Allelopathic Plants in the Malay Archipelago

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Abstract: The Southeast Asian nations of Brunei, Indonesia, Malaysia and the Philippines, otherwise also known as the Malay World constitute the three mega biodiversity centres of the world with record numbers of species of fauna and flora. Recent estimates indicated that these countries, especially the tropical rain forests, are reservoirs of no less than 150,000 flowering plant species, 5,200 species of orchids, 1,750 palm species, 3,500 fern species, 2,800 species of mosses, lichens and liverworts. A sizeable number of these plant species are allelopathic in nature, and contain allelochemicals that are released into the environment thereby having beneficial or deleterious effects on other organisms. Bioprospecting activities in the tropical forests of the Malay Archipelago among plant species have yielded a host of phytochemicals and allelochemicals. Others include *the* alkaloid - solasodine a steroid that is used to synthesize sex steroid hormone to prevent birth). Some of the plants from the Archipelago which have been used as herbal medicines are now fortified by scientific research that certain plant species contain active chemical constituents possessing pharmaceutical properties capable of relieving body and organ ailments. Two most important plant species with great pharmaceutical and nutraceutical values are *Eurycoma longifolia* Jack. otherwise known as Pasak Bumi or Tongkat Ali in Malaysia and Indonesia, and the Bintangor tree (*Calophyllum lanigerum* Miq.) and C. *teysmannii* var. *inophylloide* (King.) P. F. Stevens. The extract from Tongkat Ali is known to have aphrodisiac and other medicinal properties. *Eurycoma longifolia* has become popular for its testosterone-enhancing properties. The root extract has therefore been included in some herbal supplements in Indonesia and Malaysia for antimalarial, antipyretic, antiulcer, cytotoxic and aphrodisiac properties. The active compound in Tongkat Ali is glycosaponins and eurypeptides. Eurypeptides are large-chain amino acids that are responsible for the testosterone enhancing effects in Tongkat Ali. The Bintangor tree contains potent chemical component, selonide B which has been found to be critical element in the cocktail AIDS vaccine. Other important constituents include the possible HIV-inhibiting compounds: calanolide A, costatolide (also known as calanolide B), and new pyranocoumarins were calanolide E2, cordatolide E, pseudocordatolide C, and calanolide F, along with a simple prenylated coumarin precursor. The rich flora of Malay Archipelago could be harnessed for wealth creation by the populace at large and the nations in particular with respect to producing nutraceuticals, cosmeceuticals, herbals, and industrial and biotechnological products, and pharmaceuticals. The isolation and properties of these phytochemicals and allelochemicals as well as the largely unchartered territories of nutraceutical and pharmaceutical constituents of these plants, and their potential utilization in traditional and modern agriculture and pharmaceutical industry remain a formidable challenge to scientists in the region. With government and private sectors pledging commitment and re-emphasis on R & D in agro-forestry, particularly in biotechnology, economic utilization of plants will take centre stage for many years to come.

Keywords: Allelopathy, allelochemicals, phytochemicals, plant species, Malay Archipelago

1. Introduction

The Malay Archipelago, otherwise known as the “Malay World” comprises of the South-east Asian nations of Brunei, Indonesia, Malaysia and the Philippines with a total land area exceeding 2,540,000 km^2 and exclusive economic zones of 96,000 km^2 (Fig. 1). Together these countries are home to several hundred thousands species of flora and fauna and constitute three of the mega-biodiversity centres of the world. Recent estimates indicated that these countries, especially the tropical rain forests, are reservoirs of no less than 150,000 flowering plant species, 5,200 species of orchids, 1,750 palm species, 3,500 fern species, 2,800 species of mosses, lichens and liverworts [Mohamed Osman, *pers. comms.* 2009]. For example, an area of 100 m x 100 m contains no less than 5, 000 plant and animal species. Interestingly, these countries also constitute the major exporters of the world’s best timbers, wood and forest products. In the same vein, it is from biodiversity to wealth creation with measurable direct economic benefits to the populace at large and to the nations in particular for these countries. Biodiversity provides timber and non-timber goods in the forestry sector; food and industrial crops in the agricultural sector; food in the fisheries sector; products and services for tourism industry; and biological resources for biotechnology. Invariably, their importance has been intensified covering many phases of national development spanning for the past 40-50 decades. Interestingly, the rubber-oil palm-cocoa booms in much of the Malay World, including Thailand and Vietnam for the past decades were all based on the exotic plant species, imported from Africa and South America!

On the home front, rubber and palm oil research recognized globally while innovative pollination methods has saved the palm oil industry RM200 million annually. With rubber wood research has spawned a multi-million ringgit furniture industry the Federal Land Development Authority (FELDA) in Malaysia has been upheld worldwide as an effective economic solution for rural empowerment and amelioration of poverty are all outstanding Malaysian examples where biodiversity contribute to wealth creation.

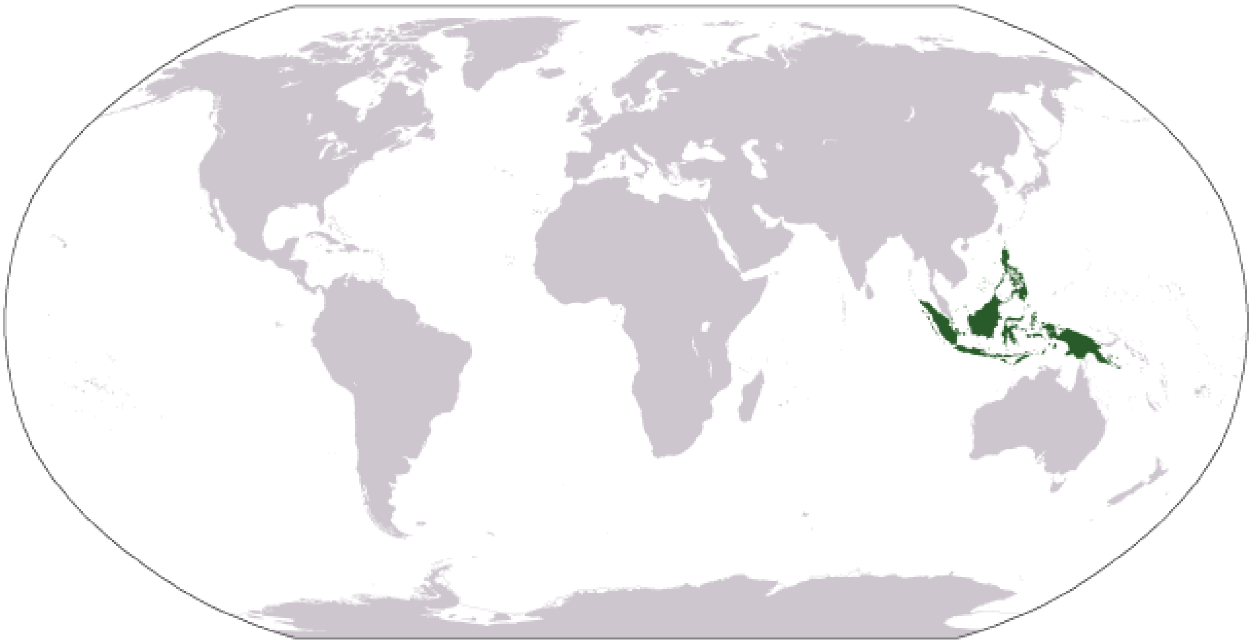

Figure 1. The Malay Archipelago (■)

The ensuing discussion centres on the tripartite link between mega-biodiversity, phytochemicals and allelopathy in the Malay Archipelago. Short discourses on why allelopathy becoming increasingly fashionable in this millennium and the dichotomous nature of allelopathy with phytochemical are also highlighted. Discussion briefs on the possible roles of allelopathy and traditional and modern agriculture are also made. This communication ends with brief notes on recent initiatives and developments in allelopathy research in Indonesia, Malaysia and the Philippines. Future trends are also discussed.

2. Mega-Biodiversity, Phytochemicals and Allelopathy – The Link

The mega-biodiversity of the Malay Archipelago could be harnessed for the benefits of mankind at large. The tropical forests of Brunei, Indonesia, Malaysia and the Philippines are actually phytochemical laboratories in nature. Scientists in Indonesia, Malaysia and the Philippines are actively engaged in isolating active compounds from plants and these active compounds besides having the nutraceutical and pharmaceutical properties are also allelopathic in nature. This is evident from the number of scientific papers published covering various aspects of phytochemistry and allelopathy of tropical plants and patents sought for products obtained from such studies. It is not an exaggeration today that allellopathy and phytochemistry are directly link to mega-biodiversity status of the Malay Archipelago as such.

a) Phytochemicals and Allelopathy – The Dichotomy

The need to understand or identify phytochemical constituents from plants or the secondary metabolites produced by plants, algae, bacteria, and fungi that influences the growth and development of agricultural and environmental systems is the underlying principle of the dichotomous nature of phytochemicals and allelopathy. This makes phytochemistry and phytochemicals as the frontage of allelopathy. In fact, the initial pathway to allelopathy research begins with phytochemical analysis and screening with sequential characterization of allelochemicals entity followed by allelopathic tests prior to the commercialization of allelochemical products.

b) Plant Species and Allelochemical Entities

Different plant species would exudes different allelochemicals as bio-communicators in juxtaposition either in balanced or imbalanced quanta and manner probably explained their prevalence in a community or communities. It is an uphill task for any body to try to explain this juxtaposition of plant species in a tropical rainforests of the Philippines, Malaysia and Indonesia. Further, our knowledge on the allelochemical entities of individual plant species, let alone those in tropical rainforest dipterocarp communities, and their multi-facet roles is very limited. Nevertheless, bioprospecting work is being done on plant species that show great potentials not only as allelochemicals but also as nutraceuticals and pharmaceuticals. This is exemplified by *Eurycoma longifolia* of the family in the family Simaroubaceae, otherwise known as Pasak Bumi or Tongkat Ali in Malaysia and Indonesia. The extract from this plant is known to have aphrodisiac and other medicinal properties. *Eurycoma longifolia* has become popular for its testosterone-enhancing properties. It has therefore been included in some herbal supplements for bodybuilders. Historically, South East Asian countries of Indonesia and Malaysia has utilised the herb for its suggested antimalarial, antipyretic, antiulcer, cytotoxic and aphrodisiac properties [Johari Saad, *pers. comms.*]. The active compound in Tongkat Ali is glycosaponins and eurypeptides. Eurypeptides are large chain amino acids that are responsible for the testosterone enhancing effects in Tongkat Ali. It is also important to verify if the Tongkat Ali extract contains any maltodextrine or other fillers [1–6]. Another plant species with special properties is the Bintangor tree (*Calophyllum lanigerum*). The potent chemical component, Selonide B has been found to be critical element in the cocktail AIDS vaccine, which is currently being developed by scientists from Sarawak in collaboration with its partners in the United States. Other important constituents include the possible HIV-inhibiting" compounds: Calanolide A could be extracted from the leaves and twigs, and Costatolide (also known as Calanolide B) from the latex (sap) of the tree. These are two out of 150,000 plant species found in the Malay Archipelago, not to mention thousands of species of palms, orchids, mosses, liverworts, lichens, etc. prevailing there.

c) Allelopathy in Vogue

Following the universal definition of allelopathy as plant interference mediated through release of chemicals by one species into the environment of another via roots, rhizomes, leaves, stems, and litter, allelochemicals could have beneficial or deleterious effects on other organisms when prevailing as sympatric species. These dichotomies in effect could be translated to have possible role as chemical plant defences, repellants, and toxicants. Further these allelochemicals being secondary plant metabolites include a host of alkaloids, terpenes, steroids, flavonoids, organic acids, aldehydes, aromatic acids, or simple saturated lactones and tannins, could be considered as evolutionary expressions of quiet antagonism of a plant species to its enemies/competitors.

Bio-economy has become increasingly prominent of in the 21st century. This argument is based on the fact that organic farming and natural agriculture taking centre-stage to off-set heavy reliance on agrichemicals namely pesticide, inorganic fertilizers and other xenobiotics. For examples there is global growing interest in organic farming in Brazil, Argentina China, Canada, USA, India, and Europe. Increasing use of “green products” in agricultural pursuits, (cover crops, weed and pest management), pharmaceuticals, and waste management are testimonies to these new trends in human endeavour for the betterment of the world populace at large. This is in tandem with increasing environmental health awareness by world’s populace. Could it be that allelopathy has become fashionable in the way we management our pests and environment? Or is allelopathy in vogue among scientists, pests and weed management practitioners worldwide? However, the practical application of allelopathy on large-scale everyday agriculture and environmental health management, production of pharmaceuticals remains elusive [Mortimer, *pers. comms.*]. This is because the isolation, purification and production of allelochemicals for agriculture/environmental health management/production of pharmaceuticals are still expensive/needs technique perfection for mass adoption on large scale. There are ample evidences that allelopathy impacts on agriculture and environmental health, and that allelopathy may explain how specific colonizing taxa become invaders in other ecosystems [7]. Following the arguments of Macías *et al.* [8] who expounded allelopathy as “biocommunicator” where every single chemical or mixture of chemicals employed by living organisms to exchange information, the link between allelochemicals, biocommunicator and plant growth hormones in allelopathic actions is implicit. If this argument is true then, a climax forest community is where individuals trade in bio-communicators and exist at equilibrium [9]. On the other extreme, the *Avicennia alba* dominated coastal mangrove forest community in many tropical countries including the Malay Archipelago, are in essence the ability of less dominance plant species to tolerate the exudates released by *A. alba*, or there are trade-offs among the sympatrics prevail. In the same vein, the *Dicranpteris linearis* dominated weed community in the many parts of Malaysia is indeed the manifestation of allelopathy in nature [7].

d) Allelopathy in Traditional and Modern Agriculture

Among the strategies employed include using allelopathic plants in crop rotations, as companion plants, and smoother crops. Japan, Korea, India, China, and Brazil are leaders in this technology. Using phytotoxic mulches and crop covers in weed management, also in non-tillage systems. Malaysia leads in this technology especially in rubber, oil palm and cocoa estates. Japan, India, Korea and Brazil are other leaders in this technology. Within the context of biotechnology, gene transfer of allelopathic traits into commercial crops. Geniticists and molecular biologists in USA are involved in this area of research. Others used natural or modified allelochemicals as herbicides. It is envisaged that these allelochemicals as new class of herbicides would help overcome resistance following repetitive use of synthethics. Moreover, great specificity of allelopathic effects development of highly specific herbicides. Other benefits include mulches, residues and cover crops allow exploitation of phytotoxic activity of allelopathic plants in weed management. *Calopogonium, Pueraria*, and *Stylosnathes* species are widely used in between row crops of rubber and oil palm in Malaysia to smoother weeds while at the same time fixing nitrogen to the soils (Fig. 1). The fact that allelochemicals are natural products would allow them be progressively degraded, thus considered as "environmentally soft". Further, development of new transgenic crop cultivars with allelopathic properties would reduce lower amounts of herbicides, with ensuing benefits to the environment.

3. Allelopathy, Phytochemistry, and Synthesis of Bioactive Compounds – Recent Developments and the Future

Another tripartite link for the future would be between allelopathy, phytochemistry and the synthesis of bioactive compounds. In this respect scientists in the Malay Archipelago be it in the Philippines, Indonesia and Malaysia are actively involved in the search for bioactive compounds principally from plants [10–15]. Others are active in assessing allelopathic effects of plant species against another [16–22]. The list is by mean exhaustive. The Centre for Natural Products Research (CENAR), University of Malaya, for example, is very active in pursuing research on natural products from natural plant and animal sources for medicinal, food additives and supplements, and allelochemicals. In this respect a sizeable number of papers wee published on the phyotchemical constituents of *Eurycoma longifolia*, *Calophyllum lanigerum*, *Phyllanthus* spp. *Tinospora crispa, Orthosiphon stamineus, Melastoma malabathricum).* Invariably, the phytochemical reservoirs of the mega-biodiversity centres of the Malay Archipelago remain the primary source for future research endeavours for nutraceutical, pharmaceutical and food supplements.

a) Recent Initiatives and Developments in Phytochemistry and Allelopathy and Synthesis of Bioactive Compounds Research

While there is plethora of data on phytochemistry and allelopathy research in the Malay Archipelago in the last 50 years, we highlight here some of the salient findings that we regard as those with high impact on the society at large. Two plant species of special importance in this regard are the Tongkat or Pasak Bumi (*Eurycoma longifolia* in Malaysia and Indonesia, and the Bintangor tree (*Calophyllum lanigerum* Miq.). The extract from Tongkat Ali is known to have aphrodisiac and other medicinal properties. *Eurycoma longifolia* has become popular for its testosterone-enhancing properties. The root extract has therefore been included in some herbal supplements in Indonesia and Malaysia for antimalarial, antipyretic, antiulcer, cytotoxic and aphrodisiac properties. The active compound in Tongkat Ali is glycosaponins and eurypeptides. Eurypeptides are large-chain amino acids that are responsible for the testosterone enhancing effects in Tongkat Ali. The Bintangor tree contains potent chemical component, selonide B has been found to be critical element in the cocktail AIDS vaccine. Other important constituents include the possible HIV-inhibiting compounds: calanolide A, costatolide (also known as calanolide B), and new pyranocoumarins were calanolide E2, cordatolide E, pseudocordatolide C, and calanolide F, along with a simple prenylated coumarin precursor.

b) Recent Developments

For any meaningful development in allelopathy research, one cannot escape discussing the parallel development in research on phytochemistry and biosynthesis of active compounds from plants and related organisms. In fact, assessment on the allelopathic activity of a plant exudates or resultant metabolites from micro-organisms responsible for degradation of cellulosic materials and litters in soils will be incomplete without the knowledge on the phytochemical entities themselves. We highlight some of the interesting recent development in allelopathy research with parallel discussion on phytochemicals and where possible on the biosynthesis of active compounds.

Among the crops, rice is known to have variety-mediated allelopathic activities with varying degrees. Azmi *et al*. [23] screened more than 300 varieties of both traditional and modern rice varieties in Malaysia. Of these, traditional varieties, *viz.* – Siam Er54, Jambok, Wangi, Padang Gelap, Acheh Puteh, Pasir, Singora, Merah Isi, Chatewk Kuning, Anak Naga & Anak Didek 3 displayed allelopathic activity. So were modern rice varities such as MR84 & MR77. Interestingly, common rice weeds such *Cyperus rotundus, Sagittaria guyanesis* and *Fimbristylis miliaceae* were also allelopathic. Chong & Ismail [7] recorded higher content of water-soluble phenolic compounds in *Dicranopteris linearis* infested soils (IS) (3.12 mg/100g *vis-a-vis* 1.44 mg/100g in non-infested soils (NS). They also recorded zero seedling emergences of *Ageratum conyzoides* and *Echinocloa colona* when planted in infested soils. Interestingly, the I_{50} of seed bioassay in IS compared with NS ratio of 99.55:0.45. The parallel figures for I_{50} for fresh weight of seedling bioassay in NS compared with NS ratio was 81:19, while the I_{50} for plant height of seedling bioassay in NS *vis-a-vis* NS ratio of 90:10. *Cuscuta campestris* contains alkaloids, terpenes and flavonoids [14]. They recorded varying allelopathic activity with aqueous extracts of *C. campestris* when tested on more than 80 crop and weed species. Faravani *et al.* [24] and Faravani [15] identified several secondary metabolites from *Melastoma malabathricum*, including such as hexacosanoic acid, gallic acid, flavonoids and flavonoids glycosides, phenolics, triterpenes, tannins, saponins and steroids. These terpenoid, flavonoid and phenolic compounds may have allelopathic potential. The ensuing growth of comsumptive roots and shoots of the barnyardgrass was very much affexcted when exposed to methanol extracts of *M. malabathricum*. Further analyses yielded 3 urs-12-ene pentacyclic triterpenoids, viz. ursolic acid, 2*α*-hydroxyursolic acid and asiatic acid, *β*-sitosterol 3-*O*-β-D-glucopyranoside, glycerol 1,2-dilinolenyl-3-*O*-*β*-D-galactopyranoside, and glycerol 1,2-dilinolenyl-3-*O*-(4,6-*O*-isopropylidene)-*β*-D-galactopyranoside were isolated from leaves of *M. malabathricum.* Pure compound of asiatic acid was very active against *Bacillus cereus* and *Staphylococcus aueres*. The flowers of *M. malabathricum* contain a host of compounds, namely, ellargic acid & 6 flavonoids, viz. quercetin, kaempferol, kaempferol 3-*O*-α-L-rhamnopyranoside, kaempferol 3-*O*-β-D-glucopyranoside, kaempferol 3-*O*-β-D-galactopyranoside & kaempferol 3-*O*-(2",6"-di-*O*-*E*-*p*-coumaryl)-β-D-galactopyranoside. Among these ellargic acid, kaempferol and quercetin most active compounds. Other studies conducted elsewhere yielded four flavonoid aglycones, chrysoeriol, 3',5'-demethyl myricetin, naringenin and aureusidin, whereas 2-D chromatography technique managed to detect chrysoeriol-7-glucoside, naringenin and aureusidin- 4-rhamnoside & 3,5-*O*-dimethylmyricetin, all these substances were detected in each and every group of *in vitro* seedlings of *M. malabathricum* but auresidin and auresidin-4-rhamnoside could not be detected in the mother plant. Purification of the methanol extract chromatographic method afforded quercetin.

Another plant species displaying allelopathic potential was *Chromolaena odorata*. Leaf litters of this plant yielded phytoparasitic nematode repellant compounds while fresh leaf extracts was efficacious against the burrowing nematode (*ca.* 80% mortality against *Radopholus similis)* while essential oils have insecticidal /bactericidal properties such as bactericidal action on *Staphylococcus aureus* and *Escherichia coli*. Toosi & Baki [25] reported bioherbicidal activities from aqueous extracts of *Brassica juncea* (L.) Czen. var. Ensabi against barnyardgrass and radish seedlings. Fresh extracts of at 300 g/L of *Brassica juncea* (L.) Czen. var. Ensabi reduced germination of radish and barnyardgrass by 38% -45%, respectively while dry extracts at 300 g/L of *B. juncea* totally inhibited germination and shoot and root growth of barnyardgrass and radish. The entities of allelochemical constituents in *B. juncea* extracts are being ascertained.

Umi, K. Y. *et al.* [10] conducted detailed analyses on the phytochemical constituents of *Mimosa* aggregates in Malaysia. They isolated a host of quercetins, kaempferols, luteolins, and acacetins from the aggregates. The detailed constituents are listed in Table 1. Three of the flavonoids were quercetin 3-glucoside 7-rhamnoside, kaempferol 3-rhamnoside, and acacetin 7-rutinoside.

A significant finding in the use of plant extracts for crop yield booster was developed by a research team in the University of Malaya [26]. This foliar-applied photosynthesis enhancer commercially known as SBAJA™ contains plant and other organic extracts – HUTRIOL™ as the main ingredient. Extensive multi-location field trials with SBAJA™ on rice covering more than 1000 ha for seven seasons involving more than 100 farmers registered measurable increase in rice tonnage by 20–38%. In Tanjung Karang granary this increase in rice yields was from

6.2–6.5 tons/ha in the normal NPK fertilizer regime of 100:30:20 to 7.8–8.9 tons/ha or 25–38% increase when augmented with SBAJA^{TM} application. In the MADA and KADA granaries of Kedah and Kelantan recorded 20–25% increase in rice yields. In the farm blocks of Sungai Besar some farmers get 10 tons/ha while their counterparts in Sekinchan get 12 tons/ha as a result of SBAJA^{TM} application. Extensive field trials in Kedah with SBAJA^{TM} on corn yielded 50% increase compared with those control plots. Based on a conservative yield increment of just 1 ton/ha, rice farmers in Malaysia can reap an extra income of US$ 428/ha/season with SBAJA^{TM} spray. We have witnessed many farmers reaping bigger increments in rice yields following SBAJA^{TM} application [26].

From the forest of Sarawak, a tree species belonging to the family Rutaceae yielded several isomers of pyrethroids [Baki, B. B. *unpublished data*]. Preliminary trials of ethanol, DCM and methanol extracts of the tree barks and leaves have shown promising results as very strong insect repellants and toxicants. A number species of plant parasitic nematodes were also susceptible to the extracts. Our scientists are perfecting the techniques of isolation and purification of the compounds from this tree species and we hope to pattern our findings.

Table 1. Distribution of the flavonoids in *Mimosa* species*

Compounds	*M. Pudica*	*M. Quadrivalvis*	*M. Pigra*	*M. invisa*
Quercetin 3-Rha	+++	+	+	+
Quercetin 3-G-7-Rha	–	+++	–	–
Quercetin 7-Rha	++	++	++	++
Quercetin 3-Rut	+++	++	++	++
Quercetin 3,7-diRha	+++	–	++	++
Kaempferol 3-Rha	+++	++	++	++
Kaempferol 3,7-diRha	–	–	+++	+++
Kaempferol 3-Rut	++	+++	–	–
Kampferol 7-Rut	+++	–	–	–
Kampferol 3-G-7Rha	+++	–	–	–
Luteolin 3’ -Xyl	++	+++	–	–
Luteolin 7-Arab	–	+++	++	++
Acacetin 7-Rut	+++	++	–	–

***Umi, K. Y., *et al.* [10]

c) Future trends

With fluid, restive and uncertainly in global economic situation, it would be equally difficult to predict future trends in research activities on allelopathy and the screening and development of bioactive xenobiotics in Malaysia, Indonesia and the Philippines. Nevertheless, with the opening of regional economic regions in Malaysia namely NCER (Perlis, Kedah, Penang, Northern Perak); ECER (Kelantan, Trengganu & Pahang); Iskandar Malaysia (Johore); SCORE (Sarawak), and SREZ (Sabah) as well as the regional development such as those involving Sabah, southern Philippines and eastern Indonesia, and northern Sumatra in Indonesia, southern Thailand and northern Peninsular Malaysia more active research collaboration along these lines are envisaged. Concerted activities involving more fundamental studies on phytochemical analyses and screening of allelochemicals from plants in countries of the Malay Archipelago with pharmaceutical, nutraceutical and allelopathic potentials, as well as the ensuing identification and development of potential bioactive substances for use in pharmacy, food supplements, agriculture (pesticides, allelopathy, etc.) are needed.

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