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POTENTIAL OF THE WEED ABRUS PRECATORIUS LINNAEUS (FABALES: FABACEAE) FOR CONTROL OF INSECT PESTS IN THE SOUTH PACIFIC: A REVIEW

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A B S T R A C T

Abrus precatorius L. (Fabaceae) is a woody legume plant that grows in tropical countries and is an invasive weed in other areas. Extracts of this plant have insecticidal properties against several arthropod groups including Coleoptera, Diptera, Hemiptera, Isoptera, Lepidoptera and Orthoptera. It also has inhibitory effects against other pests including fungal plant pathogens, parasitic protozoans and molluscs. Studies that have examined the efficacy of *A. precatorius* extracts against invertebrate pests found in the South Pacific region suggest that this plant may be a potential mean for controlling many important invasive agricultural pests. Harvest and usage of *A. precatorius* may serve a dual purpose to restrict weed growth whilst providing material to produce a botanically-derived insecticide.

Keywords: Botanical pesticides; Integrated Pest Management; invasive weeds; plant extracts; South Pacific.

INTRODUCTION

The rosary pea: Abrus precatorius: The leguminous plant *Abrus precatorius* L. (Fabaceae) is a high-climbing, twining or trailing woody vine that grows in many tropical areas and is propagated through seeds. The plant flowers in winter/early spring and the fruits ripen in late summer. The flowers appear in clusters, shaped like those of peas, and can be white or tinged with pink, blue, red or purple. The fruit is a flat oblong pod and has 3-8 shiny hard seeds which are 6-7 mm in diameter (Whistler, 1992). The glossy red seed, which has a distinguishing black spot, is often used in local jewellery, giving the plant one of its common names of 'rosary pea' (see Table 1). In many parts of the world this species is regarded as an invasive weed, including the USA (Bradely & Gann, 1999; Motooka *et al.*, 2003), Honduras (Holm *et al.*, 1979), Madagascar (Sussman & Rakotozafy, 1994) and the Philippines (Madulid *et al.*, 2009). In Australia, *A. precatorius* alters the structure of plant communities by smothering existing vegetation, both in the ground layer and canopy, suppressing the growth and regeneration of native species (Hosking *et al.*, 2003; Randall, 2007). *Abrus precatorius* occurs in many South Pacific countries, where it is often considered as native or an ancient introduction (Smith, 1985; Whistler, 1992 and Table (1). It has been recorded in New Caledonia (MacKee, 1994), American Samoa (Whistler, 1998), French Polynesia (Florence *et al.*, 2010), Hawai'i (Motooka *et al.*, 2003; Whistler, 2010), Niue (MacKee, 1994; Space *et al.*, 2004) and many Fijian Islands (Smith, 1985; Ghazanfar *et al*., 2001; Florence *et al*. 2010). *Abrus precatorius* may disperse to nearby islands via oceanic dispersal and undocumented populations are likely to be present on other islands in the Pacific region (Ghazanfar *et al*. 2001).

Abrus precatorius is only one example of a number of detrimental invasive plants and animals now widespread throughout the Pacific region. Examples include: invasive plants such as *Sphagnetico latrilobata* (the creeping daisy), *Spathodea campanulata* (African tulip); vertebrates, including *Bufo marinus* (the cane toad), *Herpestes fuscus* (Indian mongoose); and invertebrates including *Anoplolepis gracilipes* (the yellow crazy ant), *Wasmannia anuropunctata* (the little fire ant) and *Coptotermes gestroi* (Asian Subterranean

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Termites). All are associated with degradation of natural ecosystems, agricultural impacts and economic costs due to control efforts (Olson, 2006; Daigneault & Brown, 2013) and productivity losses (Fasi *et al*., 2013). Invasive species are considered a major global threat to biological diversity and ecosystem functioning and thought by many to be the second leading factor, after habitat destruction, in biodiversity loss and species endangerment worldwide (Wilson, 2002) including Oceania (Pyke *et al.*, 2008; Kingsford *et al.*, 2009).

Table 1. Common names for *Abrus precatorius* in the South Pacific.

Location	Common names	Reference
General / S Asia	Gunja	Anand *et al*., 2010
	Jequerity	Choudhari *et al*., 2011
	Rosary Pea	
Cook Islands	Kirikiri rangi	Whistler, 1992
	Pitipiti'o	GISD, 2010
	Uiui	
Fiji	Lele	Whistler, 1992
	Leredamu	Thaman *et al*., 2007
	Diri damu	
	Qiri damu	
	Danimana	
Guam	Kulales halom tano	Whistler, 1992
Hawai'i	Pukiawe lei	Whistler, 1992
Niue	Matakamea	Whistler, 1992
	mata'ila	GISD, 2010
	pomea	
	pomea mataila	
Samoa	Fuefue laulili'i	GISD, 2010
	Matamoso	
Tonga	Moho	Whistler, 1992
	Matamoho	GISD, 2010

Control of invasive and pest species: The primary methods for control of many invasive species depend in part on the use of synthetic herbicides or toxins, as they are generally effective and economic over large areas. Similarly, in agricultural systems, conventional chemical pest control methods can be highly effective, both in terms of reducing the intensity and occurrence of pests and diseases, and ultimately producing low cost agricultural commodities for consumers (Pimentel, 2009). However, there is a general consensus among environmentalists that the rate at which synthetic herbicides and insecticides are currently being applied is unsustainable, with a wide array of negative impacts associated with their use (Igbedioh, 1991). For example, insecticides can have direct negative impacts on human health, as well as reducing populations of beneficial biota such as predatory insects and pollinators (Brown, 1978; Ware, 1980). The manufacture of synthetic pesticides is often heavily reliant on derivatives of petro-chemicals, and indirect environmental impacts due to pollution can occur at sites distant from the actual locality of product use. Another major problem associated with incorrect use of pesticides is the evolution of resistant populations of target pests, subsequently requiring higher concentrations of chemicals to be used or more potent toxins to be developed (Georghiou, 1986; Mallet, 1989; Denholm & Rowland, 1992). With respect to the control of invasive plants such as *A. precatorius*, alternatives to chemical control of invasive and agricultural weeds are continually being sought. These include methods such as super heating or steam 'injection' of agricultural soils, the introduction of biocontrol organisms such as herbivorous insects to reduce plant biomass and physical removal of the plant and propagules by hand or mechanical means (Holt, 2009).

Botanically-derived plant protection products: Historically, many plant-derived chemicals such as nicotine and pyrethrins have been used as the basis for new insecticides in conventional pest control.

Table 2. Summary of pest arthropods tested for susceptibility to tissue extracts or products derived from *Abrus precatorius*.

		Species	Plant part /compounds	Reference
Insecta	Coleoptera	Orange Blister Beetle *Mylabris pustulata*	Petroleum ether extracts of seed(proteins)	Johri *et al* ., 2004
		Rice Weevil *Sitophyllus oryza*	Isolated abrins	Satyasree, 1999
	Diptera	Oriental Fruit Fly *Bactrocera dorsalis*	Crude ethanol extracts (Plant part not given)	Nakawiroat *et al*., 2007
		Malaria mosquito *Culexquinque fasciatus*	Methanol extracts of seeds	Muthukrishnan *et al.,* 1997 Sakthivadivel & Daniel, 2008 Nazar *et al.,* 2009
		Malaria mosquito *Culexquinque fasciatus*	Petroleum ether extract of leaves	Manimegalai *et al.,* 2011
		Mosquito *Culex vistiavi*	Ether extracts of seeds	Bagavan & Rahuman, 2011
		Malaria mosquito *Anopheles vagus*	Ether extracts of seeds	Bagavan & Rahuman, 2011
		Encephalitis Mosquito *Armigeres subalbatus*	Ether extracts of seeds	Bagavan & Rahuman, 2011
	Hemiptera	Mealybug *Maconellicoccus hirsutus*	Abrine isolated from seeds	Anitha *et al.,* 1999
		Painted bug *Bagrada cruciferarum*	Petroleum ether extracts of seeds	Johri *et al.*, 2004
		Cowpea aphid *Aphis craccivora*	Petroleum ether extract of seeds	Dimetry & Abdalla, 1988a
	Isoptera	Asian termite *Coptotermes gestroi*	Methanol extracts of leaves	Setiawan *et al*., 2009
		Asian termite *Coptotermes gestroi*	Methanol and water extracts of seed and leaf	Prasad *et al*., 2015
	Lepidoptera	White Cabbage Butterfly *Pieris brassicae*	Petroleum ether extracts of seed (proteins)	Johri *et al* ., 2004
		Diamondback Moth *Plutella xylostella*	Crude extracts of seeds	Sinchaisiri *et al* ., 1990
		Rice Moth *Corcyra cephalonica*	Isolated abrins	Satyasree, 1999
		Greater Wax Moth *Galleria mellonella*	Ethanolic extracts of seeds	Talat, 2007
		Cotton leafworm moth *Spodoptera littoralis*	Petroleum ether, ethanol, water extracts of seeds	Dimetry &Abdalla, 1988b
	Orthoptera	Grasshoppers *Poecilo cerapicta*	Aqueous extracts of seeds	Desai, 1966 & 1971
Arachnida	Ixodida	Ticks *Boophilus microplus*	Crude ethanol extracts of seed	Chungsamarnyart *et al*.,1988
	Trombidiformes	Spider mites *Tetranychus urticae*	Petroleum ether extracts of seeds	Reda *et al.,* 1989 &1990 Dimetry *et al*., 1999 & 1992

More recently attention has focused on developing insecticides and repellents from plants already used by traditional farmers, such as neem (Azadirachta indica) (Patel & Chauhan, 2013) and species of pepper *Piper (*peppers*)* (Scott *et al*., 2003; Gulzar *et al*., 2013). These 'biorational' insecticides are considered more environmentally sound as they tend to have a narrower range of target species, are less toxic to the people applying the products, and often rapidly degrade under natural conditions (Wiesbrook, 2004).

Hoddle (2004) suggested there may be scope to control invasive species in a sustainable fashion if they offer some beneficial products or 'services'. Numerous investigations report efficacy of extracts or plant-derived compounds on invertebrate crop pest and vectors of human and animal diseases (Desai *et al*., 1966; Kaushik & Khanna, 1992). Some allelopathic weed species have already been evaluated for their direct use in pest management or for development of natural herbicides (Duke *et al.* 2000; Kong *et al.* 2006; Macias *et al.* 2007). Thus, if one nuisance plant species could be harvested and utilized in some manner that contributes to the control of some other pest species, a reduction in the abundance of both problem species could be achieved.

This review investigates the potential for *A. precatorius* or its extracts for use as a botanical pesticide for control of invertebrate pest species. Studies of toxins, pharmaceuticals and other bioactive compounds derived from *A. precatorius* have been conducted for over 120 years (Stillmark, 1888; Anand *et al*., 2010; Choudari *et al*., 2011; Bhatia *et al*., 2013). A wide range of bioactive compounds have been isolated from this plant including alkaloids, quinones, and saponins (Ghosal & Dutta, 1971; Dimtery *et al*., 1992; Xiao *et al*., 2012; Hata *et al*., 2013).

Review of the Biocidal properties of *Abrus precatorius against invertebrate pests*:

Insecta: Coleoptera: Several Coleopteran species are serious pests of stored grain products. Kardinan and Wikardi (1997) reported that *A. precatorius* root powder caused significant mortality of *Sitophilus* spp., with residual toxicity lasting up to two months. Similarly, Satyasree (1999) showed that a, p and y-abrins isolated from *A. precatorius* caused up to 100% mortality in the rice weevil Sitophilus oryzae. Petroleum ether extracts of the seed protein of *A. precatorius* caused 100% antifeedant effects in the orange blister beetle *Mylabris pustulata* (Johri *et al.* 2004). However, Babu *et al*. (1999) reported that *A. precatorius* caused no inhibition of the seed beetle *Callusobruchis maculatus* under laboratory conditions. *A. precatorius* extracts may show efficacy against other coleopteran pest species in the Pacific region such as *Sitophilus oryzae* (the rice weevil) and *S. zeamais* (the maize weevil) which are widely distributed in the South Pacific (Hidayat *et al.* 1996). According to the Pacific Islands Pest List Database (2015), *Sitophilus oryzae* and *S. zeamais* are found in Fiji, Tonga and Guam, where they cause damage to a range of important agricultural crops, inlcuding cassava (*Manhihot esculenta*), cashew (*Anacardium occidentale*), Job's tears (*Coix lachryma-jobi*), nutmeg (*Myristica fragrans*), rice (*Oryza sativa*), beans (*Phaseolus* sp.), sugar cane (*Saccharum officinarum*), kola (*Sorghum halepense*) and maize (*Zea mays*).

Insecta: Diptera: *Bactrocera dorsalis* (the Oriental fruit fly) poses a serious threat to the horticultural sector. Nakawiroat *et al.* (2007) demonstrated that *A. precatorius* crude methanol extracts caused reduced hatching and complete mortality at 24 hours for various life stages after topical application. *Bactrocera dorsalis* is found in French Polynesia on crops such as *Anona mucricata* (soursoup), *Averrhoa carambola* (star fruit), *Carica papaya* (papaya), *Citrus maxima* (pomelo), *Citrus sinensis* (orange), *Mangifera indica* (mango), *Musa* sp. (banana and plantain), *Persia Americana* (avocado) and *Pisidium guajava* (guava). Further, Kriticos *et al*. (2007) determined that *B. dorsalis* could persist throughout most of the central Pacific, and that parts of New Zealand could become substantially more climatically suitable, increasing the likelihood of successful establishment of this species.

In addition to agricultural pests, studies have also demonstrated the toxicity of *A. precatorius* against other Diptera such as mosquitoes. Muthukrishnan *et al.* (1997) reported that methanol extracts of *A. precatorius* seeds showed significant larvicidal and growth regulation against the mosquito *Culex quinquefasciatus*, even at very low concentrations. Sakthivadivel and Daniel (2008) also showed that *A. precatorius* demonstrated mild larvicidal activity against 4th instar larvae of *C. quinquefasciatus, Anopheles stephensi* and *Aedes aegypti*. Nazar *et al.* (2009) in their study of 100 Indian plant extracts, reported that shoot extracts of *A. precatorius* produced the highest larvicidal activity against *C. quinquefasciatus*. Similarly, a study by Manimegalai *et al.* (2011) demonstrated that petroleum ether extract of *A. precatorius* leaves caused a mortality of 77% in larvae of

C. quinquefasciatus, but that exposure to petroleum ether and chloroform seed extracts resulted in 100% mortality. An earlier study by Khalsa *et al*. (1964) contradicts the above findings, stating that the plant was not toxic to *Culex pipiens* (house mosquitos) or *Musca domestica* (the common house fly).

Culex quinquefasciatus is a principal vector of human lymphatic filariasis, several encephalitides (including West Nile virus), avian malaria, and poxvirus (Fonseca *et al.* 2006). In addition to these primary health concerns, this mosquito may contribute to a secondary economic loss in small island nations of the Caribbean, Pacific and Indian Ocean by acting as a 'nuisance biter' at tourist sites. Also, the vector of avian malaria (*Plasmodium relictum* and *Avipoxvirus*, *C. quinquefasciatus* could have significant ecological impact on island avifaunas, including those of Pacific islands such as Hawaii, Galapagos and New Zealand (Bataille *et al*., 2009; LaPointe *et al*., 2012). This biting behaviour has implications for island resorts, such as those found around Fiji, where negative feedback from tourists can rapidly cause a loss in tourist numbers (Gretzel & Yoo, 2008).

Insecta: Hemiptera: Anitha *et al.* (1999) showed that abrine isolated from *A. precatorius* seeds caused a dose dependent depletion of free and bound sugars in the mealy bug *Maconellicoccus hirsutus* in India. They concluded that application of abrine could cause a substantial reduction in the population density of *M. hirsutus*. Dimetry and Abdalla (1988b) attributed antifeedant effects of petroleum ether extracts of *A. precatorius* for another important crop pest, *Aphis craccivora* (the cowpea aphid).

Maconellicoccus hirsutus is present in a number of Pacific island countries, such as Papua New Guinea, the Solomon Islands, Tuvalu, Tonga, Palau, New Caledonia, and Guam. It is affects *Ananas comosus* (pineapple), *Tectona grandis* (teak), *Theobroma cacao* (cocoa), *Vitis vinifera* (grape) and *Gossypium barbadense* (Sea Island cotton). *Aphis craccivora* is a very widespread pest, and is present in the Cook Islands, Tonga, Guam, the Federated States of Micronesia, Kiribati, Nauru, Fiji Islands, Australia and New Zealand. Although this species primarily utilizes legume hosts, it has been recorded on a wide range of crop plants, for example: *Phaseolus* sp. (beans), *Cajanus cajan* (pigeon pea), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Artocarpus communis* (breadfruit), *Citrus limon* (lemon), *Cucumis sativus* (cucumber), *Citrullus vulgaris* (watermelon), *Solanum tuberosum* (potato) and *Colocasia esculenta* (taro) (Pacific Island Pest List Database, 2015).

Insecta: Isoptera: In Fiji, interest in termites increased dramatically after the exotic Asian Subterranean Termite, *Coptotermes gestroi*, was detected in late 2009, causing damage to homes, schools and vegetation in Lautoka. According to the Biosecurity Authority of Fiji (Malo, 2011), between late-2009 to mid-2011 the Fiji government spent more than $3 million FJD to control *C. gestroi* termites which damaged housing structures, school buildings and vegetation in Lautoka. Setiawan *et al.* (2009) reported that *A. precatorius* leaf extracts were non-repellent and could cause 100% mortality in the termite *Coptotermes gestroi* in 12 days. Subsequently, Prasad *et al.* (2015) reported that methanol extracts of leaf and seeds at concentrations as low as 1% w/v caused mortality of *C. gestroi* within 4 days, and that concentrated methanol extracts could cause 100% mortality within 24 hours.

Insecta: Lepidoptera: Extracts of *A. precatorius* show efficacy against a number of lepidopteran pest species. Dimetry and Abdalla (1988a) reported that petroleum ether, ethanol and water extracts inhibited feeding in *Spodoptera littoralis* (the cotton leafworm), *causing* decreased larval body weight and lower adult fecundity. Sinchaisri *et al.* (1990) demonstrated that of the 43 plant extracts bioassayed in vitro, crude extracts of *A. precatorius* seeds were highly effective against *Plutella xylostella* (the diamondback moth) with 80-100% mortality of larvae. Satyasree (1999) found that abrins isolated from *A. precatorius* produced 100% mortality of *Corcyra cephalonica* larvae (the rice moth). Similarly, ethanolic extracts of *A. precatorius* caused 95-100% mortality of *Galleria mellonella* (the greater wax moth) (Zaitoun, 2007). Johri *et al.* (2004) reported that petroleum ether extracts of *A. precatorius* resulted in antifeedant effects against *Pieris brassicae* (the cabbage white butterfly).

Plutella xylostella is present in a number of Pacific countries, including Papua New Guinea, the Solomon Islands, American Samoa, Tonga, Samoa, Palau, Niue, New Caledonia, Guam, French Polynesia, the Cook Islands, Nauru, Vanuatu and the Fiji Islands. It causes damage to a wide range of brassica species, as well *Nasturtium schlechteri* (Highland cress), *Allium cepa* (onion) and *Rorippa nasturtium-aquaticum* (water cress). *Corcyra cephalonica* is present in New Caledonia and the Fiji Islands where it damages *Triticum aestivum* (wheat) and *Cocos nucifera* (coconut) (Pacific Island Pest List Database, 2015).

Insecta: Orthoptera: Desai *et al.* (1966 & 1971) showed that aqueous extracts of *A. precatorius* seeds were toxic to *Poecilocera picta* (grasshoppers) and suggested the mechanisms of this toxicity appeared to include disruption of mitosis and meiosis processes. A number of orthopterans cause general crop damage to foliage and leaves in Pacific countries: for example, *Eumossula gracilis* (coconut tree hopper), *Valanga irregularis* (giant grasshopper), *Locusta migratoria* (migratory locust) and *Gryllotalpa africana* (mole crickets) (French, 2006; Evenhuis, 2007). Additionally, *Graeffea crouanii* (the coconut stick-insect) is also a pest in this region during sporadic outbreaks, such as that observed in the Fijian Island of Taveuni in the 1960s (Paine, 1968).

Arachnida: Ixodida: Chungsamarnyart *et al.* (1988) investigated 44 species of plants for larvicidal activity against *Boophilus microplus* (the cattle tick) and found that a 10% dilution of a crude-extract of *A. precatorius* seed caused 95-100% mortality in nymphs of this species. *Boophilus microplus* is a major pest of cattle in tropical and sub-tropical agro-systems, where it appears to quickly adapt to new environments and recurrently develops resistances to pesticides used in tick-control and it appears in Northern Australia and the Pacific Island country of New Caledonia (Beugnet & Chardonnet, 1995; Frisch, 1999; Chevillon *et al*., 2007).

Arachnida: Trombidiformes: Reda *et al.* (1989 & 1990) demonstrated that petroleum ether extract of *A. precatorius* seeds, and the alkaloids found in these extracts, acted as a deterrent and reduced the reproductive potential of *Tetranychus urticae* (red spider mite) in Egypt. Working on the same mite species, Dimetry *et al.* (1990) found that coumarin, β-amyrin and a mixture of sterols isolated from petroleum ether extract of *A. precatorius* seeds caused a significant reduction in fecundity and the viability of eggs of *T. urticae*. Subsequently, Dimetry *et al.* (1992) suggested that the most efficient alkaloid isolated from seeds was hypaphorine which elongated the pre-oviposition period, significantly shortened the oviposition period and reduced the fecundity of the *T. urticae* females.

In a South Pacific context, *T. urticae* is present in New Caledonia and the Cook Islands, where it damages numerous crops, such as *Brassica sp*. (mustard), *Citrullus lanatus* (water melon), *Cucurbita sp.* (squash), *Daucus carota* (carrot), *Lactuca sativa* (lettuce), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Musa sp.* (banana) and *Carica papaya* (papaya) (Pacific Island Pest List Database, 2015).

***Other beneficial properties of Abrus precatorius*:** *Lymnaea acuminate* (the fresh water snail) is the host for *Schistosoma* worms which cause schistosomiasis in cattle. Abrin and glycyrrhizic acid in *A. precatorius* seed and root affect the nervous tissue of these snails causing mortality as shown by studies conducted in India (Singh & Singh, 1999 & 2000; Bhide *et al*., 2008). Plant pathogens, such as the fungi *Colletotrichum capsici* and *C. falcatum*, cause leaf blight on pepper and red rot in sugarcane respectively. They experience reduced mycelial growth and incidence of disease is reduced when host plants are treated with *A. precatorius* extracts as shown by studies in India (Kumaran & Balasubramanian, 2003; Jayakumar *et al.,* 2007). *Colletotrichum capsici* affects *Capsicum annum* (pepper) in New Caledonia, French Polynesia and Wallis and Futuna and has also been recorded as a pathogen in American Samoa (Kohler *et al*., 1997; Brooks, 2002). Anti-parasitic activity has also been demonstrated for *Abrus precatorius* extracts. Ethyl acetate and methanol extracts of *A. precatorius* inhibit the protozoans *Plasmodium falciparum* (which is the vector for malaria) and *Leishmania donovani* (which causes leishmaniasis or black fever) in Africa (Bagavan *et al*., 2011; Hata *et al*., 2013). *Plasmodium falciparum* is a very important parasite in the Pacific since it has been documented as a major cause of malaria in the Solomon Islands, Vanuatu, and Papua New Guinea (Kere *et al*., 1993; Lum *et* al., 2005; Chan *et al*. 2012; Chan *et al*. 2015). *Leishmania donovani* is also an important disease affecting domestic animals in Pacific Islands, including Fiji (Brioudes *et al*., 2014). The protist *Trypanosoma brucei rhodesiense,* which is transmitted by tsetse flies (*Glossina* spp) and causes trypanosomiasis (sleeping sickness) is also strongly inhibited by *A. precatorius* extract shown by studies in Africa (Hata *et al*., 2013). Contrary to the effects against protozoa, Ibrahim (1992) indicated that *A. precatorius* may not be effective as an anthelminthic as it had no inhibitory effect on the nematode *Caenorhabditis elegans* in Sudan.

***Potential environmental impacts and non-target effects of A. precatorius*:** Although botanical pesticides are generally considered more 'environmentally friendly' than their synthetic counterparts, the use of botanicals still requires careful consideration if negative environmental impacts are to be minimized. Abrin is a highly toxic ribosome-inhibiting agent in humans, with a fatal dose of ≈0.11g/kg when ingested but only ≈0.01g/kg when inhaled (Saxena *et al*., 2013). Cases of *A. precatorius* poisoning usually occur from handling leaves or seeds, or from contact poisoning by wearing jewellery made from the seeds. There is currently no known antidote to abrin poisoning, suggesting there could be health concern issues if wide-spread spraying of extracts was to be carried out, or if food crops were contaminated.

For some time there has been a push to advocate forms of integrated pest management (IPM) for control of problematic insects and weeds. In many IPM systems, chemical treatments are used in collaboration with other control methods, such as the use of crop rotation to avoid build-up of pests, mechanical barriers such as mesh covers and the use of naturally-occurring or released predatory arthropods as biocontrol agents (LaBrecque, 1981; Sandler, 2010; Merfield *et al*., 2015). The use of insecticides still has a role in IPM, but their use is reduced so as to maximize inhibition of the target species but minimize the impact on non-target beneficial species, such as predators and pollinators.

Abrus precatorius extracts can cause significant mortality of some of these beneficial insects, for example, in the braconid wasp *Cotesia flavipes*, which is a parasitoid of many species of pest lepidopteran larvae and is often used as a classical biocontrol agent (Reddy & Srikanth, 1996), and of the honey bee (*Apis mellifera*) which is the primary pollinating species of many crops worldwide (Zaitoun, 2007).

Thus the timing, location and methods of application of *A. precatorius* products would need careful consideration before they were to be used as a general insecticide.

CONCLUSIONS

Reviewing the literature on the toxic effects of *A. precatorius* derivatives against invertebrate pest species indicates that many of the important groups of insect pests in the Pacific region (*e.g.* mosquitoes, aphids and termites) are susceptible to *A. precatorius*, and that there is potential for their control by biorational pesticides developed from this plant. Due to the invasive nature of *A. precatorius*, and its negative effects on native flora, the deliberate cultivation of *A. precatorius* in new areas should not be promoted. Additionally, overuse of *A. precatorius* has led to it becoming endangered in some parts of its natural range (Mwine *et al*., 2011) and, as *A. precatorius* is considered native in many South Pacific countries (Smith,1985), its complete eradication is also not being proposed. We suggest that a sustainable harvest of *A. precatorius* leaves and seed for use in the manufacture of botanical insecticides would lead to a natural reduction in the biomass of the plant without the need of chemical herbicides, helping restrict its spread to new areas and would likely be of benefit to the local flora that was freed of the smothering effect of this plant. We recommend that additional research into the viability, development and production of effective insecticides from *A. precatorius* is carried out, and that the potential advantages that this could produce in the South Pacific, in terms of reduced use of synthetics pesticides, chemical-free control of a problem weed, and, not least, economic benefit to the local communities involved, should be further evaluated.

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REFERENCES

Anand, A. R., O. V. Kishor, S. V. Rajkumar, U. D. Chandrashekhar and N.D. Tanaj. 2010. *Abrus precatorius* Linnaeus: A phytopharmological review. J Pharm Res 3: 2585-2587.

Anitha, B., M. Arivalagan, M. S. N. Sundari and G. Durairaj. 1999. Effect of alkaloid abrine, isolated from *Abrus precatorius* Linn. seeds on mealy bug, *Maconellicoccus hirsutus* green. Indian J. Exp. Biol. 37: 415-417.

Babu, A., N. Raja, S. Albert, S. Ignacimuthu and S. Dorn. 1999. Comparative efficacy of some indigenous plant extracts against the pulse beetle *Callosobruchus maculatus* F. (Coleoptera: Bruchidae). Biol Agric Hortic 17: 145-150.

Bagavan, A. and A. A. Rahuma. 2011. Evaluation of larvicidal activity of medicinal plant extracts against three mosquito vectors. Asian Pac J Trop Med 4: 29-34.

Bagavan, A., A. A. Rahuman, N.K. Kaushik and D. Sahal. 2011. In vitro antimalarial activity of medicinal plant extracts against *Plasmodium falciparum*. Parasitol Res 108: 15-22.

Bataille, A., A. A. Cunningham, V. Cedeño, M. Cruz, G. Eastwood, D. M. Fonseca. 2009. Evidence for regular ongoing introductions of mosquito disease vectors into the Galápagos Islands. Proceedings of the Royal Society of London. Series B, Biological Sciences. pp. 3769-3775.

Beugnet, F. and L. Chardonnet. 1995. Ticks resistance in pyrethrinoids in New Caledonia. Vet Parasitol 56: 325–338.

Bhatia, M., N. A. Siddiqui and S. Gupta. 2013. *Abrus Precatorius* (L.): an evaluation of traditional herb. IAJPR 3: 3295-3315.

Bhide, M., P. Nema, G. Priyamvada, M. A. Khan, D. Ujjawal and J. Shikka. 2008. Quantitative residual analysis of methanolic and petroleum ether extracts of abrin and cerbrin glycosides in different developmental stages of *Lynaea stagnalis* and *Lymnaea acuminata*. Perspectives in Animal Ecology and Reproduction. Daya Publishing House & Astral International P Ltd. pp. 329-368.

Bradely, K. and G. D. Gann. 1999. The status of exotic plants in the preserves of southern Florida. In: D. T. Jones and B. W. Gamble [Eds]. Proceedings of a Joint Conference of the Exotic Pest Plant Council and the Florida Native Plant Society, South Florids Water Mangement District. pp. 35-41.

Brioudes, A., J. Warner, R. Hedlefs and B. Gummow. 2014. A review of domestic animal diseases within the Pacific Islands region. Acta Trop 132: 23-38.

Brooks, F. 2002. List of Plant Diseases in American Samoa. Land Grant Technical Report No. 38. pp 31.

Brown, A. W. A. 1978. Ecology of Pesticides. John Wiley & Sons, New York, USA. pp. 525.

Chan, C. W., R. Spathis, D. M. Reiff, S. E. McGrath, R. M. Garruto and J.K. Lum. 2012. Diversity of *Plasmodium falciparum* chloroquine resistance transporter (pfcrt) exon 2 haplotypes in the Pacific from 1959 to 1979. PLoSOne 7: 1. e30213. doi:10.1371/journal.pone.0030213.

Chan, C. W., N. Sakihama, S. Tachibana, Z. M. Idris, J. K. Lum, K. Tanabe and A. Kaneko. 2015. *Plasmodium vivax* and *Plasmodium falciparum* at the Crossroads of Exchange among Islands in Vanuatu: Implications for Malaria Elimination Strategies. PLoSOne 10: 3. e0119475. doi:10.1371/journal.pone.0119475.

Chevillon, C., S. Ducornez, T. de Meeuˆs, B. B. Koffi, H. Gaı¨a, J. Delathie`re and N. Barre´ d. 2007. Accumulation of acaricide resistance mechanisms in *Rhipicephalus* (*Boophilus*) *microplus* (Acari: Ixodidae) populations from New Caledonia Island. Vet Parasitol 147: 276–288.

Choudari, A. B., S. Naim, A. S. Khainer, P. V. Gomase and S. Afsar. 2011. Evaluation of antiserotonergic activity of ethyl acetate extract of *Abrus precatorius* leaves. J Pharm Res 4: 570-572.

Chungsamarnyart, N., S. Jiwajinda and W. Jansawan. 1988. Effective plant crude-extracts on the tick (*Boophilus microplus*) larvicidal action. In: Proceedings of the 6th Annual Conference on Methodological Techniques in Biological Sciences, Kasetsart University Research and Development Inst. pp. 121-122.

Daigneault, A. and P. Brown. 2013. Invasive species management in the Pacific using survey data and benefit-cost analysis. In: 57th Australian Agriculture and Resource Economics Society Annual Conference, Australian Agriculture and Resource Economics Society, Sydney, Australia. pp. 1-28.

Denholm, I. and M. W. Rowland. 1992. Tactics for managing pesticide resistance in arthropods: theory and practice. Annu Rev Entomol 37: 91-112.

Desai, V. B., M. Sirsi, M. Shankarappa and A. R. Kasturibai. 1966. Studies on the toxicity of *Abrus precatorius* L. I. Effect of aqueous extracts of seeds on mitosis and meiosis in grasshopper, *Poecilocera picta*. Indian J Exp Bio 4: 164-166.

Desai, V. B., M. Sirsi, M. Shankarappa and A. R. Kasturibai. 1971. Chemical & pharmacological investigations on the seeds of *Abrus precatorius* Linn. II. Effect of seeds on mitosis & meiosis in grasshopper, *Poecilocera picta* & some ciliates. Indian J Exp Biol 9: 369-371.

Dimetry, N. Z. and E. F. Abdalla. 1988a. Feeding deterrent effects of various extracts of the bead tree, *Abrus precatorius*, seeds extracts towards *Spodoptera littoralis* (Boisd.). Bull Entomol Soc Egypt 17: 85-92.

Dimetry, N. Z. E. F. and Abdalla. 1988b. Bioactivity of *Abrus precatorius* seeds extracts against the cowpea aphid, *Aphis craccivora* Koch. Bull Entomol Soc Egypt 17: 159-167.

Dimetry, N. Z., S. El-Gengaihi, A. S. Reda and S. A. A. Amer. 1990. P Acarol. 31: 361-366.

Dimetry, N. Z., S. El-Gengaihi, A.S. Reda and S. A. A. Amer. 1992. Biological effects of some isolated *Abrus precatorius* L. alkaloids towards *Tetranychus urticae* Koch. Anz. Schädlingskd 65: 99-101.

Duke, S. O., F. E. Dayan, J. G. Romagni and A. M. Rimanda. 2000. Natural products as sources of herbicides: current status and future trends. Weed Res 40: 99–111.

Evenhuis N. L. 2007. Checklist of the Orthoptera of Fiji. Bishop Museum Technical Report 38: 1-9.

Fasi, J., G. Brodie and C. Vanderwoude. 2013. Increases in crop pests caused by *Wasmannia auropunctata* in Solomon Islands subsistence gardens. J Appl Entomol 2013: 1-9.

French, B. R. 2006. Insect Pests of Food Plants of Papua New Guinea. Food Plants International. pp. 276.

Frisch, J. E. 1999. Towards a permanent solution for controlling cattle tick. Int J Parasitol 29: 57–71.

Florence, J., H. Chevillotte, C. Ollier and J. Y. Meyer. 2010. Base de données botaniques Nadeaud de l'Herbier de la Polynésie Française. In: Hawaiian Ecosystems at Risk project, University of Hawaii Department of Botany. http://archive.is/www.herbier-tahiti.pf.

Fonseca, D. M., J. L. Smith, R. C. Wilkerson and R. C. Fleischer. 2006. Pathways of expansion and multiple introductions illustrated by large genetic differentiation among worldwide populations of the southern house mosquito. Am J Trop Med Hyg 74: 284-9.

Georghiou, G. P. 1986. The magnitude of the resistance problem. In: Pesticide Resistance: Strategies and Tactics for Management. National Academy Press, Washington, D.C. pp. 14-43.

Ghazanfar, S. A., G. Keppel and S. Khan. 2001. Coastal vegetation of small islands near Viti Levu and Ovalau, Fiji. J Botany 39: 587-600.

Ghosal, S. and S. K. Dutta. 1971. Alkaloids of *Abrus precatorius.* Phytochemistry 10: 195-198.

Global Invasive Species Database. 2010. In: S. Pagad [Ed]. *Abrus precatorius*, accessed on 28 April, 2012 from: http://www.issg.org/database/species/.

Gretzel, U. and K. H. Yoo. 2008. Use and impact of online travel reviews. Information and communication technologies in tourism. Springer, Austria. pp. 35-46.

Gulzar, T., N. Uddin, B. S. Siddiqui, S. N. H. Naqvi, S. Begum and R. M. Tariq. 2013. New constituents from the dried fruit of *Piper nigrum* Linn., and their larvicidal potential against the Dengue vector mosquito *Aedes aegypti.* Phytochem Lett 6: 219-223.

Hata, Y., M. Raith, S. N. Ebrahimi, S. Zimmermann, T. Mokoka, D. Naidoo, G. Fouche, V. Maharaj, M. Kaiser, R. Brun and M. Hamburger. 2013. Antiprotozoal isoflavan qquinones from *Abrus precatorius* ssp *africanus*. Plant Medicai 79: 492-498.

Hidayat, P., T. Philips and R. French-Constant. 1996. Molecular and morphological characters discriminate *Sitophilus oryzae* and *S. zeamais* (Coleoptera: Curculionidae). Ann Entomol Soc Am 8: 645-652.

Hoddle, M. S. 2004. Restoring balance: using exotic species to control invasive exotic species. Conserv Biol 18: 38-49.

Holm, L. P., V. V. Juan, P. P. James and L. Donald. 1979. A geographical atlas of world weeds. John Wiley & Sons, New York. pp. 391.

Holt, J. S. 2009. Management of invasive terrestrial plants. In: MN Clout & PA Williams [Eds]. Invasive Species Management. Oxford University Press, Oxford. pp. 126-140.

Hosking, J. R., B. J. Conn and B. J. Lepschi. 2003. Plant species first recognised as naturalised for New South Wales over the period 2000–2001. Cunninghamia 8: 175–187.

Ibrahim, A. M. 1992. Antihelmintic activity of some Sudanese medicinal plants. Phytother Res 6: 155-157.

Igbedioh, S. O. 1991. Effects of agricultural pesticides on humans, animals, and higher plants in developing countries. Arch Environ Health 46: 218-224.

Jayakumar, V., R. Bhaskaran and S. Tsishima. 2007. Potential of plant extracts in combination with bacterial antagonist treatment as biocontrol agent of red rot of sugarcane. Can J Microbiol 53: 196-206.

Johri, P. K., D. Singh, R. Mourya, D. Tiwari, A. Bajpai and R. Johri. 2004. Ovicidal action and feeding response of certain plant extracts against *Bagrada cruciferarum* (Kirk), *Pieris brassicae* (Linn.) and *Mylabris pustulata* (Thunb). J Appl Zool Res 15: 37-42.

Kardinan, A. and E. A. Wikardi. 1997. The prospect of botanical insecticides on stored food insects management. BIOTROP 59: 199-208.

Kaushik, P. and P. Khanna. 1992. Insecticidal substances from in vivo and in vitro culture of *Abrus precatorius* L. Adv Plant Sci 5: 464-469.

Kere, N. K., J. Keni, J. F. Kere, A. Bobogare, R. H. Webber and B. A. Southgate. 1993. The economic impact of *Plasmodium falciparum* malaria on education investment: a Pacific Island case study. Southeast Asian J Trop Med Public Health 24: 659-63.

Khalsa, H. G., Y. C. Wal and P. N. Agarwal. 1964. Insecticidal properties of *Abrus precatorius* Linn. and *Nerium odorum* Soland. Indian J. Entomol 26: 113-115.

Kingsford, R. T., J. E. M. Watson, C. J. Lundquist, O. Venter, L. Hughes, E. L. Jhonston. 2009. Major conservation policy issues for biodiversity in Oceania. Conserv Biol 23: 834–840.

Kohler, F., F. PeJ Jegrin, G. Jackson, and E. McKenzie. 1997. Diseases of cultivated crops in Pacifie Island countries, *South Pacific Commission*, ISBN 982-203-487-3.

Kong, C. H., P. Wang, C. X. Zhang, M. X. Zhang and F. Hu. 2006. Herbicidal potential of allelochemicals from *Lantana camara* against *Eichhornia crassipes* and the alga *Microsystis aeruginosa.* Weed Res 46: 290–295.

Kriticos, D. J., A. E. A. Stephens and A. Leriche. 2007. Effect of climate change on Oriental Fruit Fly in New Zealand and the Pacific. N Z Plant Prot 60: 271-278.

Kumaran, R. S. and K. Balasubramanian. 2003. Mycotoxic effect of *Abrus precatorius* and *Rauvolfia tetraphylla* root extracts on the growth of *Colletrichum capsici*. Czech Mycol. 55: 51-56.

LaBrecque, G. C. 1981. Integrated Pest Management. IAEA Bulletin 23: 40-42.

LaPointe, D. A., C. T. Atkinson and M. D. Samuel. 2012. Ecology and conservation biology of avian malaria. Ann N Y Acad Sci 1249: 211-226.

Lum, J. K., A. Kaneko, K. Tanabe, N. Takahashi, A. Bjorkman and T. Koyabakawa. 2005. Malaria dispersal among islands: human mediated *Plasmodium falciparum* gene flow in Vanuatu, Melanesia. Acta Trop 90: 181-5.

Macias F. A., J. M. G. Molinillo, R. M. Varela and J. C. G. Galindo. 2007. Allelopathy – a natural alternative for weed control. Pest Manag Sci 63: 327–348.

MacKee, H. S. 1994. Catalogue des Plantes Introduites et Cultivées en Nouvelle-Calédonie. Muséum National d'Histoire Naturelle, Paris. pp. 164.

Madulid, D. A., D. N. Tandang and E. M. G. Agoo. 2009. Assisted natural regeneration and biodiversity in the Philippines. In: P. B. Durst, P. Sajise and R. N. Leslie. Proceedings of the regional workshop on advancing the application of assisted natural regeneration for effective low-cost forest restoration, Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific. pp. 1-30.

Malo, M. 2011. Termite user-pay system costly. The Fiji Tmes. Fiji Times Limited, Suva. pp. 14.

Mallet, J. 1989. The evolution of insecticide resistance: Have the insects won? Trends Ecol Evol 4: 336-340.

Manimegalai, K., C. A. Annapoorani and D. Dhanalakshmi. 2011. Evaluation of larvicidal activity of the leaf and seed extracts of *Abrus precatorius* against *Culex quinqefasciatus* (Diptera: Culicidae). Plant Archives 11: 311-313.

Merfield, C. N., I. J. Geary, R. J. Hale and S. Hodge. 2015. A field evaluation of the effectiveness of mesh crop covers for the protection of potatoes from tomato potato psyllid. New Zeal J Crop Hort Sci (in press).

Motooka, P. C., N. Luisa, D. N. Guy and C. Lincoln. 2003. Weeds of Hawaii's pastures and natural areas; An identification and management guide. College of Tropical Agriculture and Human Resources, University of Hawaii, pp. 184.

Muthukrishnan, J., E. Pushpalata and A. Kasthuribhai. 1997. Biological effects of four plant extracts on *Culex quinquefasciatus* say larval stages. Insect Sci Appl 7: 389-394.

Mwine, J., P. V. Damme, J. Kamoga, C. Kudamba, M. Nasuuna and F. Jumba. 2011. Ethnobotanical study of pesticidal plants used in Southern Uganda and their need for conservation. J Med Plant Res 5, 1155-1163.

Nakawiroat, P., S. Visetson, J. Milne and C. Sudthongkong. 2007. Efficiency of deadly crab's eye extracts (*Abrus precatorius* L.) against oriental fruit fly (*Bactrocera dorsalis Hendel*) In: The 5th International Symposium on Biocontrol and Biotechnology. Mongkut's Institute of Technology Ladkrabang, Khon Kaen University, Nong Khai Campus, Nong Khai, Thailand. pp. 174.

Nazar, S., S. Ravikumar, G. P. Williams, M. S. Ali and P. Suganthi. 2009. Screening of Indian coastal plant extracts for larvicidal activity of *Culex quinquefasciatus*. Indian J Sci Technol 2: 24-27.

Olson L. J. 2006. The economics of terrestrial invasive species: a review of the literature. Agr Resource Econ Rev 35: 178–194.

Pacific Islands Pest List Database. 2015. Plant protection Service, Secretriat of the Pacific Community, Fiji; http://www.spc.int/pld/.

Paine, R. W. 1968. Investigations for the biological control in Fiji of the coconut stick-insect *Graeffea crouanii* (Le Guillou). Bull Entomol Res 57: 567-604.

Patel, B. M. and N. B. Chauhan. 2013. Indigenous and scientific knowledge of the farmers about various agricultural uses of neem. Agric Sci Dig 33: 131-134.

Pimentel, D. 2009. Pesticides and pest control. In: R. Peshin & A. K. Dhawan [Eds.] Integrated Pest Management: Innovation-Development Process. Springer, Holland. Pp. 83-87.

Prasad, R. R., G. Brodie, Vanderwoude and C. S. Hodge. 2015. Extracts of the rosary pea, *Abrus precatorius,* are toxic to the invasive termite, *Coptotermes gestroi.* Weta (in press).

Pyke, C. R., R. Thomas, R. D. Porter, J. J. Hellmann, J. S. Dukes, D. M. Lodge. 2008. Current practices and future opportunities for policy on climate change and invasive species. Conserv Biol 22: 585-592.

Randall, R. P. 2007. The introduced flora of Australia and its weed status. CRC for Australian Weed Management, Department of Agriculture and Food, University of Adelaide-Waite Campus, Western Australia. pp. 13.

Reda, A. S., N. Z. Dimetry, S. A. A. Amer and S. El-Gengaihi. 1990. The role of *Abrus precatorius* alkaloid on settling, reproduction and development in *Tetranychus urticae* Koch. Ann Agri Sci 28: 2643-2653.

Reda, A. S., N. Z. Dimetry, S. A. A. Amer and H. M. Motawe. 1989. Activity of *Abrus precatorius* L. extracts and compounds isolated on orientation and oviposition behaviour of the two-spotted spider mite *Tetranychus utticae* Koch. J Appl Entomol 107: 395-400.

Reddy P. V. R. and J. Srikanth. 1996. Effect of plant extracts on larval parasitoid *Cotesia flavipes* (Cameron) and its parasitisation efficacy. Insect Environ 2: 106-108.

Sakthivadivel, M. and T. Daniel. 2008. Evaluation of certain insecticidal plants for the control of vector mosquitoes viz. *Culex quinquefasciatus*, *Anopheles stephensi* and *Aedes aegypt*i. Appl Entomol Zool 43: 57-63.

Sandler, H. A. 2010. Integrated Pest Management. In: UMass Cranberry Station Best Management Practices Guide. pp. 11-15.

Satyasree, J. G. 1999. Biochemical characterization of Abrus lectins, toxins and aggulutinins. Ph.D, University of Hydrabad, Hyderabad. pp. 70.

Saxena N., P. Yadav and O. Kumar. 2013. The Fas/Fas ligand apoptotic pathway is involved in abrin-induced apoptosis. Toxicol Sci 135: 103-118.

Scott I. M., H. Jensen, J. G. Scott, M. B. Isman, J. T. Arnason and B. J. R. Philogène. 2003. Botanical insecticides for controlling agricultural pests: piperamides and the Colorado potato beetle *Leptinotarsa decemlineata* Say (Coleoptera: Chrysomelidae). Arch Insect Biochem Physiol 54: 212–225.

Setiawan K. H., D. Tarmadi, A. H. Prianto and S. Yusuf. 2009. Termicidal activities of *Abrus Precatorius* L. leaves extract against subterranean termite *Coptotermes gestroi*. In: W. Diwanto & A. Kusumaningtyas [Eds]. Proceedings of The First International Symposium of Indonesian Wood Research Society. IWORS. pp. 212-215.

Sinchaisri, N., D. Roongsook and N. Chungsamarnyart. 1990. Efficacies of plant-crude extracts on the Diamond Back Moth larvae. Kasetstar J Natural Science 24: 49-53.

Singh, S. and D. K. Singh. 1999. Effect of molluscicidal components of *Abrus precatorius*, *Argemone mexicana* and *Nerium indicum* on certain biochemical parameters of *Lymnaeu acuminata*. Phytother Res 13: 210-213.

Singh, S. and D. K. Singh. 2000. Effect of active molluscidal components of *Abrus precatorius*, *Argemone mexican* and *Nerium indicum* on certain enzymes in the nervous tissue of *Lymnae avuminata*. J Sci I R Iran 11: 187-194.

Smith, A. C. 1985. Flora *Vitiensis nova*: a new flora of Fiji. NTBG 3: 758.

Space, J. C., B. M. Waterhouse, M. Newfield and C. Bull. 2004. Invasive plant species on Niue following cyclone Heta. United Nations Develeopment Program NIU/98/G31, United Nations, Rome. pp. 37.

Stillmark, H. 1888. Ueber Ricin, ein giftiges Ferment aus dem Samen von *Ricinus communis* L. und einigen anderen Euphorbiaceen. Arb Pharmak Inst Dorpat 3: 59-151.

Sussman, R. W. and A. Rakotozafy. 1994. Plant diversity and structural analysis of a tropical dry forest in southwestern Madagascar. Biotropica 26, 241-254.

Talat, S. 2007. The effect of different mediterranean plant extracts on the development of the great wax moth Galleria mellonella L. (Lepidoptera: Pyralidae) and their toxicity to worker honeybees Apis mellifera L. (Hymenoptera: Apidae) under laboratory conditions. Int J Food Agric Environ 5, 289-294.

Thaman, R. R., S. Takeda, S. Robinsom, T. Fong and A. W. Whistler. 2007. Vascular plants of Nukulau island. The University of the South Pacific, Suva, Fiji. pp. 2.

Ware, G. W. 1980. Effects of pesticides on nontarget organisms. Residue Rev 76, 173-201.

Wiesbrook, M. L. 2004. Natural Indeed: Are natural insecticides better and safer than convential insecticides? Illinois Pesticide Rev 17: 3.

Whistler, A. 1992. Flowers of the Pacific Island Seashore. University of Hawaii Press, Honolulu. pp. 154.

Whistler, A. 1998. A study of the rare plants of American Samoa. The US Fish and Wildlife Service Honolulu, Hawai'i. pp. 15.

Whistler, A. 2010. Botanical survey for *Bidens micrantha* subsp. *ctenophylla* at Kamakana villages North Kona, island of Hawai'i. US Department of the Inteior, Fish and Wildlife Services, Honolulu, Hawai'i. pp.1-22.

Wilson, E. O. 2002. The future of life. Random House, New York, United States. pp. 256.

Xiao, Z. H., F. Z. Wang, A. J. Sun, C. R. Li, C. G. Huang and S. Zhang. 2012. New triterpenoid saponin from *Abrus precatorius* Linn. Molecules 17: 295-302.

Zaitoun, S. T. 2007. The effect of different mediterranean plant extracts on the development of the great wax moth *Galleria mellonella* L. (Lepidoptera: Pyralidae) and their toxicity to worker honeybees *Apis mellifera* L. (Hymenoptera: Apidae) under laboratory conditions. Int J Food Agric Environ 5: 289-294.