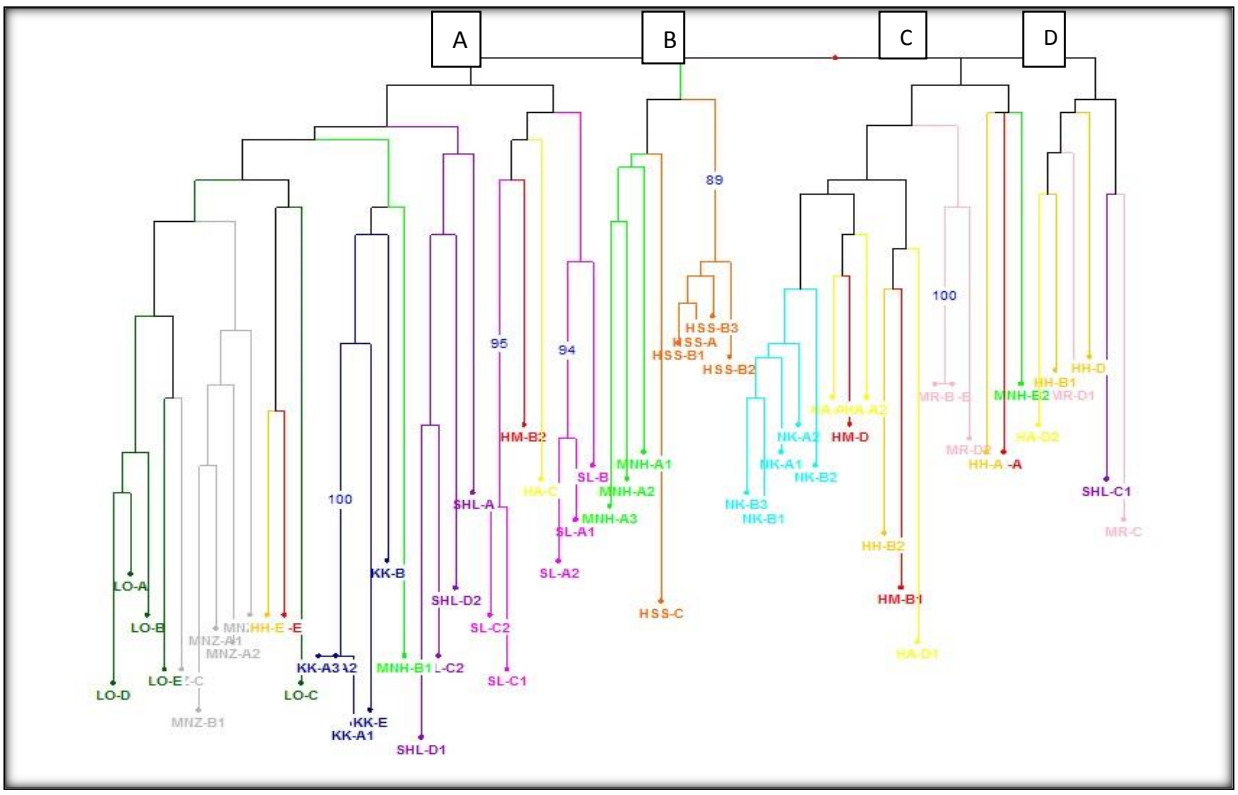

Fig. 5. Dendrogram of similarity coefficients based on UPGMA cluster analysis of 12 genotypes using 10 microsatellite (SSR) primer pairs**.**

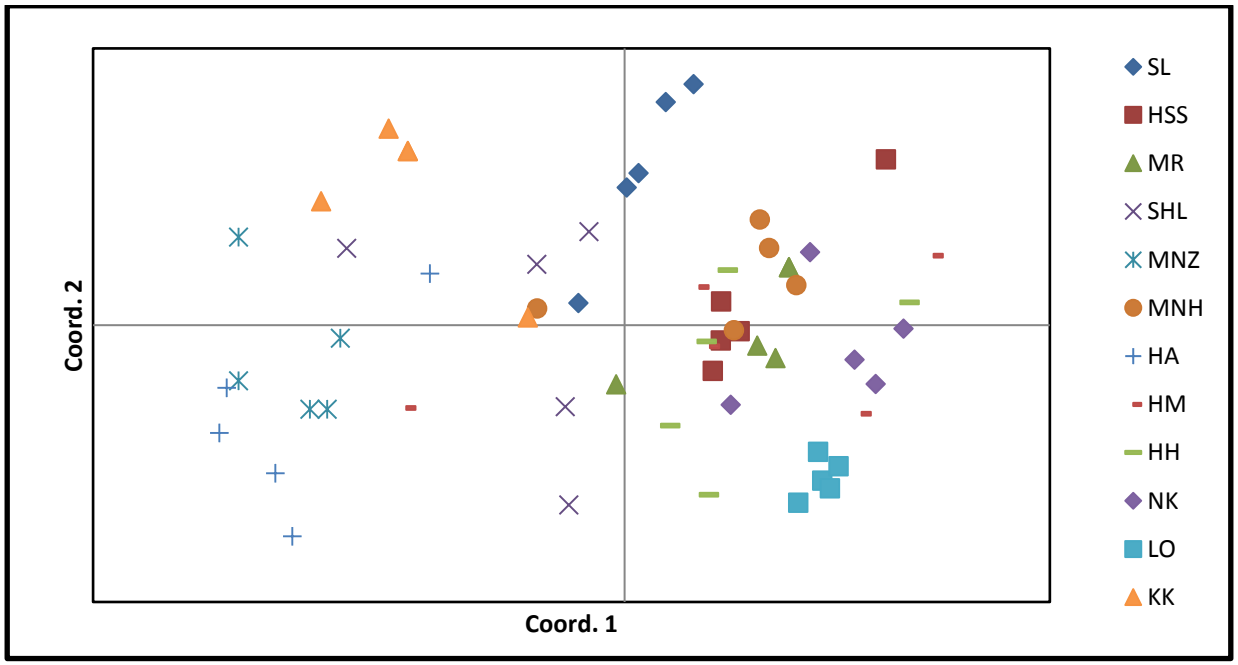

Fig. 6. Principal Coordinates Analysis (PCoA) of 12 Omani date palm cultivars

EVALUATION OF DATE PALM (*Phoenix dactylifera* L.) PRODUCTION UNDER ORGANIC MANURE APPLICATION WITH *arbuscular mycorrhizal* fungi ADDS ON SANDY SOILS IN STATE OF KUWAIT

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The Sixth International Date Palm Conference (SIDPC)
Abu Dhabi -UAE: 19 – 21 March, 2018.

Abstract: An experiment was conducted at Amghara Station of the State of Kuwait on date palm *Barhee* cv with ten treatment combinations involving different sources and levels of organic manure application in conjunction with arbascular mycorrhizal fungi (AMF) on sandy soils during 3 seasons (2013-2016). The experimental design adopted was RCBD with five replications.

The results showed that the Date palm Tamar fruit yield increased with increasing rates of sewage sludge and compost manure as compared to control. The influence of sewage sludge in conjunction with AMF on the Tamar yield of crop was more pronounced than that of compost manure. Such an increase in the yield may be attributed to the improvement in the fruit yield parameters such as number of fruiting spikelet's and fruits per bunch; weight, length and girth of fruit.

On an average over 3 years, application of 10 t/ha of sewage sludge (71.97 t/ha or 22.57% increase) or compost manure (70.00 t/ha or 19.31% increase) along with AMF over control (58.43 t/ha) could be recommended to date palm to increase the yield levels and fertility status especially the organic matter content of the soil.

Keywords: Organic manure, AMF, sewage sludge, compost manure, date palm, date yield.

INTRODUCTION

Date palm is one of the most important dry fruit crops grown under the hot arid conditions in Kuwait. Since the soils are sandy in nature, the growth of date palm (*Phoenix dactylifera* L.) is highly affected by organic matter content, water and nutrient availability in the soil.

Sewage sludge can substitute for commercial fertilizers and organic matter, if applied in the right amounts to soil. By using sludge, it is a possibility for farmers to supply their lands with organic fertilizer at low costs. Therefore, recycling of sludge for agricultural purpose seems to be an

appealing solution for sustainable management of sludge. Sewage sludge (bio-solids), which is enriched in nitrogen, phosphorus, organic matter and other trace elements, represents a good source of nutrients for plant growth and a good soil conditioner to improve soil physical properties. Due to its high organic matter content, sewage sludge can improve physical, chemical, and biological properties of soil (Alcantara et *al*., 2009). Thus, sludge application helps to reduce soil erosion and improves the soil quality as a plant growth medium. The fertilizer effect enables a reduction in cost for nitrogen and phosphorus mineral fertilizers and may improve crops yield on sludge treated fields (Wild and Jones, 1991; Petersen et *al*., 2003).

According to the study by Veysel et *al*. (2010), sewage sludge when applied to the soil with increasing amounts raised the mineral matter content of plant and resulted in the increase of growth and herbage yield of bird's foot trefoil. Heavy metal contents were below the critical levels in the soil and plant. Delgado Arroyo et *al*. (2002) reported that the application of sewage sludge compost @ 12 t/ha plus 350 kg urea/ha resulted in 20% greatest growth of maize than the mineral fertilization. No toxic effects arising from the heavy metals in the plant were observed. Moreover, the concentration of heavy metals in the soil was below Spanish and European legal limits.

Considerable research has been accomplished worldwide on the use of sewage sludge on soil and crop. In many investigations with different climatic and soil conditions have reported a substantial increase in plant growth, crop yield and biomass production upon sewage sludge application (Samaras et *al*., 2008; Togay et al., 2008). Using organic wastes such as sewage sludge, compost and cow manure is a proper practice for returning organic matter and some nutrients into the soil, particularly in arid and semi-arid regions. Application of sewage sludge, compost and cow manure at 25 Mg/ha significantly increased available Fe and Zn of the soil. The application of organic wastes increased the dry matter yield of the corn, alfalfa and targets flower plants (Sharifi et *al*., 2011).
Application of FYM with higher fertilizer level has given maximum tuber yield of potato in sandy clay loam soil (Krishnamurthy *et al*., 1999). Poultry waste compost under VAT method is agronomically efficient in sunflower production (Jayabharat *et al*., 2000). Application of organic manure 25 t/ha resulted in significantly higher tuber yield of potato (27.9%) as compared to 12.5 t/ha (Al Khalak *et al*., 2007).

This study was conducted in order to evaluate date palm production and soil properties in relation to the sources and levels of organic manure application in conjunction with AMF on sandy soils in Amghara area of The State of Kuwait.

MATERIAL AND METHODS

An experiment was conducted at Amghara Station of The State of Kuwait on *Barhee* cv of date palm with ten treatment combinations involving different sources and levels of organic manure application in conjunction with AMF on sandy soils during October, 2013 to September, 2016. The experimental design adopted was randomized complete block with five replications. The treatment combinations included in the experiment were as detailed below.

F1 – Control
F2 – AMF
F3 – Sewage sludge @ 5 t/ha
F4 – Sewage sludge @ 5 t/ha + AMF

F5 – Sewage sludge @ 10 t/ha
F6 – Sewage sludge @ 10 t/ha + AMF
F7 – Compost manure @ 5 t/ha
F8 – Compost manure @ 5 t/ha + AMF
F9 – Compost manure @ 10 t/ha
F10 – Compost manure @ 10 t/ha + AMF

The sandy loam soil at Amghara initially had a pH of 7.52, EC 9.48 dSm^{-1} , OM 0.29%, PO_4 4.24 ppm, K 1.91 meq/l, Ca 24.76 meq/l, Mg 13.22, Na 77.73 meq/l, Cl 78.07 meq/l, HCO_3 3.66 meq/l, SO_4 36.19 meq/l, and B 1.08 ppm(Table 1).

Soil sampling was done from 2 depths (0-25cm & 25-50cm) for initial physical, chemical and microbial analysis. Sewage sludge and organic manure with and without Mycorrhiza were incorporated as per the treatments @ 5 or 10 t/ha/year in October by opening a furrow to a depth of 15-20cm around each tree in the basin. The organic manure with or without mycorrhiza were mixed well and covered. Mycorrhizal inoculum (Glomus intraradices L.) procured from Germany was used in the experiment.

Compost manure had a pH of 7.2, O.M. 45%, N 2.3%, P_2O_5 1.01% & K 0.63 meq/l (Table 2). Sewage sludge manure had a pH of 8.88, O.M. 14.3%, N 1.002%, P_2O_5 1.63% & K 16 meq/l with a moisture content of 34.86% (Table 3).

First and second split dose of N, P_2O_5 and K_2O complex fertilizer (18-18-18 + TE) @ 1 kg//tree was applied in to the small furrows opened 5-10 cm deep around each date palm tree in the basin during the months of December and February. Micro nutrient mixture in the form of micromel combi @ 100g/tree was also applied during February. Later the fertilizers were mixed well in the soil and covered. Whereas, the third split dose of complex fertilizer (20-20-20 + TE) @ 1 kg//tree along with potassium sulphate @ 200 g/tree was applied during the month of April. After each application, irrigation was given to dissolve the fertilizer which helps in further uptake of nutrients by date palm crop.

Fourth stage treated sewage water was used for irrigation and it had a pH of 7.5, EC 0.25 dSm^{-1}, TDS 160 ppm, K 0.3 meq/l, Na 1.1 meq/l, Mg 0.2 meq/l, Ca 1.6 meq/l, HCO_3 1.2 meq/l, Cl 1.6 meq/l and SO_4 0.4 meq/l. Total Coliforms count was 140 MPN/100 ml (Table 5).

Bubbler irrigation was scheduled to the crop as per the requirement of the trees depending upon the climatic conditions and growth stages (Table 2).
All the crop management practices were adopted as per the recommendation. The necessary data on soil properties, soil moisture, irrigation water and biometrics were recorded. The Tamar fruit yield data was subjected to statistical analyses as per standard procedure and presented.

RESULTS AND DISCUSSION

The results of the average of 3 seasons (2013-2014, 2014-2015, 2015-2016) obtained and the discussion on the evaluation of date palm (Phoenix dactylifera L.) production and soil properties in relation to the sources and levels of organic manure application in conjunction with

AMF on sandy soils in Amghara area of the State of Kuwait is presented in tables 5, 6 & 7 and graphically represented also in Figures 2 &3.

Use of sewage sludge manure is economically advantageous to compost manure as the sewage sludge manure is locally available from the waste water treatment plants in Kuwait & hence the cost involved will be reduced. Hence, either compost or sewage sludge manure could be used favorably in the sandy soils of Kuwait.

The results showed that the dates yield increased with increasing rates of sewage sludge and compost manure as compared to control. The influence of sewage sludge in conjunction with AMF on the Tamar yield of crop was more pronounced than that of compost manure (Table 6 & Fig. 2). Such an increase in the yield of Tamar may be attributed to the improvement in the fruit yield parameters such as number of fruiting branches and fruits per bunch; weight, length and girth of fruit (Table **7** & **8**). This may further be related to the maintenance of higher moisture and availability of nutrients in the soil (Table **9** & Fig. 3). Similar results were also reported by other workers in different crops (Khalak and Kumaraswamy, 1993; Veeranna *et al*., 2001; Khalak et *al.* 2007).

On an average over 3 years, 10 t/ha of sewage sludge (71.97 t/ha or 22.57% increase) or compost manure (70.00 t/ha or 19.31% increase) along with AM fungi over control (58.43 t/ha) could be recommended to date palm crop to increase the yield levels and fertility status especially the organic matter content of the soil.

Treatment wise soil nutrient status at 0-25 cm and 25-50 cm depths after the harvest of dates from the date palm trees in the ICARDA experimental site during 2015-2016 at Amghara Station, Kuwait has been presented in Tables 10 & 11.

Similarly, according to the study by Veysel Saruhan et al. (2010), sewage sludge when applied to the soil with increasing amounts raised the mineral matter content of plant and resulted in the increase of growth and herbage yield of bird's foot trefoil. Heavy metal contents were below the critical levels in the soil and plant. Delgado Arroyo et *al*. (2002) reported that the application of sewage sludge compost @ 12 t/ha plus 350 kg urea/ha resulted in 20% greatest growth of maize than the mineral fertilization. No toxic effects arising from the heavy metals in the plant were observed. Moreover, the concentration of heavy metals in the soil was below Spanish and European legal limits.

The motivation for recycling of sewage sludge to agricultural soil is the low cost of this disposal method, the soil organic matter preservation effect and the fertilization effect. Sewage sludge (biosolids), which is enriched in nitrogen, phosphorus, organic matter and other trace elements, represents a good source of nutrients for plant growth and a good soil conditioner to improve soil physical properties. Due to its high organic matter content, sewage sludge can improve physical, chemical, and biological properties of soil (Alcantara et *al*., 2009).

Thus, sludge application helps to reduce soil erosion and improves the soil quality as a plant growth medium. The fertilizer effect enables a reduction in cost for nitrogen and phosphorus mineral fertilizers and may improve crops yield on sludge treated fields (Wild and Jones, 1991;

Petersen et al. 2003). Application of sewage sludge, compost and cow manure at 25 Mg/ha significantly increased available Fe and Zn of the soil (Sharifi et *al*., 2011). Sewage sludge can substitute for commercial fertilizers and organic matter, if applied in the right amounts to soil. By using sludge, it is a possibility for farmers to supply their lands with organic fertilizer at low costs. Therefore, recycling of sludge for agricultural purpose seems to be an appealing solution for sustainable management of sludge.

In the present study, the date palm crop has responded well to the application of both the sources of organic manure at with the increasing rates of their application in sandy soils of Kuwait. However, the influence of especially the sewage sludge manure addition at 10 t/ha was more pronounced than compost manure. Likewise, considerable research has been accomplished worldwide on the use of sewage sludge on soil and crop. In many investigations with different climatic and soil conditions have reported a substantial increase in plant growth, crop yield and biomass production upon sewage sludge application (Samaras et *al*., 2008; Togay et *al*., 2008). Using organic wastes such as sewage sludge, compost and cow manure is a proper practice for returning organic matter and some nutrients into the soil, particularly in arid and semi-arid regions. The application of organic wastes increased the dry matter yield of the corn, alfalfa and targets flower plants (Sharifi et *al*., 2011).

According to the study by Veysel et *al*. (2010), sewage sludge when applied to the soil with increasing amounts raised the mineral matter content of plant and resulted in the increase of growth and herbage yield of bird's foot trefoil. Heavy metal contents were below the critical levels in the soil and plant. Delgado et *al*. (2002) reported that the application of sewage sludge compost @ 12 t/ha plus 350 kg urea/ha resulted in 20% greatest growth of maize than the mineral fertilization. No toxic effects arising from the heavy metals in the plant were observed. Moreover, the concentration of heavy metals in the soil was below Spanish and European legal limits.

Several earlier workers (Krishnamurthy *et al*., 1999 and Jayabharat *et al*., 2000 and Abd Al Khalak et *al*., 2007) also reported that the application of higher quantities of organic manure is responsible for the improvement in the growth and yield of potato and sunflower crops. Since the soils are sandy and poor in organic matter content, incorporation of sunflower plants after harvesting organic manure @ 25t/ha and enriches soil fertility and addition of organic manures sustains sunflower production for long time in Kuwait. Veeranna *et al*. (2001) have also revealed similar results and quoted that potato production can be sustained over a long time by maintaining the soil moisture and nutrient status.

CONCLUSION AND RECOMMENDATIONS

The results of adding sewage sludge in conjunction with AMF in Al Amghara research station in Kuwait increased the Tamar yield. This increase of yield may be attributed to the improvement in the fruit yield parameters such as number of fruiting spikelet's and fruits per bunch; weight, length and girth of fruit.

Below some recommendations of this research experimentation are presented:

- It is possible to grow successful crop of Date palm on sandy loam soils of Kuwait in the open field under bubbler irrigation by adopting proper management practices.

- The influence of addition of sewage sludge manure to the Date palm crop was more pronounced than compost manure, as it was largely responsible for the improvement in the physical, chemical and biological properties of the soil.

- Since the soils are sandy, poor in organic matter and nutrient content, it is advisable to apply organic manure in the form of sewage sludge (71.97 t/ha or 22.57% increase in yield) or compost manure (70.00 t/ha or 19.31% increase in yield) when applied @ 10 t/ha along with Mycorrhiza and the recommended dose of fertilizers gives higher Date palm Tamar fruit yield.

- Addition of organic manure in the form of sewage sludge/ compost manure enriches soil fertility which in turn also helps in sustaining the production for long time in Kuwait.

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Tables

Table 1. Initial soil nutrient status of ICARDA Date palm organic manures and AMF at Amghara Station, Kuwait during October, 2013.

Parameter	Unit	Soil depth(cm)		
		0-25	**25-50**	**Mean**
1. pH	-	7.52	7.52	7.52
2. ECe	dSm^{-1}	12.28	6.68	9.48
3. K	meq/l	3.04	0.78	1.91
4. O.M.	%	0.37	0.22	0.29
5. Ca	meq/l	28.32	21.80	24.76
6. Mg	meq/l	16.44	10.00	13.22
7. Na	meq/l	106.32	49.14	77.73
8. Cl	meq/l	105.32	50.82	78.07
9. HCO_3	meq/l	4.00	3.32	3.66
10. SO_4	meq/l	44.80	27.58	36.19

11. PO_4	ppm	7.20	1.28	4.24
12. B	ppm	1.00	1.15	1.08

Table 2. Annual irrigation schedule applied to date palm experimentation plot

Month	Water Requirement (Imperial Gallons/day)	Irrigation Interval (days)
January	10	8
February	12	8
March	18	4
April	24	4
May	32	3
June	40	2
July	40	2
August	36	2
September	28	3
October	20	4
November	14	8
December	10	8

Table 3. Chemical analysis of the compost manure used in Amghara Station, Kuwait.

Parameter	Unit	Value
1. pH	-	7.20
2. O.M.	%	45.0
3. N	%	2.30
4. P2O5	%	1.01
5. K	meq/l	0.63
6. Cu	ppm	0.15
7. Mn	ppm	0.50
8. Mg	ppm	2.70

9. Fe	ppm	1.10
10. Zn	ppm	0.71

Table 4. Chemical analysis of the sewage sludge used in Amghara Station, Kuwait.

Parameter	Unit	Value
1. pH	-	8.88
2. EC 1:5	dSm^{-1}	1.79
3. MC	%	34.86
4. OM	%	14.30
5. N	%	1.002
6. P2O5	%	1.63
7. Na	meq/l	2.93
8. K	meq/l	16.00
9. Cu	ppm	0
10. Mn	ppm	0.554
11. Cd	ppm	0.10
12. Zn	ppm	0.78
13. Fe	ppm	7.50
14. Ni	ppm	0.57
15. Pb	ppm	3.00
16. E. coli	MPN/ g	240
17. TotalColiforms	MPN/ g	135

Table 5: Chemical and microbial analyses of irrigation water (fourth stage treated sewage water) used in the experimentation

Parameter	Unit	Value
1. pH	-	7.5
2. EC	dSm^{-1}	0.25
3. TDS	ppm	160
4. Na	meq/l	1.1
5. K	meq/l	0.3
6. Ca	meq/l	1.6

7. Mg	meq/l	0.2
8. CO3	meq/l	-
9. HCO3	meq/l	1.2
10. Cl	meq/l	1.6
11. SO4	meq/l	0.4
12. Total Coliforms	MPN/100 ml	140

Table 6. Dates yield as influenced by the sources and levels of organic manure application in conjunction with AMF in Amghara (average of 3 years).

Treatment	**Tamar yield (kg/tree)**	**Tamar yield (tons/ha)**	**Increase over control (%)**
F1 – Control	58.43	11.92	-
F2 – AMF	61.20	12.49	4.30
F3 – Sewage sludge @ 5 t/ha	64.70	13.20	10.07
F4 – Sewage sludge @ 5 t/ha + AMF	67.00	13.76	14.34
F5 – Sewage sludge @ 10 t/ha	66.30	13.53	12.82
F6– Sewage sludge @ 10 t/ha + AMF	71.97	14.69	22.27
F7 – Compost manure @ 5 t/ha	63.73	13.00	8.70
F8 – Compost manure @ 5 t/ha + AMF	65.53	13.37	12.03
F9 – Compost manure @ 10 t/ha	64.67	13.20	10.55
F10 – Compost manure @ 10 t/ha + AMF	70.00	14.29	19.31
S.Em.+_	3.242	0.662	-
C.D. at 5%	9.102	1.857	-
Mean	**65.40**	**13.55**	**-**

Table 7. Moisture content and yield parameters of date palm fruits as influenced by the sources and levels of organic manure application in conjunction with AMF in Amghara (average of 3 years).

Treatment	Moisture content of fruits at Khalal stage (%)	Fruit bunch wt(kg)	Fruit stalk wt(kg/ bunch)	Fruit wt(kg/ bunch)	No. of fruits/ bunch
F1 – Control	23.0	7.60	0.50	7.10	738
F2 – AMF	24.4	8.15	0.75	7.40	780
F3 – Sewage sludge @ 5 t/ha	35.0	9.60	0.65	8.95	1087
F4 – Sewage sludge @ 5 t/ha + AMF	43.9	10.50	0.80	9.70	1189
F5 – Sewage sludge @ 10 t/ha	40.1	10.25	0.63	9.62	1130
F6– Sewage sludge @ 10 t/ha + AMF	47.3	11.20	0.70	10.50	1423
F7 – Compost manure @ 5 t/ha	25.6	9.10	0.45	8.65	930
F8 – Compost manure @ 5 t/ha + AMF	36.9	9.95	0.56	9.39	1094
F9 – Compost manure @ 10 t/ha	29.6	9.25	0.55	8.70	1045
F10 – Compost manure @ 10 t/ha + AMF	46.2	11.00	0.65	10.35	1320
Mean	**35.2**	**9.50**	**0.63**	**8.87**	**1074**

Table 8. Fruit yield parameters of date palm fruits as influenced by the sources and levels of organic manure application in conjunction with AMF in Amghara (average of 3 years).

Treatment	No. of fruit branches/ bunch	Weight/ fruit (g)	Fruit length (cm)	Fruit girth (cm)
F1 – Control	64	7.72	2.42	1.90
F2 – AMF	67	8.68	2.57	1.92
F3 – Sewage sludge @ 5 t/ha	68	9.15	2.68	1.97
F4 – Sewage sludge @ 5 t/ha + AMF	80	9.95	2.77	2.07
F5 – Sewage sludge @ 10 t/ha	71	9.85	2.77	2.03
F6– Sewage sludge @ 10 t/ha + AMF	88	11.10	2.93	2.18
F7 – Compost manure @ 5 t/ha	67	8.86	2.58	1.93

F8 – Compost manure @ 5 t/ha + AMF	71	9.32	2.73	2.02
F9 – Compost manure @ 10 t/ha	68	8.98	2.68	1.95
F10 – Compost manure @ 10 t/ha + AMF	86	10.00	2.78	2.17
Mean	**73**	**9.36**	**2.69**	**2.02**

Table 9. Soil moisture content (%) before irrigation at 30cm depth during flowering of date palm crop as influenced by the sources and levels of organic manure application in conjunction with AMF in Amghara**.**

Treatments	**Actual soil moisture content (%)**			
	2013-14	**2014-15**	**2015-16**	**Mean**
F1 – Control	7.54	8.04	7.69	7.76
F2 – AMF	7.98	9.48	9.91	9.12
F3 – Sewage sludge @ 5 t/ha	8.94	10.44	10.46	9.95
F4 – Sewage sludge @ 5 t/ha + AMF	11.42	12.92	13.03	12.46
F5 – Sewage sludge @ 10 t/ha	9.49	10.99	11.10	10.53
F6– Sewage sludge @ 10 t/ha + AMF	12.97	14.47	14.60	14.01
F7 – Compost manure @ 5 t/ha	8.49	9.99	9.96	9.48
F8 – Compost manure @ 5 t/ha + AMF	11.12	12.62	12.74	12.16
F9 – Compost manure @ 10 t/ha	9.17	10.67	11.98	10.61
F10 – Compost manure @ 10 t/ha + AMF	12.36	13.86	13.96	13.39
Mean	**9.95**	**11.35**	**11.54**	**10.95**

Table 10. Treatment wise soil nutrient status at 0-25 cm depth after the harvest of Tamar fruits from the date palm trees during September 2016 at Amghara.

Parameter	**Unit**	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**
1. pH	-	8.00	7.41	8.04	7.81	8.03	7.91	7.62	7.35	7.61	7.93
2. ECe	dS^{-m}	1.15	3.40	0.60	2.13	0.77	1.31	3.59	5.62	3.43	0.95
3. Ca	Meq/L	2.6	11.8	1.4	3.6	8.1	3.0	8.4	14.0	5.8	2.2
4. Mg	Meq/L	0.4	4.0	1.4	1.8	1.2	0.8	1.4	5.8	2.0	0.8
5. HCO_3	Meq/L	3.4	6.6	5.0	3.0	4.4	3.4	6.0	7.6	2.4	4.0
6. Cl^-	Meq/L	8	17	5	17	7	8	25	3.4	35	7
7. O.M	%	0.71	1.48	0.67	1.82	0.98	1.45	0.07	0.17	1.88	0.84
8. B	ppm	0.681	0.404	0.046	0.271	0.359	0.306	0.989	0.791	0.433	0.143
9. N	%	0.008	0.006	0.009	0.008	0.005	0.007	0.008	0.005	0.006	0.009
10. P_2O_5	ppm	25.4	59.2	37.4	80.4	41.8	27.8	31.2	45.2	64.487.56	36.6
11. Sand	%	82.64	81.28	83.28	78.56	82.28	81.6	82.64	83.28	87.56	87.92
12. Silt	%	14.36	13.72	12.72	15.44	13.72	12.44	13.36	12.72	12.44	11.08
13. Clay	%	3	5	4	6	4	6	4	4	0	1

Table 11. Treatment wise soil nutrient status at 25-50 cm depth after the harvest of Tamar fruits from the date palm trees during September 2016 at Amghara.

Parameter	**Unit**	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**
1. pH	-	7.91	7.65	8.00	7.83	7.93	7.84	7.82	8.08	7.41	7.91
2. ECe	dS^{-m}	5.17	5.44	0.84	1.18	1.16	1.48	5.84	1.07	7.36	4.99
3. Ca	Meq/ L	1.4	10.8	2.2	2.4	3.2	3.0	10.8	2.1	13.0	12.0
4. Mg	Meq/ L	0.7	2.6	2.4	0.8	3.0	2.6	4.0	1.8	3.0	4.4
5. HCO_3	Meq/ L	3.6	6.0	4.0	3.8	3.8	2.6	4.0	3.0	5.6	5.2
6. Cl^-	Meq/ L	28	39	6	8	10	10	34	7	6	35
7. O.M	%	0.47	0.94	0.30	0.57	0.81	1.31	0.57	0.07	1.72	0.81
8. B	ppm	0.514	0.662	0.737	0.206	0.163	0.454	0.269	0.244	0.712	0.469
9. N	%	0.038	0.008	0.005	0.007	0.008	0.005	0.011	0.010	0.007	0.005
10. P_2O_5	ppm	19.16	31.2	29.8	45.2	46.0	12.6	21.4	8.2	49.4	15.2
11. Sand	%	82.28	81.28	80.92	75.56	83.28	77.56	87.28	83.92	74.56	81.28
12. Silt	%	13.72	13.72	14.08	17.44	11.72	14.44	10.72	14.08	17.44	13.72
13. Clay	%	4	5	5	7	5	8	2	2	8	5

Figures

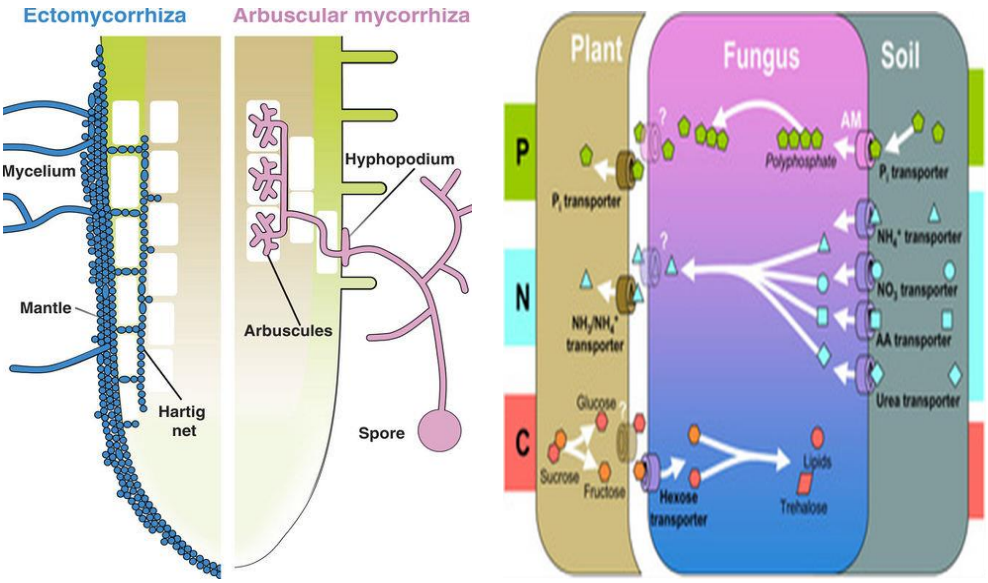

Fig. 1. Mycorrhiza & its association with plant & soil system

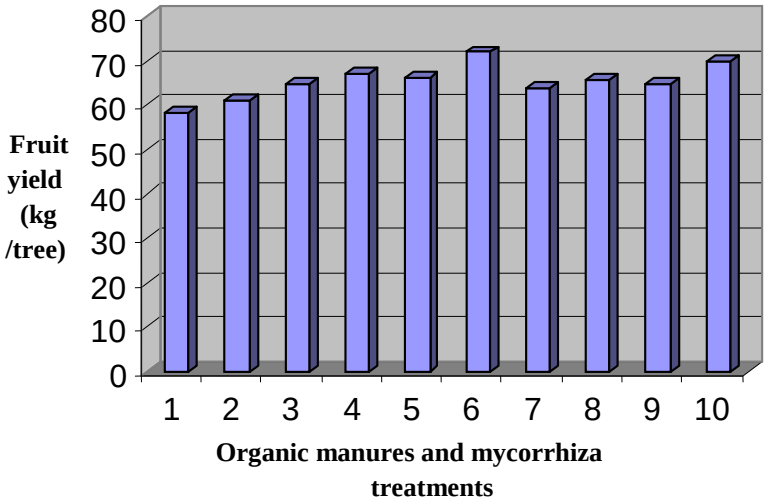

Fig. 2. Fruit yield of date palm as influenced by organic manures and AMF (average of 3 years).

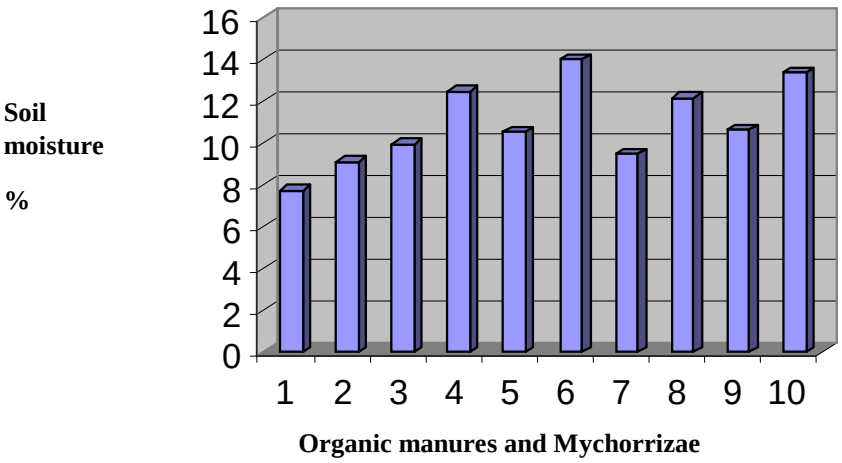

Fig. 3. Actual soil moisture content before irrigation as influenced by organic manures and AMF in date palm crop (average of 3 years)

LIQUID POLLINATION TECHNOLOGY AS NEW TECHNOLOGY TO AMELIORATE DATE PALM POLLINATION AND FACILITATE DATE PALM FIELD OPERATIONS

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The Sixth International Date Palm Conference (SIDPC)
Abu Dhabi -UAE: 19 – 21 March, 2018.

Abstract: Pollination of date palm is normally carried out by hand in almost all date palm groves in Oman. Farmers mostly use various hand pollination techniques. Dry pollination is used utilizing hand and motorized dusters with no negative effect on fruit yield. However, larger pollen volumes are used with the dusters and uneven distribution of pollen grains is found when the palms are tall.

With Liquid Pollination (LP) female trees flowers are sprayed with pollen grains suspended in water using knapsack or motorized sprayers. LP is much quicker, cheaper and equally effective. In addition, the use of this technology contribute to saving time, reducing cost, and consequently, reduces the risk of climbing accidents to laborers.

LP was evaluated economically versus the traditional manual pollination (TMP) for Fardh cultivar based on the data collected from researchers from the Date Palm Research Center in Wadi Quriyat in Oman.

The reduction in pollination cost using LP in comparison with TMP is about 89% and, consequently, a reduction in the total variable costs per hectare against those for manual pollination of about 42-56%.

Economic indicators showed that LP will be highly profitable for Omani farmers. The Net Return (NT) using liquid pollination was very high (+ 674%). The benefit-cost ratio (BCR) is three times higher when using liquid pollination.

ADOPT (Adoption and Diffusion Outcome Prediction Tool) tool was used to focus groups of date palm growers in Sultanate of Oman to predict the proportion of a target population that might adopt an innovation over time. The empirical findings obtained from the LP technology assessment indicates that peak adoption rate for the technology in Al Batinah is predicted to be 95% after a period of 14-16 years. The predicted adoption level in 5 years and 10 years from start is expected to be 35-47% and 86-91%, respectively.

Key words: Date palm, pollination, LP, Economic evaluation, ADOPT, Oman.

INTRODUCTION

Date palm (*Phoenix dactylifera* L.) is the widest spread crop and attain great cultural, social and religious importance in the Sultanate of Oman. The total number of date palm trees in Oman is estimated at about 8 million which occupies about 49% of total area under cultivation and 85% of the area cultivated by fruit trees. Currently, Oman is the eighth largest world producer of dates with a total production reaching 361,000 ton (MAF, 2017). The dates are mainly harvested for fresh fruit consumption. However, alternative goods, such as date syrup, date sugar, and other by-products, can also be found in the local markets.

Oman has diverse topographical and climatic eco-regions that allow for the cultivation of various types of date palm cultivars, particularly in the northern coastal and interior regions. There are approximately 180 females and 48 male cultivated varieties. Given the variability in the topographic and climatic growing conditions, the date palm production season extends from May to November, the longest season of any date-producing country. According to Al-Marshudi (2002) and Al-Yahyai and Khan (2015), the yield of the date palm is considered to be low (40-80 kg/tree) compared to the yields in neighboring countries (i.e. Saudi Arabia and UAE). This low yield is a result of traditional management, lack of farmer know-how, high infestation by several pests, limited field expansion because date growing regions are fully dependent on groundwater extraction for irrigation, in addition to logistic problems, including an insufficient number of skilled laborers and underdeveloped facilities (transport, storage, market outlets, and large processing factories).

The date palm, being a dioecious plant, need to be pollinated. Pollination is performed traditionally in Oman and elsewhere by climbing the female trees to insert the male flower strands into the female spathe. This is laborious, time consuming and a risky operation to farm labors. A number of successful studies have been done in Oman and other countries to use machine for pollination in which farmers can perform the operation from the ground quickly and easily. Al-Bakr (1972) mentioned that pollination machine was introduced to the USA as early as 1952 to dust the pollen from ground level. The operation was completed in just few hours as compared to as long as two days to manually pollinate an area of two feddans. El Mardi, et al. (2002) found that the fruit set, yield and fruit quality in mechanical pollination was similar to that of traditional method which was supported by Brown et al. (1969) and Shabana et al., (1985) in: Dhehibi et al. 2018).

As a result, there is a great need and potential for improving the current date palm growing practices. In the current project a novel approach was used to pollinate female date palm flowers using pollen grains suspended in water (Liquid Pollination = LP) which is sprayed from ground level using motorized sprayers. Technical and economic aspects of adopting this technique were studied.

METHODOLOGY

A number of consecutive field experiments were conducted by the researchers of date palm horticulture research section, date palm research center (DPRC) starting from 2003/2004 season. The aim of the experiments was to standardize the LP technique by assessing various pollen grain concentrations using different varities in different agro-ecological zones in Oman. Subsequently, the technology was demonstrated at farmers' field level. Following the success of LP, it was disseminated to the various agricultural governorates through the extension specialists after

conducting a series of workshops for training of the subject matter specialists. LP technique was disseminated to the various Gulf Cooperation Council (GCC) countries through the regional project entitled "Development of Sustainable Date Palm Production Systems in the GCC Countries of the Arabian Peninsula" coordinated by ICARDA. Furthermore, eeconomic comparison and evaluation of manual and liquid pollination methods of date palm trees was performed in the Sultanate of Oman for the varieties Fardh and Khalas by the project experts. A Case Study was performed from the date palm growers in the Sultanate of Oman for predicting farmers' willingness to adopt LP technique.

RESULTS AND DISCUSSION

The series of field trials conducted by DPRC revealed that LP resulted in fruit set and other fruit quality parameters similar to those obtained by TMP. The study conducted on Fardh variety proved that pollen grain suspension spray at 0.5g/L water resulted in fruit set (75.9 %) compared to the TMP (71.3%) with no statistically significant difference between the treatments (P>0.05). LP also resulted in as good fruit weight and total yield as the TMP with no significant difference. Increasing pollen grain concentration even up to triple the concentration, did not improve the studied parameters. However, significant reduction (P>0.05) on fruit set was observed on Barni variety fruit set using LP at 0.5g/L water (66.0%) when compared to TMP. However, the total yield (Kg/palm) was not affected (106.9 Kg/palm for LP V.S. 102.9 Kg/palm for TMP). Moreover, the fruit weight at the full mature Tamr stage was significantly increased (P>0.05) with LP (4.4g) compared to TMP (3.8g) (Table 1). Similar results were obtained with the variety Jabri (MAF, 2005/2006). This is considered as an advantage of LP resulting in less competition of the fruits for water and nutrients which plays as natural thinning of fruits.

Economic evaluation of LP with farmers in Sultanate of Oman

Economic assessment of the liquid pollination technology was performed from two perspectives, i.e, research and the end users (farmers) for Fardh as commercial variety in Oman. Affordability and profitability were analyzed using a partial budget analysis tool and disaggregated data gathered from researchers and farmers, using rapid rural appraisal surveys.

Results (Table 2) indicates a reduction in pollination cost using liquid pollination in comparison to that for manual pollination of about 89.05% and, consequently, a reduction in the total variable costs per hectare against those for manual pollination of about 56.48%. Moreover, the analysis reveals a total reduction in the variable costs of OMR1273.95 from using LP. This reduction in total variable costs results from an increase in the net revenue over that resulting from manual pollination of OMR2593.95/ha. The economic indicators (Table 2) show also the clear profitability of using liquid pollination where the percentage change in net returns is very high (+ 674.71%). The benefit-cost ration (BCR) is three times higher when using liquid pollination. Thus, with an internal rate of return with 12.04 and higher BCR, we can conclude how profitable it is for Omani farmers to use liquid pollination.

Analyze of Adoption of LP in Sultanate of Oman

The adoption of new agricultural technologies has generally been found to be a function of farm and farmer characteristics and specific features of the technology (Feder et *al*., 1985; Marra and Carlson, 1987; Rahm and Huffman, 1984 in Dhehibi et al. 2018). A considerable set of literature

was developed regarding factors that influence the adoption of new technologies by farmers through use of innovation theory (Feder et *al*., 1985; Griliches, 1957, and Rogers, 1995 in Dhehibi et al. 2018).

Rogers (1995) identified five characteristics of an innovation that affect an individual's adoption decision:

- Relative advantage: how the innovation is better than existing technology;
- Compatibility: the degree to which an innovation is seen as consistent with existing experiences, needs, and beliefs of adopters;
- Complexity: how difficult the innovation is to understand and use;
- Trialability: the degree to which the innovation may be used on a limited basis;
- Observability: the degree to which the results of an innovation are visible to others.

As the relative advantage, compatibility, complexity, trialability, and observability of liquid pollination have caused more farmers to adopt it in the Sultanate of Oman, in particular, and in the GCC countries in general. We can consider the adoption of LP as an innovation. The utilization and critical mass adoption of such technologies is an important prerequisite for agricultural development, particularly for the date palm producing countries in the Arabian Peninsula.

The results obtained about the LP technology adoption (Figure 1) in North Al-Batinah region as example (Dhehibi et al. 2018), indicate that sustainable increases in productivity of date palm in the Sultanate of Oman can be achieved if farmers are encouraged to adopt the liquid pollination technology. The peak adoption rate for liquid pollination technology in the "North Al-Batinah" is predicted to be 95% after a period of 14.5 years. The predicted adoption level in 5 years and 10 years from start is expected to be 46.9% and 91.5%, respectively. However, the adoption of such technology needs to be accompanied by a supporting extension system and an enabling political environment to ensure the scaling-up and widespread use of this promising and profitable technology.

CONCLUSION

Extension of LP as new technology, economic evaluation and analyze of adoption in Sultanate of Oman shows the following advantages and constraints regarding the use of this technology:

The main advantages of using liquid pollination are:

- Saves time and effort (reducing labor cost and improving the effectiveness and productivity of the labor used)
- Reduces the quantity of pollen needed
- Reduces labor and pollen costs
- Reduces the risk low fruit set by pollinating during the peak period of flowering
- Improves the quality of the fruits and consequently the profitability of the varieties intended for export
- Improves the fruit setting percentage
- Contributes to reducing harvesting losses
- Reduces the risk of climbing accidents to laborers.

Liquid pollination has also some constraints:

- The pollination extraction device is expensive (around OMR3500), which small-scale farmers cannot afford,
- Limited number of date palm trees per farmer (the investment in the pollination extraction device is not profitable),
- Resistance of farmers to adopting the new technology and to changing their practices (farmers are accustomed to the old technology of hand pollination),
- Lack of specialized extension staff for the date palm,
- No interest from the younger generation in date palm production.

Some suggested policy options for accelerating the adoption process and scaling-up the use of liquid pollination technology include:

- Development of an agricultural management program for date palm tree services, the application of quality control measures, and an increase in capacity building to reduce the cost of production,
- Creation of private companies to carry out and monitor the liquid pollination operations with support from the government,
- Enhancing the extension services (more and specialized extension agents) and the development of an effective extension service for Omani date palm growers,
- Reinstatement of the subsidy system in the sector,
- Enhancing the awareness of farmers regarding the profitability of using this technology in comparison to the manual pollination method.

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Tables

Table 1. Fruit set, total yield and fruit weight at Tamr stage of Barni date palm variety as affected by Liquid pollination (LP) compared to traditional manual pollination (TMP) during 2004/2005 seasons

Season	First season			Second season		
Treatment	Fruit set (%)	Total yield (Kg/palm)	Fruit weight (g)	Fruit set (%)	Total yield (Kg/palm)	Fruit weight (g)
Control (TMP)	83.1	102.9	3.8	77.3	63.4	5.6
LP (0.1 g/L)	58.7	85.6	5.4	57.4	68.9	6.7
LP (0.3 g/L)	68.5	102.2	4.8	52.1	52.5	7.4
LP (0.5 g/L)	66.0	106.9	4.4	62.2	60.2	7.0
LSD 5%	8.3	8.3	0.4	8.3	8.3	0.4

Source: (MAF, 2005/2006).

Table 2. Partial budget analysis for using liquid pollination with the date palm variety *Fardh* in the Sultanate of Oman

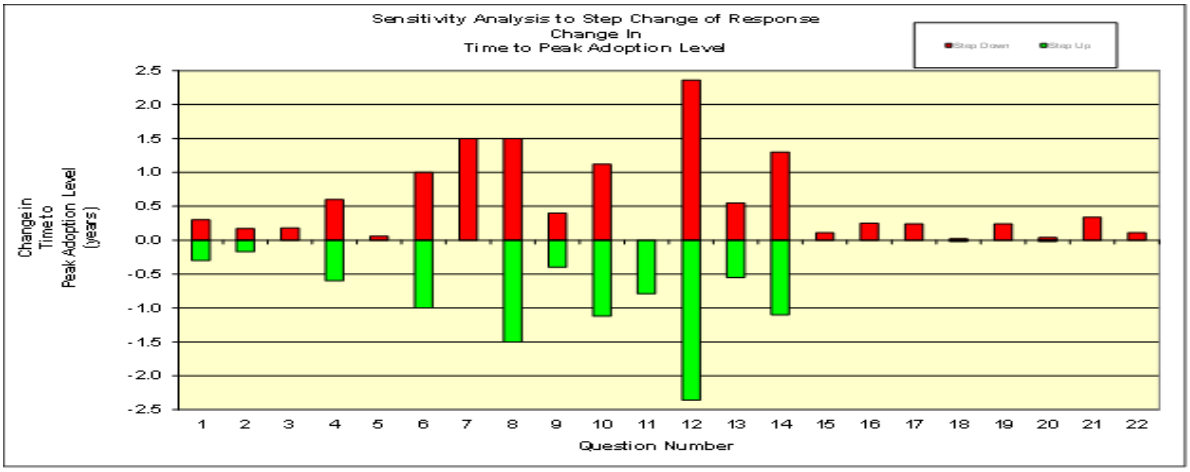
Variable	With technology option (liquid pollination)	Without technology option (manual pollination)
Yield (kg/tree) [(a)]	40	40
Number of date palm trees/ha	165	165
Yield (kg/ha)	6,600	6,600
Price (OMR/kg) [(b)]	0.6	0.4
Total value of production (OMR/ha)	**3,960**	**2,640**
Cost of pollen (OMR/ha)	125	935.55
Cost of device (OMR/ha)	11.6	0
Labor cost for pollination (OMR)	20	495
Total cost of pollination (OMR/ha) [(c)]	156.6	1,430.55
Other costs (irrigation, fertilization, pruning, thinning, harvesting, and post-harvest handling) (OMR/ha) [(d)]	825	825
Total variable costs (OMR/ha)	**981.60**	**2,255.55**
Net revenue (OMR/ha)	**2,978.40**	**384.45**
Economic indicators (1)		

Reduction of pollination cost per ha over manual pollination (%)	89.05	
Reduction of total variable costs per ha over manual pollination (%)	56.48	
Variable costs between the two technologies (OMR/ha)	- 1,273.95	
Increased net revenue over manual pollination (OMR/ha)	2,593.95	
Economic indicators (2)		
Net returns (NR)	**2,978.40**	**384.45**
Change in net returns (NR) (%)	674.71	
Change in total costs (TC) (%)	56.48	
Internal rate of return (IRR)	12.04	
Benefit-cost ratio (BCR)	4.03	1.17

Source: Dhehibi et al. 2016

Figures

Fig. 1. Sensitivity Analysis of Adoption Curve of Liquid Pollination Technology at "North Al Batinah" Governorate - Sultanate of Oman



Source: Dhehibi et al. 2018

EFFECT OF MYCORRHIZAE INOCULATION ON THE GROWTH OF YOUNG DATE PALM PLANTS UNDER NURSERY CONDITIONS

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Abu Dhabi -UAE: 19 – 21 March, 2018.

Abstract: Two years' experiments were carried out at Al Hamrania Research Station (UAE) during (2015-2016) to explore the role of Mycorrhizal inoculation on the growth of date palm plants from micro-propagation growth under nursery conditions. Uniform plants of four date palm cultivars (Barhi, Khalas, Sultana and Madjool) were planted into 10-L pots. The Randomized Complete Block Design (RCBD) was used in this study experiments which involved application of: (T1) recommended 100% chemical fertilizer only, (T2) 100% of recommended organic fertilizer only, (T3) Mycorrhizae without any fertilization, (T4) Mycorrhizae + 100% recommended chemical fertilizer, (T5) Mycorrhizae + recommended 50% organic fertilizer, (T6) Mycorrhizae + 50% chemical fertilizer and (T7) Mycorrhizae +25% chemical fertilizers +25% organic fertilizers.

The results indicated that the use of Mycorrhizae with 100% of recommended organic fertilizers rate were increased significantly by 23% and 25% of the seedling leave growth rate and leave numbers per seedlings, respectively, when compared with the control treatment (without Mycorrhizae inoculation). This greenhouse study also indicated that half the amount of organic fertilizers application had similar effects when compared with 100% organic fertilizer when mixed with mycorrhiza for number of product leaves for all date palm cultivars.

Key words: Mycorrhizae, Date palm, organic fertilizers, Compost, seedling, leave growth rate.

INTRODUCTION

Date palm is important crops in the United Arab Emirates, where numbers of date palm trees planted is increasing annually. Date palm trees are grown under harsh climatic conditions characterized by low rainfall and high evaporation rates and mainly with a weak soil material organic fertility.

Growing of date palm is accompanying with use of large amounts of organic and chemical fertilizers with high water supply. These practices may lead to salinization of soil and fertilizer salts to leak of deep soil layers which bad impacts on groundwater in addition to the high cost of fertilizers. Since most soils of United Arab Emirates are sandy and light texture, this limit their

ability to retain water and fertilizer originally created in clay content and repotting and organic matter and also poor fertilizer formulations elements.

Most farmers in the United Arab Emirates to fertilize date palm trees by sprinkling the compost and organic fertilizer around the tree with global irrigation, but this method may not live up to expectations of higher growth and production because most fertilizers lose by washed away from the root zone or loss of soil surface directly.

Therefore, the use of advanced agricultural suitable techniques may become important in cultivating a sustainable date palm under the environmental conditions prevailing in the region to limit the negative effects of higher use of fertilizer and water scarcity and increased tree growth and productivity of promising technologies. That has drawn worldwide attention in recent years using Mycorrhizae which provides benefits through improvement of use of water and fertilizer by developing the ability of plants to absorb nutrients from the soil and increase their ability to withstand environmental stress factors Such as drought, salinity, etc.

Mycorrhizae can provide benefits to plants through the enormous plant roots volume that stretches into the soil to reach the soil layers away to common rooting zone to absorb minerals and transferred to the plant in addition to protecting the plant from soil pests such Nematodes and improve soil properties and protected from erosion.

The present paper presents the results of use *Mycorrhizae* with young date palm plants produced by micro-propagation before their final plantation in the field.

Objectives of the study the sustainability and further development of palm cultivation and improve productivity study of saving in irrigation water and fertilizer amounts. additive and protect the environment from pollution and studying the efficiency of fertilizers on the date palm plants. This experiment serves also as filed study for Ministry staff and farmers in employment optimization of natural resources under the prevailing conditions.

MATERIAL AND METHODS

This study was conducted is conducted in Al Hamrania research station in Ras Al Khaima for three years (2015-2017). Plants used are “Khalas”, “Sultana”, “Barhi” and “Medjool” date palm cultivars of one year of age cultivated by micro-propagation. All the four cultivars are grown in Al Hamrania date palm gene bank with other more than 100 date palm accessions.

For all treatments when the *Mycorrhizae* was inoculated to plants with fertilizer. The quantity even organic and chemical fertilizer was 100 % of recommended quantity, at 50% and 25% quantity compared with *Mycorrhizae* alone. All treatments with control was seven in total.

All treatments received 25% of the water requirements based on Date palm in the field K_C irrigation by Allen et al. (1998). *Mycorrhizae* is added 50 cm depths around plant roots before applying fertilizer.

The Randomized Complete Block Design (RCBD) was used in this study experiments which involved application of 7 treatments using *Mycorrhizae* with organic and chemical fertilizers as recommended by the Ministry and applied to the young date palm plants when cultivated directly in filed. The composition shown in Table 1 is 100%, 59% and 25% of fertilizer (Organic and chemical) alone or mixed with or without inoculation by *Mycorrhizae*. As control *Mycorrhizae* was inoculated to young plants without any fertilization other than soil content.

RESULTS AND DISCUSSION

The results (Figure 1 and 2) indicated that the use of Mycorrhizae with 100% of recommended organic fertilizers rate were increased significantly by 23% of the plants number of leaves and by 25% the growth rate (leaves length after 22 months of growing under nursery conditions. It was related by Shabbir et al. (2011) that inoculation of date palm by Mycorrhizae initiate vegetal growth as number of leaves, their length and width and the trunk growth.

When compared with the control treatment (without Mycorrhizae inoculation). This study also indicated that half the supply rate (50%) of organic fertilizers application had similar effects when compared with 100% organic fertilizer in the treatment of inoculation of the young plants by Mycorrhizae for the leaves numbers for all date palm cultivars. Young date palm plants growth quickly with inoculation by *Mycorrhizae* (Janos, 2007; Meddich et al., 2015).

It is recommended to continue following the plants under field conditions. The shape of plants needs to move them from nursery to plantation in the field.

It also recommended to reduce the supply of fertilizer (Organic or chemical) as no significate difference was recorded between 100% and 50% fertilizer supply. This confirmed other results that Mycorrhizae improve the roots absorption and use of water and fertilizers (Bouhired et al. 1992: Ghazi et al. 2013).

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Table 1. Treatments applied on date palms plants of 1-year age from micro-propagation

Treatment	Composition
T_1	Chemical fertilizer alone (100%)
T_2	Organic Fertilizer alone (100%)
T_3	Mycorrhizae alone
T_4	Mycorrhizae + 50% of Chemical fertilizer
T_5	Mycorrhizae + 50% of Organic Fertilizer
T_6	Mycorrhizae + 100 % Organic Fertilizer
T_7	Mycorrhizae + Chemical fertilizer 25%+ Organic Fertilizer 24%

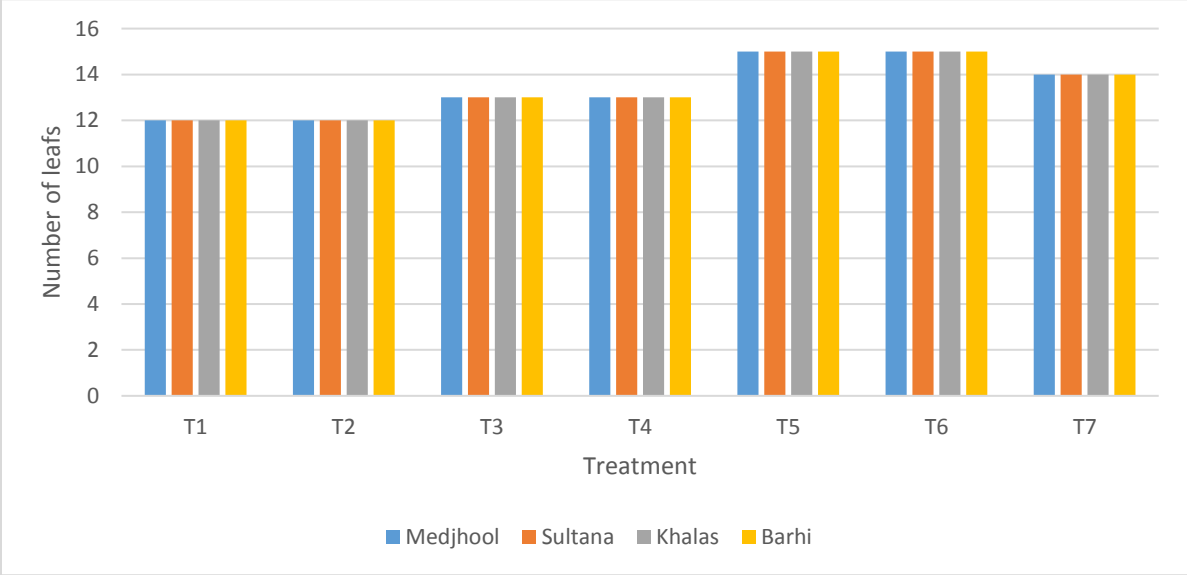

Fig. 1. Length of date palm leaves of 4 cultivars of date palm inoculated and no inoculated by *Mychorrizae* after 2 years' cultivation under nursery

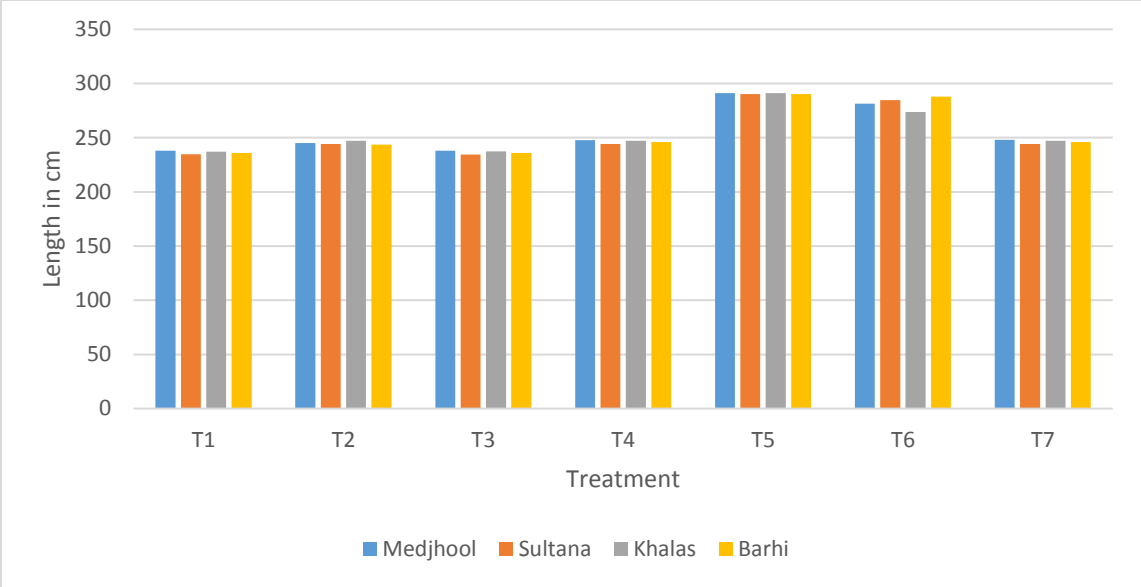

Fig. 2. Number of date palm leaves of 4 cultivars of date palm inoculated and no inoculated by *Mychorrizae* after 2 years' cultivation under nursery

Plants in April 2015 (starting experiment)	
Plants in July 2015 (after 3 months of inoculation)	

Plants in January 2016 (after 9 months of inoculation)	
Plants in February 2017 (after 24 months)	

Fig. 3. Evolution of the date palm plants growth under nursery conditions in Al Hamrania Research Station-UAE (2005-2007).

DRYING DATES USING SOLAR ENERGY UNDER POLYCARBONATE HOUSE- NEW PROMISING TECHNOLOGY TO DRY DATES IN OMAN

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Abstract: The project "Development of Sustainable Date Palm Production Systems" in GCC countries aims to use of proper agro-management techniques, and to develop proper post-harvest techniques to reduce losses and improve marketing.

Drying dates by solar energy under Polycarbonate Drying House (PDH) is developed by the project. The PDH is a drying chamber cover by polycarbonate sheet equipped by exhaust fan. The polycarbonate sheet has superior properties in terms of transparency, transmissivity, property, anti-corrosion, tensile properties, tear-resistant, anti-puncture, water and moisture proof.

Principal advantages on using the PDH technology are the following: (1) Improves the quality of the dates, especially in humid areas; (2) Avoids the contamination of dates by insects, birds, dust, and rain; (3) Accelerates the drying process and (4) Reduces the loss rate.

The implementation of this improved technology can have positive socioeconomic impacts on local income generation, food security and consequently a sustainable date palm farming system.

Economic evaluation of the polycarbonate drying houses in Sultanate of Oman reveal the high profitability of the polycarbonate drying system, even when it is not subsidized by the government. At a real discount rate of 5%, the net present value (NPV) is positive and very high in all cases. The estimated Internal Rate Return (IRR) was higher than the current interest rate in the Sultanate, which could encourage both date palm growers and private investors to invest in polycarbonate drying houses.

Adoption and Diffusion Outcome Prediction Tool (ADOPT) was used to focus groups of date palm growers in Al Batina region in Sultanate of Oman to predicts the proportion of a target population that might adopt an innovation over time. The assessment of adoption of the (PDH) technology reveal that 95% of the farmers in Al Batina region would adopt the innovation after 21 years. However, the predicted adoption levels in 5 and 10 years from start is 23% and 73%, respectively.

Key words: Date palm, dates, Drying, DPH, Economic evaluation, ADOPT, Oman

INTRODUCTION

In Oman, date palm is the primary agricultural crop, and it constitutes 80% of all fruit crops produced and 50 % of the total agricultural area in the country (FAO, 2013). Oman is the eighth largest producer of dates in the world with an average annual production of 260,000 tons per annum. There are approximately more than over seven million date palms and 250 cultivars in cultivation, primarily in the

northern governorates of the sultanate. Only half of the dates produced are used for human consumption, with the other half being utilized primarily for animal feed or considered surplus and wasted (Al-Yahyai and Khan, 2015). The loss is high and estimated to more than 30% of the production.

Given the variability in the topographic and climatic growing conditions, the date palm production season extends from May to November, the longest season of the date production. In the region of Al Batina, major production is soft and semi-soft dates. For conservation it need to dry fruits. Traditional way of drying date is makes under the sun and dates are exposed to dust, birds and insects.

A series of experiments have been conducted to identify the appropriate technical specifications and dimensions of the drying houses to increase their efficiency. Drying dates inside plastic room was performed for the first time to ameliorate drying process. The quantity of dates to dry was limited and the colour was affected because limited aeration of the small plastic houses. Drying dates by solar energy under Polycarbonate Drying House (PDH) is developed by the project. The PDH is a drying chamber cover by polycarbonate sheet equipped by exhaust fan. The polycarbonate sheet has superior properties in terms of transparency, transmissivity, property, anti-corrosion, tensile properties, tear-resistant, anti-puncture, water and moisture proof.

The present paper present results of assessment in research station using one of the main important date palm cultivar (Khasab) compared with one other seedling selection, Economic evaluation of PDH with farmers in Sultanate of Oman and prediction of adoption of the technology in the Omani conditions.

MATERIALS AND METHODS

Dates of Khasab cultivar and dates of seed grown palm coded 6 were entered in the chamber at Bisr and Rutab stages of maturity. Simultaneously, a representative sample were placed in well aerated spot-on stainless-steel mesh under the direct sun and temperature and humidity were monitored using weather station data loggers set to take a reading every 30 minutes. Polycarbonate chamber is manufactured locally and placed in the Rumeis Research Station.

The dates' moisture was measured upon reception and after maturity when the fruits' weight stabilized. Data loggers (watch dog) supplied by Spectrum Technologies Inc., Aurora, USA was used to follow temperature inside and outside the polycarbonate house. Moisture balance supplied by KERN & Sohn, Baligen, Germany.

For technology economic evaluation, data was collected from two farmers in the Sultanate of Oman with two different polycarbonate drying houses sizes, using rapid rural appraisal surveys with a direct interview method conducted at the same time as the survey. The information collected covered the capital cost, capacity of dryer, maintenance costs, life of dryer, amount of subsidy received, and some technical information related to the condition of the fresh and dried dates. The data was used to assess and evaluate the economic significance of the polycarbonate dryer using the payback period method.

To evaluate a level of adoption of this technology, a focus group discussion (FGD) methodology was used to apply the ADOPT with group of date palm growers in North and South Al Batinah in Oman. Streamlined 22 discussion questions around four categories of influences on adoption: characteristics of the innovation, characteristics of the target population, relative advantage of using the innovation and learning of the relative advantage of the innovation.

RESULTS AND DISCUSSIONS

Drying dates assessment in research station

The dates drying process involves the loss of weight due to evaporation of moisture from the fruits which is assisted by high temperature and low humid moving air. The design of the Polycarbonate Drying House (PDH) (Fig. 1) is an attempt to provide optimal conditions to achieve drying requirements.

Data collected of the changes temperature and humidity in 24 hours during the maturing process in and outside the DPH are depicted in (Fig. 2), the highest temperature recorded was 69.6 at 1:26 p.m., the highest humidity was 62.7 at 4:56 a.m. while the highest temperature recorded outside was 99.9 and continued from 00.56 a.m. to 2:26 a.m., the highest humidity was 62.7 at 4:56 a.m.

Fruits of two cultivars (namely Khasab and seed grown cultivar coded C6) are ripened at Bisr or Rutab stages (as they are naturally mixed in the bunches) and immediately % moisture is measured, and three samples (each weighed between 400-500g) are placed in stainless steel trays and entered in the PDH, the same was repeated for samples to be placed in the open air under the sun and all are monitored daily for changes in their weight.

It was observed with Khasab cultivar (Fig. 3) that decrease in weight started rapidly from the first day and continued for four days in the PDH then stabilized. In the traditional drying the decrease was slower and continued for 12 days.

The decrease in weight was less prevalent in the C6 cultivar (Fig. 4), while decrease was steeper inside the PDH and prevailed in day 5 the difference between PDH drying and traditional was slight. However, due to higher humidity the samples placed outside started gaining weight after day 7 which is attributed to the hygroscopic nature of the dates.

Economic evaluation of PDH with farmers in Sultanate of Oman

PDH were evaluated economically based on Payback Period (PBP) (Nayak et al., 2012) under two scenarios: with and without governmental subsidies (Table 3, Fig. 4 and 5). Empirical findings reveal the high profitability of the polycarbonate drying system, even when it is not subsidized by the government. At a real discount rate of 5.1%, the Net Present Value (NPV) is positive and very high in all cases. Given this, the decision criterion states that an investment is usually acceptable if the NPV is positive (the investment is profitable). This criterion was also supported by both the Internal Rate Return (IRR) and the PBP criteria. The estimated IRR was higher than the current interest rate in the Sultanate, which could encourage both date palm growers and private investors to invest in polycarbonate drying houses. The PBP was found, in the worst case scenario, to be 3.77 years, which is relatively short considering the life of the system (15-20 years). This suggests that investment or action costs in this dryer system are recovered quickly reducing the risk involved in the investment.

Prediction of adoption of the technology

The ADOPT tool predicts the proportion of a target population that might adopt an innovation over time. The assessment of PDH technology (Table 4, Fig. 6 and 7) reveal that 95% of Al Batinah community would adopt the innovations after 20.9 years. However, the predicted adoption levels in 5 and 10 years from start is 23.5% and 72.9%, respectively. These results are expected since the upfront cost of investment is quite high while the economic viability of this technology make the evidence of its profitability. Results suggest that triability of the innovation on a limited basis before a decision is made to adopt it on a larger scale, the perception and evaluation of the PDH technique. The size of the up-front cost of the investment relative to the potential annual benefit from using the innovation are the driving adoption factors for the PDH technology in the target area.

CONCLUSION

The PDH was proved to be an efficient method to mature dates by providing optimal conditions to assist the drying of dates process. The drying in the PDH reduce the time of drying date to 4 days, instead 8-12 days by the traditional drying way in addition to protecting the dates from different elements such as high humidity, dust and attacks of insects and birds.

Based on economic indicators (NPV, IRR and PBP) the investment is highly profitable. The investment is usually acceptable if the NPV is positive.

The results of predict of the adoption of the PDH indicate that to meet the technical, economic, and socioeconomic requirements, there is a need for a greater political and institutional input into polycarbonate drying houses projects. In particular, there is a need to design and develop alternative policy instruments (other than subsidies) and institutions for extension, technical assistance, training, and credit services that will facilitate adoption of this technology.

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Tables:

Table 1. Moisture (%) of Khasab dates before and after maturity

Sample	Initial	Final
Inside the PDH	70.09	11.3
Outside	70.09	21.45

Table 1. Moisture (%) of C6 dates before and after maturity

Sample	Initial	Final
Inside the PDH	43.43	15.8
Outside	43.43	21.62

Table 3. Computation of economic indicators and financial indicators (NPV, IRR, and PBP) of the PDH

Items	**Subsidized dryer - FIRR**	**No subsidy for dryer - EIRR**
Fresh dates (OMR/kg)	0.8	0.8
Dried dates (OMR/kg)	1.2	1.2
Product net weight (kg/kg of fresh date)	0.75	0.75
Capacity of dryer (kg/year)	6000	6000
Cost of fresh materials	6000*0.8*0.65 3120	6000*0.8*0.65 3120
Labor and maintenance costs (OMR)	300	300
Electricity costs (OMR)	36	36
Cost of insurance (OMR)	0.0	0.0
Total cost of fresh materials	3456	3456
Capital cost of dryer (OMR)	1000	3000
Life of dryer (years)	15	15
Depreciation (OMR/year)	66.66	200
Total revenue (OMR)	(6000*0.75*0.75*1.2)+(6000*0.75*0.25*0.8) 4950	(6000*0.75*0.75*1.2)+(6000*0.75*0.25*0.8) 4950
Total cost (OMR/year)	4522.66	6656
Net income (OMR/year)	427.34	-1706
Financial Indicators		
Net present value (NPV)	12,764.184	7486.52
Financial and economic internal rates of return (FIRR, EIRR)	Very high (+100%)	76%
Payback period (PBP, years)	0.7	2.31

Source: Dhehibi et al. (2017)

Table 4. Predicted Adoption Levels of PDH Technology at "South Al Batinah" Governorate – Sultanate of Oman

Predicted Peak Level and Time of PDH Adoption	Al Batinah Governorate

Predicted years to peak adoption	20.9
Predicted peak level of adoption	95%
Predicted adoption level in 5 years from start	23.5%
Predicted adoption level in 10 years from start	72.9%

Source: Dhehibi et al (2017)

Figures

Fig. 1. Polycarbonate Drying House (PDH)

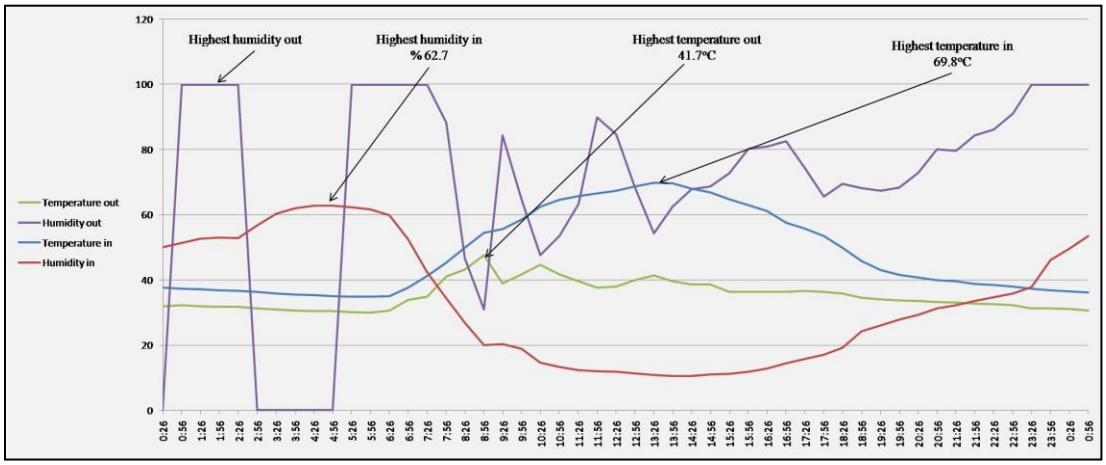


Fig. 2. Changes in temperature and humidity in and out of the PDH

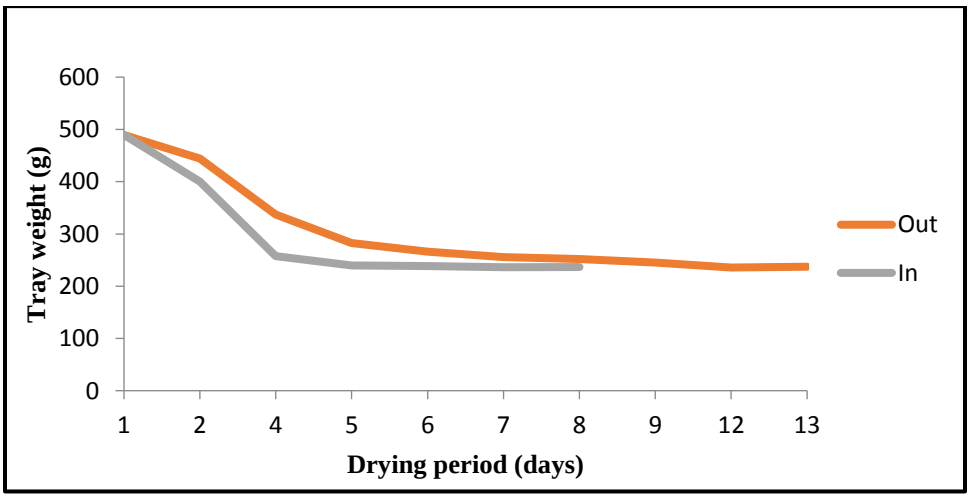


Fig. 3. Changes in Khasab dates weight maturity

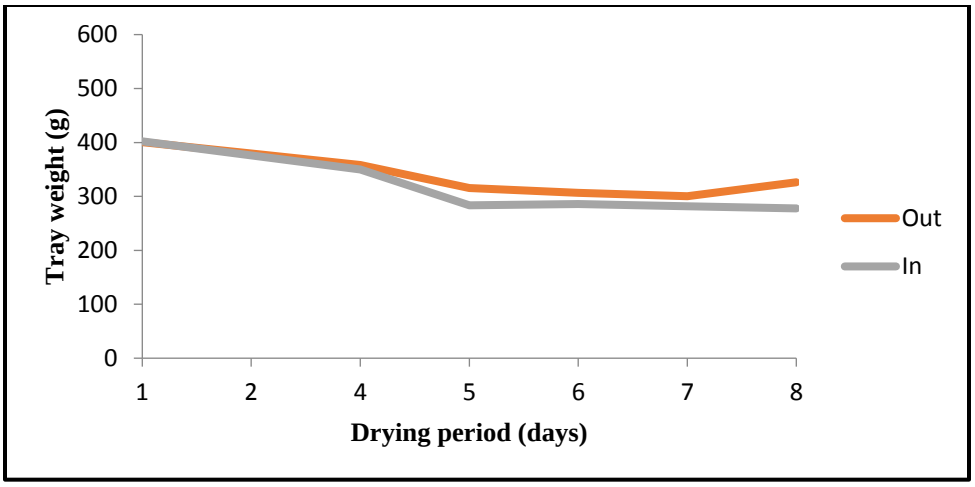
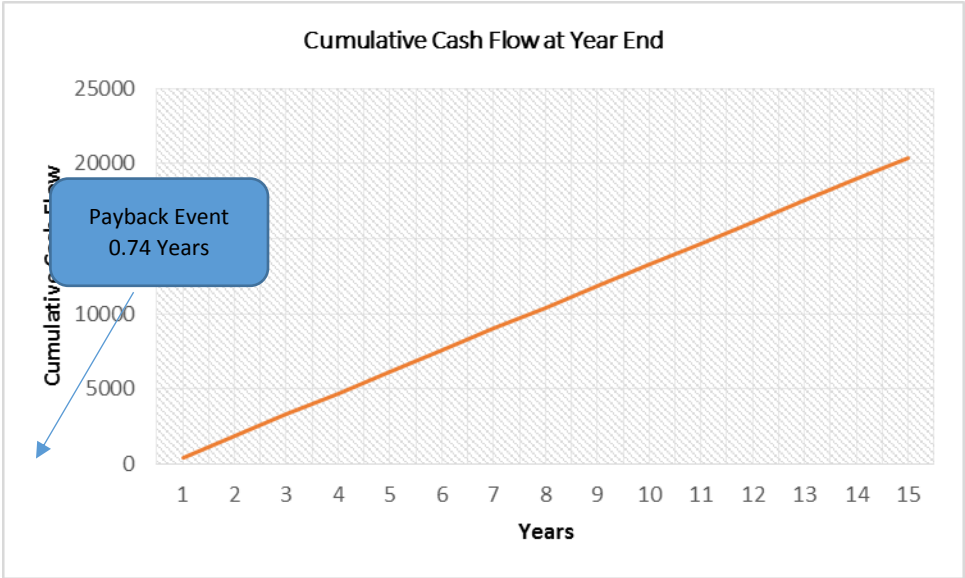
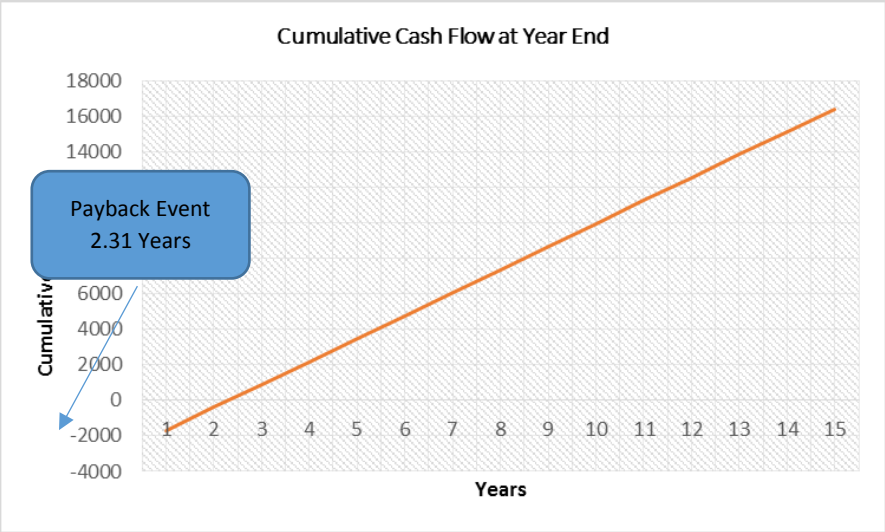


Fig. 4. Changes in C6 seedling dates weight maturity



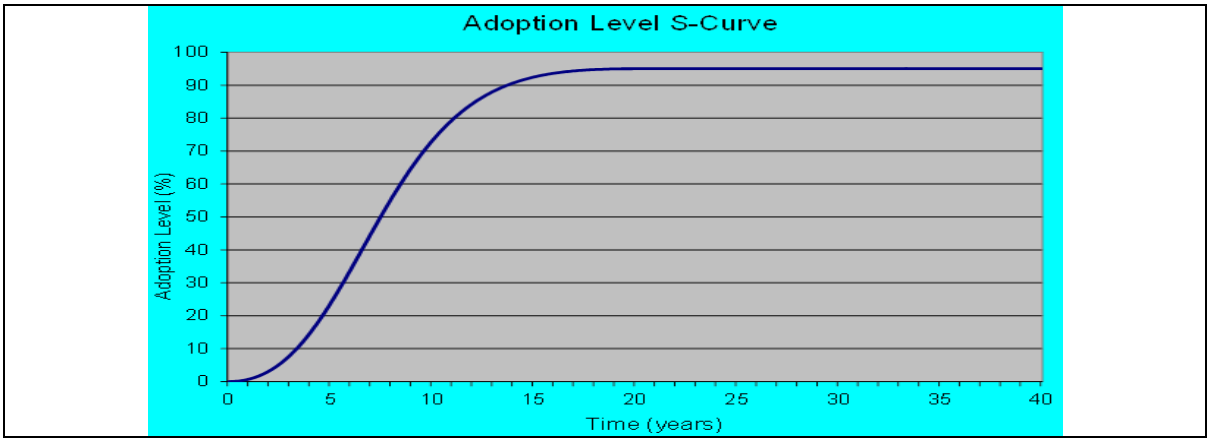
Source: Dhehibi et al. (2016)

Fig. 5. Cumulative cash flow at year end (PBP) when the PDH is subsidized



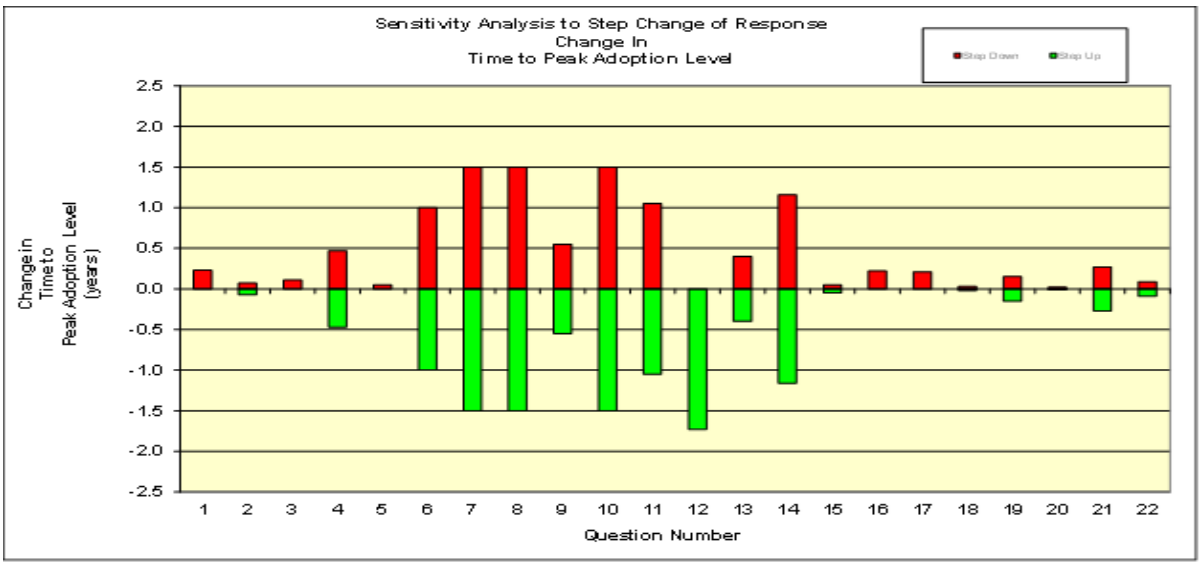
Source: Dhehibi et al. (2016)

Fig. 6. Cumulative cash flow at year end (PBP) when the PDH is not subsidized



Source: Dhehibi et al. (2017)

Fig. 7. Predicted Adoption Curve of PDH Dryer Technology at the "South Al Batinah" Governorate - Sultanate of Oman



Source: Dhehibi et al. (2017)

Fig. 8. Sensitivity Analysis of Adoption Curve of PDH Dryer Technology at the "South Al Batinah" Governorate - Sultanate of Oman

DATE PALM PRODUCTION AND WATER PRODUCTIVITY UNDER SUBSURFACE DRIP IRRIGATION SYSTEM

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Abstract: The majority of date palm cultivation in Oman is irrigated using flood irrigation method and just limited area irrigated by Bubbler Irrigation (BI) system. Subsurface Drip Irrigation (SDI) has been proved as a water saving method that increase both crop production and Water-Use efficiency (WUE). However, it is being not tested for date palm irrigation. An experiment at Al-Kamil Research Station in Al-Sharqiyah North governorate was conducted from 2013 to 2016 to evaluate subsurface drip irrigation system in terms of date palm production and Water Productivity (WP) for date palm irrigation and compared with bubbler irrigation system which is recommended for date palms irrigation. Four irrigation treatments were 100% ETc using bubbler irrigation, 60%, 40% and 20% ETc Subsurface irrigation system. Irrigation scheduling was developed based on crop evapotranspiration (ETc= ETo x Kc), ETo was calculated by Penman-Monteith equation on CROPWAT program using climatic data from nearby weather station. Crop coefficient was taken to be 0.90 (FAO, 1991). The results show no significant differences in fruit production between date palm trees irrigated by 100% ETc using bubbler system and those irrigated with 60% of the water requirement under sub-surface drip irrigation system. Fruit production was significantly reduced under the irrigation with 40% and 20% of ETc under sub-surface drip irrigation system as compared to that irrigated with 60% ETc. The highest WP of 4.7 kg/m3 was obtained at the rate of 20% of the water requirements under sub-surface drip irrigation system. All the results proved that sub-surface drip irrigation system contributes to 40% water saving without reduction in fruit production of date palm trees.

Key words: Date palm, Water productivity, Subsurface drip irrigation

INTRODUCTION

Oman is in arid regions, where water quantity and quality is the limiting factor for agriculture production. Average annual rainfall does not exceed 100 mm and agriculture production depends entirely on irrigation from groundwater which has been depleted in some agriculture areas. Therefore, efficient water application methods are necessary to increase water use efficiency and productivity of agriculture crops. Date palm is the main fruit crop cultivated in Oman. There are more than 7.5 Million date palm trees in Oman and about 75% of trees are irrigated by the basin flood irrigation method, which has an efficiency of not more than 60%. The remaining 25% is irrigated by bubbler irrigation system which is recommended by the irrigation specialists in the country.

Subsurface drip irrigation system has been proved to give higher water use efficiency and better WP than other irrigation systems. Ayars et al. (2015) stated that subsurface drip irrigation improves WUE since undesirable water loss can be reduced or eliminated such as evaporation from soil surface evaporation, deep percolation and water runoff. Several previous studies indicated that subsurface drip irrigation is one of the promising technologies that contributes to improve water use efficiency and productivity in addition it is considered as the most effective way to provide water and nutrient directly to the plant and to increase productivity of crops (Thomson et al., 2002, 2003). This subsurface drip irrigation represents the recent improvement of irrigation as it significantly reduces losses of direct evapotranspiration, runoff, and deep percolation (Hanson and May, 2007). Many studies suggest the use of subsurface drip irrigation as a water saving technology in arid areas, but it is necessary to study and examine the performance and the efficiency of the subsurface drip irrigation in comparison with other irrigation systems such as bubbler irrigation systems in these areas.

The main objective of this study is evaluating SDI system on date palm productivity and water use efficiency as compared to bubbler irrigation system which is currently used for irrigating date palm in Sultanate of Oman.

MATERIALS AND METHODS

The experiment was conducted in Al-Kamil Research Station in Al-Sharqiyah North governorate, Sultanate of Oman (22^{o} 14' 13.00 N, 59^{o} 11' 04.00 E) during 2013-2016 growing seasons. The soil at the experimental site is sandy loam has an average electrical conductivity of 1.1 dS/m and pH of 7.8. The Field Capacity and Permanent Wilting Point of the soil are 23.2% and 13.5% respectively. The experiment consisted of four irrigation treatments in RCBD with three replications each of 3 date palm trees. The total number of trees is 36. The applied irrigation treatments were managed based on different percentage from evapotranspiration (ETc), which was calculated by using CROPWAT program using climatic data from weather station located at the Al Kamil Research Station. Crop coefficient was taken to be 0.90 (FAO, 1991). The tested irrigation treatments were T1: 100 % ETc using BI, T2: 60% ETc using SDI, T3: 40 % ETc SDI, and T4: 20 % ETc SDI. Irrigation scheduling was developed based on the crop evapotranspiration, ETc (ET0 x Kc), ETo was calculated by Penman-Monteith equation on CROPWAT (Table1). The time of irrigation for both BI and SDI systems was calculated based on the discharge for each irrigation system. Two bubblers each of 4 liter/min were place at the basin of each tree. Ditches were dug around each date palm tree with a depth of 50 cm and at a distance 120cm from the tree trunk (Fig. 1). The subsurface drip lines each of 60 drippers were placed at the ditch around the tree trunk (Fig. 2). The size of subsurface dripline is 13 mm and the drippers spaced 50cm with discharge rate of 4 l/h. The actual water applied was measured using water meters. The soil water was measured using soil moisture sensors. They were placed at a depth of 30cm, 60cm and 90cm from soil surface. Date palm production was measured at fresh stage and water productivity was calculated as a ratio between the marketable yield and the seasonal values of actual water application using the following equation WUE = Y/W (Howell, 2001).

RESULTS AND DISCUSSION

The results are presented in table 2, showed that there are no significant differences in fruit production between date palm trees irrigated by (100%) of the water requirements using BI system and those irrigated with 60% of the water requirements using SDI system. The average fruit production reaches 78.7kg/tree. Fruit production significantly reduced when irrigating by 40% and 20% of its water requirements under subsurface drip irrigation system. The average fruit production reduced to 69.3kg /tree.

The results also indicated that the water productivity (kg/m^3) increased as irrigation water decreased and the highest water productivity 4.7 kg/m^3 was obtained at the rate of 20% of the water requirements under SDI system. WP was higher by 53.8% when irrigating with 60% of the water requirements using SDI compared to irrigation by 100% of the water requirements using BI system. The results proved that SDI system contributes to (40%) water saving without reduction in fruit production of date palm trees.

CONCLUSION

The aim of this experiment was to evaluate SDI system in terms of date palm production and WP for date palm irrigation and compared with BI. The results yield and water productivity proved that SDI system contributes to 40% water saving without reduction in fruit production of date palm trees. However, WP increased by 53% compared to BI system. Water requirements of date palm can be reduced from 7800 m^3/ha to 4680 m^3/ha if BI is replaced by SDI.

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Tables

Table 1. Irrigation scheduling calculation based on ETo calculated by using CROPWAT program using climatic data from weather station located at the Al Kamil Research Station and Crop coefficient was taken to be 0.90 (FAO, 1991).

Month	ET_o mm	Kc	ETc mm	Irrigated area m^2	Total Water applied liter
January	2.82	0.9	2.5	38	96
February	3.97	0.9	3.6	38	136
March	4.36	0.9	3.9	38	149
April	5.45	0.9	4.9	38	186
May	6.99	0.9	6.3	38	239
June	7.64	0.9	6.9	38	261
July	7.23	0.9	6.5	38	247
August	6.93	0.9	6.2	38	237
September	6.48	0.9	5.8	38	222
October	5.76	0.9	5.2	38	197
November	4.13	0.9	3.7	38	141
December	3.32	0.9	3.0	38	114

Table 2. Date palm Yield and water productivity under the four irrigation treatments

Treatments	**Yield (Kg/tree)**	**WP (Kg/m^3)**
Irrigation with 100 % of ETc using bubbler system	79.0 ^{a}	1.3 ^{d}
Irrigation with 60 % of ETc using Subsurface drip system	78.3 ^{a}	2.0 ^{c}
Irrigation with 40 % of ETc using Subsurface drip system	69.8 ^{b}	2.7 ^{b}
Irrigation with 20 % of ETc using Subsurface drip system	68.8 ^{b}	4.7 ^{a}
LSD	**8.4**	**0.45**

LSD = 0.45, Values with different superscripts are significantly different at p=0.05

Figures

Fig. 1. Ditches around the date palm trunk (Radius 120 cm and Depth 50 cm)

Fig. 2. Installation of the subsurface drip lines around tree

Project Development of Sustainable Date Palm Production Systems in the GCC Countries of the Arabian Peninsula: Objectives, Activities and Major Achievements

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International Center for Agricultural Research in the Dry Areas (ICARDA)

The Sixth International Date Palm Conference (SIDPC)
Abu Dhabi -UAE: 19 – 21 March, 2018.

ABSTRACT

The project Development of Sustainable Date Palm Production systems in the GCC Countries of the Arabian Peninsula, is executed in the six GCC countries (Oman, UAE, KSA, Bahrain, Qatar and Kuwait) and financed by the GCC.

The project aims to: Use of Proper agro-management techniques, develop of proper IPM programs against pests and diseases, Development of proper post-harvest techniques to reduce losses, and improve marketing, Characterize and finger prints the major date palm local cultivars, reinforce building of national programs in the area of date palm agro-management and Enhance Networking capabilities for the exchange of information, databases, services derived from the project activities.

The project has 4 technical fields in problem-solving research component (Propagation and Crop Management, Integrated Pest Management, Postharvest and processing and Biotechnology and Genetic Resources conservation). In the Capacity Building component, the project provides specialized training to strength the national agricultural research systems. In the Technology transfer component the project facilitate the transfer and adoption of suitable technologies developed regionally and/or internationally. The approach of the project is based on participative research between farmers and researchers and between the national systems of research (NARS) and the exchange and cooperation between the all GCC countries.

The major achievements of the project are in Field operations are: Applying liquid pollination to facilitate the operation and maintain good level of fruit set ; Selecting bio-pesticides for controlling infestation by borers and mites and identification of some natural enemies for the control of Lesser date Moth ; Ameliorating the quality of dried dates and reducing the loss and the drying time by using Polycarbonate houses) ; Selecting SSR markers to characterize 60 cultivars from GCC countries (10 major cv from each country).

Keywords: GCC, Date Palm, Competitive advantages, competitiveness indices, market share, revealed comparative advantage, trade balance index, dates marketing, Gulf cooperation council (GCC).

INTRODUCTION

The project "Development of sustainable systems of date palm production in the GCC" funded by the General Secretariat of the Arabic Gulf Cooperation Council (GCC) is executed by the International Center for Agricultural Research in the Dry Areas (ICARDA) in the 6 GCC countries: Kingdom of Saudi Arabia, United Arab Emirates, Kingdom of Bahrain, Sultanate of Oman and States of Kuwait and Qatar.

The project activities starts in July 2006 and started its first phase for a period of five years (2006-2011) which enables the achievement of expected results in research areas of date palm systems management and establish an integrated pest management principles and develop postharvest and trading techniques in research on biotechnologies in addition to his success in creating the exchange and integration between countries participating in the development of the date palm, making the project Steering Committee proposes to extend the project activities for the second phase of five years (2013-2017). In the second phase of the project, other than continuous research programs in water supply IPM and Genetic Resources, transfer of technologies for the end users was the main focus on the project.

The present paper presents the project main components in research, capacities building and technology transfer and the major achievements in the field of date palm cropping, production, genetic resources and protection.

MAIN AREAS OF ACTIVITIES OF THE PROJECT

The project contains three complementary axes: (1) Applied research activities of the date palm production systems covering field operations (Crop management), Integrated Pest Management (IPM), Post-harvest operations and Genetic resources; (2) Capacity development and (3) Transfer of technologies.

APPROACH OF THE PROJECT

The project fulfills an approach-based participation and exchange among the six Gulf Countries. For each applied research subject one or more states are the main responsible of the research subject. Other countries can also help of complementary research actions within the exchange with the leader.

The leader of the crop management component is Kuwait, of Integrated Pest Management are Kingdoms of Bahrain and Saudi Arabia, of Post-Harvest and trade are United Arab Emirates and Biotechnologies and of Genetic resources are State Qatar and the Sultanate of Oman.

MAJOR ACCOMPLISHMENTS OF THE PROJECT

Crop management

1. Research of new subsurface irrigation techniques

The subsurface drip irrigation represents the recent improvement of irrigation, because it is considered the most efficient irrigation technique that significantly contribute to reduce water losses of direct evaporation, runoff and deep percolation. The precise application of water and

fertilizers resulted in the increased water use efficiency, application uniformity of water and consequently the improvement in crop yield and prevents the growth of weeds around the date palm trees.

Many studies suggest the use of surface drip irrigation as a water saving technology in arid areas, but it is necessary to study and examine the performance and the efficiency of the subsurface drip irrigation in comparison with other irrigation systems such as drip irrigation in these areas. Results of the project on new techniques on date palm irrigation reduce of water supply for date palm by 30-40% water saving without reduction in date production.

2. Date palm pollination

Liquid pollination developed within the project increased efficiency of pollination and better fruit production and this led to increased profitability of farms in addition to reducing the cost of pollination to the farms and the possibility of doing this process to large farms in reduced time than traditional hand pollination. And thus increase the economic returns to palm sector through: reducing the need for trained manpower where one or two operator can do the job, the economy in the amount of liquid pollination needed to less than a quarter of the quantity used in traditional way, short time so it will be possible to pollinate nearly 500 date palm tree during the day. Single action, reducing labor costs, risk of falling during climbing tree to pollinate date palm.

Adoption of liquid pollination technique conducted by some farmers in Sultanate of Oman and UAE reduce outstandingly pollen required quantity, increased the efficiency of pollination and improve the production quality in addition to reducing labor costs and time requirement significantly. Economic study shows a big reduction of the cost reaching 90%.

Pollen extraction and drying and storage conditions was also improved to maintain good vitality using pollen extractor drying chamber and storage facilities in the same unit. The integrated technical pollination package is applied actually in Sultanate Oman and it is expected to develop the same package in other GCC countries.

3. Selection of pollinators

Research actions was conducted in Saudi Arabia to select good pollinators by their effect on date palm production and dates quality to improve quantitative and qualitative characteristics of dates and confirmed the impact of use of some local males on improving date palm productivity. Field surveys were also conducted at several locations in Al Hassa date palm plantations. Good discovered pollinators were planted in the Genetic National Bank in the Date Palm Research Center in Al Hassa.

4. Fruit thinning

Fruit thinning was applied in GCC countries and field tests showed that the ratio of bunches to green leafs is 1 bunch to 8-10 leafs. It showed that is the appropriate proportion to produce good dates. Fruit thinning must be applied 15-20 days after fruit set. Fruit thinning is now conducted in all the research farms in GCC countries.

5- Use of treated waste water on date palm

The use of triple treated water for date palm irrigation carried out in the Kingdom of Bahrain is very encouraging. The analyses showed a lower concentration of pollutants remains particularly heavy elements which is below the maximum allowed. The test results also showed that triple water irrigation treatment did not affect the soil and plants in terms of increasing the level of pollutants. Accordingly, this type of water is a good source for the sustainability of date palm cultivation in dry areas. Bubbler irrigation method proved useless over date palm productivity compared with other techniques such as drip irrigation.

5. Fertigation

Use of fertigation by Hydraulic injector method has significantly increased the date palm productivity by about 70% in comparison to the traditional surface fertilization method for date palm. Fruit weight, date tree production and water productivity were significantly increased by use of fertigation.

6. Use of Mychorrizae

Mycorrhizae was added to organic fertilizer for seedling date plants under control conditions in UAE conditions. Results showed increased growth of date palm plants fronds by 40% compared to traditional fertilization. In Kuwait, it was found that adding Mycorrhizae with compost sludge increase the date palm growth 24 percent compared to use compost alone and 21 percent without adding compost.

Post-harvest dates

1. Drying dates under polycarbonate rooms

This technology is considered as promising application of solar energy systems in the GCC countries where the losses of production is about 30%. This is with the aim to improve the quality of dried dates, accelerate their drying process, getting cleaner fruits and free from dust. This technology aims to reduce the cost of labor, gaining time and improving the quality of the fruits.

A series of experiments have been conducted to identify the appropriate technical specifications and dimensions of the drying houses to increase the efficiency of this technology. Drying dates inside plastic room was performed for the first time to ameliorate drying process. The quantity of dates to dry was limited and the color was affected because limited aeration of the small plastic houses.

Drying dates using polycarbonate houses shorted the period of drying fruits from 8 to 4 days in addition to improving the quality of dried dates. The pH of dried dates under polycarbonate houses still under the allowed values.

It also improves the quality of dried dates by reduction of insects' infestation which affect the marketing of dates. Dates dried in polycarbonate houses avoid infestation with dust, insects and birds maintaining healthy nutritional benefits of dates. It also improves the quality of the fruit by reducing darkening fruit color.

The polycarbonate drying chambers is one of the promising technologies introduced by the project for the farmers. Expansion of the technique and ameliorating the chambers, need more applied research and efforts.

2. Dates packaging

Studies were conducted to improve dates packaging respecting the packaging standards. Preference of manufacturers (90%) was oriented to easy open packs. In terms of quality of packing, it was noted that the consumer prefers (65%) packed dates under vacuum and (70%) transparent packs. It also demonstrated that most consumers do not prefers metallic and polystyrene pack.

Integrated Pest Management

Excessive use of chemical pesticides in date palm pest control damaged local environment in addition to environmental pollution by toxic pesticides and eliminate the predators. In the other hand the Loss of the date palm production by pest attacks is valued to about 30-40%.

Within this the IPM component of the project was aiming to search for alternatives to chemical pesticides.

Old World Date Dust mite (*Oligonychus afrasiaticus* McGregor) and the lesser date moth (LMD) *Batrachedra amydraula* Meyrick) are considered the dominant acarian pest of date palm in the GCC region is a serious pest of the date palm and causes severe yield loss, particularly in young developing date fruit.

In Oman, the organic-pesticide Coragen 0.15ml/L gave the best results in comparison with the other insecticides on (LDM). In KSA, three bio pesticides (Matrin 0.5%, Paraffin oil, Abamectin1.8% and Sulfur) and in Bahrain two bio pesticides (Biotrine and Sulfur) gives good results against Dust Palm Mite.

Biological control including the use of biological pesticides, gives good results against the two pests. Exploiting biological control utilizing the egg parasitoid (*Trichogramma cacoeciae* Marchal) was started in KSA and Oman. Efforts have to be undertaken for the multiplication of the parasitoid and its release in field.

Biotechnology and genetic resources

1. Morphological description of major date palm cultivars in GCC countries

Vegetative and fruit description is achieved in the six Gulf countries. The book: Atlas of Major Gulf Countries Date Palm Cultivars is in editing.

Morphological description integrates date palm tree stem, leaves, leaflets and spines. Pomological description is interested to bunches, spikelet's, fruit and seed.

1. Genetic fingerprinting of cultivars

DNA study completed for sixty date palm cultivars collected from all GCC countries: Saudi Arabia, UAE, Bahrain, Oman, Kuwait and Qatar. Thirty ISSR markers were previously selected for genetic characterization.

One program search for genes resistant to environmental stress is started between the project and the Research Centre of the UAE University Al Ain and American University in Abu Dhabi. Promising SNP markers are in identification to undertake GWAS study to map these candidate genes for salinity tolerance in date palm

3. Research of new cultivars and pollinators

In Saudi Arabia 27 screened pollinators developed from date palm seedlings naturally in saline environment Al Ugair Beach and cultivated with some local date palm cultivars offshoots for comparison.

Field surveys were also conducted at several locations in Al Hassa searching good pollinators according to their good effect on quality and productivity in Al Hassa date palm plantations. Good discovered pollinators were planted in the Genetic National Bank in the Date Palm Research Center in Al Hassa.

CONCLUSION

The research efforts of the date palm project team in the 6 GCC Countries through experiments carried out within the framework of the project over the past years in participative research program accomplished some important results in the field of date palm field operations.

The main accomplishments are in date palm water supply. Subsurface irrigation was conducted in 3 countries in different conditions and different techniques. The results are reduction of 35-50 quantity of water within reducing date palm tree growth and production. Date palm pollination was improved using liquid pollination reducing the cost of pollination by increase the efficiency of pollination in addition to reducing the cost of labor hands. Liquid pollination technique reaches 394 farmers and is actually applied in no less than 80 farms, integrating 2 big farms of (12,000 date palm trees) in Kuwait and (200,000 date palm trees) in KSA.

Dates post-harvest operations through drying dates under polycarbonate houses improved the quality of dried dates and reduce notably the losses. This help to raise dates value and ease their marketing, particularly in coastal production areas with high humidity. Polycarbonate houses are used in about 180 farmers in UAE and Oman.

To reduce chemical effect of chemical pesticides on the nature and improve plant protection the research for alternatives some biological pesticides gives good results against the Old-World Date Dust mite (*Oligonychus afrasiaticus* McGregor) and the lesser date moth (LMD) *Batrachedra amydraula* Meyrick) are considered the dominant acarian pest of date palm in the GCC region. Exploring biological control using parasitoid *Trichogramma cacoeciae* Marchal and predators is started in KSA and Oman. Efforts have to be undertaken for the multiplication of the parasitoid and its release in field.

In the genetic resources characterization and vegetative and fruit description is achieved in the six Gulf countries. Atlas of Major Gulf Countries Date Palm Cultivars is ready for edition and printing. Research for genes resistant to environmental stress in the date palm genome is started between

the project and the Research Centre of the UAE University Al Ain and American University in Abu Dhabi. Promising SNP markers are in identification to undertake GWAS study to map these candidate genes for salinity tolerance in date palm.

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DATES TRADE IN GCC COUNTRIES COMPETITIVITY AND COMPLEMENTARITY

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The Sixth International Date Palm Conference (SIDPC)
Abu Dhabi -UAE: 19 – 21 March, 2018.

Abstract: In the GCC countries, date-palm sector is strategically important for the economic, social and environmental development. Therefore, markets globalization has had a huge impact on the comparative advantages of date exports from the GCC countries, highlighting a new range of necessary determinants for competitiveness of these countries on the international market of date. It aims to provide updated estimates of competitiveness indicators of the GCC countries on the international market of dates palm.

After summary description concerning date's production and consumption trends and patterns of the different GCC countries, this paper presents the date trade matrix (destinations of exports and imports) of the considered countries. In a second part of this section, a set of competitiveness indicators were calculated to better reflect on the date trade balances performances of each of the GCC countries. The measures of competitiveness conducted in this paper include: i) the Market Share (MS); ii) the Revealed Comparative Advantage (RCA); and iii) the Trade Balance Index (TBI). The MS indicator was used to identify size advantages and the degree of specialization of a given country on the international market of a given commodity. The RCA has been defined as a measure of performance of international trade competitiveness of a given country for a given commodity. And finally, the TBI is used to analyze whether a country has specialization in export (as net-exporter) or in import (as net-importer) for a specific group of products. The sum of market shares of the 6 GCC countries is about 30% (2015). GCC countries market are progressing quite positively with increasing shares from one year to another. The highest RCA value was recorded for Saudi Arabia (about 43.5 in 2013). TBI results show the existence of structural differences between Saudi Arabia and UAE in terms of dates export and import patterns. These two countries are both the main players in date export in the GCC area. TBI of UAE is much lower than of Saudi Arabia, showing that UAE is also importing a higher proportion of its exported dates compared to Saudi Arabia. The date trade patterns among the GCC countries shows that there is a wide scope of coordination between the different trade strategies of these countries, through specialization and division of tasks. This can generate important opportunities for gaining more weight on the world market of dates.

Keywords: Competitive advantages, competitiveness indices, market share, revealed comparative advantage, trade balance index, dates marketing, Gulf cooperation council (GCC).

INTRODUCTION

Date palm production is a strategic sector in most of the GCC countries. The sector is one of the oldest economic activity in the Arabian Peninsula and continue to play a key role in the culture of its population. In addition to the importance of dates for domestic consumption, the date sector is also a source of employment, income generation, and trade in many of these countries.

The date fruit, known for its nutritive as well as spiritual value, is marketed all over the world under different forms (fresh fruits, or high value confectionery). In some very arid areas, date fruit remains as an important source of subsistence and resilience for local populations.
The share of the GCC countries in the total world export value was about 25% in 2013 (FAO, 2013). The largest exporting countries of date on the international market are Tunisia, Algeria, Egypt, Saudi Arabia, and United Arab Emirates. The high competitiveness on the international market of dates involves developing analytical reflections and studies on sources of competitiveness as well as its indicators, which can serve to set targets, objectives, and trade strategies. This competitiveness analysis and performances of the GCC countries on the international market of dates is the purpose of this study.
There is however no unique definition of the concept of competitiveness. Divergent approaches to competitiveness have produced different definitions. The concept is indeed very general and multifaceted and has a multidimensional nature linked to the optimal use of resources and geared to capturing development perspectives (Biggeri, 2007).
Lachaal (2001) provides a comprehensive assessment of what can be considered as determinants of competitiveness (see Fig 1). These include national (natural resources endowment, level of technology use, productivity of production within the cluster of firms of a given sector, scale economies, transport and marketing costs, etc.) and international (exchange rate, world market conditions, international transport costs: distance of countries from their relevant markets) determinants.
Biggeri (2007) considers that measures of competitiveness at economic sector level include the overall profitability of one nation's firms in the sector, the trade balance in the industry, the balance of outbound and inbound foreign direct investment, and direct measures of cost and quality at industry level. In line with this statement, Lachaal (2001) states that measures of the competitiveness may include different types of indicators such as:

- Measures related to the production costs (comparative advantages/relative costs/absolute costs, etc),
- Measures related to the factor productivity, and
- Measures of trade performances.

In this research, we rather focus on the last bullet by calculating a set of trade performance indicators for the GCC countries operating on the international date market. We present these indicators, as well as the way they are calculated and the source of data used for their collection. The aim of this study is analyze the trade performances of GCC countries on the international market of dates. A list of performance indicators will be measured and reported. These include: i) the market share of a given country on the world export market of date, ii) the revealed comparative advantage, and iii) the trade balance index. The assessment and comparison of these indicators among the GCC countries, as well as with other major competitors at the international level would provide insights that can be used for setting improved trade strategies and market opportunities.

METHODOLOGICAL FRAMEWORK

Competitiveness is a complex concept which embed different indicators and involves different methods for their calculation. The competitiveness of a given sector (or subsector) can be analyzed from several perspectives (Han, Wen, & Kant, 2009). After a quick overview of the

trends of different production and trade aggregates, we provide a calculation of a list of indicators which are widely used in competitiveness studies.

Market Share (MS)

The Market share indicator is used to identify size advantages and the degree of specialization of a given country on the international market of a given commodity (Han et al., 2009). It is expressed as the percentage of the total available market of commodity *i* (market segment) which captured by a country *j*. MS is calculated as shown in the following equation.

$$MS_{ij} = X_{ij}/X_{iw}$$

Where X_{ij} is the export of commodity *i* of country *j*; and X_{iw} is the world export of commodity *i.*

Revealed Comparative Advantage (RCA)

The RCA has been defined by Balassa (1979) as a measure of international trade competitiveness of a given country for a given commodity. It is calculated as being a ratio of the export share of commodity j of a country I, compared to his total exportations (all sectors/commodities included), by the world export share of the same commodity compared to total world export (all sectors/commodities included). The RCA can be calculated as by the following equation.

$$RCA_{ij} = \frac{X_{ij} \Big/ \sum_i X_{ij}}{\sum_j X_{ij} \Big/ \sum_i \sum_j X_{ij}}$$

Where, X is the export of commodity *i* by country *j*; $\sum_i X_{ij}$ are total exports of country *j*; $\sum_j X_{ij}$ are total world exports of commodity *i;* and $\sum_i \sum_j X_{ij}$ are the total world exports. If RCA > 1, then a comparative advantage is revealed; if RCA < 1 then a comparative disadvantage of the respective country is revealed.

Trade Balance Index (TBI)

Trade balance index (TBI). It is employed to analyze whether a country has specialization in export (as net-exporter) or in import (as net-importer) for a specific group of products. TBI was used as one of the crucial variables for analyzing the catching-up economies comparative advantage. The TBI value indicates a qualitative structure of product export and import and trade flows. It is formulated as follows:

$$TBI_{ij} = \left(X_{ij} - M_{ij}\right)/\left(X_{ij} + M_{ij}\right)$$

Where Xij and Mij represent exports and imports, respectively, of country i for product j. The TBI value varies between –100 (if a country only imports) and 100 (if a country only exports). Any value within –1 and +1 implies that the country exports and imports a commodity simultaneously. A country is referred to as "net importer" in a specific group of product where the value of TBI is negative and as "net exporter where the value of TBI is positive.

Source of data

UN COMTRADE and FAO annual time series (from 1961 to 2011) of all national aggregates including average yield, total country production, consumption, export, and import are the primary source of data used in this research. Data from both sources was continuously cross checked in order to be sure of its reliability.

RESULTS AND DISCUSSION

Production and consumption trends, and patterns of date palm in the GCC countries

Official FAO statistics (Table 1) show that dates areas, production and yield are progressing quit differently among the GCC countries. Saudi Arabia, Oman, and United Arab Emirates (UAE) have the highest harvested areas in 2014 with respectively 107 281 ha; 36 255 ha and 28 485 ha in the three countries.

Harvested areas in Bahrain, Kuwait and Qatar are still very limited with respective values of 3195 ha; 8931 ha; and 2290 ha during 2014. However, harvested areas in these three countries have been quickly progressing during the last two decades with an average annual increase of about 20%, 40%, and 1.38% in respectively Bahrain, Kuwait, and Qatar (see table 1).

The highest average yields (calculated over the period 2000-2014) are recorded in Qatar, Bahrain, and Kuwait with respectively 112006 Kg/ha; 86950 kg/ha; and 85173 Kg/ha (see Fig.1). Average yields are the lowest in Saudi Arabia and UAE, with respectively 63105 Kg/ha and 49001 kg/ha in both countries. These yield values combined to the statistics on harvested areas makes Saudi Arabia the first producer of dates in the GCC region, with an average annual production of 933 899 tons per year, followed by UAE producing and average of 623 900 tons per year. More insight about the production levels (total domestic production quantities) of dates and their historical trends, including annual growth rates are given in Fig. 2.

In terms of consumption, the FAO data show that dates consumption per capita is the highest in Oman with a value of 68 Kg/capita/year, followed by Saudi Arabia with a value of 34 Kg/capita/year (see Fig. 3).

Part of date production is also used as feed in some countries. This practice is not only observed in GCC countries, but is also frequent in other North African countries such as Tunisia. Another part of date production is wasted. Fig. 4 shows some of dates quantities used as feed and wasted in the considered GCC countries. It shows that up to 38% of the dates production was served to animals as feed in UAE during 2013. For Oman and Tunisia, is variable between 4% and 15%, among years. The volume of wasted dates is also important in the considered countries. The lowest wasted percentage (of production) is recorded in Saudi Arabia (1%), while a highest rate of 13% is recorded in Kuwait.

Date palm trade matrix of the GCC countries

The trade matrix of dates for the GCC countries is represented through a list of exported quantities from each of these countries to different destinations in the world. However, due to the high number of destinations, we only summarized in Table 2 the number of countries to which each of the respective GCC countries are exporting to. We also added the exported quantities of dates and their respective value, for each GCC country. Results in table 2 shows that Saudi Arabia and Emirates are the most active in terms of market diversification expressed by the number of countries to which they are exporting dates. In 2015, Emirates was exporting to 103 countries, while Saudi Arabia was exporting to 66 countries. Qatar and Oman are also exporting to high number of countries, with respectively 62 and 28 export destinations.

In addition to data in table 2, we wanted to stress the intensity of dates exchange, particularly among the GCC countries (see Fig. 5). It shows again that Saudi Arabia and Emirates are the most active in terms of export on the GCC market, with high and growing export values to the different GCC countries. On the GCC market, UAE is mostly exporting to Oman, followed by Saudi Arabia and Qatar. While Saudi Arabia is mostly exporting to UAE followed by Kuwait and Qatar. Most of the Omani dates is also exported in the destination of UAE, which is showing that UAE is the

first exporter and importer partner of Oman. This can be due to different consumers' preferences for dates in both countries and/or to different performances of dates processing companies in both countries.

Trade performances of dates: Results of indicators calculations

1. Market share indicator (MSI)

The analysis shows that GCC and North African countries are holding more than 70% of the international market of dates. Fig. 6 shows how this market is shared among the GCC countries and their direct competitors from North Africa, such as Tunisia, Algeria, and Egypt. In addition to Israel, who constantly holds around 10% of the international market of dates, Tunisia is dominating in terms of market share, with an average value of around 25% over the last decade. Algeria and Egypt are simultaneously holding around 4.2% and 3.8% of the market (Fig. 6).

The sum of market shares of the 6 GCC countries was about 30% of the international date market during 2015. This is showing that these countries together have strong potential for dominating the dates market (see Fig. 6). This total share was constantly progressing during the last decade, from a total value of 22.98% in 2005 to 30.49% in 2015. This progress especially refers to the rapid increase of the shares of Saudi Arabia, UAE, and Oman, as shown in Fig. 7.

Fig. 8 is providing the values of market shares separately for the GCC countries. The reason is that the market shares of Bahrain, Kuwait, and Qatar are much smaller than these of Oman, UAE, and Saudi Arabia.

In terms of progress, it is clear that all GCC countries, including the least present on the international market are progressing quite positively with increasing shares from one year to another. This is especially true for Qatar and Kuwait. Oman, Saudi Arabia, and UAE, also have the same trend with market shares increasing respectively from 0.34%, 8.65%, and 13.97% in 2005 to 1.14%, 12.95%, and 16.33% in 2015.

It is clear that coordination between the different trade strategies of the GCC countries, through specialization and division of tasks, can generate important opportunities for gaining more weight on the world market of dates. Dates producers and producer's organizations in major GCC producer countries, for instance, can interact regularly with dates processing and packaging manufactories and learn about exigencies and requirements on different markets. Processing manufacturers can also develop strong interactions with date producer's organization to ensure the alignment of production procedures with specific international markets standards and norms. This type of interactions among the professional organizations within the GCC countries can be mutually advantageous and self-reinforcing, but will not happen without effective coordination at the policy making levels.

2. Revealed Comparative Advantage of dates for the GCC countries (RCA)

The revealed comparative advantage is an index used in international economics for calculating the relative advantage or disadvantage of a certain country in a certain class of goods or services as evidenced by trade flows. It is based on the Ricardian comparative advantage concept, with the assumption that the commodity pattern of trade reflects inter-country differences in relative costs as well as in non-price factors.

The higher the RCA index value, the greater the importance of date relative to other agricultural exports. Thus, an RCA index of 43.5 for Saudi Arabia in 2013, would indicate that the country dates export share for 2013 is 43.5% higher than its share in total world export of agricultural goods.

Results of the RCA calculation, shown in table 3 are very close the RCA patterns identified by El-Habba & Al-Mulhim (2013), with Kuwait and Bahrain having no RCA during the study period, and Saudi Arabia and Emirates having the highest comparative advantages among the GCC countries. Among competitors, Tunisia and Algeria are the countries with the highest RCA in terms of date trade.

In this study, we also used both FAOSTAT and UN COMTRADE data bases as some small differences exists among both in terms of quantities and values of date traded. Results in Table 3 below were computed from UN COMTRADE data, while the results showing the trends of RCA in each of the GCC countries were calculated from FAOSTAT data and are shown in Fig. 9. Results from both data sources are converging and confirming the RCA patterns also identified by other studies such as El-Habba & Al-Mulhim (2013).

3. Results of "Trade Balance Index" (TBI)

The trade balance index is an indicator of countries specialization in either export or import of a given commodity. As argued in section 3.3, any TBI value comprised between -1 and +1 indicates that the country is both importing and exporting date on the international market. Negative values of TBI (as highlighted in table 10), refer to countries which are net importers while positive values refer to net exporter countries.

Table 4 shows the existence of structural differences between Saudi Arabia and UAE in terms of dates export and import patterns. These two countries are both the main players in date export in the CC area. However, even though UAE is a net exporter of dates, its TBI is much lower than the TBI of Saudi Arabia, showing that UAE is also importing a higher proportion of its exported dates compared to Saudi Arabia. Saudi Arabia is a net exporter with very limited quantities of date importation. Most of its date export is actually driven by domestic production.

In 2013, Bahrain, Kuwait, and Qatar were recorded as net importers of date, with most of their domestic consumption coming from importations. In 2013, the TBI values for these countries were respectively about -0.97, -0.91, and -1.

CONCLUSION

The present study was mainly focusing on analyzing the trade performances of GCC countries on the international market of dates. A list of performance indicators, including the Market shares, revealed comparative advantage, and trade balance index, have been be measured. The assessment and comparison of these indicators among the considered countries can be used for setting improved trade strategies and access to more valuable market opportunities.

Results of our analysis have shown that the market share of the 6 GCC countries considered was about 30% of the international date market during 2015. This is showing that these countries together have strong potential for dominating the international date market. In terms of RCA, the highest RCA value was recorded for Saudi Arabia, showing that the country dates export share for 2013 is 43.5% higher than its share in total world export of agricultural goods. Moreover, Saudi Arabia had a positive trade balance, showing that this country is the only net exporter of date in the region. Despite the high RCA of UAE, its TBI was lower than Saudi Arabia showing that UAE is also importing a higher proportion of its exported dates.

The date trade patterns among the GCC countries shows that there is a wide scope of coordination between the different trade strategies of these countries, through specialization and division of tasks. This can generate important opportunities for gaining more weight on the world market of dates. ~~Dates producers and producer's organizations in major GCC producer countries, for~~

~~instance, can interact regularly with dates processing and packaging manufactories and learn about exigencies and requirements on different markets. Processing manufacturers can also develop strong interactions with date producers' organizations to ensure the alignment of production procedures with specific international markets standards and norms.~~

Acknowledgment
We would like to express our sincere gratitude and appreciation to the Gulf Cooperation Council (GCC) Secretariat for funding this research conducted in the framework of the "*Development of sustainable date palm production systems in the GCC countries of the Arabian Peninsula*" project. We are very grateful to the Ministries of Agriculture, Agricultural Authorities, and Agricultural Research Institutions and Universities in the GCC countries for their continuous support and great collaboration.

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Tables

Table 2. Date areas, production and yield of the GCC countries

GCC Countries	Items	Units	2000	2005	2010	2014
Bahrain	Area harvested	ha	823	1400	1588	3195
	Production	tons	16508	12000	12472	11164
	Yield	kg/ha	200583	85714	78527	34937
Kuwait	Area harvested	ha	1350	2000	5089	8931
	Production	tons	10155	15800	32561	115213
	Yield	kg/ha	75222	79000	63977	129004

Oman	Area harvested	ha	35508	31353	31353	36255
	Production	tons	280030	247331	276405	328392
	Yield	kg/ha	78864	78887	88159	90578
Qatar	Area harvested	ha	1931	1444	2469	2290
	Production	tons	16116	19844	21491	27482
	Yield	kg/ha	83459	137424	87043	120009
Saudi Arabia	Area harvested	ha	142450	150744	155118	107281
	Production	tons	734844	970488	991546	766800
	Yield	kg/ha	51586	64380	63922	71476
United Arab Emirates	Area harvested	ha	185330	185330	197400	28485
	Production	tons	757601	757601	825300	255182
	Yield	kg/ha	40878	40878	41809	89586

Source: FAOSTAT (several years).

Table 3. Number of dates exporting markets for each of the GCC countries

	2012			2015		
	Number of countries	**Exported quantities (Tons)**	**Value of export (1000 US$)**	**Number of countries**	**Exported quantities (Tons)**	**Value of export (1000 US$)**
Oman	23	5814.9	7745.6	28	9141.6	11981.5
Bahrain	2	43.8	33.1	4	10.0	16.5
Kuwait	19	363.9	337.7	18	564.4	397.2
Qatar	n.a	n.a	n.a	62	534.8	351.4
Saudi Arabia	60	64299.0	74859.5	66	120358.0	136263.6
UAE	98	304090.5	129177.2	103	309782.1	171897.1

Source: UN COMTRADE database; (na: not available). Number of countries shows the number of countries to which each of the respective GCC countries is exporting dates; Exported quantities are expressed in Tons; Value of export is expressed in 1000 US$.
Note: n.a: not available.

Table 4. Revealed comparative advantage of date trade for the GCC countries and their competitors

Countries	**2002**	**2005**	**2007**	**2010**	**2013**
Algeria	672.79	384.06	436.61	318.33	110.97
Bahrain	1.51	0.37	0.94	0.36	0.06
Israel	32.04	60.66	44.62	54.06	78.38
Jordan	4.97	6.30	6.83	7.71	7.08
Kuwait	4.09	na	0.73	1.71	1.04
Oman	9.71	5.39	22.67	17.29	12.98
Qatar	1.48	3.17	2.94	na	na
Saudi Arabia	104.68	45.11	31.67	47.13	43.51
UAE	na	37.54	40.35	na	45.10
Tunisia	463.26	199.43	227.93	323.80	228.73
Egypt	7.23	4.02	3.43	14.67	10.19

Source: Calculations from UN COMTRADE dataset (several years).
Note: n.a: not available.

Table 5. Trade Balance Index of dates for the GCC countries and their competitors

Countries	2001	2005	2008	2010	2013
Algeria	1	1	1	1	1
Bahrain	-0.83	-0.95	-0.67	-0.90	-0.97
Israel	1	1	1	1	1
Jordan	-0.72	-0.50	-0.40	-0.41	-0.44
Kuwait	-1.00		-0.99	-0.95	-0.91
Oman	0.98	-0.32	-0.60	-0.18	0.01
Qatar	-1	-0.95	-1	-1	-1
Saudi Arabia	1	0.90	0.83	0.96	0.95
Emirates		0.17	0.05		0.14
Tunisia	1	1	1	0.99	0.99
Egypt	-0.04	0.77	0.55	0.84	0.68

Note: Positive values indicate that the country is a net exporter. Negative values indicate the country is a net importer.

Figures

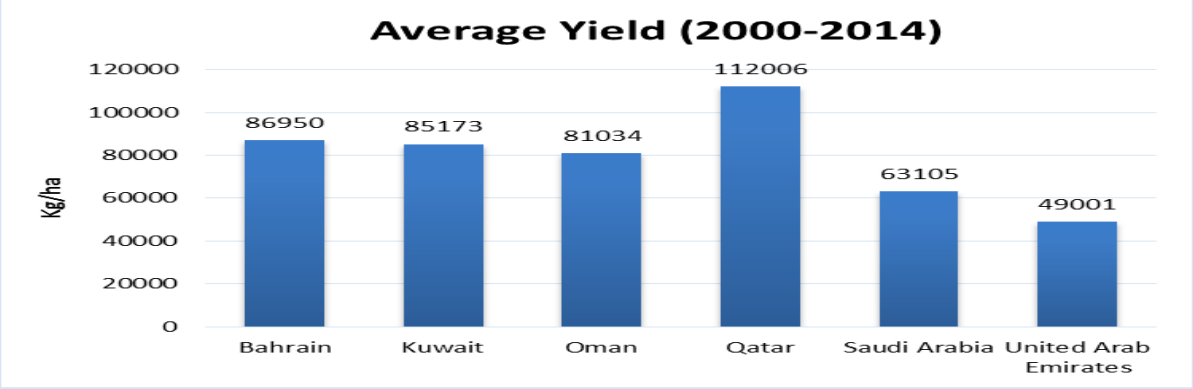

Fig. 3. Average yield of dates in GCC countries calculated over the period 2000-2014

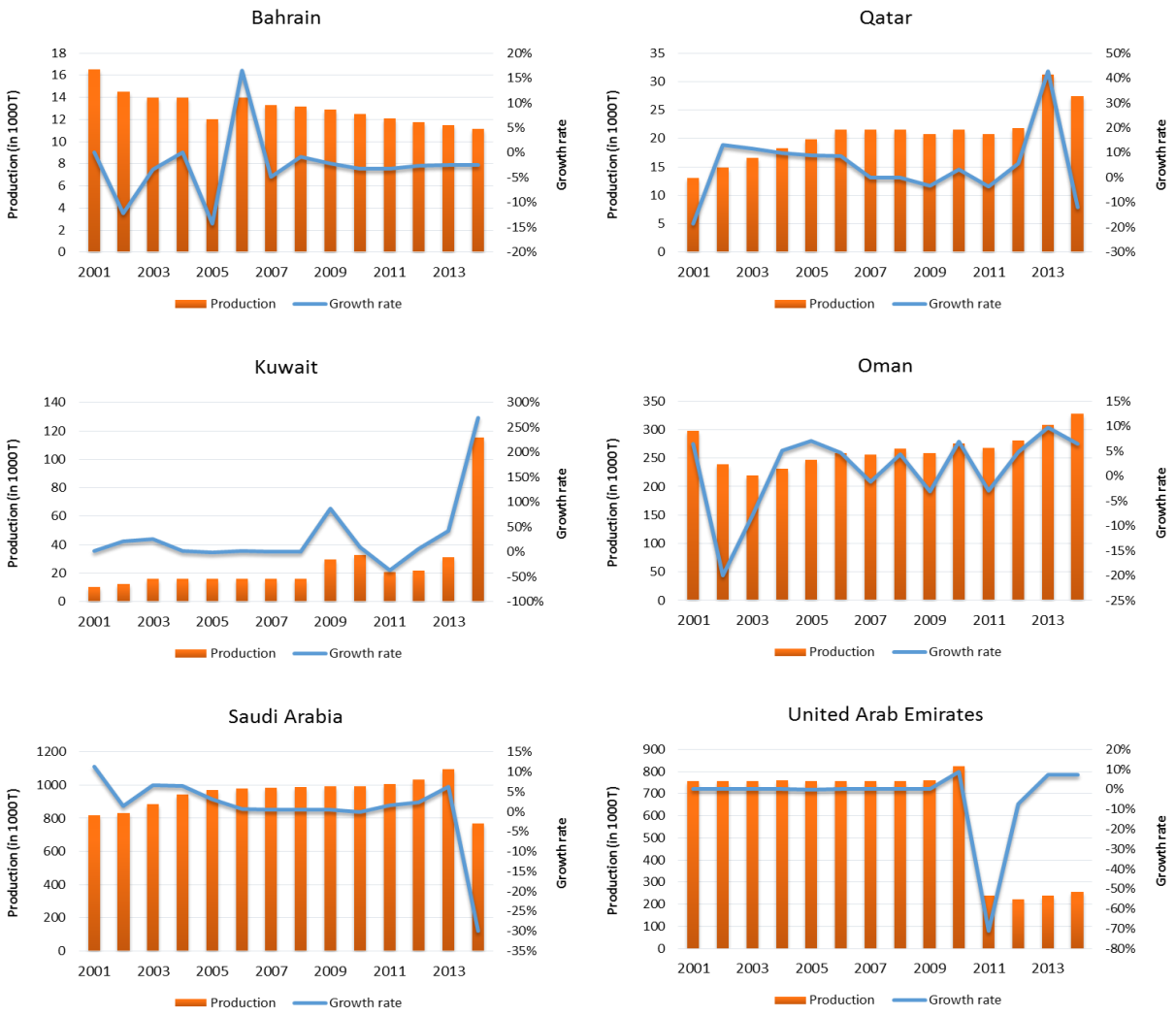

Fig. 4. Production trends of dates in GCC countries

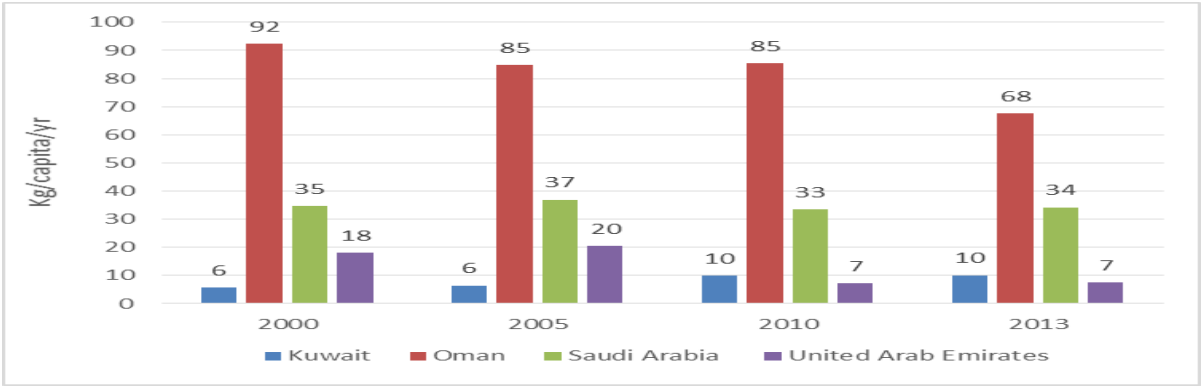

Fig. 5. Trend of date consumption per capita, year (in Kg), 2013 data

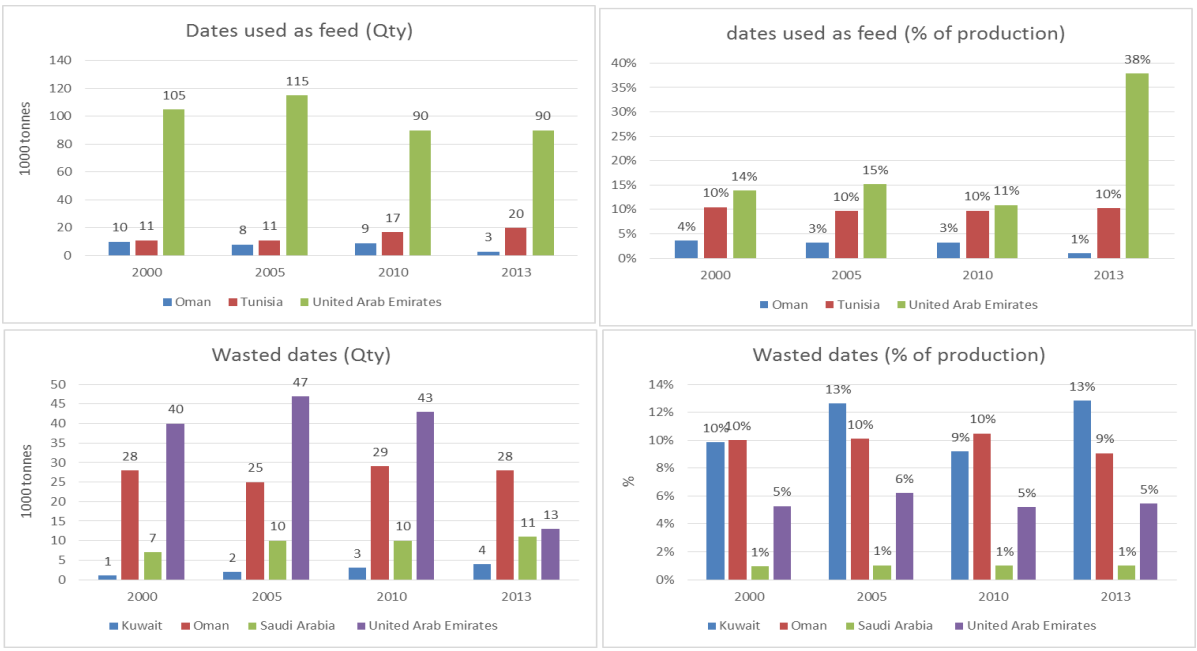

Fig. 6. Quantities and percentages of wasted dates and dates used as feed for selected countries

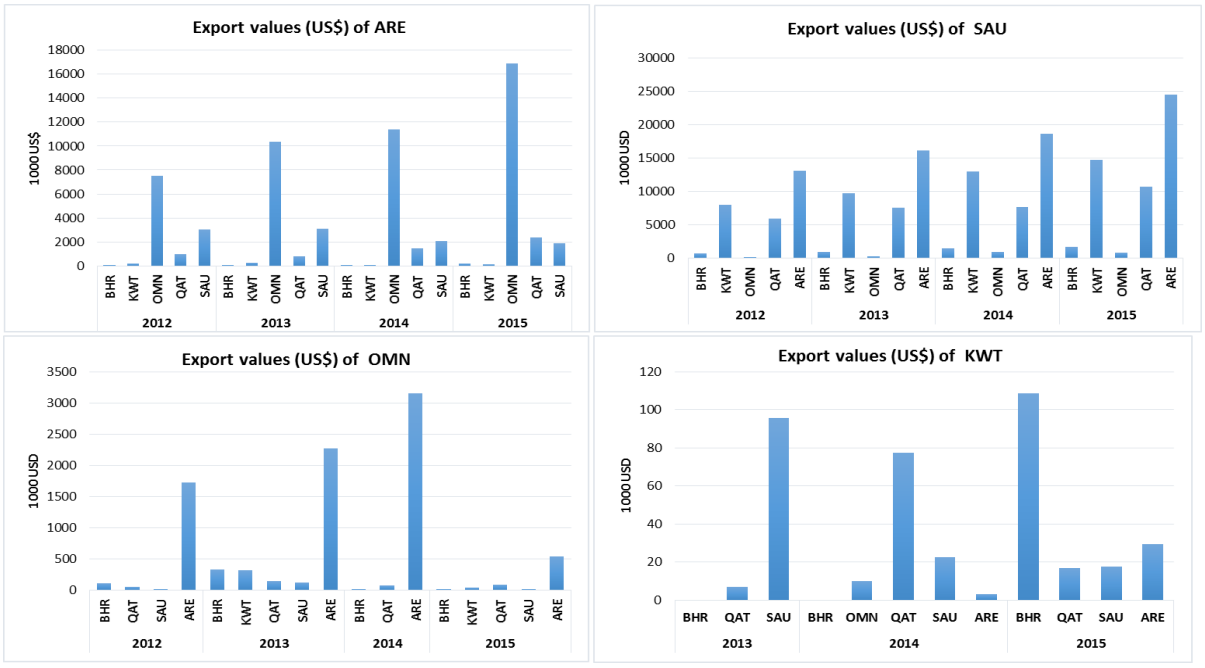

Fig. 7. Export trade of dates among the GCC countries (UAE: United Arab Emirates, SAU: Saudi Arabia; OMN: Oman; and KWT: Kuwait) (Source: COMTRADE UN database)

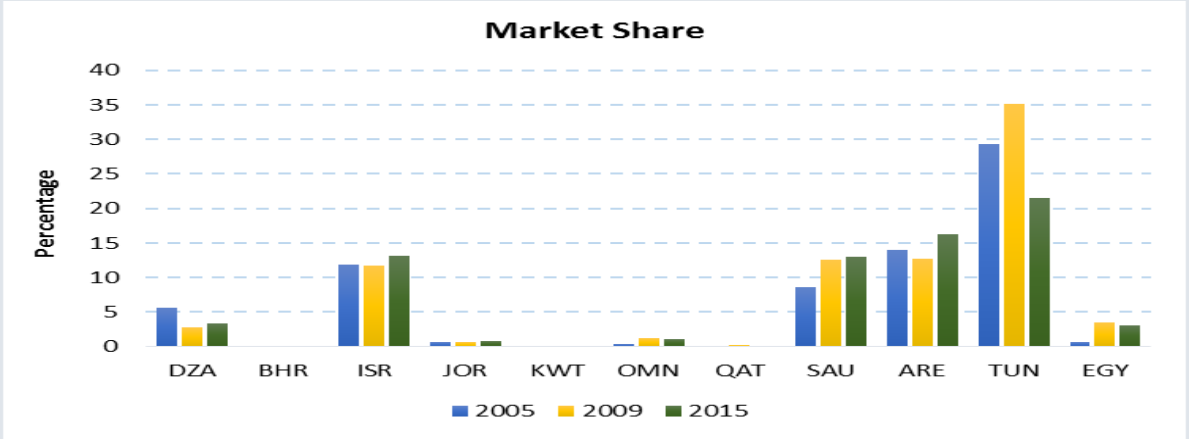

Fig. 8. Market share of selected dates exporting countries, including GCC countries and their competitors

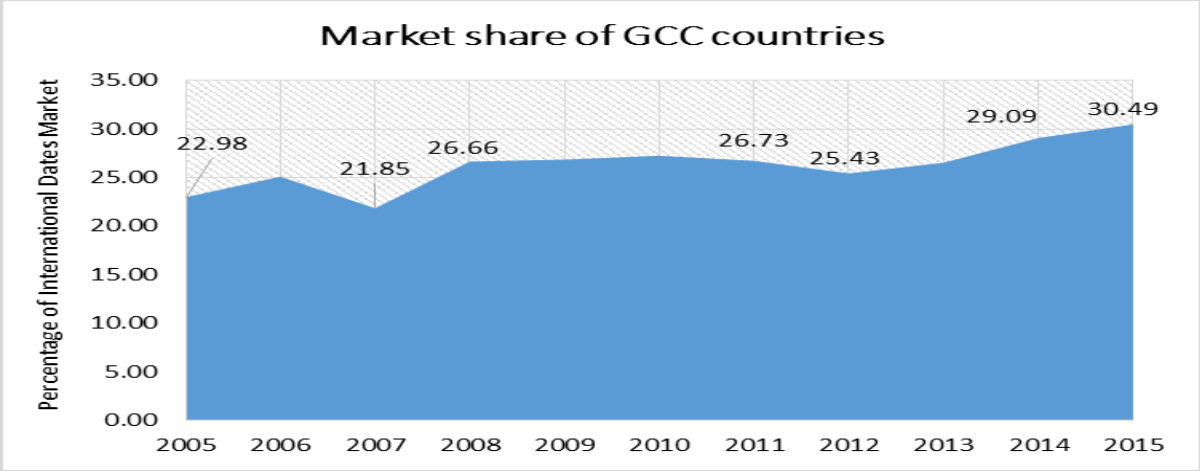

Fig. 9. Trend of the GCC market share (sum of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and Emirates) during the last decade (2005-2015)

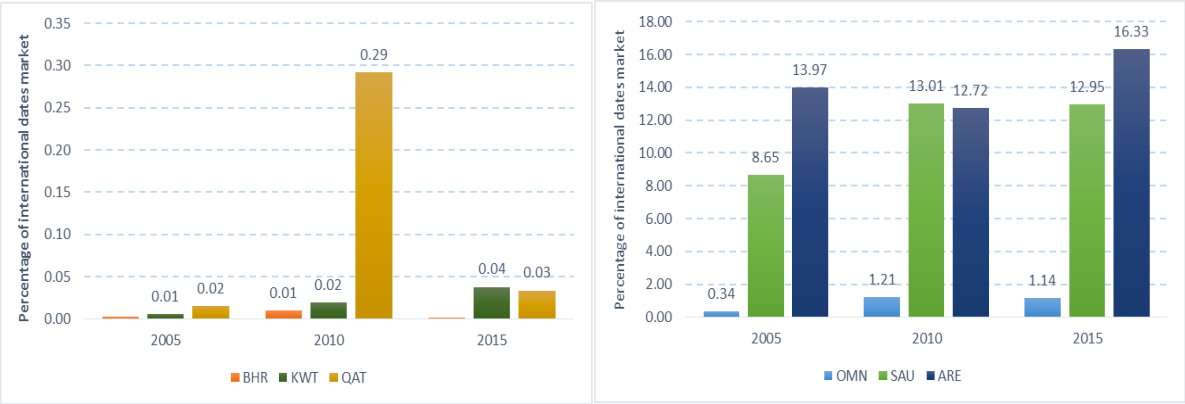

Fig. 10. Market share of GCC countries on the international date market

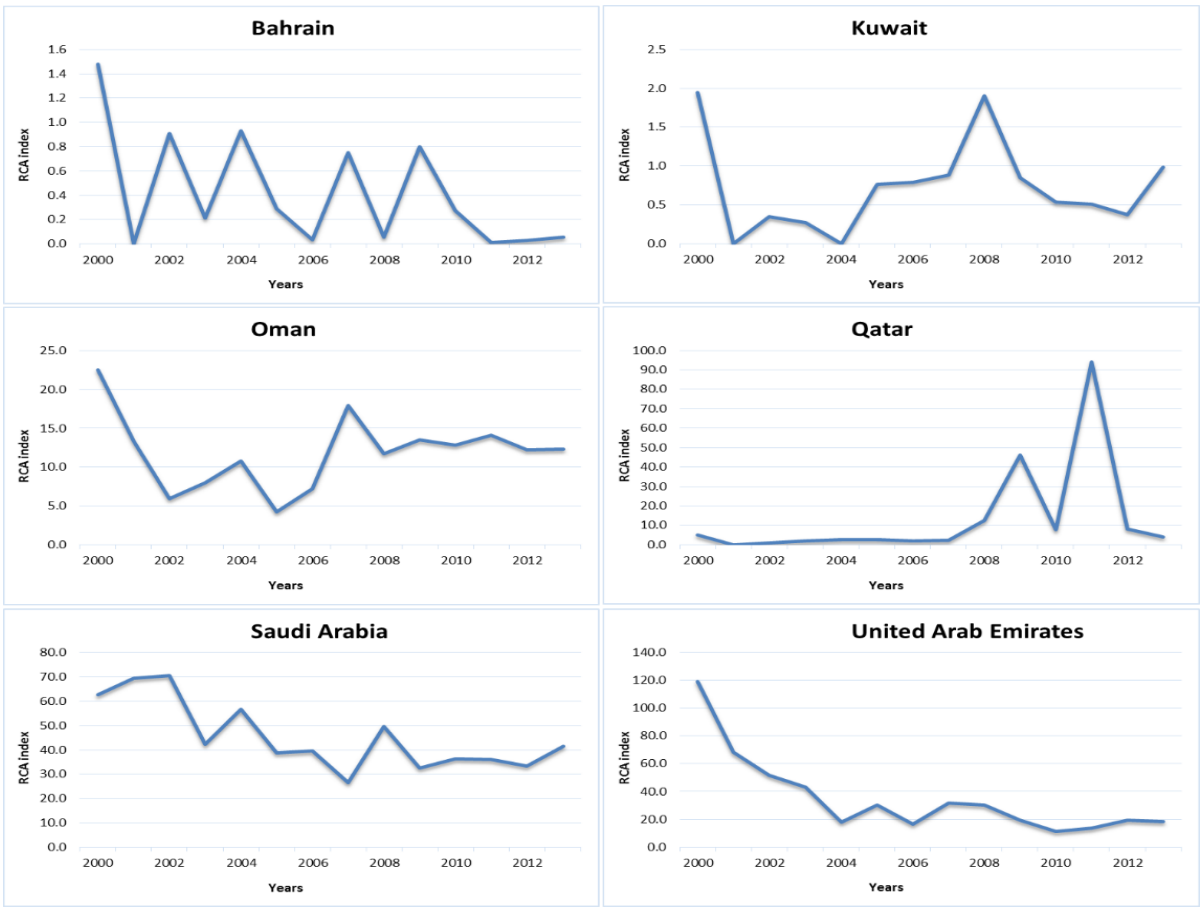

Fig. 11. Trend of the Revealed comparative advantage of date trade for the considered GCC countries (for the period 2000 - 2013) source: Calculations from FAO dataset

ADOPTION OF THE PROJECT INTRODUCED TECHNOLOGIES FOR DATE PALM IN SULTANATE OF OMAN

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The Sixth International Date Palm Conference (SIDPC)
Abu Dhabi -UAE: 19 – 21 March, 2018.

Abstract: The aim of this research paper is to assess the adoption level of the two technologies (liquid pollination and polycarbonate drying houses) developed by the date palm project in the Sultanate of Oman. The methodological framework used is based on the implementation of the ADOPT (Adoption and Diffusion Outcome Prediction Tool) tool in two localities of the Sultanate of Oman through focus groups discussion (FGD's).

Empirical findings obtained from the assessment of the Liquid Pollination (LP) technology indicate that peak adoption rate for liquid pollination technology in "North Al Batinah" is high and predicted to be around 95% (of the total population) after a period of 14.5 years. The predicted adoption level after 5 and 10 years from introducing the technology in the region is expected to be 46.9% and 91.5%, respectively. The assessment of the rate of adoption of the Polycarbonate Drying Houses (PHD) technology and the identification of factors affecting the peak and adoption levels, and constraints that limit the adoption process and widespread of such technology among the date palm growers of Oman indicates that peak adoption rate for PDH technology in the target study region is predicted to be 95% after a period of 21 years. The predicted adoption level after 5 and 10 years is expected to be 23.5% and 72.9%, respectively.

The presented results suggest that sustainable increase in date palm productivity can be achieved if farmers are encouraged to adopt the LP and PDH technologies. However, the adoption of such technology needs to be accompanied by a supporting extension system and an enabling policy environment to ensure the scaling-up and widespread use of these promising and profitable technologies.

Key words: Adoption, liquid pollination, polycarbonate drying houses, date palms, FGD's, ADOPT, Oman.

INTRODUCTION

Within the framework of the project "*Development of sustainable date palm production systems in the GCC countries of the Arabian Peninsula*", funded by the GCC Secretariat, researchers succeeded to introduce two promising technologies: LPPDH. The aim to introduce LP technology is to improve the quality of fruits, reduce and save the time and effort during the pollination operation, reduce the risk of low fruit setting by pollination during the peak period of flowering. Therefore, the objective to introduce PDH technology is to improve the quality of dried dates, accelerate their drying process, and obtain cleaner fruits that are free from dust, insects and birds damage. The justification for solar driers is that they are more effective than sun drying traditional system (*Mistah*), with lower operating costs than mechanized drier.

These technologies have received a great deal of attention from the Government decision makers in recent years. The success of both technologies will not only depend on how well from a technical perspective, but also on its affordability and profitability. The utilization and critical mass adoption of appropriate innovations is an important prerequisite for agricultural development.
The aims of this research paper is to assess the adoption level of the two technologies in the Sultanate of Oman with emphasis on identifying influencing factors of the adoption process and exploring resulting policy implications.

DATE PALM SECTOR IN OMAN

Date palm (*Phoenix dactylifera* L.) is a major fruit crop in the Arabian Peninsula, where it has been closely associated with the life of the people since pre-historic times (Al-Farsi et al., 2005; Al-Yahyai and Khan, 2015). In Oman, date palm is the primary agricultural crop, and it constitutes 80% of all fruit crops produced and 50 % of the total agricultural area in the country (FAO, 2013). Oman is the eighth largest producer of dates in the world with an average annual production of 260,000 tons per annum.Around 70 % of the total date production is harvested from only 10 cultivars, and a small fraction (2.6%) of the total date production is exported. Only half of the dates produced are used for human consumption, with the other half being utilized primarily for animal feed or considered surplus and wasted (Al-Yahyai and Khan, 2015).
According to Al-Marshudi (2002) and Al-Yahyai (2007), the yield of the date palm is considered to be low (40-80 kg/tree) compared to the yields in neighboring countries (i.e. Saudi Arabia and UAE). This low yield is a result of traditional management, lack of farmer know-how, high infestation by several pests, limited field expansion because date growing regions are fully dependent on groundwater extraction for irrigation, in addition to logistic problems, including an insufficient number of skilled laborers and underdeveloped facilities (transport, storage, market outlets, and large processing factories).

CHARACTERISTICS OF THE TECHNOLOGIES

LIQUID POLLINATION

Presentation of the technology

Pollination of date palm is normally carried out by hand in almost all date palm groves in Oman. Farmers are unaware of Liquid pollination which may be easiest and most productive and convenient. According to Al-Yahyai and Khan (2015), there are several male palm cultivars that are used for pollination, most notably *Khoori* and *Bahlani*. El Mardi *et al.* (2002) pollinated varieties of date palm by hand, and using a hand duster and motorized duster with no effect on fruit yield, despite the larger fruit volumes when dusters were used. They also reported that a pollen/flour (1:5) ratio for mechanical pollination produced lower sucrose and dry matter and a higher yield. In this regard, the project develops a new liquid pollination technology.

Socio Economic Evaluation of LPT

The intervention introduced by the project for the pollination of date palm trees was evaluated economically against the manual method for the *Fardh* cultivar based on the data collected from

researchers and experts at the Date Palm Research Center, Experimental and Research Farm – Wadi Quriyat. In the findings reported in Dhehibi *et al.* (2016a), it was assumed that the yield will be maintained the same using the two options (LP technology and manual pollination). The premise that even if the quantity produced of dates is slightly reduced using liquid pollination, the weight of fruit will increase – given the advantage of a decreased proportion of the fruit setting and concomitant increase in the quality of the fruit. In this case it was considered as natural fruit thinning. This improvement in the quality will affect the market price and for that it was considered a higher price for the dates produced using liquid pollination. From this research study, it was found that a reduction in pollination cost using liquid pollination was observed in comparison to that for manual pollination of about 89.05% and, consequently, a reduction in the total variable costs per hectare against those for manual pollination of about 56.48%.

Moreover, the analysis revealed a total reduction in the variable costs of OMR1273.95 from using liquid pollination. This reduction in total variable costs results from an increase in the net revenue over that resulting from manual pollination of OMR2593.95/ha. Economic indicators showed also the clear profitability of using liquid pollination where the percentage change in net returns is very high (+ 674.71%). The benefit-cost ratio (BCR) is three times higher when using liquid pollination. Thus, with an internal rate of return of 12.04 and higher BCR, it was concluded that liquid pollination will be highly profitable for Omani farmers.

From the same study, it was reported also that similar results were achieved from the data obtained from farmers for the *Khalas* cultivar. With the same assumptions on yield and related price-quality, it was found that an increase in the value of production of about 20% from using liquid pollination rather than the manual pollination. The analysis showed that using liquid pollination reduced the pollination operation costs by 89.05% (which is the equivalent of OMR1273.95/ha) compared to traditional pollination. The reduction in pollination induces a reduction in the total variable costs of 22.10%. Economic analysis results revealed also that the net benefit to date palm farmers, using the cultivar *Khalas*, and applying liquid pollination was OMR15,310.5/ha (an increase of around 42.60% compared to manual pollination). The analysis of the Internal Rate of Return (IRR) indicates that investment in liquid pollination technology is a profitable decision. Generally, using LP will yield a cost-benefit ratio that reaches 3.41, which is almost twice the ratio obtained from using manual pollination.

POLYCARBONATE DRYING HOUSE FOR DATE PALM PRODUCTS (PDH)

Presentation of the technology

The PDH dryer is a unique cost efficient method of drying agricultural products such as date palm products at commercial scale. It consists of a drying chamber and an exhaust fan. The roof and the wall of a PDH are made by transparent plastic films that are mounted on a metal frame.

Shahi *et al.* (2011) found that the solar drier sheet has a transmissivity of approximately 92% for visible radiation which traps the solar energy during the day and maintains an optimum temperature for drying of produce. In addition, the authors indicated that UV-stabilized films play an important role in PDH dryers. The UV radiation in the sun rays tends to cause changes in the organoleptic properties such as texture, color and flavor of food materials (Shahi *et al.*, 2011). From technical characteristics, UV-stabilized polyethylene sheets are used to prevent such deterioration, and consequently the sheet allows only short wavelength which is converted into long wavelength when it raids on the surface of the dried product. Since the long wavelength

cannot move out, it increases the temperature inside the dryer. In addition to the outlined advantages mentioned above, the sheet has superior properties in terms of transparency, transmissivity, property, anti-corrosion, tensile properties, tear-resistant, anti-puncture, water proof, moisture proof, and dust-proof.

According to Janjai *et al.* (2011), polycarbonate covers have been used recently for PDH construction. Contrary to the polycarbonate, plastic sheets and glass covers have the distinct property to allow light to enter the PDH dryer and retaining it inside the chamber, the heating mechanism is as black surface inside the PDH improves the effectiveness of converting light into heat. Hence, the objective of a PDH dryer is to maximize the utilization of solar radiation. Based on the mode of heat transfer, the technology is classified into passive and active PDH dryers. The passive mode dryer works on the principle of thermosyphic effect i.e. the moist air gets ventilated through the outlet provided at the roof of the dryer (Janjai *et al.*, 2011).

Sangamithra *et al.* (2014) showed that trapped light is converted into heat energy to remove moisture from dates in the PDH dryer. The dryer can be connected in series and hence its capacity can be enhanced as per requirement and it can be dismantled so that its transportation is easy from one place to another. Prakash and Kumar (2014) indicated that for active PDH dryer, there are two energy sources namely the air saturation deficit and the incident global solar radiation. Both natural and forced convection methods circulate the hot air to the food material. One of the differences is that, at the initial stage of drying, the value of mass transfer coefficient is double in the active mode than in passive PDH dryers.

Socio Economic Viability of PDH for Date Palm Products

The traditional methods used in Oman for drying dates under direct sunshine called "*Mustah*" is a slow process with problems like dust contamination, insect infection, bad quality of fruits, and spoilage due to unexpected climatic changes. To overcome this problem, one of the main objectives of the "*Development of Sustainable Date Palm Production Systems in GCC*" project is to produce new knowledge and practices to improve date palm production systems in the Gulf region.

Other alternative options are available to overwhelm the problem such as the use of conventional fuel fired or electrically operated dryers. However, in many rural areas, the supply of electricity is not available or it is too expensive and could not be affordable by the small date palm growers for drying purpose. Moreover, the fossil fuel fired dryer's technology possesses several financial barriers due to large initial investment and operational running cost which are beyond the reach of small farmers. The main objective if introducing this technology by this development project was to improve the quality of dried dates, accelerate their drying process, and obtain cleaner fruits that are free from dust. This technology is considered to be one of the most attractive and promising applications of solar energy systems in the GCC countries can be utilized in date palm production areas as a better alternative to dehydrate the date and other agricultural products without any difficulties. Also and from and environmental perspective, the use of PDH can result in reduced emissions if conventional fuel is replaced.

The implementation of this improved technology can have positive socioeconomic impacts on local income generation, food security and consequently a sustainable date palm farming system. In the practice, Chavada (2009) found that the lifetime cost of drying with solar power is only a

third of the cost of using a dryer based on conventional fuels. According to Janjai *et al.* (2009, 2011), the price of dates dried in PDH was found to be 20% higher than that obtained from the open sun drying. The estimated payback period (PBP) of the former technology was 2.3 years. Dhehibi *et al.* (2016) found that a PDH dryer can function successfully and efficiently with minimum maintenance at low cost.

With no further disadvantages, it could be a substitute to the conventional dryers thereby making it assessable and affordable by local farmers in the Omani date palm producers. In this study, PDH dryer for dates were evaluated economically for two types (small vs large PDH) under two scenarios: with and without governmental subsidies. Empirical findings reveal the high profitability of the PDH, even when it is not subsidized by the government. At a real discount rate of 5.1%, the net present value (NPV) is positive and very high in all cases. Thus, such an investment is usually acceptable if the NPV is positive (the investment is profitable). This criterion was also supported by both the IRR and the PBP criteria (Figures 1-4).

The estimated IRR was higher than the current interest rate in the Sultanate, which could encourage both date palm growers and private investors to invest in polycarbonate drying houses. The PBP was found, in the worst case scenario, to be 3.77 years, which is relatively short considering the life of the system (15-20 years). This suggests that investment or action costs in this dryer system are recovered quickly reducing the risk involved in the investment.

ASSESSMENT METHODOLOGY

Conceptual Framework

The adoption of new agricultural technologies has generally been found to be a function of farm and farmer characteristics and specific features of the particular technology (Feder et *al*., 1985; Marra and Carlson, 1987; Rahm and Huffman, 1984). A considerable set of literature was developed regarding factors that influence the adoption of new technologies by farmers through use of innovation theory (Feder et *al*., 1985; Griliches, 1957, and Rogers, 1995). Adoption and diffusion theory also have been widely used to identify factors that influence an individual's decision to adopt or reject an innovation. Rogers (1995) defined an innovation as "…an idea, practice or object that is perceived as new by an individual or other unit of adoption. The perceived newness of the idea for the individual determines his or her reaction to it". He further identified five characteristics of an innovation that affect an individual's adoption decision: (i) Relative advantage: how the innovation is better than existing technology; (ii) Compatibility: the degree to which an innovation is seen as consistent with existing experiences, needs, and beliefs of adopters; (iii) Complexity: how difficult the innovation is to understand and use; (iv) Trialability: the degree to which the innovation may be used on a limited basis; and (v) Observability: the degree to which the results of an innovation are visible to others.

The relative advantage and observability of an innovation represents the immediate and long-term economic benefits from using it, whereas compatibility, complexity, and trialability indicate the ease with which a potential adopter can learn about and use an innovation (Boz and Akbay, 2005; King and Rollins, 1995). As the relative advantage, compatibility, complexity, trialability, and observability of liquid pollination and polycarbonate drying house have caused more farmers to

adopt them in the GCC countries, in general and, in the Sultanate of Oman, in particular, we can consider the adoption of the two technologies as an innovation. The utilization and critical mass adoption of such technologies is an important prerequisite for agricultural development, particularly for the date palm producing countries in the Arabian Peninsula.

Methodological Framework: Adoption Analytical Model:

ADOPT is an MS Excel-based tool that evaluates and predicts the likely level of adoption and diffusion of specific agricultural innovations for particular target population. The tool uses expertise from multiple disciplines to make the knowledge about adoption of innovations more available, understandable and applicable to researchers, extension agents and research managers. ADOPT predicts the proportion of a target population that might adopt an innovation over time (Figure 5).

The tool makes the issues around the adoption of innovations easy to understand. ADOPT is useful for agricultural research organizations and people interested in understanding how innovations are taken up. The tool has been designed to:

1. **Predict** the likely peak level of adoption of an innovation and the time taken to reach that peak.
2. **Encourage** users to consider the factors that affect adoption at the time that projects are designed.
3. **Engage** research, development and extension managers and practitioners by making adoptability knowledge and considerations more transparent and understandable.

ADOPT users respond to qualitative and quantitative questions for each of twenty-two variables influencing adoption. Going through this process also leads to increased knowledge about how the variables relate to each other, and how they influence adoption and diffusion. ADOPT is structured around four categories of influences on adoption (Figure 5 above): (1) Characteristics of the innovation; (2) Characteristics of the target population; (3) Relative advantage of using the innovation; and (4) Learning of the relative advantage of the innovation.

Data Collection and Data Sources

The study took place in two governorates in the Sultanate of Oman (South and North Al Batinah) characterized by an extensive date palm production and the common testing of the liquid pollination technology and implementation of the polycarbonate drying houses. The data were collected using focus group discussion (FGD) methodology (Krueger, 2002) to apply the ADOPT tool (Kuehne *et al.,* 2013) with a group of farmers in the two Governorates. To assess the liquid pollination technology, we interviewed 24 date palm growers divided in two equal FGD's, each covering 12 farmers'. For the polycarbonate drying house technology, a group composed of ten (10) farmers was also interviewed. The study took place in the two governorates during January 2017.

We also organized a FGD with Ministry technical staffs representing both Agricultural Development Centers. All of them were males. One researcher from the Omani Date Palm Research Centre, the date palm project manager and the socio economic leader of the project

economic activities from the International Center for Agricultural Research in the Dry Areas (ICARDA: http://www.icarda.org) conducted the FGD with farmers. In the two cases, we streamlined 22 discussion questions around four categories of influences on adoption. The format of the discussion group consisted of both analytical questions (i.e., they discuss and collectively decide what they believe the answer is), and clarifying questions (i.e., questions that help clearing up confusion and explain why they had chosen this answer). Farmers were asked to think about their problems related to implementing liquid pollination and the most challenging for them.

RESULTS AND DISCUSSION

Factors Influencing Adoption of LP Technology

The issue of this technology adoption by agricultural producers has not been assed. This study has generally focused on the technology adoption processes at the firm level and on identifying the main factors affecting its adoption process. The results of the program predicted that 95% of the South and North Al Batinah Communities would adopt the innovations after 16.9 and 14.5 years, respectively (Table 1).

As displayed in the table above, the peak adoption rate for liquid pollination technology in the "North Al Batinah" is predicted to be 95% after a period of 14.5 years. The predicted adoption level in 5 years and 10 years from start is expected to be 46.9% and 91.5%, respectively. In "South Al Batinah" Governorate, the predicted adoption levels are similar. Indeed, the predicted years to peak adoption is 16.9 years and the peak level of adoption is around 95%. This peak is predicted to be 35.8% and 85.8% after 5 and 10 years from start, respectively.

Results from the sensitivity analysis (Figures 6 & 7) indicates that farmers' conditions of severe short-term financial constraints, the triability of the innovation on a limited basis before a decision is made to adopt it on a larger scale, the perception and evaluation of the liquid pollination technique; i.e. how the innovation allow the effects of its use to be easily evaluated when it is used, the paid advisory delivery system, the development of substantial new skills and knowledge to use the innovation by the farmers, and finally the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation are the driving adoption factors for the liquid pollination technology in the two targeted areas.

Factors Influencing Adoption of PDH Technology

The predicted years to peak adoption and the predicted adoption level, including the level in 5 and 10 years from start, is presented in Table 2. Even though adoption and diffusion of the PDH dryer is very difficult to forecast— the issue is complex and crosses economic, social and psychological disciplines—there is an ongoing need and demand for specific estimates to be made.

Empirical findings from the table below revealed that 95% of "South Al Batinah" Community would adopt the innovations after 20.9 years. However, the predicted adoption levels after 5 and 10 years from start is 23.5% and 72.9%, respectively. Even though the time to peak adoption was longer than what we expected (bearing in mind that this figure affected the attractiveness of the technology in the future funding), these results are expected since the upfront cost of investment is quite high while the economic viability of this technology make the evidence of its profitability. Indeed, the outcomes from this tool could be considered as real values to inform the different stakeholders about the influences on adoption and diffusion of the PDH technology in Oman.

After presenting these indicators, the FGD's outputs discussion outlined that farmer's most commonly cited motivations for adopting this technology although the high upfront cost of investment. Our study and FDG's discussion found that both adopters and non-adopters saw the greatest benefits of this technology in terms of its potential benefit on the quality of the final agricultural dried products (dates, in this case). Another way to better understand the factors associated the rapid and large adoption of the PDH technology was by conducting a sensitivity analysis. Important factors to farmer decision making differ according to geographic, economic, and social context.

However, taken together, the results from the sensitivity analysis regarding the main factors affecting the adoption decision of PDH technology in AL Batinah Governorate are displayed in Figure 8. The figure content indicates that triability of the innovation on a limited basis before a decision is made to adopt it on a larger scale, the perception and evaluation of the PDH technique; i.e. how the innovation allow the effects of its use to be easily evaluated when it is used, the paid advisory delivery system capable of providing advice relevant to the use and management of the technology, and finally the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation are the driving adoption factors for the PDH technology in the target area.

CONCLUSIONS

The empirical findings obtained from the LP technology assessment indicates that peak adoption rate for LPin "North Al Batinah" is predicted to be 95% after a period of 14.5 years. The predicted adoption level in 5 years and 10 years from start is expected to be 46.9% and 91.5%, respectively. In "South Al Batinah" Governorate, the predicted adoption levels are similar. Indeed, the predicted years to peak adoption is 16.9 years and the peak level of adoption is around 95%. This peak is predicted to be 35.8% and 85.8% in 5 and 10 years from start, respectively.

The assessment of the rate of adoption of the PDH technology and the identification of factors affecting the peak and adoption levels, and constraints that limit the adoption process and widespread of such technology among the date palm growers of Oman indicates that peak adoption rate for PDH technology in the target study region is predicted to be 95% after a period of 21 years. The predicted adoption level after 5 and 10 years is expected to be 23.5% and 72.9%, respectively. The presented results suggested that sustainable increases in productivity of date palm in the Sultanate of Oman can be achieved if farmers are encouraged to adopt LP and PDH technologies. However, the adoption of such technologies needs to be accompanied by a supporting extension system and an enabling policy environment to ensure the scaling-up and widespread use of this promising and profitable technology. Such findings can provide a useful framework for decision-making as date palm producers and policy makers confront sustainable date palm farming system. In addition, the results can facilitate the policy formulation process as policy makers, responding to societal pressures, attempt to move date palm farming system in a more sustainable direction while trying to improve the profitability of the sector, in general. Implications can be derived for producers for whom local environmental quality is closely linked to date palm production systems in Oman. The results from the present research study suggest the following:

- Creation of private service companies to carry out and monitor the LP operations. These companies can even be operated by small farmers in order to diversify their income sources;
- Enhancing the extension services (more and specialized extension agents) and the development of an effective extension service for Omani date palm growers;
- Reinstatement of the subsidy system in the sector;
- Creation of private services and marketing companies with support from the government;
- Enhancing the awareness of farmers regarding the profitability of using this technology in comparison to the manual pollination method;
- Development of an agricultural management program for date palm tree services, the application of quality control measures, and an increase in capacity building to reduce the cost of production;
- Make introducing the technology to the responsibility of the government; it cannot be left to farmers;
- Valorization of the date palm by-products (to generate more profit for the date palm producers).
- Polycarbonate projects should be targeted at areas with high levels of date production.

Acknowledgment

We would like to express our sincere gratitude and appreciation to the Gulf Cooperation Council (GCC) Secretariat for funding this research conducted in the framework of the "*Development of sustainable date palm production systems in the GCC countries of the Arabian Peninsula*" project. We are very grateful to the Ministries of Agriculture, Agricultural Authorities, and Agricultural Research Institutions and Universities in the GCC countries of the Arabian Peninsula for their continuous support and great collaboration. We also would like to acknowledge the support of the Date Palm Research Center, in addition to Al Batinah" Agricultural Development Departments and farmers of Al Batinah" Governorates for their dedication, time and partnership.

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Tables

Table 6. Predicted Adoption Levels of LP at North and South Al Batinah – Sultanate of Oman

Predicted Peak Level and Time of LP Adoption	North Al Batinah Governorate	South Al Batinah Governorate
Predicted years to peak adoption	14.5	16.9
Predicted peak level of adoption	95%	95%
Predicted adoption level in 5 years from start	46.9%	35.8%
Predicted adoption level in 10 years from start	91.5%	85.8%

Source: Own elaboration from ADOPT (2017).

Note: Focus groups (# 12 farmers).

Table 7. Predicted Adoption Levels of PDH at "South Al Batinah" Governorate – Sultanate of Oman

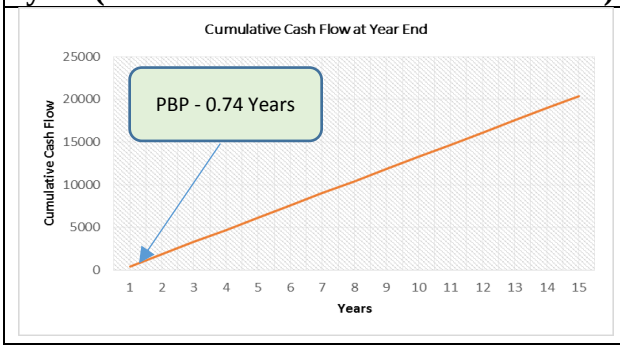
Predicted Peak Level and Time of PDH Adoption	South Al Batinah Governorate
Predicted years to peak adoption	20.9
Predicted peak level of adoption	95%
Predicted adoption level in 5 years from start	23.5%
Predicted adoption level in 10 years from start	72.9%

Source: Own elaboration from ADOPT (2017).

Note: Focus groups (# 10 farmers).

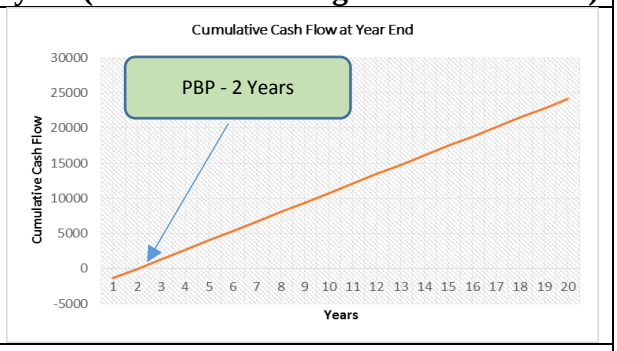
Figures

Figure 12: Cumulative Cash Flow at end of year (PBP when the small PDH subsidized)



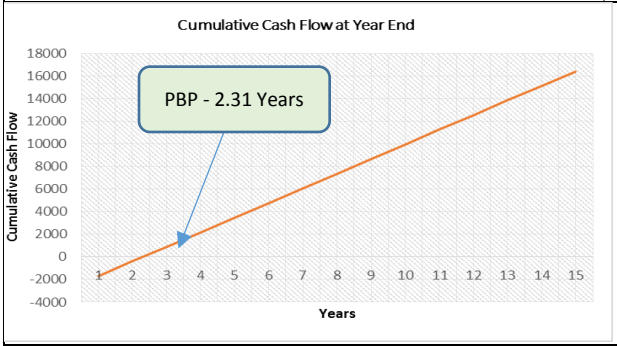
Source: Dhehibi et al., (2016).

Figure 13: Cumulative Cash Flow at end of year (PBP when the large PDH subsidized)



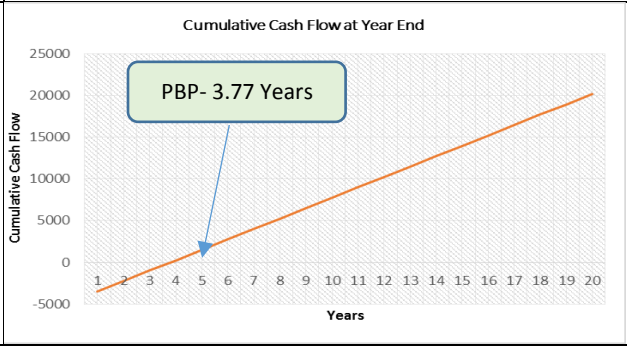
Source: Dhehibi et al., (2016).

Figure 14: Cumulative Cash Flow at end of year (PBP when the small PDH is not subsidized)

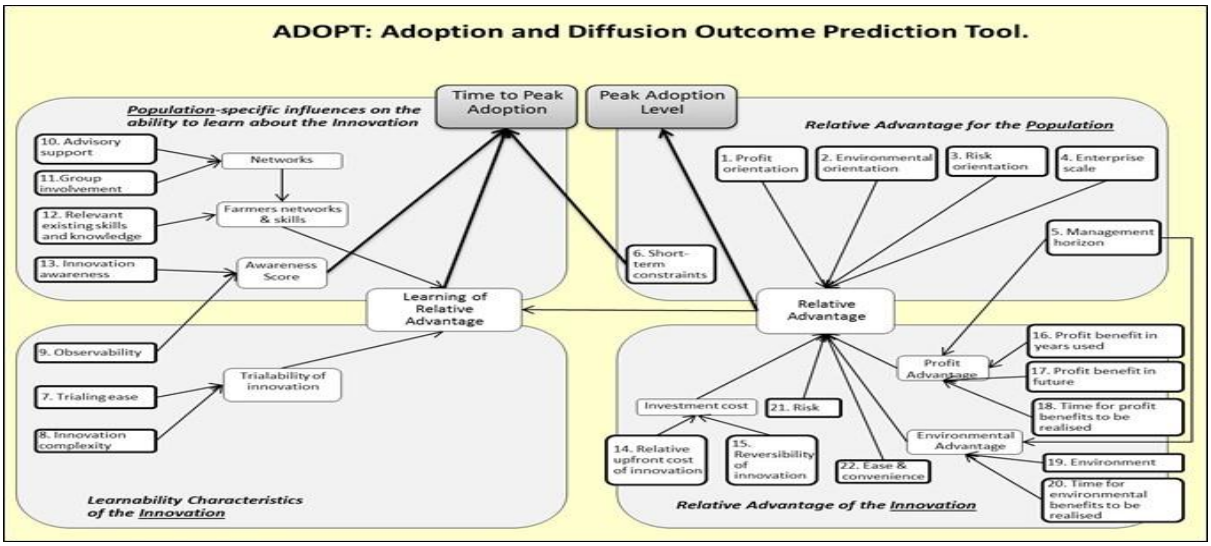


Source: Dhehibi et al., (2016).

Figure 15: Cumulative Cash Flow at end of year (PBP when the large PDH is not subsidized)

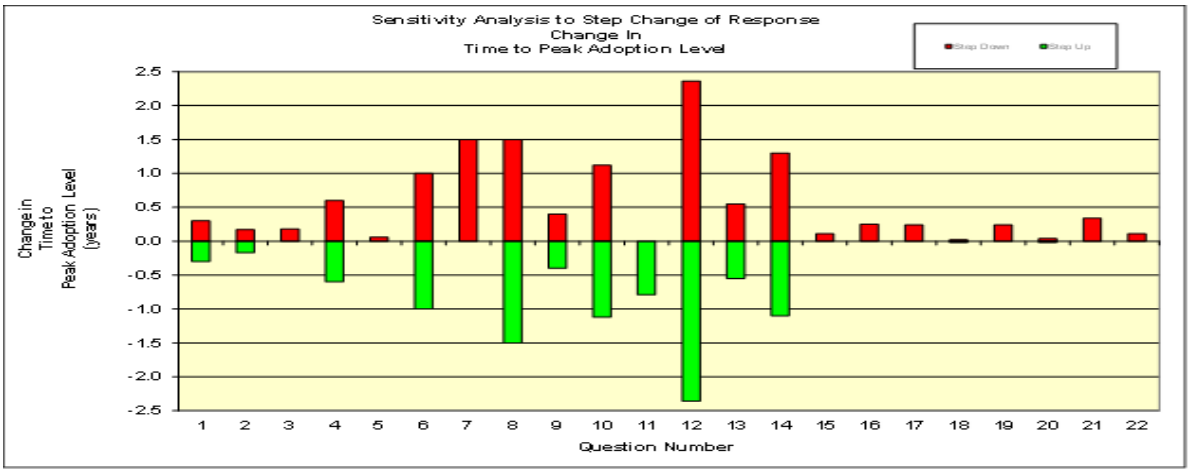


Source: Dhehibi et al., (2016).



Source:
http://aciar.gov.au/files/node/13992/adopt_a_tool_for_evaluating_adoptability_of_agric_94588.pdf.

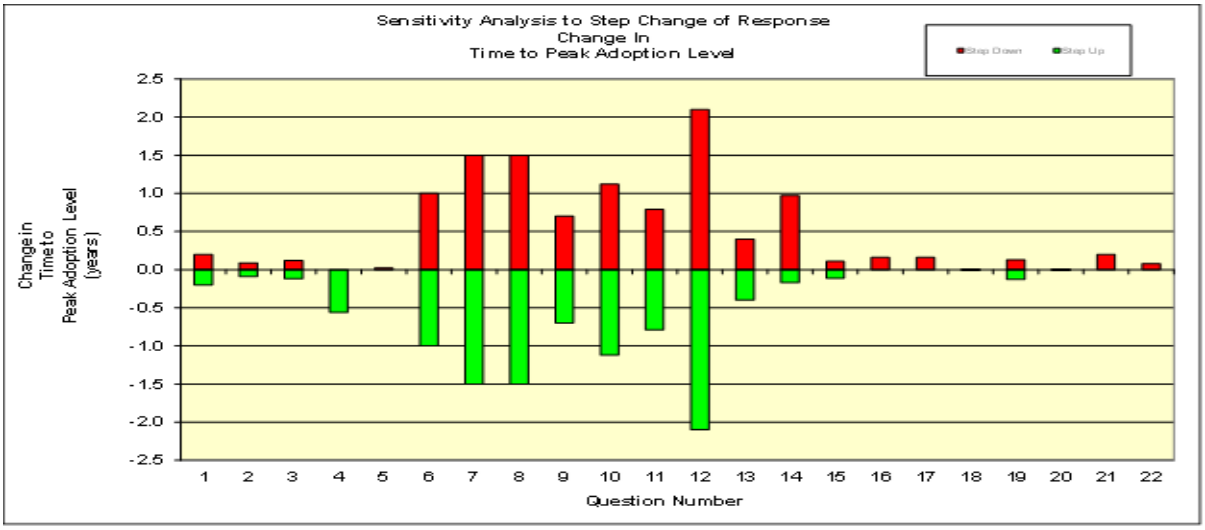
Figure 16: Adoption and Diffusion Outcome Prediction Tool (ADOPT)



Source: Own elaboration from ADOPT (2017).
Note 1: Red Column: Step Down; Green Column: Step Up.
Note 2: Focus groups (# 12 farmers).

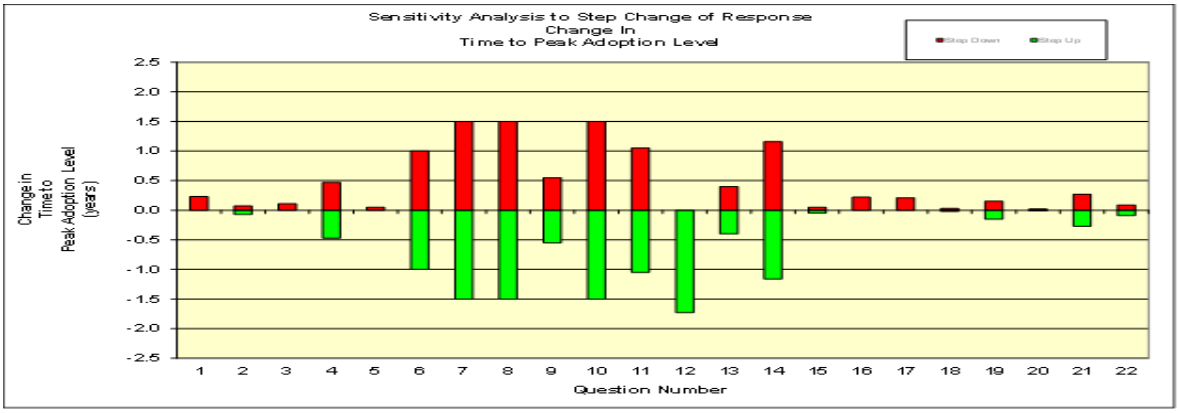
Figure 6: Sensitivity Analysis of Adoption Curve of LPT at "North Al Batinah" Governorate - Sultanate

of Oman



Source: Own elaboration from ADOPT (2017).
Note 1: Red Column: Step Down; Green Column: Step Up.
Note 2: Focus groups (# 12 farmers).

Figure 7: Sensitivity Analysis of Adoption Curve of LPT at "South Al Batinah" Governorate - Sultanate of Oman



Source: Own elaboration from ADOPT (2017).
Note 1: Red Column: Step Down; Green Column: Step Up.
Note 2: Focus groups (# 10 farmers).

Figure 8: Sensitivity Analysis of Adoption Curve of PDH Dryer Technology at the "South Al Batinah" Governorate - Sultanate of Oman