Review

Worldwide status of micropropagation in date palm (*Phoenix dactylifera* L)

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ABSTRACT

Date palm (*Phoenix dactylifera* L) is a most potential fruit crop having high nutritional value for the arid and semi-arid regions of the world and India. The slow nature of traditional vegetative method of propagation limits the expansion of cultivation of date palm on commercial scale. For commercial expansion there is a need for rapid mass multiplication of date palm which can be achieved by micropropagation techniques. In micropropagation there are two methods viz organogenesis and somatic embryogenesis. In these two methods organogenesis is dependent on potentiality of meristimatic tissue to form direct organs whereas in somatic embryogenesis somatic cells develop into somatic embryos and their germination. The present article summarizes the literature of micropropagation through organogenesis and somatic embryogenesis work in date palm.

Keywords: *Phoenix dactylifera*; micropropagation; organogenesis; somatic embryogenesis

INTRODUCTION

Date palm (*Phoenix dactylifera* L) is a most potential fruit crop belonging to family Arecacea for the arid and semi-arid regions of the world and India. Date palm fruit is a nutritious one having high calorific value (3,150 calories/kg) and is a good source of iron and potassium (Al-Shahib and Marshall 2002, 2003; Elleuch et al 2008). It is distributed in Middle East and Arab countries, North Africa and South Sahel areas of East and South Africa, Asia and even in parts of Europe and USA. In India, Thar desert fully and partially meets the climatic conditions of date palm. Thar covers maximum area in Rajasthan followed by Gujarat, Haryana and Punjab.

Date palm cultivation has been recorded for thousands of years and over that time selection procedures have developed for more than 3,000 known varieties of date palm around the world (Johnson 2011). Date fruits possess important nutritional and medicinal values, are used as a part of religious practice and are consumed by people all over the world (Vayalil 2012).

In these recent years, the diversity of the date palm has declined due to its over-exploitation. The production and utilization of the date fruits vary with the countrys' individual demand. There are various factors which affect or lower the production of date palm like major pests and diseases, salinity, drought, poor harvest and postharvest practices (Al-Khayri et al 2015a, 2015b) but the major element is heterozygous nature. It is conventionally propagated vegetatively by offshoots. Due to their heterozygous nature seeds cannot be used for the propagation of commercially elite cultivars because they produce off-type propagules (Abahmane 2011). The number of offshoots produced by a date palm tree during its life span is only about 20-30 (Zaid et al 2011) and their survival rate is also low (Abahmane 2011). To meet the industrial high demand it is necessary to propagate the date palm on mass level which is only possible through in vitro propagation of it. It produces disease free, high yielding and true to type plants.

Since from the early reports of date palm in vitro regeneration (Tisserat 1979, 1982) many researchers described different approaches to achieve

date palm micropropagation such as somatic embryogenesis (Al-Khayri 2003, 2005; Fki et al 2003, 2011; Mazri et al 2017, Naik and Al-Khayri 2016, Roshanfekrrad et al 2017) and organogenesis (Bekheet 2013, Jazinizadeh et al 2015, Khan and Bi 2012, Khierallah and Bader 2007, Meziani et al 2015, 2016). In addition for providing a means for rapid clonal propagation of date palm (Khierallah and Bader 2007) tissue culture techniques can be utilized for the production of synthetic seeds (Bekheet et al 2002), cell suspension culture (Othmani et al 2009), cryopreservation (Fki et al 2013), somaclonal variation introduced stress tolerant, disease resistance and with high quality fruits (El Hadrami and El Hadrami 2009, Jain 2001).

The aim of present article is to give a status and summarize the literature of micropropagation through organogenesis and somatic embryogenesis work in date palm throughout the world.

Planting material and disinfection

In the beginning era of date palm tissue culture researchers used different kinds of explants such as embryos, immature fruits, roots, leaf petioles, lateral buds, shoot tips, pieces of stem and rachilla tissue (Sharma et al 1986, Tisserat 1979).

Shoot tips obtained from offshoots are the most used explants for somatic embryogenesis and organogenesis. The use of shoot tip explants has resulted in successful regeneration in many date palm genotypes such as Iklane and Jihel (El Hadrami et al 1995), Khanizi and Mordarsing (Esharaghi et al 2005), Khasab and Nabout (Al-Khayri 2010), Barhee, Zardai, Khalasah, Muzati, Shishi and Zart (Aslam et al 2011). But shoot tip requires the sacrifice of offshoots. Many researchers used inflorescence as explant (Abul-Soad 2012, Bhaskaran and Smith 1992) but there responsiveness rate was very low. Similarly other explants' responsiveness was also not successful.

Cultivars response towards micropropagation also varies (Bhati et al 2014). Zygotic embryos derived from green fruits can be used to induce somatic embryogenesis in date palm (Reynolds and Murashige 1979). Pinker et al (2009) also used zygotic embryos to induce somatic embryogenesis in cultivars Zahdi, Khistawi, Asabe Elarous and Barban. Nevertheless such explants are not appropriate for true-to-type propagation.

Different methods have been used for explants' disinfection like sodium hypochlorite, mercuric chloride and sodium hydroxide (Al-Khayri 2010, Khierallah et al 2015, Bhati et al 2014, Naik and Al-Khayri 2016). In addition to it many researchers used antioxidants to prevent oxidation activity of phenolic compounds present in date palm. Antioxidants such as ascorbic acid, citric acid, polyvinylpyrolydon (PVP), anhydrous caffeine and/or sodium diethyldithiocarbonate have been widely used during disinfection in order to reduce explant browning (Al-Khayri 2010, Aslam et al 2011, Khierallah et al 2015).

Organogenesis

Organogenesis is the process by which explants undergo changes which lead to the formation of a unipolar structure (shoot or root primordium) with a vascular connection to the parent tissues (Thrope 1993). In the case of date palm the purpose of this technique is the formation of adventitious buds directly on the explant without the callus formation step. The regeneration of date palm plantlets through organogenesis was achieved by many countries but for commercial production the multiplication rate is very low. This process involves initiation of meristematic shoot buds, shoot multiplication, shoot elongation and rooting (Loutfi and El Hadrami 2005)

Initiation of meristematic shoot buds: Most of the meristematic shoot bud initiation from date palm cultivars has been established from the internal face of young bases taken from offshoots (Balal and El-Deep 1997, Mater 1987), petiole of female date palm and male inflorescence. However shoot tip is also used for in vitro plantlet generation to avoid the contamination (Tisserat 1982). Meristematic bud induction takes 5-6 months under dark conditions to avoid browning and phenolic compounds having temperature 25 ± 2°C. Meristematic induction from explants depends on several factors like hormone combination, explants preparation, light intensity, mother plant genotype, age and stage of offshoots. Various researchers used different combinations of auxin and cytokinin ratio with MS media with full and half strength. The hormones: auxins like 2,4-D (Bhati et al 2014), NOA (Beauchesne et al 1986), IBA (Balal and El-Deep 1997, Mater 1987), NAA (Asemota et al 2007) and cytokinins like 2-iP, kinetin, BA (Balal and El-Deep 1997, Mater 1987) combinations and concentrations were used. The variations were observed in same medium by different cultivars response. Induction requires the low light intensity (1000-1400 lux) with temperature 27 ± 2°C

and sub-culturing once in a month. According to Al-Khateeb (2006) low PGRs concentrations promote the formation of buds while high concentrations induce abnormal growth without bud formation. Salama (1990) reported that the explants taken between October and February show the highest bud formation rate whereas Zaid et al (2011) reported that the best period for the in vitro culturing of offshoot-derived explants is from the onset of flowering.

Shoot multiplication: Shoot bud multiplication in date palm is affected by especially the basal formulation of the culture medium, the genotype and PGRs. Abahmane (2011) mentioned that the main basal formulation used is MS at full or half-strength supplemented with PGRs at low concentrations as compared with the bud initiation stage. Zaid et al (2011) reported that for shoot bud multiplication NAA, NOA, IAA, BAP and kinetin might be used at 0.5-5 mg/l. Beauchesne et al (1986) suggested half-strength MS medium supplemented with 2 mg/l NOA, 1 mg/l NAA, IAA 1 mg/l, BAP 0.5 mg/l, 2iP 1 mg/l and kinetin 1-5 mg/l. For cultivar Khalas, Aslam et al (2011) used 7.84 ìM BAP for high shoot bud multiplication. Khierallah and Bader (2007) recommended MS medium with a combination of 1 mg/l NAA, 1 mg/l NOA, 4 mg/l 2iP and 2 mg/l BAP for date palm cv Maktoom while Khan and Bi (2012) found that MS medium containing 0.5 mg/l BAP and 0.5 mg/l kinetin yields the highest number of shoots per explant in cv Dhakki.

Shoot elongation and rooting: The medium with or without hormone promotes shoot elongation and rooting in date palm. Mazri and Meziani (2013) found that in the cv Najda shoot elongation was faster in the medium supplemented with hormones when compared to hormone-free medium which also adds high frequency of root formation; the hormone-free medium showed wider and green leaves with optimum survival rates. Bekheet (2013) suggested that 1 mg/l NAA induces better and optimum rooting at the same concentration of IAA or IBA. Meziani et al (2015) reported that cv Medhjool shoots grew to an average of 13.4 cm with an average 4.6 roots number per shoot with wide and green leaves from 3 months old hormone-free half MS medium.

Somatic embryogenesis

Somatic embryogenesis is a developmental process where a plant somatic cell can dedifferentiate to a totipotent embryonic stem cell that has the ability to give rise to an embryo under appropriate conditions. This new embryo can further develop into a whole plant (Guan et al 2016). The somatic embryogenesis involves the phases induction of callus from explants, somatic embryo development, maturation and germination.

Induction of callus from explants: This phase involves the conversion of differentiated tissue to dedifferentiated tissue which is a group of cells known as callus. Various explants have been used to initiate callus. The explants used were shoot tip (Bhati et al 2014, Mater 1987, Tisserat 1979, Yadav et al 2001, Asemota et al 2008), inflorescence (Tisserat 1979, Fki et al 2003, Abul-Soad 2012), mature and immature zygotic embryos (Bekheet et al 2002), leaf segments and meristematic tissues (Asemota et al 2007), auxillary buds (Jain 2001) and roots (Roshanfekrrad et al 2017). The most frequently explants used are apical shoot tips for good results (Jain 2001).

To induce embryogenic callus in most of the cases for either shoot tip or inflorescence, a high concentration of auxins is used. Most researchers suggest 2,4-dichlorophenoxyacetic acid (2,4-D) as the most efficient auxin to induce embryogenic callus used at 100 mg/l concentration (Al-Khayri 2005, 2010; Eshraghi et al 2005, Naik and Al-Khayri 2016). Fki et al (2011) reported that high concentrations of 2,4-D cause somaclonal variations. Many researchers applied low concentration of 2,4-D such as 1.5, 5 and 10 mg/l to induce somatic embryo (Aslam et al 2011, El Hadrami et al 1995, Othmani et al 2009). Depending on the genotype, the somatic embryo formation period also varies from a few to several months (Eshraghi et al 2005, Hassan and Taha 2012, Othmani et al 2009). Recently Mazri et al (2017) reported somatic embryogenesis from the adventitious bud of date cv Najda where the MS medium was supplemented with 2,4-D, kinetin (KN) or 6-dimethylallylamino purine (2iP). Proximal leaf segment showed embryogenesis only in the medium supplemented with 2,4-D or picloram.

Somatic embryo development and maturation

Development of somatic embryo from pro-embryogenic calli is the important and crucial phase in somatic embryogenesis. The large scale multiplication of somatic embryos decides its commercialization. Many factors are involved in somatic embryo development and maturation like hormone composition, media, cultural conditions, sub-culturing and genotypes. Many researchers used MS media (Eshraghi et al 2005, Hassan and Taha 2012, Fki et al 2003, Abul-Soad 2012,

Aslam et al 2011, El Hadrami et al 1995) as a base with additives whereas many used hormone-free media for somatic embryo development and maturation (Al-Khayri 2003, Eke et al 2005, Othmani et al 2009).

Date palm has the capacity to develop as a mature embryo in both semisolid and liquid medium. The authors reported that in the date palm cv Deglet Nour 1-month old suspension culture produces 200 embryos from 100 mg fresh weight callus inoculums; on the other hand it produces 10 embryos on semi-solid medium (Fki et al 2003). In the date cv Khalas application of thiamine and biotin showed an increased number of embryos and also helped in the elongation process (Al-Khayri 2001). The embryogenic calli with fine chopping and partial desiccation significantly improve the embryo maturation in cv Boufeggous as reported by Othmani et al (2009).

Somatic embryo germination: Mature somatic embryos can germinate on the same medium used for its development and maturation. The germination can also occur on hormone-free medium with very low success rate. It is also reported that hormone NAA (Fki et al 2003, Eke et al 2005), IBA (Al-Khayri 2003), 2,4-D (Othmani et al 2009) and BA (Fki et al 2003) induce germination. Ibrahim et al (2012) reported that the germination frequency of somatic embryos varies with the genotype used.

REFERENCES

Abahmane L 2011. Date palm micropropagation via organogenesis. In: Date palm biotechnology (SM Jain, JM Al-Khayri and DV Johnson eds), Springer, Nethetrlands, pp 69-90.

Abul-Soad AA 2012. Influence of inflorescence explant age and 2,4-D incubation period on somatic embryogenesis of date palm. Emirates Journal of Food and Agriculture **24(5):** 434-443.

Al-Khateeb 2006. Role of cytokinen and auxin on the multiplication stage of date palm (*Phoenix dactylifera* L) cv Sukry. Biotechnology **5(3):** 349-352.

Al-Khayri JM 2001. Optimization of biotin and thiamine requirements for somatic embryogenesis of date palm (*Phoenix dactylifera* L). In Vitro Cellular and Developmental Biology- Plant **37:** 453-456.

Al-Khayri JM 2003. In vitro germination of somatic embryos in date palm: effect of auxin concentration and strength of MS salts. Current Science **84(5):** 680-683.

Al-Khayri JM 2005. Date palm (*Phoenix dactylifera* L). In: Protocols of somatic embryogenesis in woody plants (SM Jain and PK Gupta eds), Springer, Netherlands, pp 309-319.

Al-Khayri JM 2010. Somatic embryogenesis of date palm (*Phoenix dactylifera* L) improved by coconut water. Biotechnology **9(4):** 477-484.

Al-Khayri JM, Jain SM and Johnson DV 2015a. Date palm genetic resources and utilization. Vol 1, Africa and the Americas, Springer, Netherlands, 546p.

Al-Khayri JM, Jain SM and Johnson DV 2015b. Date palm genetic resources and utilization. Vol 2, Asia and Europe, Springer, Netherlands, 566p.

Al-Shahib W and Marshall RJ 2002. Dietary fibre content of dates from 13 varieties of date palm *Phoenix dactylifera* L. International Journal of Food Science and Technology **37:** 719-721.

Al-Shahib W and Marshall RJ 2003. The fruit of the date palm: its possible use as the best food for the future? International Journal of Food Science and Nutrition **54(4):** 247-259.

Asemota O, Eke CR and Odewale JO 2007. Date palm (*Phoenix dactylifera* L) in vitro morphogenesis in response to growth regulators, sucrose and nitrogen. African Journal of Biotechnology **6(20):** 2353-2357.

Aslam J, Khan SA, Cheruth AJ, Mujib A, Sharma MP and Srivastava PS 2011. Somatic embryogenesis, scanning electron microscopy, histology and biochemical analysis at different developing stages of embryogenesis in six date palm (*Phoenix dactylifera* L) cultivars. Saudi Journal of Biological Sciences **18(4):** 369-380.

Balal AH and El-Deep MD 1997. Direct organogenesis of date palm (*Phoenix dactylifera* L) in vitro. Assuit Journal of Agricultural Sciences **28(2):** 67-77.

Beauchesne G, Zaid A and Rhiss A 1986. Meristematic potentialities of bottom of young leaves to rapidly propagate date palm. Proceedings of the Second Symposium on Date Palm, King Faisal University, Saudi Arabia, pp 87-94.

Bekheet SA 2013. Direct organogenesis of date palm (*Phoenix dactylifera* L) for propagation of true-to-type plants. Scientia Agriculturae **4(3):** 85-92.

Bekheet SA, Taha HS and Saker MM 2002. In vitro long-term storage of date palm. Biologia Plantarum **45:** 121-124.

Bhaskaran S and Smith RH 1992. Somatic embryogenesis from shoot tip and immature inflorescence of *Phoenix dactylifera* cv Barhee. Plant Cell Reports **12:** 22-25.

Bhati A, Chandra A and Singh D 2014. Somatic embryogenesis of date palm (*Phoenix dactylifera* L) cultivars and the

use of RAPD for detection of genetic stability of regenerated plantlets. Indian Journal of Horticulture **71(4):** 447-451.

Eke CR, Akomeah P, and Asemota O 2005. Somatic embryogenesis of date palm (P*hoenix dactylifera* L) from apical meristem tissues from Zebia and Loko landraces. African Journal of Biotechnology **4:** 244-246.

El Hadrami I and El Hadrami A 2009. A. Breeding date palm. In: Breeding plantation tree crops: tropical species (SM Jain and PM Priyadarshan eds), Springer, New York, pp 191-216.

El Hadrami I, Cheikh R and Baaziz M 1995. Somatic embryogenesis and plant regeneration from shoot-tip explants in *Phoenix dactylifera* L. Biologia Plantarum **37:** 205-211.

Elleuch M, Besbes S, Roiseux O, Blecker C, Deroanne C, Drira NE and Attia H 2008. Date flesh: chemical composition and characteristics of the dietary fibre. Food Chemistry **111:** 676-682.

Eshraghi P, Zaghami R and Mirabdulbaghi M 2005. Somatic embryogenesis in two Iranian date palm cultivars. African Journal of Biotechnology **4(11):** 1309-1312.

Fki L, Bouaziz N, Chkir O, Benjemaa-Masmoudi R, Rival A, Swennen R, Drira N and Panis B 2013. Cold hardening and sucrose treatment improve cryopreservation of date palm meristems. Biologia Plantarum **57(2):** 375-379.

Fki L, Masmoudi R, Drira N and Rival A 2003. An optimised protocol for plant regeneration from embryogenic suspension cultures of date palm, *Phoenix dactylifera* L cv Deglet Nour. Plant Cell Reports **21(6):** 517-524.

Fki L, Masmoudi R, Kriaa W, Mahjoub A, Sghaier B, Mzid R, Mliki A, Rival A and Drira N 2011. Date palm micropropagation via somatic embryogenesis. In: Date palm biotechnology (SM Jain, JM Al-Khayri and DV Johnson eds), Springer, Netherlands, pp 47-68.

Guan Y, Li SG, Fan XF and Su ZH 2016. Application of somatic embryogenesis in woody plants. Frontiers in Plant Science **7:** 938, doi: 10.3389/fpls.2016.00938.

Hassan MM and Taha RA 2012. Callogenesis, somatic embryogenesis and regeneration of date palm *Phoenix dactylifera* L cultivars affected by carbohydrate sources. International Journal of Agricultural Research **7:** 231-242.

Ibrahim AI, Hassan MM and Taha RA 2012. Partial desiccation improves plant regeneration of date palm in vitro cultures. Wudpecker Journal of Agricultural Research **1:** 208-214.

Jain SM 2001. Tissue culture-derived variation in crop improvement. Euphytica **118:** 153-166.

Jazinizadeh E, Zarghami R, Majd A, Iranbakhsh A and Tajaddod G 2015. In vitro production of date palm (*Phoenix dactylifera* L) cv Barhee plantlets through direct organogenesis. Biological Forum **7(2):** 566-572.

Johnson DV 2011. Introduction: date palm biotechnology from theory to practice. In: Date palm biotechnology (SM Jain, JM Al-Khayri and DV Johnson eds), Springer, Nethetrlands, pp 1-11.

Khan S and Bi TB 2012. Direct shoot regeneration system for date palm (*Phoenix dactylifera* L) cv Dhakki as a means of micropropagation. Pakistan Journal of Botany **44(6):** 1965-1971.

Khierallah HSM and Bader SM 2007. Micropropagation of date palm (*Phoenix dactylifera* L) var Maktoom through organogenesis. Acta Horticulturae **736:** 213-224.

Khierallah HSM, Al-Hamdany MHS, Abdulkareem AA and Saleh FF 2015. Influence of sucrose and pacloburtazol on callus growth and somatic embryogenesis in date palm cv Bream. International Journal of Current Research and Academic Review **1(1):** 270-276.

Loutfi K and El Hadrami I 2005. *Phoenix dactilyfera* date palm. In: Biotechnology of fruit and nut crops (RE Litz ed), CAB International, Wallingford, pp 144-156.

Mater AA 1987. Production and cryogenic freezing of date palm germplasm and regeneration of plantlets from frozen material. Iraqi Journal of Agricultural Sciences **5:** 35-49.

Mazri MA and Meziani R 2013. An improved method for micropropagation and regeneration of date palm (*Poenix dactylifera* L). Journal of Plant Biochemistry and Biotechnology **22(2):** 176-184.

Mazri MA, Belkoura I, Meziani R, Mokhless B and Nour S 2017. Somatic embryogenesis from bud and leaf explants of date palm (*Phoenix dactylifera* L) cv Najda. 3 Biotech **7(1):** 58, doi: 10.1007/s13205-017-0676-y.

Meziani R, Jaiti F, Mazri MA, Anjarne M, Chitt MA, El Fadile J and Alem C 2015. Effects of plant growth regulators and light intensity on the micropropagation of date palm (*Phoenix dactylifera* L) cv Mejhoul. Journal of Crop Science and Biotechnology **18(5):** 325-331.

Meziani R, Jaiti F, Mazri MA, Hassani A, Salem SB, Anjarne M, Chitt MA and Alem C 2016. Organogenesis of *Phoenix dactylifera* L cv Mejhoul: influences of natural and synthetic compounds on tissue browning and analysis of protein concentrations and peroxidase activity in explants. Scientia Horticulturae **204:** 145-152.

Naik PM and Al-Khayri JM 2016. Somatic embryogenesis of date palm (*Phoenix dactylifera* L) through cell suspension culture. In: Protocols for in vitro cultures and secondary metabolite analysis of aromatic and

medicinal plants, 2nd edn, Methods in molecular biology (SM Jain ed), , Vol 1391, Human Press, New York, pp 357-366.

Othmani A, Bayoudh C, Drira N, Marrakchi M and Trifi M 2009. Somatic embryogenesis and plant regeneration in date palm *Phoenix dactylifera* L cv Boufeggous is significantly improved by fine chopping and partial desiccation of embryogenic callus. Plant Cell, Tissue and Organ Culture **97:** 71-79.

Pinker I, Ibraheem YM and Bohme MH 2009. Propagation of some date palm cultivars by using tissue culture methods. Acta Horticulturae **839:** 71-78.

Reynolds JF and Murashige T 1979. Asexual embryogenesis in callus cultures of palms. In Vitro **15:** 383-387.

Roshanfekrrad M, Zarghami R, Hassani H, Zakizadeh H and Salari A 2017. Effect of $AgNO_3$ and BAP on root as a novel explant in date palm (*Phoenix dactylifera* cv Medjool) somatic embryogenesis. Pakistan Journal of Biological Sciences **20(1):** 20-27.

Salama A 1990. Observations histologiques sur l'organogenèse et le développement des bourgeons du palmier dattier (*Phoenix dactylifera* L) en culture in vitro. Doctorat ou Doctorat National, As-Samlalia, Marrakech.

Sharma DR, Deepak S and Chowdhury JB 1986. Regeneration of plantlets from somatic tissues of date palm (*Phoenix dactylifera* L). Indian Journal of Experimental Biology **24:** 763-766.

Thorpe TA 1993. In vitro organogenesis and somatic embryogenesis: physiological and biochemical aspects. In: Morphogenesis in plants (KA Roubelakis-Angelakis and KTT Van eds), Plenum, New York, pp 19-38.

Tisserat B 1979. Propagation of date palm (*Phoenix dactylifera* L) in vitro. Journal of Experimental Botany **30(11):** 1275-1283.

Tisserat B 1982. Factors involved in the production of plantlets from date palm callus cultures. Euphytica **31:** 201-214.

Vayalil PK 2012. Date fruits (*Phoenix dactylifera* Linn): an emerging medicinal food. Critical Reviews in Food Science and Nutrition **52(3):** 249-271.

Yadav NR, Yadav RC, Chowdhury VK and Chowdhry JB 2001. Explant and cultivar response to in vitro clonal propagation of female date palm (*Phoenix dactylifera* L). In: Proceedings, 2nd International Conference on Date Palms, 25-27 March 2001, Abu Dhabi, UAE, pp 491-499.

Zaid A, El-Korchi B and Visser HJ 2011. Commercial date palm tissue culture procedures and facility establishment. In: Date palm biotechnology (SM Jain, JM Al-Khayri and DV Johnson eds), Springer, Nethetrlands, pp 137-180.