

## Influences of Environmental Conditions to Phytoconstituents in *Clitoria ternatea* (Butterfly Pea Flower) – A Review

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**Abstract:** Extreme environmental conditions will consequently become a disturbance on all phases of plant growth. Malaysia is one of the developing countries that face challenges of extreme environmental conditions from climate change such as water availability and soil salinity. In response to global climate change, plants are trying to survive through several adaptation mechanisms. *Clitoria ternatea* or also known as Butterfly pea flower is a potential plant that can tolerate different environmental parameters. Besides, *C. ternatea* contains essential phytochemical compounds for pharmaceuticals, textile, medicinal and food industries. *C. ternatea* is originated from tropical Asia countries and it is widely available in the Asian region. Butterfly pea flower has attractive petal colours due to the presence of its bioactive compounds. *C. ternatea* is claimed as curing various ailments and has great antioxidant activity due to their bioactive compounds such as anthocyanins, alkaloid, steroid, tannin, reducing sugars and flavonoid. *Clitoria ternatea* has been evaluated as a potential medicinal plant, such as antiviral, anti-inflammatory, anti-allergic and prevent from cardiovascular damage. Meanwhile, by varying different environmental parameters, the adaptations of phytochemical in *C. ternatea* is expressed variously. Hence, this paper reviews the physiological effect of growth conditions on *Clitoria ternatea* and its effect on the production of beneficial phytoconstituents.

**Keyword:** *Clitoria ternatea*; Butterfly pea flower; environmental impacts; phytoconstituents; climate change;

### 1. Introduction

The physiological processes in plants during stress and the adaptation of plants towards extreme environments may alter the metabolite profiles. The naturally occurring secondary metabolites in plants, including various elicitors, may overcome the stress conditions. The local geoclimate-, and external conditions such as water, soil aeration and soil fertilizer affect the composition of bioactive compounds. Malaysia is rich in species diversity and hosts approximately 12,500 species of flowering plants and 185,000 species of fauna, which are endemic to tropical forestry in the region [1]. *Clitoria ternatea* is moderately resistant to abiotic stress regardless of its beneficial phytoconstituents that could be applied in the industrial sector.

*Clitoria ternatea* is a tropical flower that is widely found growing in gardens and also in the wild. *Clitoria ternatea* is also known as butterfly pea and blue pea in various countries [2]. *C. ternatea* is very easy to grow and maintain. Butterfly pea flower is a plant species

that is in the Fabaceae family. *C. ternatea* classified as kingdom Plantae, phylum Tracheophyta, class of Magnoliopsida and a family of Fabaceae. Morphologically, *C. ternatea* is a herbaceous perennial legume and can vary with different growing conditions. The plant is a native to Zimbabwe, Ghana, Guinea, Malaysia and Indonesia. However *C. ternatea* has been introduced to tropical Australia, America and South Africa [3]. Since *Clitoria ternatea* is widely spread over many countries, it is also known by many common names. For Malaysia it is 'bunga telang', while in Konkani it is 'shankha pushpa' and 'gokarna' [4] blue-pea, cunha (Brazil), pokindong (Philippines), kordofan pea (Sudan), Kokkattan (Tamil), Aparajita (Bengali) and also Aparajit in Hindi [5].

In Ayurveda medicine, *Clitoria ternatea* is considered as a nootropic herbs (Medhya-Rasayana) comprising herbs such as *Conscora decusata* (Gentianaceae), *Evolvulus alsinoides* (Convolvulaceae) and *Convolvulus pluricaulis* (Convolvulaceae).

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Ecologically, the butterfly pea flower commonly prefers full sunlight, however sometimes partially shaded is more favourable. Seeds can be germinated by soaking them in water overnight [6]. Germination occurs within 1-2 weeks while flowering occurs within 4 weeks. The propagation for *Clitoria ternatea* includes the stems which are fine twinning as it can grow to 3 m long. Other than that, the leaves are pinnate with 7 leaflets. Leaflets are nearly orbicular or ovate 3 cm wide (max) and 5cm long (max) [7].

The flower can either be single or paired with colour ranging from white, mauve, light blue to dark blue and the size is 9 mm long [8]. Pedicels can grow to 4-9 mm long and bracteoles are around 12 mm long, broadly ovate or rounded. The campanulate calyces can grow to 2.2 cm long (max). The flower lobes can either be oblong or triangular where it can grow up to 1cm long and is acute or acuminate [9]. Besides that, the standard flower is 2-4 cm wide funnel-shaped, rounded or with notched apex, and can reach to 5.5 cm long.

The pods of *Clitoria ternatea* is flattened and is linear-oblong with size 4-13 cm long, and 0.9-1.2 cm wide [10]. Butterfly pea flower pods have thickened margins and pale brown in colour. When in dry conditions, *Clitoria ternatea* will dehiscence. Each pods has 6-10 seeds. The seeds are 5-7 mm long and 3-4 mm wide which is often mottled, brown and shiny [11]. Moreover, it adapts easily to a wide range of different types of soils with different pH.

It has been reported that butterfly pea flower plays an important role in nervine medicine as well as improving brain system and boosting memory [12]. In terms of *C. ternatea* as a medicinal plant, the whole part of the plant is beneficial for medical treatment. The juice extract from the flowers of *C. ternatea* has been reported to cure skin diseases and insect stings [13]. The roots are used to treat inflammation, burning sensation, in ophthalmology, amentia, asthma, ascites and hemicranias [14]. In addition, the stem, root and flower of *C. ternatea* are recommended for the treatment of animal sting, such as snakebite or scorpion in India [15].

The flower of *C. ternatea* resembles a conch-shell is said to be good for treatment of mental illness (Masasika Roga) [16]. Butterfly pea flower contains high amounts of anthocyanin pigments. Many evidences indicate *Clitoria ternatea* to be rich in

antioxidant properties compared to other flowers and medicine elements. In ancient human civilization, *Clitoria ternatea* has been used to treat neurological disorders [17].

Besides that, anthocyanin pigment from *Clitoria ternatea* also showed anti-viral, anti-inflammatory, antioxidant, anti-allergic, and anti-microbial properties, prevent diabetes, protect the cardiovascular system from damage and many more health benefits [18]. Their stability in colour and antioxidant properties are influenced by several varying environmental parameters, including light, pH, moisture content, fertilizer, soil aeration, and temperature. Due to the environmental standard imposed by pollution control and biodiversity policy of various countries in response to allergic reactions and toxin in synthetic dye, a natural dye from *Clitoria ternatea* can be used as a colouring agent for making products.

Moreover, there has been a research suggesting that anthocyanin helps in protecting the cell, as an anti-ageing agent, protects cell damage and promoting healthy eyes [19]. Therefore, in realizing the many benefits of *C. ternatea* to humans, it is very important to investigate the phytochemicals of the plant by varying several parameters for better quality. The production of phytoconstituents in *C.ternatea* can be controlled by changing the environmental condition.



**Fig. 1** Blue flower of *Clitoria ternatea*

## 2. Water

Exposure to drought is a very common problem in Malaysia, which will lead to cellular dehydration. It will cause osmotic stress and removal of water from the cytoplasm to the vacuoles [20]. Research has stated that *Clitoria ternatea* is drought sensitive, where the study measures plant shoot and root lengths [21]. Maximum germination has been observed at 42.5% during drought stress while the control is 56.25%. Meanwhile, the minimum shoot length showed 4.9 cm in stress, and 6.4 cm in control. The evidence revealed that in water shortage *C. ternatea* reduced its germination percentage and shoot length in comparison to control.

## 3. Soil Salinity

Salinity has become the most extreme environmental factor where it may limit the crop production of plants. Plus, high concentrations of salinity in soil will be sensitive to some plants. Most regions in the world recently has experienced climate change as the soil exposed to water become less from time to time, which leads to the increase in soil salinity. Consequently, salinity stress is becoming a major limiting factor to agricultural sector, primarily in Malaysia as it experiences equatorial climate.

A wide range of strategies and adaptation are needed to cope with this impact, to increase the resource management to overcome the salinity stress. The agricultural area might become arid or semiarid as they are affected by saline conditions due to climate change. Many irrigated areas use brackish water which also affects salinity. At the same time, plant production may vary in arid lands, where adverse conditions including salinity and limited water affect the development of plant growth.

The response of plants towards salinity has been revealed in two phases; first is the occurrence of shoot ion-independent, within minutes to days and has thought to be related to  $\text{Na}^+$  sensing and signaling [22]. In the first phase, the effects of salinity cause stomatal closure and inhibition of leaf expansion [22, 23]. However, during the second phase, the ion-dependent response to salinity, involves build-up of ions in the shoot to toxic concentrations,

mainly in old leaves that causes reduction of yield and plant death [22, 24].

The impact of soil salinity includes complex interactions in morphological, physiological and biochemical process such as seed germination, plant growth, water and nutrient uptake. Nevertheless, salinity may reduce the economic growth as well as agricultural productivity and causes soil erosions [25].

The germination, vegetative growth and reproductive development may change since soil salinity possesses ion toxicity, osmotic stress and deficiency of nutrient and limit water uptake from soil. Moreover, plants may take up improper balance of nutrients they need for healthy growth under saline conditions. The rate of germination parameters, the length of shoot and root, and the dry weights of the fresh shoot and the root of some forage cultivars is influenced by the levels of salinity [26].

On top of that, *Clitoria ternatea* has been shown as moderately tolerant in salt stress [27]. For instance, *C. ternatea* shows a positive result in sodium chloride, NaCl concentration of 0.5%, 1.5%, 2.5% and 3.5%. However, at 4.5% of salinity, it showed a negative result. Therefore, under saline environments this legume would be tolerant to salt moderately.

Research has been carried out to compare plant *Centrosema pubescens*, *Macroptilium atropurpureum* and *Clitoria ternatea* under salinity tolerance during germination and early seedling growth (28). The seeds from each plant have been inoculated with salinity by mixing the different salts like NaCl,  $\text{Na}_2\text{SO}_4$ ,  $\text{MgCl}_2$  and  $\text{CaSO}_4$  and the control. It has been reported that *M. atropurpureum* was moderately tolerant than *C. ternatea* and *C. pubescens* under salt stress [28].

Besides that, research had been done previously by using mutant *Clitoria ternatea* on salinity stress and the outcome showed that the mutant *C. ternatea* exhibited highest tolerance to 130 mM NaCl treatment, whereas the normal *C. ternatea* exhibited highest susceptibility at seedling stage in salinity stress [23, 29].

On the other hand, in plant cells oxidative stress was induced by salinity via the generation of reactive oxygen species (ROS). There is evidence to show that *Clitoria ternatea* potentially increased their quality, yield and nodulation in organic fertilizers as compared to inorganic fertilizer under saline environment [30]. *Clitoria ternatea* (Butterfly pea flower)

plant was grown in arid saline environment and treated with composted organic fertilizer (poultry and cow manure) and inorganic nutrients (NPK) in Saudi Arabia [30]. Thus, it was shown that arid and saline soil could be enriched using composted organic fertilizer.

#### 4. Light

In terms of the photosynthesis system, light has become the main energy source and may trigger structural differentiation and growth in plants. The growth and differentiation of plant cells, tissue, organ cultures and morphogenesis are influenced by the light quality, quantity and photoperiod [29]. Besides, the development of plant growth is influenced by the light quality, referring to wavelength and colour that reaches plant surface [30]. As such, light sources such as high-pressure sodium, fluorescent, incandescent and metal-halide lamps have been used for plant cultivation.

However, these types of sources may promote low quality growth due to its wavelengths being located outside the photosynthetically active radiation spectrum [31]. Gallium-aluminium-arsenide light emitting diode (LED) lighting systems have better light sources than those conventional light sources. Furthermore, with their ability to control spectral composition, durability, small size, wavelength specificity and photon output which correlates with electrical input current, these solid-state light sources might be ideal for plant lighting designs, contributing to optimal production and enhancing the plant metabolism and morphology [32].

Plants survive on the amount of light within a range that they can tolerate. As mentioned earlier, the light sources have three principal characteristics that affect plant growth, namely, duration, quality and quantity. Light quantity refers to the intensity of sunlight and total amount of light that the plant receives, usually maximum in the summer and minimum in the winter season.

As the plants use sunlight to produce food, hence the more sunlight a plant uptakes, the higher the ability for the plant to produce food via photosynthesis. Likewise, when the plant receives less sunlight (usually on cloudy or rainy days), it will decrease the photosynthetic processes. The light quantity might be decreased in a garden or greenhouse by the aid

of shade-cloth above the plants [33]. However, it can be increased by placing the surrounding plants with white or bright material.

#### 5. Temperature

The productivity and development of the plant is influenced by temperature for both the cool-season and the warm-season crops. Other than that, temperature is also a key factor for the development of the plant. If the temperature is too low or too high for a warm-season crop, this will hinder the growth of fruits. Extreme temperatures might prevent pollination and the plants become unviable.

Besides, plants survive and grow best at optimum temperatures within their varied range. The range might be wide for some species and narrow for other species [34]. However, plants can only survive when the temperature allows them to bring about chemical reactions. The temperature stress has become a major problem to many scientists as climate changes have a potential of contributing to agricultural impacts [35].

Furthermore, unfavourable temperatures may cause poor development and stunted growth of the plant. Usually temperatures have been correlated with the length of day 1 to manipulate the flowering of plants [36]. Besides, in terms of respiration, the higher the temperature, the higher the rate of respiration [37]. Corresponding to the increasing in respiration, the products of photosynthesis has also rapidly increased. Besides that, low temperatures may result in poor growth as well as the decrease in the rate of photosynthesis. Therefore, this results in lower yields since the growth of plant is slowed.

#### 6. Soil pH

All plant species need nutrients which are greatly affected by the soil pH. Certain nutrients required for growth are taken up by the plant roots. By measuring the acidity or alkalinity of the soil, the ability of plant roots to take up nutrients can be determined. Besides, plants grow at their best in neutral soils with pH 7.0. However, some of the plant species might grow well in soils with pH 6.0 or below.

The acidity of the soil can be changed by using lime and any materials that contain sulphates in order to lower the soil pH. Moreover, soil pH greatly affects the solubility

of minerals and nutrients. The solubility of many trace elements is influenced by pH and only soluble forms of micronutrients are taken up by plants [38]. Iron compound is not soluble and are often present in high pH soil.

Highly acidic soil (pH 4.0 to 5.0), contains high concentrations of iron, aluminium and manganese which is toxic to the growth of plants [39]. Hence, soil pH ranging from pH 6.0 to pH 7.0 promotes the best availability of plant bioactive compounds and nutrients. Some plants such as blueberries and conifer trees tolerate strong acid soils and grow well in them [40].

On the other hand, if the soil is alkaline with higher pH range, it will cause low nutrient to those plants and eventually lead to mortality. Other than that, the acidity of soils also has an influence on the activity of microorganisms which decompose organic matters [41]. These microorganisms (such as bacteria) are prevented from breaking down these organic matter thus, preventing the release of nutrients and nitrogen.

## 7. Soil Moisture

Soil moisture content is the amount of water in the soil. The response of plant growth to soil moisture content, usually in agricultural areas, is of significance to the farmers. The development of the plant and its subsequent survival also depends on the presence of abiotic and environmental factors. Furthermore, moisture content plays an important role in the germination of seed in plant [42]. If dry conditions occur in the soil within six days of planting, the seeds of the plant might not survive, hence no crop will be established from the seed.

In addition, the availability of water is essential for the turgidity of the cell for growth and enlargement. The amount of water used by the crop depends on the plant morphology and wind speed. Besides, different plants need different amounts of water [43]. Soil moisture content is also correlated with weather conditions, either in summer or winter. Some species tolerate drought during summer such as *Clitoria ternatea*. On the other hand, some plants need a continuous supply of moisture to grow well such as *Oryza sativa* or also known as Asian rice.

## 8. Soil Aeration

Besides soil moisture, soil aeration is needed for the growth of plants. In order to live, everything in nature needs oxygen, hence soil aeration will allow oxygen and any vital nutrients to reach the plant roots. Moreover, soil aeration benefits plants because enough quantity of oxygen is supplied to the roots and the quick removal of carbon dioxide from the soil creates a healthy plant growth [44]. On the other hand, if supply of oxygen is insufficient, the growth of plant will slow down as carbon dioxide is accumulated in the plant roots.

If the soil aeration is insufficient, root development becomes abnormal as is most notably seen in the shape of the roots. Insufficient aeration in the root system causes poor penetration and subsequent development of the roots, resulting in insufficient amount of nutrient being absorbed from the soil [45]. Other than that, the presence of microorganisms in the soil will also increase due to the presence of oxygen for the metabolism and respiration process of these microorganisms. The most important activity of the microorganisms is the decomposition of organic matter. Hence, if the oxygen in the soil is lacking, it will slow down the rate of microbial activity.

As mentioned earlier, soil moisture is closely related to soil aeration, thus the decomposition of organic matter by the microorganism plays the same role in affecting the growth of plant. Furthermore, insufficient amount of oxygen in the soil due to poor aeration will result in the formation of the toxic substances, such as carbon dioxide gas and ferrous oxide in the soil [46]. Furthermore, with poor soil aeration, it is found that plants exhibit water and nutrient deficiency affecting the bioactive compounds present in that plant. This will lead to the development of diseases.

## 9. Soil Fertilizer

Plant nutrients are essential for crop production and soil fertility. Various types of fertilizers are added to crops to enhance the capability to produce sustainable agriculture. Chemical, organic and biofertilizers are widely used and these types of fertilizers possess their own advantages and disadvantages to crop growth.

Chemical fertilizer is a non-organic fertilizer which mainly consists of phosphate,

nitrate, ammonium and potassium salts to increase agricultural activities efficiency [47]. Besides, chemical fertilizers present several advantages to plants such as its nutrients are immediately available to plants, the price is cheap compared to the organic fertilizer and it is synthetically made to contain high amounts of nutrients [48]. Thus, chemical fertilizer provides a direct and quick effect to plant growth.

However, overuse of chemical fertilizer can produce negative effects on fertilizer efficiency. Over application of chemical fertilizer can result in the pollution of water resources, crop susceptibility to disease attack, reduction in soil fertility and acidification or alkalization of the soil [48]. Therefore, these negative effects cause an irreparable damage to the overall plant system.

The use of organic fertilizer has been given more consideration as the continuous use of non-organic fertilizer create potential environmental pollution. Furthermore, the advantages of using organic fertilizer are the nutrient supply is more balanced and slowly released. Thus, it contributes to the residual pool of organic nitrogen (N) and phosphorus (P) and reduce N leaching loss and P fixation. Besides, organic fertilizers can also suppress several plant diseases, increase root growth and intensify soil biological activity [48]. Therefore, more organic fertilizers are needed to meet the demand of plant nutrients [49].

The sources for organic fertilizer can be from the animal and human manure [50] and vegetable compost. However, due to the naturally occurring content in the organic fertilizer, it makes the fertilizer to be highly variable in terms of its nutrient composition. Moreover, organic fertilizers are also comparatively low in nutrient content and the rate of nutrient release is slow. Another obvious disadvantage of organic fertilizer is the increase of heavy metals in soils specifically Cadmium (Cd), lead (Pb) and Arsenic (As). The lead and arsenic concentrations were found to be increased dramatically in comparison to cadmium concentration in wheat [50].

Biofertilizer is produced through a simple technology and low cost of installation as compared to chemical fertilizers. Seaweed is a growing and widely available resource that is utilized as a source of food, industrial raw materials and botanical applications. In addition, the presence of many plant growth-

stimulating compounds in seaweed and seaweed-derived products has made it useful in the crop production system [51]. Unlike chemical and organic fertilizer, biofertilizers do not directly supply any nutrients to plant but they are cultures of beneficial bacteria and fungi.

Several main microorganisms that are used as biofertilizers are rhizobia [52], azotobacters and azospirillum [53], phosphate-solubilizing bacteria (PSB) [54], vesicular arbuscular mycorrhiza (VAM) [55] and plant growth promoting rhizobacteria (PGPR) [56]. Moreover, PGPR is a type of bacteria that are commonly used to promote plant growth. These beneficial bacteria or rhizobacteria can influence the plant growth through direct and indirect mechanism.

Directly, these rhizobacteria can stimulate plant growth through stimulation of root growth, rhizoremediation and act as biofertilizer. Meanwhile, rhizobacteria can also promote growth indirectly by reducing the level of disease and inducing systemic resistance [57].

## 10. Phytoconstituents

*Clitoria ternatea* contains high nutritional value of primary metabolites in different parts of the plant. The leaves contain 30 % of crude protein and 14 % of crude fibre [58]. The plant seeds contain 20 % of carbohydrates, 7 % of lipid and 3 % of total ash. These primary metabolites are important as precursors or pharmacologically active metabolites in pharmaceutical compounds. The high level of protein in the plant is used to isolate protein base bioactive compounds. Additionally, the content of fatty acid in *C. ternatea* includes stearic acid, linolenic acids, palmitic acid and oleic acid [59].

As such, many researches are done on bioactive compound and crude extraction which has a potential benefit to replace synthetic components with natural and effective antioxidants. Moreover, the plants present a great alternative in producing health supplements and therapeutic products in many parts of the world including Malaysia and other Asian countries [60].

Phytochemical screening showed active secondary metabolites present in *C. ternatea*. All parts of the plant body has synthesized many bioactive components such as from the

flower, root, stem, seeds, bark and leaves. It has been reported that *C. ternatea* has major phytoconstituents such as taraxerone and taraxerol [61]. The phytochemical analysis of *C. ternatea* on different plant parts has been confirmed for the presence of tannins, resins, steroids, flavonoids, saponins, triterpenoids, anthocyanins, xanthenes and many more [62].

The flower parts contain great natural antioxidants including flavonoids, anthocyanin, flavonol glycosides, phenolic acids and procyanidins. Other sources reported that petal of *C. ternatea* contained flavonol glycosides, eight anthocyanins (ternatins C1, C2, C3, C4, C5 and D3 and preternatins A3 and C4), delphinidin-3, 5-diglucoside, kaempferol [30]. These phenolic antioxidants acts as a resistance to cancer due to their protective chemical components.

The phenolic antioxidants or also known as phytochemicals have been shown to scavenge radicals in a dose-dependent manner and favourable as therapeutic drug for free radical pathologies [63]. Eventhough many possible constituents of *C. ternatea's* have still not been discovered, those that have been are proving to be effective worldwide.

### Alkaloid

Alkaloid is considered as one of the phytochemical compound that is found in *Clitoria ternatea*. In terms of bioactive compounds, it was revealed that alkaloids strongly inhibit lipid peroxidation whereas isolated tissues were induced by its antioxidant activity [64]. Even though some studies have been done on the application of the alkaloid constituent of *c. ternatea*, it has nit been put to clinical use. The phytochemical analysis of *C. ternatea* showed the presence of alkaloid among the other constituent. There are possibilities of alkaloid presence which might produce and provide similar effects.

The alkaloid has been consumed to treat tissue damage for centuries. The crude alkaloid has been tested using animals to obtain possible mechanisms. The abdominal constrictions were significantly reduced, paw licking time is increased and significant increase in latency ( $P \leq 0.05$ ) was observed by the alkaloid treatment. Thus, the alkaloid has the ability to become a significant and important analgesic potential through inhibition of peripheral nervous system [65].

Also, alkaloid can become an antidepressant agent. The plant-based alkaloid has been consumed as a significant clinical efficacy in placebo-controlled studies in patients of bipolar and unipolar depression [66].

In addition, herbs-isolated alkaloid exhibit antimetastasis and antiproliferation in both in vivo and in vitro types of cancer. Camptothecin and vinblastine, alkaloids have been completely and successfully developed into anticancer drugs and have been used to help patients with cancer. The consumption of alkaloid to fight against cancer and as an anticancer agent has become very promising [67].

Moreover, the reserpine, an alkaloid, has been consumed to treat hypertension. Reserpine, the antihypertensive agents were introduced into hypertensive rats. After the onset of hypertension, the rat was treated with reserpine. The blood pressure and prolly hydroxylase activity were decreased. Thus, the treatment of reserpine is an effective alternative and treatment to diminish and decrease the arterial hydroxylase activity of hypertension [68].

On the other hand, quinidine, an alkaloid has been used as an antiarrhythmic agent. 25 patients with Brugada syndrome have been treated with quinidine. Quinidine has prevented the ventricular fibrillation for 88%, 22 out a 25 patients. The quinidine has been administered for 6 to 219 months to 19 patients and none of the patients has the arrhythmia. Thus quinidine has the ability to become a vital and significant alternative to deal with the arrhythmias [69].

Symptomatic and asymptomatic infections are caused by human protozoal pathogens and affect all humans. Emetine also an alkaloid, has been used to treat and help patients with protozoal infection [70].

Alkaloids have been used for the Alzheimer's disease. Physostigmine alkaloid treatment towards patients has suggested that the treatment improved and helped the constructional disability in some of the Alzheimer's cases. The hypothesis of central cholinergic potentiation could be supported as the treatment might be another piece of evidence to improve and ameliorate some of the Alzheimer's diseases impairment [71].

Besides, quinine, another alkaloid has been consumed as an antimalarial activity. The quinine content in plant extract has a vital

potential as an antipyretic and antimalarial activities with no cytotoxicity in vitro [65].

### **Steroid**

As described earlier, steroid compounds have been found to be present in *Clitoria ternatea* which correlates to sex hormones. The steroidal compounds are of interest to pharmaceuticals due to their capability as sex hormones [72]. Besides, postoperative pain, postoperative and postdischarge nausea and vomiting may be decreased due to the consumption of the steroids. It also induce a sense of well-being and stimulate appetite [73].

Even though some studies have been done on the application of the steroid constituent of *C. ternatea* and not many have been put to clinical practice, the phytochemical analysis of the *C. ternatea* showed the presence of steroid. There are possibilities of steroid presence in the *C. ternatea* that might produce and provide similar effects.

Moreover, glucocorticoid, biological active synthetic derivatives of corticosteroids has a physiological effect on metabolism. Gluconeogenesis will occur by increasing the blood glucose concentration in the liver stimulated by the glucocorticoid cortisol, an essential regulator of lipid, protein, carbohydrate and nucleic acid metabolism. The oxidation of fatty acids in cells and the mobilization of fatty acid from adipose tissue are promoted by glucocorticoid cortisol [74]. Furthermore, the steroid might be consumed during perioperative period of patients suffering from hypoadrenocorticism. It is used to treat one of the vital stress response components in our [75].

Sex steroids play an essential and crucial role on the adverse effect of hormone deficiencies in young and old, men and women, and in the maintenance of bone health. The clinical management of osteoporosis might be improved when the bone is treated with the sex steroid [76].

Furthermore, steroids have been used for the Epidural Steroid Injection, ESI to cure and treat patients with back pain. The affected nerve root will be provided with some relief by the ESI. Besides, ESI is also introduced as therapy to patients suffering from lumbar disc disease, as an effective alternative towards surgical treatment. Additionally, patients with spinal pathology, for example, vertebral fractures,

spinal stenosis, radiculopathy, disk space narrowing, annular tears, spondylosis, spondylolisthesis, and postlaminectomy syndrome might have the opportunities to be treated with the ESI [77, 78].

In addition, steroids have been used in traumatic spinal cord injuries. Methylprednisolone, a steroid is used in the first eight hours of their injuries. After six months, the treated patients have a significant improvement compared to patients who were placebo-treated in motor function (neurological change scores of 16.0 and 11.2,  $P = 0.03$ ) neurological recovery. Thus, the methylprednisolone, steroid might be an alternative to improve neurologic injuries and to treat acute traumatic spinal cord injuries [79, 80].

Moreover, steroids have been used in hyperactive airways. The intranasal aqueous beclomethasone dipropionate, steroids is used as a treatment for allergic rhinitis and asthma. Global rhinitis symptom scores ( $p = 0.05$ ) significantly reduced by intranasal beclomethasone dipropionate after 4 weeks of the treatment. Morning asthma tended to decrease ( $p = 0.07$ ) and evening asthma significantly decreased for week 2 and 3, ( $p = 0.001$ ,  $p = 0.02$ ) by the treatment of intranasal beclomethasone dipropionate. Thus, the treatment of steroids can reduce and decrease the bronchial hyperactivities and help to improve asthma symptoms [81].

Steroid too, have been consumed and used in Post Intubation Laryngeal Oedema. An intraluminal polypoid lesion was observed at the site of the cuff of the endotracheal tube of a patient suffering from a progressive tracheal stenosis disease. A treatment of beclomethasone inhaler cured the disease within 5 days of treatment. Thus, the systemic steroid may be beneficial to the early post-intubation tracheal stenosis [82].

The corticosteroid contributes towards anti-inflammatory action by the inhibition of the arachidonic acid by the cells [83]. The steroid affects a collagen deposition and growth factor in wound healing by decreasing hydroxyproline content in the tissue and TGF- $\beta$  and IGF-I in the level of wound fluid [84].

### **Reducing Sugars**

The presence of reducing sugar in the plant showed the ability of bioactive compound as

anti-diabetic. Other sources reported that extracts of *Clitoria ternatea* leaves and flowers possess an essential antidiabetic, antioxidant and anti-inflammatory activity [85].

### **Tannin**

*Clitoria ternatea* too has been reported to contain tannin compound. The presence of tannin and terpenoids are indicated for anti-inflammatory activities and analgesic. Other than that, tannin compound was related to faster healing of wounds and swollen mucous membrane [86]. In addition, the secondary metabolites of *C. ternatea* such as tannin and flavonoid act as defence mechanism against insects and microorganisms.

Phytochemical analysis of crude extract of the *C. ternatea* showed the presence of tannin among the other constituents. Tannins are found to produce anthelmintic activities. The presence of tannin in *C. ternatea* crude extract might produce and provide similar effects. The free proteins within and in the gastrointestinal tract can be bound by tannin to exert anthelmintic effects of the tannins.

The possible mechanisms of tannin's actions are, firstly, uncoupling oxidative phosphorylation to interfere with energy generation. Secondly, the tannins may interfere with glycoprotein of cell surface and lastly, the tannins can bind to free proteins in parasites' glycoprotein on the cuticle or in gastrointestinal tract of host animal and cause death. Anthelmintic activities were significantly determined with the extract of *Clitoria ternatea*'s root and leaves [87, 88].

Tannins obtained from *C. ternatea* plant inhibit monoamine oxidase (MAO) which might lead to antidepressant activity, hence increasing the dopamine and norepinephrine levels in the brain. Thus, *C. ternatea* might serve to have a crucial and important role as a resource for psychotherapeutic agent for mood disorders and depression [89].

Terpenoids, tannins, flavonoids, saponins, alkaloids and anthraquinones are secondary metabolites shown in vitro to have antimicrobial properties. These bioactive compounds such as phenols, tannins and flavonoids act as antioxidant, anti-microbial, antihelmintic and anti-diarrhoeal activity [90]. On top of that, flavonoid compounds of *Clitoria ternatea* were found with the presence of kaempferol-3-neohesperidoside [91]. The

presence of these phytochemicals indicate the potential of the plant as a medicinal plant. The medicinal plants today can be considered as potential sources of antioxidant compounds [92]. Therefore, plant *C. ternatea* deserves attention due to their phytoconstituents.

### **Flavonoid**

Flavonoids have been indicated as having antioxidative activity, scavenge free radical, anti-inflammatory, anticancer, hepatoprotective, antiviral activities and prevent any coronary heart diseases. The biological functions in flavonoids include protection against ulcers, viruses, tumors, platelet aggregation, inflammation, allergies and microbes [93]. Besides, in terms of plant system, flavonoid stands for growth regulators and assists in repelling oxidative stress. Natural sources of phytochemical flavonoid possess a variety of advantages, for instance as dietary element in promoting health. In addition, the fruits and vegetables that contained flavonoids are thought to have high antioxidant capacity by in vivo and in vitro system [94].

Some of the researches reported that flavonoids are able to activate human protective enzyme systems. Moreover, studies have suggested that flavonoids protect against infectious degenerative diseases, viral and bacterial diseases and other age-related diseases [95]. Since flavonoids play a part in the defence system, it can also act as secondary antioxidants.

Furthermore, flavonoids comprising of very effective antioxidants such as flavonols, chalcones, flavones, flavonones and isoflavones are found in a large group of naturally occurring plants [96]. Other classes of phenolic compounds and flavonoids are important phytochemicals [97].

### **Anthocyanins**

*C. ternatea* was also identified as having phytochemical compounds as the flower contains a deep blue colour that consists of anthocyanins. Anthocyanins are a Greek word which refers to 'anthos' meaning flower, while 'kyanos' means blue [98]. The word anthocyanin has been used in order to express blue pigments of the cornflower *Centura cyanus* [99]. Apart from that, anthocyanins, present in fruits, roots, leaves and caudices act

as an alternative for synthetic pigments due to their physiological functionality [100].

In addition, anthocyanins consist of two distinct patterns such as anthocyanin glycosides and sugar free anthocyanidin aglycones [101]. Since anthocyanidin is insoluble in water and unsteady to light, it does not occur in the free state. However, at acidic pH anthocyanin shows it is positively charged and forms flavylium cation (equilibrium form). All of the anthocyanin structures are based on a single basic chemical structure, which is flavylium ion. There are 17 types of anthocyanins [102]. Some of these include cyanidin (magenta), aurantinidin (orange), delphinidin (blue/purple), europinidin (bluish red) and many more.

Anthocyanin can occur as a blue, purple and red flavonoid pigment found in the *Clitoria ternatea* flower. Moreover, the colours of anthocyanin change depending on the reading of pH from acid to base [103]. As mentioned earlier, anthocyanins are found in *Clitoria ternatea* petals, are water-soluble and are a vacuolar pigment.

In addition, anthocyanins belong to the flavonoid group as it is synthesized through the phenylpropanoid pathway. Anthocyanins are flavourful but odourless as it is derived from anthocyanidins by adding sugars [104]. Mostly occurring in nature are cyanidin, malvidin, peonidin, delphinidin, petunidin of glycosides [105]. Around 2 % of all hydrocarbons in photosynthesis were converted into flavonoid and anthocyanins. Apart from that, it is found that blackberries, grapes, blueberries, avocados, oranges, sweet potatoes and mangoes are rich in anthocyanins [106].

Since anthocyanin acts as an antioxidant, this photosynthetic pigment is water soluble. Anthocyanins are water soluble glycosides of polyhydroxyl and polymethoxyl. The colour of anthocyanins can vary with the number and position of hydroxyl groups [107]. Corresponding to the hydroxyl groups, anthocyanin can differ by aromatic acylation, substitution pattern, nature of glycosyl units and potential aliphatic. Stability of anthocyanins will increase by the presence of acylation of sugar residues with aliphatic acids.

The use of many artificial food colouring agents in food, drinks, and cosmetic industries will trigger health problems among consumers over a long period. Therefore, anthocyanin can be used to replace these artificial colouring as it

is a natural pigment and a phenolic compound that has a range of colours from orange to blue. At pH 1-2, the colour of the pigment is red, at pH 3-7, the colour is shown as purple to blue and at pH 8-14, the colour shown is yellow green [108].

However, blue colour solution is shown favourable from pH 1-12 [109]. The natural pigment is safe and non-toxic and it satisfies the criteria for consumers in food colours or manufacturing industry. Besides, the capability of the phenol structure in gaining free-radicals as antioxidant has been reported to be higher than vitamin C and E [110].

The stability of the phytochemicals are influenced by many factors among which are the structural modifications of hydroxyl groups, environmental factors and storage. Several different colours will be displayed in this photosynthetic pigment, which leads to beautiful colorants for the food or manufacturing industries. The purple colour of *Clitoria ternatea* indicates the presence of anthocyanin compounds. The white petals do not contain anthocyanin compound. Anthocyanins are in high demand due to their preventive effect against various diseases [111].

These natural compounds in *C. ternatea* possess many benefits as it is harmless and environment friendly. These phenolic compounds as secondary metabolites in plants play a major potential as antioxidants, coming from natural sources and associated with health benefits. The phytochemicals have several physiological effects to humans such as preventing platelet aggregation [112]. In some conditions, the bioactive compounds help in inhibiting oxidative damage of lipid and low density lipoprotein [113].

Besides that, natural compounds help in reducing the risk of coronary heart disease and cancer [114]. Furthermore, these phenolic compounds contain great in vivo and in vitro antioxidant properties, act as metal chelators, break radical chain reactions and scavenge free radicals [115].

The presence of flavonoids in plants act as guardians in environmental stress, while in humans, it serves as biological response modifiers. These phytochemicals contain nutrients to help in slowing the aging process and also reducing the risk of critical diseases such as cancer, heart diseases, high blood pressure, osteoporosis, stroke, urinary tract

infection and cataracts. Moreover, *Clitoria ternatea* act as therapeutic agents for several conditions.

Researches on anthocyanins in fruits and plants have increased in the past three or four decades due to their potential health effects and as nutraceuticals. Anthocyanins (a flavonoid category) were found in one study to have the strongest antioxidizing power of 150 flavonoids [116]. The presence of anthocyanin in plant enhances their defence mechanism as it is very essential in pollination and reproduction.

Moreover, anthocyanins protect the plant from UV-light as they contain high antioxidants. Anthocyanins assist in reducing the risk of cardiovascular disease, cancer and cognitive decline and are anti-diabetic [117]. Other than that, anthocyanins are high in antioxidants which may lead to improved vision in man. Anthocyanin is a strong antioxidant with its capability in reducing radical scavenger by glycosylation. However in aglycone it decreases the ability of anthocyanin radical to delocalize electrons.

The researches have investigated the ability of anthocyanins to act as anti-viral, anti-allergic, antioxidant, anti-microbial and anti-mutagenic and to prevent diabetes, and to improve eye function. The colour of anthocyanins depends on the structure of anthocyanins, water activity, pH, light, oxygen and temperature. All these factors influence the stability of pigments.

Thus, insufficient light may lead to pigment destruction and high temperature can destroy structure of flavylium ion hence, loss of more colours. The oxidizing reagents such as vitamin C and peroxides lead to changes of the colour [118]. Water activity plays an active role in pigment production. The more water the plants take in, the faster the blue of anthocyanin produced. With antioxidant activities in the human diet, many chronic diseases can be prevented.

An anthocyanin will exhibit a wide range of therapeutic benefits such as reducing the risk of heart disease, anti-carcinogenic activity and improving cognitive behaviour [119]. As mentioned earlier, anthocyanins act as anti-inflammation agent. It has been reported that anthocyanin is important in the treatment of damaged blood vessel walls. During inflammation, connective tissues in capillaries are damaged due to presence of enzymes.

Hence, the surrounding tissue is full of blood due to leaking. These enzymes will be neutralized by anthocyanins. Thus, antioxidant activities inside would prevent the connective tissue from continuing damage. With the benefits of *Clitoria ternatea* in response to anti-ageing and antioxidant properties it can be used in anti-wrinkle cream in the cosmetic industry.

Due to the environmental standard imposed by pollution control and biodiversity policy of various countries in response to allergic reactions and toxicity in synthetic dye, a natural dye from *Clitoria ternatea* could be used as a colouring agent for making products. Therefore, this will minimize the use of chemical coating material in the manufacturing industry.

In addition, many cosmetic industries use harmful elements in their products, especially using excessive acid or mercury to get effective results. By using natural or organic elements in their products, it is better and safer for the skin. Since the colour of the pigments of *Clitoria ternatea* is fascinating and the dye extracts contain antioxidant agents, it could be applied in the cosmetic industry as it is natural and harmless.

Furthermore, *C. ternatea* has the ability in affecting female reproductive organ. The plant has been effective in treating female sexual disorders such as infertility, gonorrhoea, to correct menstrual disorders, and as an aphrodisiac. It can also be used to treat male infertility by increasing sperm mobility [120]. This photosynthetic plant is also effective in treating piles by using the whole plant paste and applying it over the swelling, infected and bleeding area.

Other sources reported that the leaves of *Clitoria ternatea* contain antibacterial and antimicrobial agents [121]. The root extract has shown beneficial effects on the brain hippocampal cell recovery [122]. Besides that, the roots of the white flowered plant have been used for skin diseases [123]. Moreover, anthocyanin is very useful in improving blood flow at the neuro-retinal rim of the optic nerve and peripapillary retina [124]. Anthocyanin also acts in improving blood circulation to the eye and lead to eye health and function over a long term.

Butterfly pea is used as a natural food colouring agent in Malay cooking by extracting the juice from the flower. It is used to colour glutinous rice for 'kuih ketan'. In Malaysia it

is also widely used to colour the food known as 'nasi kerabu'. In Burma (Myanmar) the flowers are dipped in batter and fried. In Thai cuisine the extract is made into a syrupy blue drink known as 'nam dok achan' and adding some lime juice to increase acidity [125]. The flowers are shredded and added to rice salad in Thai cuisine. It is also used for making tea, and by adding lemon it turns the colour to purple [126].

Besides that, the blue concentrate from *Clitoria ternatea* applied in hair products contribute to healthy hair growth. In the Philippines and Kerala (India), young shoots, pods, flowers and leaves of *Clitoria ternatea* are eaten as vegetable [127]. An essential component in the flower acts as a hepatoprotective agent which can improve liver function.

### 11. Heavy Metal

Heavy metal is a toxigenic and poisonous metallic chemical element with low concentrations. There are a list of many heavy metals and the most common toxigenic heavy metals that bring to a bigger and serious issues are lead, mercury, cadmium, and chromium. Widely used in the cosmetics industries, they are toxic and lead to health issues.

It has been reported that consumers using cosmetics containing heavy metals face serious skin conditions after prolonged use of these cosmetics. Thus, a lot of research has been done to discover new potential of natural resources from herbs. This will help to solve the growing problems by understanding the reactions and mechanisms of the plants towards the heavy metals.

Nevertheless, *Clitoria ternatea* could survive and grow in mercury supplemented soil, overcoming heavy metal stress through hyperactivity of antioxidants defence system. *C. ternatea* showed its capabilities by being able to tolerate mercury accumulation in their leaves. Mercury induces oxidative stress of *C. ternatea* [128]. The studies between the activities of antioxidants enzymes with the influence of mercury exposure indicated that, estimated on the fresh weight basis, the SOD, CAT, and POD activities were significantly increased by the mercury supplemented exposure [129].

### 12. Environmental Factors Affecting the Natural Compounds

The stability of anthocyanin in *Clitoria ternatea* corresponds with structural characteristics of anthocyanin and also influenced by factors such as temperature, pH, light, presence of enzymes, oxygen, metal ions, sulphur dioxide and phenolic acids [130]. Recent studies showed that blue *Clitoria ternatea* has great thermal stability and capability to withstand high temperature (27°C-45°C) for certain food and cosmetic products [131]. It has been stated that anthocyanin of *Clitoria ternatea* has a good potential in being a functional blue colorant in a variety of food, cosmetic, food supplement and pharmaceutical products as it contains antioxidant activities [132].

As the blue *Clitoria ternatea* has high thermal stability, the pH is near to neutral. Light would cause photodegradation of anthocyanin [133]. Therefore, anthocyanin maintains better when kept in the dark. Some observations have indicated that the chromophore of anthocyanin is protected from photodegradation by stacking of the glycosyl or acyl residues [134]. In addition, *Clitoria ternatea* has been shown to reach their stability by using biofertilizers. *Clitoria ternatea* could grow in mercury sprayed soil and accumulate high amount of mercury in leaves [134].

As mentioned earlier, the phytochemicals of *Clitoria ternatea* serve as protector or guardian to the plant, thus the mercury induced oxidative stress was tolerated by this plant via the hyperactivity of antioxidants as defence system.

Furthermore, it has been reported that other phenolic compounds and flavonoids are specifically increased when plants are exposed to sunlight [135]. Besides that, the protective compounds including flavonoids tolerate warmer and drier areas which may lead to higher concentrations of these phytochemical compounds [136].

### 13. Promising Future Prospect

Natural pigments such as anthocyanins, carotenoids and chlorophyll have been used to colour foods. Commercialization of natural pigments has increased tremendously due to their harmless nature and beautiful coloration

and is thus used in the food industry, besides having antioxidant abilities and health benefits. Natural compounds in medicinal plants are also known to produce more antioxidants. Antioxidants are able to protect humans against the damage induced by free radicals acting at several levels. The traditional Indian diets, such as spices, are also rich sources of antioxidants.

As mentioned before, *Clitoria ternatea* has also been indicated as having anti-cancer properties due to their phytochemical constituents. Hence, researchers may use this natural compound as it is non-toxic and safe to use. Current cancer therapy may cause cytotoxicity. The cytotoxicity might become a constraint to cancer treatments. The researchers should look into the effect of using these natural compounds to human cells. In addition, *C. ternatea* has many bioactive compounds which benefit human health including as therapeutic agents.

Relating to their natural compounds, *Clitoria ternatea* can be used as an alternative to drugs in the pharmaceutical industries, since its bioactive components play a great role in healthcare. Other than that, since the dye is natural and non-toxic, the food industry can apply this natural pigment of *Clitoria ternatea* in their food. With the current issue in colouring preservatives, the researchers or food technologists should look into the potential of using medicinal plants in various ways to aid in human health.

#### 14. Conclusion

Natural resources such as plants have been used during ancient times as traditional medicines. Plants such as *Clitoria ternatea* has recently been reported as a main source of antioxidants due to their phytochemical contents. The use of *Clitoria ternatea* in relation to their bioactive compounds mainly correlates to human health and it could be as an alternative medicine for future generations. With the stress on health issues, researchers or scientists should develop and produce health supplements and boosters using the benefits of secondary metabolites of *Clitoria ternatea*, by extracting the leaf, root and flower parts.

It is also found that physical factors might affect the plant in producing sufficient amounts of natural compound. Thus, serious consideration needs to be given to plants under

environmental conditions to assure their sustainability.

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