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REGULAR ARTICLE

Envision of an international consortium for palm research

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Abstract

An increasing number of insects and diseases are destroying palm trees of high economic and aesthetic value throughout the world. Global climate change presents another challenge for palm distribution. Efforts to reduce damage caused by these biotic and abiotic stresses are being made by scientists worldwide. Individual efforts may be duplicative and sometimes unsuccessful. Interdisciplinary approaches combining expertise of pathologists, entomologists, biotechnologists, and breeders should be more effective. We propose the formation of an International Consortium for Palm Research (ICPR) to foster innovative international research collaborations for palm improvement, productivity and utilization. Funding of this nonprofit Consortium is envisioned to include donations from potential beneficiaries in proportion to the potential benefits received. Potential donors might include agricultural ministries and public and private organizations in various affected countries as well as international organizations interested in palm development. The host of ICPR is envisioned to be the Kingdom of Saudi Arabia with an international board directing activities and awarding meritorious research proposals. Tangible evidence of scientific accomplishment, publications, ancillary funding, and international patent applications would be key criteria for receiving research awards. Current research priorities are highlighted including the extremely serious red palm weevil (*Rhynchophorus ferrugineus*) occurring from the Middle East to Asia and California, USA; *R. palmarum* vectoring the very serious red ring nematode (*Bursaphelenchus cocophilus* baujard) in the Caribbean and Central and South America; at least three species of *Fusarium*, one possibly airborne, occurring from Morocco to Florida, USA; *Phytophthora palmivora* destroying the oil palm industry in Colombia; Ganoderma causing serious losses from Malaysia to Florida, USA; and phytoplasmas including lethal yellowing and Al-Wijam.

Key words: agriculture; Arecaceae; biotechnology; collaboration; consortium; development; research; palm; pests

Introduction

Many species of palm trees provide food, shelter, fiber, income and aesthetic value to millions of the world's citizens. Despite these major economic and social contributions, palm production throughout the world is threatened by an increasing number of insect and disease pests as well as overall production inefficiency (El-Juhany, 2010). Moreover, abiotic factors such as water availability, soil composition, and temperature range are main determinants of agricultural productivity. Many palms are grown under adverse environmental conditions to which they have acclimatized. Current global climate change is perceived to negatively impact crops and thus threaten global food security (Schmidhuber and Tubiello, 2007). Global warming may encourage the appearance of new insects and diseases and the disappearance of some beneficial organisms. Plant breeders and agronomists are faced with the difficulty of predicting the impact of climate changes on global or regional or national agriculture and therefore new varieties must be developed and distributed regularly at the national and regional levels for sustainable crop production. In addition to developing new varieties that can be readily adapted in a short period on different locations with varying agro-climatic and growing conditions, and low available resources (Jain, 2010). Conservations of genetic resources along with the applications of conventional breeding in combination with the appropriate biotechnological techniques such as mutagenesis, genetic engineering, and molecular breeding are essential for such strategies. Expanding the utilization of palm species to innovative technologies, like the

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production of natural pharmaceuticals and the potential use in biofuel industry, would further the economic importance of these species.

In this communication, we propose the establishment of an International Consortium for Palm Research (ICPR) to foster research collaboration with the objective of supporting palm improvement and utilization on a global basis. Despite notable research progress, numerous problems still persist and threaten the existence of many palm species.

Consortium is a Latin word meaning partnership, association or society. It can be further defined as "an agreement, combination, or group (as of companies) formed to undertake an enterprise beyond the resources of any one member" (Merriam-Webster Online Dictionary, http://www.merriam-webster.com/). This organizational and funding approach is a common practice to support various aspects of agriculture worldwide, where the research needs for a commodity are greater than the resources of a single member. These groups may be formed under several different names including associations, foundations and growers groups for commodities as diverse as potatoes, grapes, wheat, hops, soybeans, corn, cotton, horseradish, citrus, etc. Each consortium collectively funds research specific to their commodity needs through a self-tax or check-off system. The growers contribute a certain amount or percentage per unit of production (pound, box, bushel, barrel, acre, hectare, etc.). The funds are collected and pooled, and then allocated to support meritorious competitive research projects deemed necessary to improve production practices and sustain yields for that particular commodity. We propose this consortium approach for solving problems in palm production on a global basis.

Background

The order Arecales contains only one family, the Arecaceae (syn. Palmae), which comprises 2,400 species in 190 genera. Recently a new phylogenetic classification of Arecaceae was published (Dransfield et al., 2005), and modern molecular techniques have contributed significantly to establishing genetic relationships among the palms (Anzizar et al., 1998; Baker et al., 1999; Asmussen et al., 2006). Moore and Uhl (1973, 2011) stated that the palms with the greatest importance in world commerce are the coconut (*Cocos nucifera*) and the African oil palm (*Elaeis guineensis*); both are prime sources of vegetable oil and fat.

The top coconut producing countries are Indonesia, Philippines, India, Brazil and Sri Lanka, respectively. Collectively, they produce 50.7 million tons annually, or 93% of the world's production (FAOSTAT data, http://faostat.fao.org). Coconut has culinary, domestic and industrial uses, and nearly 12 million hectares are planted in 86 countries. About 96% of the crop is grown by 10 million resource-poor families, on holdings under 4 ha, and more than 80 million people depend directly on coconut and its processing for their livelihoods (http://www.fao.org/docs/eims/upload/216252/Infosheet_Coconut.pdf).

Oil palm provides a major source of oil for cooking, biodiesel fuel production and many industrial uses. It is cultivated in tropical areas of Asia, Africa and South America. With the global demand for edible vegetable oils increasing strongly in recent decades, palm oil production has expanded rapidly to meet that demand. Since the 1990s the area under cultivation increased about 43%. Seventeen countries produce palm oil, and about 4.5 million people earn a living from it. The five major producing countries are Indonesia, Malaysia, Thailand, Colombia and Nigeria, respectively. Collectively, they produce 47 million MT annually, or 94% of the 50.2 MMT produced, with Indonesia alone producing 51% of the total (http://www.greenpalm.org/en/about-palm-oil/ where-is-palm-oil-;grown http:// www. indexmundi.com/ agriculture/? commodity=palm-oil&graph= production).

The date palm (*Phoenix dactylifera*) also is of major importance. It has been cultivated as a tree crop for at least 5,000 years (Johnson, 2011). A very important plant throughout the world, it is perhaps the most important plant in Saudi Arabia and throughout the Middle East. It has high socioeconomic importance, due not only to its food value, but also its capacity to provide many other products such as shelter, fiber, clothing, aesthetic beauty and furniture (Mousavi et al., 2009). It has high natural tolerance to very adverse growing conditions, including drought, salinity and high temperatures (Bakheet et al., 2008). In 2007 nearly 1.1 million ha of date palm were harvested, yielding 6.91 million tonnes. The major producers were Egypt (19%), Iran (15%) and Saudi Arabia (14%) (FAOSTAT data, http://faostat.fao.org).

In addition, many species of palms are used extensively as ornamentals in warm regions throughout the world, or indoors when a tropical effect is desired. The word palm is even used to indicate the tropical or verdant nature of municipalities such as Palm Beach, Palm Coast and

Palm Springs in the United States. Sales of palms for ornamental purposes provide millions of dollars annually to economies throughout the world. Annual sales are valued at $70 million in California and $127 million in Florida alone (Anonymous, 2010).

Breeding palms for pest resistance or for other desirable characteristics by traditional breeding techniques is very difficult and time consuming. It is hindered by life cycle longevity, the palm's highly heterogeneous genetic nature, and the difficulty to propagate uniform plants in large numbers. However, with recent scientific advances palm improvement can be accomplished through biotechnological approaches (Jain et al., 2011), such as genetic transformation (Saker et al., 2007; Habashi et al., 2008; Mousavi et al., 2009; Saker et al., 2009) and *in vitro* selection (El Hadrami et al., 2005; Al Mansoori and Alaa El-Deen, 2007; Jain, 2010). Combining these approaches with other emerging molecular techniques holds great promise to control insects (Whyard et al., 2009) and disease pests of palm (Niblett and Bailey 2012, this issue). Mutagenesis is another effective approach to combat palm diseases (Jain, 2005, 2007, 2010, 2011).

Consortium Structure and Function

Justification

Numerous researchers are working on palm improvement worldwide. Unfortunately, many are working in isolation, their research may be poorly funded, and their research may be inadvertently duplicated. To minimize these issues, to maximize research output and to give palm research new visibility we envision the creation of the International Consortium for Palm Research (ICPR).

Objective

To foster innovative international research collaborations for palm improvement, productivity and utilization.

General priorities

The consortium is perceived to engage in research towards: improving resistance to palm pests, diseases, and other biotic stresses, enhancing palm tolerance to abiotic stresses and global climate change, promoting conservation and utilization of genetic diversity of palm, and developing novel industrial applications for palm products (e.g. bio-energy, pharmaceuticals, etc.)

Multidisciplinary

This consortium advocates interdisciplinary research approach involving different science disciplines including biotechnology (e.g. bioinformatics, genetic engineering, genomics, molecular biology, and plant tissue culture), entomology, plant breeding and genetics, plant pathology, plant physiology, and food science and nutrition.

Membership

Membership is open to individuals and organizations with nominal fee. Members should be affiliated with industry or academia and have demonstrated significant research activities related to palms.

Location

We propose that the consortium headquarters be located at the Date Palm Research Center, King Faisal University, Al-Hassa Saudi Arabia. This location was selected because of their proven expertise in palm technology, the interest of the institution, and the proximity to major date palm agricultural areas.

Governance

The consortium will be managed by unsalaried Board of Directors (BoD) representing different geographical regions, commodities and expertise. They will normally serve three-year terms except for the initial BoD members who may be reassigned to ensure continuity and orderly succession. The BoD will make the daily management decisions, and their decisions will be made by majority vote and announced to the Membership. The BoD shall present proposed bylaws to the membership for ratification and adoption, and they shall solicit the involvement of the membership by electronic polls and for review of manuscripts and submitted grant proposals, and for other issues as they may occur.

Bylaws

The consortium bylaws will be drafted by the BoD in consolation with members and financial donors. Those of the West Chester University Research Consortium might be viewed as an example at: http://www.wcupa.edu/wcurc/bylaws.htm

Funding acquisition

Support funding will be solicited from growers and grower organizations involved with date, oil, coconut and ornamental palms. Equally important are the countries, states, municipalities and companies that depend on palm trees to provide the ambiance in which they do their business. These include such diverse agencies as the governments of Saudi Arabia and Malaysia, Colombian Oil Palm Growers, the Walt Disney Company, cities of Palm Springs, Palm Beach, Miami, Miami Beach, California Date Growers Association, Florida, Arizona, Nevada and California Departments of Tourism, Florida and California Ornamental Growers and Nurserymens Associations, etc.– all contributing in proportion to the value that palms bring to their agency or institution.

Information resources

A full-time paid computer specialist will be responsible to maintain an active and up-to-date website, with a bulletin board for notices of general interest, a list of active members and their affiliations, a periodic electronic newsletter, and a literature collection of recent major palm publications, in addition to links to existing information resources. The consortium website is intended to be the first place an interested party would go to for information related to palms. Examples of linked resources include: International Palm Society website, Coconut group, Oil palm group, Date Palm Global Network, and Arab Palm League.

Funding of research proposals

The BoD will set annually the research priorities. Whenever funds are available a call for proposals will be sent to the membership. Proposals will be peer-reviewed by a selection panel comprised of experts selected by the BoD, who will maintain database of international experts. The high quality research proposals will qualify for funding, that would include appropriateness of the proposal, tangible evidence of scientific accomplishment, publications in international refereed journals, ancillary funding, and international patent applications. The project director would submit an annual progress report and further planning of the project. The further renewal of project funding would be done based on the annual progress. Within three months following completion of the research, a detailed report will be submitted to the BoD, along with any publications or patent applications. Ownership of patents would be mutually agreed upon according to predefined rules governing this process.

Examples of Research Priorities

Palms are affected by large number of pests, including insects, nematodes and diseases caused by fungi, bacteria and phytoplasma (Downer et al., 2009). Four of these major pests will be discussed as examples:

Red palm weevil

The red palm weevil (RPW), *Rhynchophorus ferrugineus*, a member of Coleoptera: Curculionidae, is a concealed tissue borer and lethal pest on over 20 species of palm, including date palm (Figure 1) and coconut palm (Abraham et al., 1998; Esteban-Duran et al., 1998). Gomez and Ferry (Gomez and Ferry, 2002) indicate it "has become the most important pest of the date palm in the world". Its aboriginal home is South and Southeast Asia, where it is a key pest of coconut (Nirula, 1956; Faleiro and Kumar, 2008). First reported on date palm in Iraq (Buxton, 1920), then from Rass-El-Khaima in the UAE in 1985, it reached the eastern region of the Kingdom of Saudi Arabia in 1985, and afterwards spread to numerous other areas in the Kingdom (Abuzuhairah, 1996). It was recorded in Iran in 1990 (Faghih, 1996), then in Egypt in 1992 (Cox, 1993). By 1994, it had been found in the south of Spain (Barranco et al., 1995) and in 1999 in Israel, Jordan and the Palestinian Authority Territories (Kehat, 1999).

The RPW has now spread to all the countries of the Gulf region in the Middle-East, infesting approximately 5% of the palms in the region with an annual infestation rate of about 1.9% (Abraham et al., 1998; Zaid et al., 2002). FAO has now identified it as a category-1 pest of date palm in the Middle-East (El-Sabea et al., 2009). Subsequently, the weevil moved from North Africa into Europe, where it was reported for the first time in Spain, Portugal and the Canary Islands (Faleiro, 2006a,b) and in 2009 in the Caribbean (Curacao, Dutch Antilles), potentially from date palms imported from Egypt for landscaping (Reijnaert, 2009). In August of 2010 the RPW was reported in Laguna Beach California (Anonymous, 2010), where it now poses a serious threat to California’s $30 million dollar date crop industry, as well as ornamental palm tree sales valued at $70 million in California and $127 million in Florida.

The RPW can be controlled by insecticide applications, but it is expensive and pollutes the environment. Instead, an integrated pest management approach has been adopted. It includes prohibition of movement of infested plants, extensive monitoring of insect populations, the use of food-baited pheromone traps to reduce adult weevil populations and strategic insecticide applications. But this program is labor intensive and expensive to implement. The consortium is in support of using advanced technologies to tackle this insect problem. Technologies intended include biological control aspects, genetic engineering of baculovirus containing neuro-toxin gene and Bt gene for examples.

Figure 1. Red palm weevil infestation. Source: (El-Sabea et al., 2009).

Fusarium diseases

Bayoud disease (BD) of date palm is caused by the soil-borne fungus *Fusarium oxysporum* f. sp. *albedinis* (FOA). It is a lethal root rot and vascular wilt disease of date first reported in 1870 in the Drâa valley of Zagora, Morocco. It has been spreading continuously eastward, and within one century had killed more than twelve million palms in Morocco and three million in Algeria (Zaid, 2002; Quenzar, 2001). Oases that formerly had 300-400 palms per hectare were reduced to 40-50 palms per hectare (Djerbi et al., 1986), and BD was destroying the most renowned varieties such as Medjool, Deglet Nour, and Bou Fegouss). BD also has reduced the production of desirable annual crops formerly supported under date palm culture, and has accelerated the desertification of the region, with farmers abandoning their land and moving to large urban centers.

FOA is a soil inhabiting fungus, persisting as hard-walled chlamydospores in dead tissues of diseased palms. Chlamydospores are released from disintegrating tissues into the soil, where they remain dormant and survive for more than eight years. Controlling BD is difficult, if not impossible, by current cultural methods once FOA becomes establishes in a plantation, because of the persistence of the fungus, the movement of soil and the flow of irrigation water. Individual infected plants can be eradicated and the soil fumigated with methyl bromide or chloropicrin, but this is expensive and time-consuming. Some BD-resistant date palm selections have been reported (Djerbi et al., 1986), but introgression of resistance into desirable varieties by conventional breeding is difficult and time-consuming.

Fig. 2. Queen palm in Florida dying from Fusarium wilt.

In addition to FOA there are several additional Fusarium pathogens of palm. Elliott (Elliott, 2009) recently confirmed the spread of new palm diseases in Florida including two formae speciales of *Fusarium oxysporum*, with f. sp. *canariensis* (FOC) causing Fusarium wilt of Canary Island date palm (*Phoenix canariensis*) and a new forma specialis causing Fusarium wilt of queen palm (*Syagrus romanzoffiana*) (Figure 2) and Mexican fan palm (*Washingtonia robusta*). FOC also attacks Canary Island date palm in Australia, Italy, France, Japan, the Canary Islands and California, where it can kill 40-50 year old trees (Feather et al., 1989; Simone and Cashion, 1996; Smith et al., 2003). The California isolate caused sufficient concern to warrant a quarantine to protect the California date industry (Feather et al., 1989). Fusarium remains a threat to palm species worldwide. Resistant to Fusarium may be developed by mutation technology and genetic engineering in conjunction with genomic studies of palms and their pests and diseases. Radiation-induced mutation proved applicable to the development of date palm resistance to FOA (El-Hadrami et al., 2005; Jain, 2005, 2007, 2011).

Phytophthora palmivora

Bud rot disease or "pudricion del cogollo" is a major disease of African oil palm in Colombia (Fig. 3). This soil and air borne disease has killed thousands of trees and been known for more than 40 years in Central and South America. But the causal agent has only recently been identified as *Phytophthora palmivora* (Torres et al., 2010). It has spread widely in Colombia and threatens to make oil palm production unprofitable. Bud rot of coconut also is caused by *P. palmivora* (Ridings, 1972). It would be economically ruinous to the Malaysian oil palm industry if *P. palmivora* was introduced there. Two species of Ganoderma currently cause butt rot and serious losses in oil palm production in Malaysia (Zakaria et al., 2005).

Phytoplasmas

Phytoplasmas are bacteria without cell walls, and they cannot be cultured in microbiological media. There are several different phytoplasmas that affect palms. These diseases usually occur in tropical or subtropical climates and cause symptoms ranging from mild yellowing to death of the infected plants. Transmission from plant-to-plant requires an insect vector, usually a leafhopper or plant hopper.

Probably the best known and most destructive phytoplasma disease is lethal yellowing (LY) of coconut, which has killed millions of coconut palms in Florida and throughout the Caribbean (Fig. 4). It infects and kills many species of palm including *P. dactylifera*, and is vectored by a planthopper, *Haplaxius crudus* (previously *Myndus crudus*) (Torres et al., 2010). Texas *Phoenix* palm decline (TPPD) occurs on *Phoenix canariensis* in Texas and on *Phoenix sp.* and *Sabal palmetto* in Florida (Harrison and Elliott, 2009b). Al Wijam (AW), another phytoplasma disease, was first observed on date palm in Al Hassa, Saudi Arabia (Nixon, 1954), and it was recently characterized by Alhudaib et al. (Alhudaib et al., 2007). Phytoplasma are currently classified by comparing restriction fragment length polymorphism (RFLP) patterns for polymerase chain reaction (PCR) amplicons of their 16S rDNA and naming them after the major phytoplasma whose RFLP pattern they most closely resemble. Therefore, LY is *Candidatus Phytoplasma palmae* subgroup 16SrIV-A; TPPD is Candidatus Phytoplasma palmae subgroup 16SrIV-D; and AW is *Candidatus* Phytoplasma asteris group 16SrI (Alhudaib et al., 2007; Harrison and Elliott, 2009a,b).

Figure 3. Thousands of oil palms dying in Colombia from infection by *Phytophthora palmivora*.

Figure 4. Coconut palms in Jamaica dying from lethal yellowing phytoplasma.

Phytoplasma diseases cannot be controlled, but symptoms are diminished and tree life extended by injections of tetracycline. This is practical only for "specimen trees" in an expensive landscape (Harrison and Elliott, 2009a).

Genetic resistance is available in palm species to some or all of the serious pests of palm, but it has not been introgressed into those which are susceptible because of the difficulties in palm breeding. Current and emerging molecular techniques show promise for overcoming many of these impediments.

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