REVIEW ARTICLE Agricultural Reviews, Volume 40 Issue 4: 296-302 (October-December 2019)

Black Pepper in Malaysia: An Overview and Future Prospects

A.H. Izzah, W.Y. Wan Asrina

10.18805/ag.R-129

ABSTRACT

Cultivating black pepper in Malaysia started in early 10th to the 11th century when the South Indian Kings began to extend their empire. The crop was brought to East Malaysia in 1840 by Chinese settlers, actively planted until it was hit by the massive flood, fluctuation of the price and outbreak of foot rot. High yielding cultivars such as Kuching, Semenggok Emas and Semenggok Aman provided promise for better production, but resulted in increased soil degradation and reduced crop growth in Sarawak. The paper aims to discuss the black pepper industry in Sarawak and present scenario of its cultivation including future prospects. Cultivating on hilly topography with coarse textured dominant soil becomes one of the limiting factors. This factor is observed due to high rainfall intensity and steeper slopes. Neglected soil conservation also affects crop production and lead to a lower return on investments. Technologies such as land conservation and practising precision agriculture need to be adopted to reduce the impact of soil degradation and better production.

Key words: Black pepper, Cultivars, Erosion, Sarawak, Topography.

Black pepper has been used enormously in the world to flavour a dish, pharmaceutical and even cosmetics. It originated from the south western region of India which is now known as Malabar Coast (Ravindran, 2000). The history of black pepper cultivation in Malaya (known as Malaysia) started in early 10th to 11th century when the powerful South Indian kings, Raja Raja Chola and his sons extended their empire to the Malay archipelago and Java-Bali Islands (Ravindran, 2000).

East Malaysia (now known as Sabah and Sarawak) under the reign of King Brooke has been reported to start in 1840 where the Chinese settlers actively grew black pepper in Bau, Baram, Trusan and Limbang, in the state of Sarawak. As the crop steadily grew during the time, a disease outbreak and massive flood diminished the crop (1918 to 1919) with later troubled by the fluctuation of black pepper price causing a serious problem to the farmers (in 1928) and alternatively start to shift their black pepper to other more profitable crops such as cocoa, oil palm and rubber.

The crop is more suitable to humid, tropical with relatively 2,000 to 3,000 mm of rainfall (Sivaraman *et al.*, 1999). Malaysia is among the top seventh world producer accounted to 23,500 metric ton of black pepper in year 2017 (Malaysian Pepper Board, 2018a). This is beneficially caused by profitable world market which provides more competitive price for pepper growers and income.

The cultivation in Peninsular Malaysia is majorly planted on flat land with lower rainfall (~1,800 to 3,000 mm) while in Sabah and Sarawak, the crop was planted on hilly topography with higher rainfall (~2,800 to 4,700 mm). The differences between these two areas (Peninsular Malaysia and Sabah and Sarawak) were mainly due to their land topography and weather characteristics. According to Paulus *et al.* (2011a) and Ravindran (2000), the area with higher rainfall needs to be closely monitored due to the sensitivity of the crops to excessive moisture which increases the severity of the infection by foot rot. Meanwhile, a continuous drought season may reduce the flowering potential which also affects potential yields (Paulus *et al.*, 2011a).

Department of Crop Science, Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, 97008, Bintulu, Sarawak, Malaysia.

Corresponding Author: W.Y. Wan Asrina, Department of Crop Science, Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, 97008, Bintulu, Sarawak, Malaysia. Email: asrina@upm.edu.my

How to cite this article: Izzah, A.H. and Wan Asrina,W.Y. (2019). Black Pepper in Malaysia: An Overview and Future Prospects. Agricultural Reviews, 40(4): 296-302.

Source of support: Nill

Conflict of support: None

Submitted: 15-06-2019 **Accepted:** 11-10-2019 **Published:** 06-12-2019

Due to this geoclimatic difference, the scenario in each area was according to its own nature. For that reason, the objective of this paper is to give an overview of the black pepper industry in Malaysia with the scenario of black pepper in Sarawak.

THE BLACK PEPPER INDUSTRY IN SARAWAK

Sarawak is known as a major producer which cover 17,134 ha area in 2018 (Malaysian Pepper Board, 2018b). The fraction of area is showing Serian contributing most than other areas (Fig 1). This industry is monitored and supported by Malaysian Pepper Board (MPB) and local universities helps in black pepper production, marketing and others.

Till now, Sarawak leads the production of black and white pepper in Malaysia, which about 23,780 tonnes of black pepper and 6,794 tonnes of white pepper in 2018 (Malaysia's Open Data Portal, 2019). The black pepper trends are increasing since 2009, while fluctuation of white pepper production was recorded since 2017 due to hard to produce. Production of pepper has indicated 30,433 tonnes in 2017 which far behind other leading production countries such as Vietnam (200,000 tonnes), Indonesia (70,000 tonnes), Brazil (65,000 tonnes) and India (57,000 tonnes) (Malaysia's Open Data Portal, 2019).

The emerge of Vietnam as leader in this industry was due to good support from local government by providing some initiatives to sustain black pepper production through training, media and good agricultural practice have embarked USD 1,119,729,000 profit in 2017 with only 110,000 ha compared to their competitors. Use of traditional breeding such as trunk and vines cutting is another successful cultivation here compared to India, which uses a pre-rooted cutting from runner shoot (Prabhakaran Nair, 2011). In Malaysia, support by MPB has a remarkable effect on the growth of black pepper; however, juggling with market price has diversified the crop even abundant availability of cutting.

CROP AND FEATURES IN SARAWAK REGION

Black pepper or *Piper nigrum* L. belong to family Piperaceae which is easily classified as climbing crops that need a support to keep growing. It is a perennial crop and may grow up to 15 years depending on crop management practices applied by farmers. The crop can grow well in humid tropics with 2,000 to 3,000 mm rainfall per year and require a proper drainage system to avoid foot rot (Paulus *et al.*, 2011b; Prabhakaran Nair, 2011). Excessive drainage during the flowering period has been reported to affect flower pollination and thus reducing berries production. The crop can be cultivated in a wide range of soil topography including slopes of less than 10° (Tanaka *et al.*, 2009). In the case of Sarawak where certain divisions in parts of Sarawak received heavy rainfall per annum and geographically it is more hilly than Peninsular Malaysia (Sa'adi *et al.*, 2017), farmers were indirectly tend to cultivate black pepper on hilly steeps with the slope ranging from 25 to 30°. Another reason caused the farmer in Sarawak to grow in hilly area is to reduce soil-borne diseases caused by *Fusarium* spp. and *Phytophthora* spp. that favoured water logged condition (Kifelew and Adugna, 2018; Nguyen, 2015).

This crop has two types of vine namely orthotropic and plagiotropic classified according to its growth. Orthotropic grow vertically, monopodium and has adventitious root. This root provides climbing internodes which support crop growth. This vine is used to produce new cutting for new crops either for personal or commercial use. Plagiotropic have lateral, sympodium and hold flower inflorescence which lead to production of black pepper within internode.

Table 1 lists major characteristic of Malaysian peppers as recommended by Malaysian Pepper Board for commercial farming and recent cultivars. Leaf shape, apex, base, inflorescences, branch and flowers of black pepper highlights the potential of the conversion ratio for black pepper production. This will be highly useful for the farmers' and researchers to do field classification of recommended cultivars.

RECOMMENDED VARIETY AND ITS FEATURES

There are multiple varieties reported in Malaysia that originated from India and Indonesia. The common variety cultivated in Malaysia since 1957 are Balancotta, Cheriakaniakadan, Kuluvallay, Uthirancotta, Bangka, Belantung dan Djambi (Paulus *et al.*, 2011a). However, only Uthirancotta or India/Tambi cultivar was widely grown in Malaysia due to its adoption. There is also three recommended cultivars produced by Malaysia, namely

Table 1: Selected agronomic differences between black pepper cultivars.

Cultivar	Leaf			Number of flowers per inflorescence	Number of spikes per branch	Conversion rate fresh pepper (%)	
	Shape	Apex	Base			Black pepper	White pepper
Kuching	Lanceolate-ovate	Acute	Acute	<80	>40	40-50	>30
Semenggok Emas	Lanceolate-ovate	Obtuse	Acute	80-90	<20	40-50	>30
Semenggok Aman	Lanceolate-ovate	Rounded	Rounded	80-90	<20	<40	20-30
Semenggok Perak	Lanceolate-ovate	Obtuse	Acute	<80	20-30	<40	20-30
Semenggok 1	Ovate	Obtuse	Ovate	>100	<20	40-50	20-30
India/Tambi	Lanceolate	Acute	Acute	80-90	20-30	40-50	20-30
Sarikei	Lanceolate-ovate	Acute	Acute	<80	30-40	<40	20-30
Nyerigai	Lanceolate-ovate	Obtuse	Acute	<80	30-40	40-50	>30
Yong Petai	Lanceolate-ovate	Obtuse	Acute	90-100	<20	<40	20-30
Lampung Daun Lebar	Lanceolate-ovate	Obtuse	Oblique	>100	<20	<40	20-30

* Adapted from Chen *et al.* (2018).

Kuching, Semenggok Emas and Semenggok Aman (Paulus *et al.*, 2011a). These three cultivars become familiar due to its characteristics inherited from their parent materials. Semenggok Emas was produced through hybrid cross-breeding between Uthirancotta and Kuching and made its debut in 1991 (Paulus *et al.*, 2011a). Meanwhile Semenggok Aman was released from clonal germplasm from Costa Rica and was first announced in 2006.

To date, only three known cultivars are recommended by the Malaysian Pepper Board (MPB) to be cultivated in Malaysia based on berries productivity, disease resistance, piperine and oleoresin content, and the percentage of conversion to black or white pepper (Chen *et al.*, 2018; Sruthi *et al.*, 2013). Their composition and characteristic is presented in Table 2. These characteristics were finalised by the MPB and widely cited to explain the importance of these cultivars to the farmers.

NUTRIENT REQUIREMENT

The consumption of nutrients in black pepper increased over the years. However, early fertilisation was practised to supply equivalent nutrient to support all crop growths such as root, leaves and stem elongation. Once the crop reaches 24 months, significant increase of fertiliser to support growth and preparation for the mature phase is applied. This phase was optimum once it reaches 36 months when the entire crop is fully developed and black pepper berries production starts (Ann, 2012).

The differences between varieties and types of soil have highlighted different nutrient requirement to satisfy their growth. A cultivar such as Semenggok Aman needs greater nutrient uptake due to its characteristic yielding longer fruit spike (Ann, 2012). Guajarina also exhibits similar nutrients consumption like Semenggok Aman (Partelli, 2009). In order to maximise crop growth, a large amount of N and K were used to satisfy nutrient uptake. This is according to research conducted on Semenggok Aman and Indian variety which recorded nutrient removal of 293.08 and 138 kg ha^{-1}, 264.95 and 189 on N and K, respectively (Ann, 2012; Ravindran, 2000).

Nitrogen

Large N quantities need to support fruit development, especially after 24 months. Research by Ann (2012) on cultivating Semenggok Aman on clay loam has indicated increasing N application for three constitutive cropping years yielded 62, 237 and 390 kg ha^{-1}. However, N supply in India only limited to 34, 68 and 100 kg ha^{-1} for three cropping years, respectively (Satyagopal *et al.*, 2014). The differences between variety cultivated in Malaysia and India has close relationship to the crop variety and soil characteristics present in an area (Shamshuddin *et al.*, 2014). Moreover, critical management on soil fertility and soil N have gained serious consideration among researchers to boost crop productivity (Niranjana *et al.*, 2018; Singh, 2018).

Phosphorus

Supplementation of P fertiliser in black pepper was proposed according to soil texture. Ann (2012) demonstrates about 10, 22 and 62 kg ha^{-1} of P on three cultivated years on clay to clay loam texture in compared to sandy soil. George *et al.* (2005) in his research on sandy soil has concluded at the rate of 70, 140 and 140 kg ha^{-1} for three constitutive years. Accordingly, the second and third year in sandy soil was fixed to 140 kg ha^{-1} attributed to limited adsorption surface and promoted leaching from the soil profile (Fujii *et al.*, 2017; Yanai *et al.*, 2007).

Potassium

The uptake of K is often related to fruit formation in black pepper (Ann, 2012; Paulus *et al.*, 2011a). The importance of K is comparable to N which about 0.72 g kg^{-1} is recorded as early crop cultivation in nursery level (Thankamani *et al.*, 2007). The amount of K fertiliser was applied at 62, 246 and 352 kg ha^{-1} K for three constitutive years, respectively (Ann, 2012). However, in shale soils, the amount of K was about 80, 160 and 400 kg ha^{-1} for three conservative years. Interestingly, both soil either in clay loam or shale showed an increasing trend of K on the third year which highlights the importance of this nutrient for berries production.

Calcium

Amendment of Ca in soil from liming based often practised by the farmer to alleviate acidity and prevent leach of cations. The importance of this element due to behaviour on regulating crop growth and development. About 1 kg dolomite was applied per vine prior to cultivation and 0.5 kg may apply subsequent year. Increasing accumulation of Ca in black pepper tissue sample up to 22 months after plating has reported by Ann (2012). A remarkable effect on adequate

Table 2: Characteristics of recommended black pepper in Malaysia for cultivation.

Characteristics	Cultivars		
	Kuching	Semenggok Emas	Semenggok Aman
Green berry yield (kg/vine/year)	6-8	6-8	6-8
Length of fruit spike (cm)	9.7	9.9	10.1
Piperine (%)	3.5	3.4	5.4
Oleoresin (%)	11.0	11.0	15.5
Volatile oil (%)	2.8	3.0	3.8
Non-volatile (%)	7.9	8.0	11.5
Harvesting rounds per season	4-6	2-3*	2-3*
Susceptible to Phytophthora foot rot disease	Highly susceptible	Susceptible	Less susceptible
Susceptible to black berry disease	Highly susceptible	Tolerant	Tolerant

*more uniform ripening compared to Kuching.
**adapted from Paulus *et al.* (2011a)

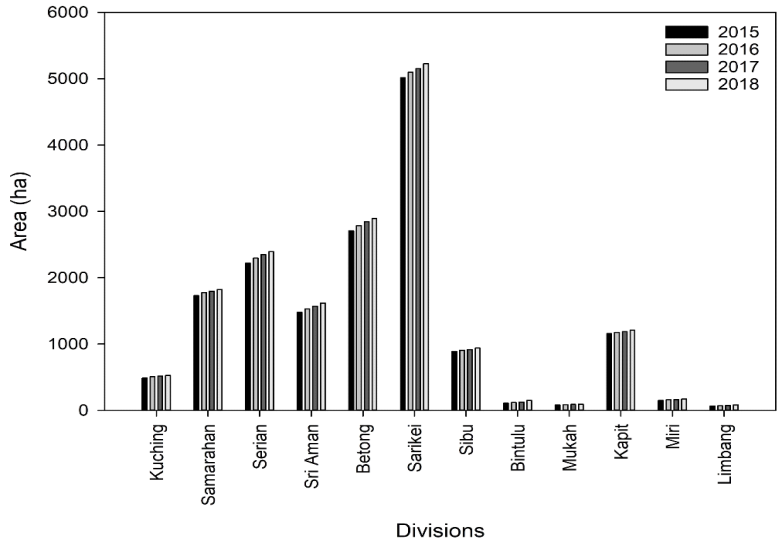


Fig 1: Division of areas in Sarawak actively cultivated black pepper in year 2015 to 2018. Adapted from Malaysia's Open Data Portal (2019).

Ca also reported in bean plants, which increase the dry mass of the shoot and root, thus lead to high grain yield (Domingues *et al.*, 2016).

Magnesium

Deficiency of Mg occurs on mature vine compared to the immature caused by low pH value. Excessive application of K fertiliser provides antagonism effect which inhibits the absorption of Mg. This tendency has indicated a common Mg deficiency which may correct exactly supplementation of 1 kg of dolomite and 0.5 kg in a subsequent year (Paulus *et al.*, 2011a). A sufficient Mg concentration in black pepper soil may promote photosynthesis activity through the production of chlorophyll. Moreover, insufficient Mg to a crop provides significant reduction of root/shoot ratio, thus lead to poor crop canopy and abilities to produce fruit (Farhat *et al.*, 2016).

Iron

Cultivating black pepper on a coarse-textured hastened deficiency of Fe including over liming activity. The primary function of Fe is regulating photosynthesis and lead to plant growth and development, and insufficient affect length of internode, especially terminal shoots and lateral branches (Zhang *et al.*, 2019). Deficiency of Fe mainly occurred on the immature vine and corrected slowly as the crop growth older. Formation of a more extensive root system with increasing the age of crop help in absorbing the ion in soil colloids.

Manganese

Application of excessive animal manure, which contains an element of Ca affect the availability of Mn. This element recommended for black pepper was 215 mg kg^{-1} to sustain the growth. Important of Mn was illustrated in various crops on chlorophyll production, which essential on photosynthesis activity (Mousavi *et al.*, 2011). Increasing yield of corn and wheat also reported, which affect its dry matter and yield (Asad and Rafique, 2000).

Zinc

Supplementation of Zn to black pepper has a remarkable effect on the yield of black pepper. Moreover, sufficient application of Zn at 2.5 mg Zn kg^{-1} soil has increasing content of oleoresin (22.83%) and piperine(7.57%), however applying 0.1% Zn EDTA as foliar has a greater yield of black pepper for about 89 g $bush^{-1}$ of dry pepper (Hamza and Sadanandan, 2005b). The remarkable effect on yield also reported in other crops such as onion (Goyal *et al.*, 2017), jojoba (Atteya *et al.*, 2018) and chickpea (Pooja and Sarawad, 2019).

Molybdenum

Application of organic matter as a source of micronutrient, especially Mo practised by the farmers to affect the growth and N utilisation on protein and amino acid synthesis. An increase in yield of black pepper, especially on application rate at 0.5 mg kg^{-1} soil (Hamza and Sadanandan, 2005a). This application of Mo also enhances the quality of black pepper, especially their oleoresin and piperine contents.

TOPOGRAPHY AND CULTIVATION PRACTICES IN SARAWAK

Growing black pepper in a hilly area with multiple slope orientations has been practised in Sarawak as attributed to the natural formation of its topography. This has formed new guidelines proposed by the Malaysian Pepper Board (MPB) to construct terracing along the slopes and intercropping with the selected cover crop which benefit the black pepper, for example, *Centrosema pubescens* and *Arachis pintoi* (Paulus *et al.*, 2011b). Promoting land conservation techniques has close relationship to reduce land degradation, improve soil fertility and crop productivity (Tanaka *et al.*, 2009).

Even though guidelines were provided to the farmer, it is still unfollowed due to the high cost of constructing terraces and the level of awareness on the benefits of cover crop is still weak among farmers especially those who live in rural area. A traditional approach used by farmers is usually clearing secondary forest through slashing and burning its residue, direct cultivation without any visible terracing, using non-living pole (e.g. *Eusideroxylon zwageri*, *Commersonia bartramia* and others) and bare soil surface through clearing

any other crops than black pepper. All the traditional practices indeed promote higher crop productivity in the first year, however, the deterioration of crop and land will be seen on wet seasons (Prabhakaran Nair, 2011; Tanaka *et al.*, 2009). The loss of topsoil from this area with high rainfall, especially in Sarawak (e.g. 2,800 to 4,700 mm/year) has hastened this process. Due to the higher rainfall, massive soil loss occurs and the farmer practically applying wood plank around black pepper mound to control soil movement. This has disturbed crop growth by exposing black pepper root, reduce nutrient uptake and affecting the development of the crops (Izzah and Wan Asrina, 2018; Ravindran, 2000).

Cultivating black pepper in flatland is hardly to find in Sarawak because preventive to infection by foot rot disease. However, cultivating on flatland is a common in Peninsular Malaysia which drier season and equipped with drip irrigation. There also significant different cultivation practices in Sarawak and Peninsular Malaysia, especially, using a different type of support either living or non-living, fertiliser scheme, water availability and management.

HILLY TOPOGRAPHY

The cultivated black pepper on hilly topography has documented the loss of 62.7 t ha^{-1} soil in the first year of cultivation on a slope of 25^{o} (Frenken, 2012; Hatch, 1981). Every slope has their effect on the amount of soil loss for example from a ridge, upslope, midslope, downslope, valley and flat land was about 17.15, 16.90, 21.88, 17.54, 21.48 and 3.24 t ha^{-1}, respectively (Sun *et al.*, 2014). However, the amount will be elevated if the steepness of the area increases.

For black pepper, the application of fertiliser needs to also consider the slope of the area. This consideration is particularly attributed to the nutrient transportation and accumulation whereas N found greater in middle and slope position, P in footslope and K in upper slope (Uzoho *et al.*, 2016; Samndi and Mahmud, 2014). One of the ways to increase fertiliser efficiency and reduce soil pollution derived from fertiliser application for pepper planted at the steep area is growing a barrier crop nearby the surface water (Yulnafatmawita *et al.*, 2017; Tuan *et al.*, 2014). Moreover, several techniques on fertiliser application has been introduced such as split fertiliser according to microclimate and semi terracing area (Sarker *et al.*, 2015).

SANDY SOIL TEXTURE

Coarse textured soil has been reported to cause lower crop productivity which is related to its incapability to hold water, lower cation exchange capacity (CEC), lower pH and lower nutrient retention (Izzah and Wan Asrina, 2018; Pal and Marschner, 2016). This will promote the leaching of nutrients caused by high soil permeability (Tahir and Marschner, 2017; Nalina *et al.*, 2016). To alleviate this problem, mixing clay with sandy fraction may increase CEC and promote the absorption of NH_4^+ by eight to 20 folds and P by two folds (Tahir and Marschner, 2016). However, with appropriate management practices such as cover crop and, organic matter amendment proposed on BRIS soil in Malaysia which has been used in sweet potato, tobacco and maize cultivation, therefore, may provide a significant improvement on black pepper productivity (Laha *et al.*, 2011; Choudhury and Khanif, 2003). This may slowly improve the crop and sustain the soil health for long term production.

Black pepper cultivated on sandy soil with higher rainfall intensities is often practised to avoid waterlogged condition and preventing disease incidence, the foot rot disease (Ravindran, 2000). However, the problem in retaining cations become an issue because it causes leaching and intensifies soil acidity. Retaining nutrient and improvement in soil pH on sandy soil can be achieved through mixing manure with chemical fertiliser (Zingore *et al.*, 2008). Generally, the improvement of P on signal grass has been achieved by supplying with 15 mg ha^{-1} poultry manure (Gerola *et al.*, 2014). In a tropical country, the monitoring season may enhance flower pollination and production of flower spike (Rao *et al.*, 2016). Moreover, with appropriate management practices such as establishing cover crop, amendment of soil with organic matter practices by other researchers on sweet potato, maize and kenaf cultivation eventually may be practised on black pepper (Ishaq *et al.*, 2014; Roslan *et al.*, 2011). This may increase the black pepper productivity when cultivating on sandy soil texture thus sustaining soil health for long term production.

CONCLUSION

The black pepper industry in Malaysia emerges accordingly to the current demand from other countries. Since the crop was successfully grown in humid tropical, it becomes the most important characteristic that influences other farmers to join in. The lucrative price and multiple schemes offered by the Malaysian Pepper Board facilitated this trend. Moreover, successful cultivars namely Kuching, Semenggok Emas and Semenggok Aman as high yielding berries become another promising growth in this industry.

Cultivating black pepper on hilly topography in Sarawak is one of the most important characteristics as the natural land formation occurred. This practice alleviates water retention which otherwise may enhance the infection by the foot rot disease. However, improper farm management practices among rural farmers could lead to extreme soil erosion and becoming one of the limiting factors to support black pepper growth. Thus, good agricultural practices which are affordable, accessible, effective and easy such as cover crop (e.g. *Centrosema pubescens* and *Arachis pintoi*) and providing mulch at slope area should be well explained to rural farmers that will eventually protect the farm sustainability in the long term.

ACKNOWLEDGEMENT

This research was supported by the project number GP-IPB/2018/9557605 from Universiti Putra Malaysia.

REFERENCES

Ann, Y.C. (2012). Determination of nutrient uptake characteristic of black pepper (*Piper nigrum* L.). Agricultural Science and Technology. 2:1091-1099.

Asad, A. and Rafique, R. (2000). Effect of zinc, copper, iron, manganese and boron on the yield and yield components of wheat crop in Tehsil Peshawar. Pakistan Journal of Biological Sciences. 3:1615-1620.

Atteya, A.K.G., Al-Taweel, S.K., Genaidy, E.A.E., Zahran, H.A. (2018). Effect of gibberellic acid and zinc sulphate on vegetative, flowering, seed yield and chemical consistent of jojoba plant (*Simmondsia chinensis*). Indian Journal of Agricultural Research. 52:542-547.

Chen, Y.S., Dayod, M., Tawan, C.S. (2018). Phenetic analysis of cultivated black pepper (*Piper nigrum* L.) in Malaysia. International Journal of Agronomy. 2018:1-11.

Choudhury, A.T.M.A. and Khanif, Y.M. (2003). Potassium adsorption behaviour of three Malaysian rice soils. Pakistan Journal of Scientific and Industrial Research. 46:117-121.

Domingues, L.d.S., Ribeiro, N.D., Andriolo, J.L., Possobom, M.T.D.F., Zemolin, A.E.M. (2016). Growth, grain yield and calcium, potassium and magnesium accumulation in common bean plants as related to calcium nutrition. Acta Scientiarum. 38:207-217.

Farhat, N., Elkhouni, A., Zorrig, W., Smaoui, A., Abdelly, C., Rabhi, M. (2016). Effects of magnesium deficiency on photosynthesis and carbohydrate partitioning. Acta Physiologiae Plantarum. 38:1-10.

Frenken, K. (2012). Irrigation in Southern and Eastern Asia in figures: AQUASTAT Survey – 2011. Food and Agriculture Organization of the United Nations, Rome.

Fujii, K., Hayakawa, C., Panitkasate, T., Maskhao, I., Funakawa, S., Kosaki, T., Nawata, E. (2017). Acidification and buffering mechanisms of tropical sandy soil in northeast Thailand. Soil and Tillage Research. 165:80-87.

George, C.K., Abdullah, A., Chapman, K. (2005). Pepper Production Guide for Asia and the Pacific. International Pepper Community, Bangkok.

Gerola, J.G., Rocha, J.R., Matoso, S.C.G., da Silva, L.D. (2014). Contribution of the incorporation of poultry litter and limestone for the fertility of sandy soil in the Brazilian Amazon. Natural Resources. 5:958-967.

Goyal, R., Uike, V., Verma, H. (2017). Effect of foliar application of micronutrients on growth and yield of onion (*Allium cepa* L.) cv Agri found dark red. Agricultural Science Digest. 37:285-288.

Hamza, S., and Sadanandan, A.K. (2005a). Soil amendments and molybdenum on yield and quality of black pepper (*Piper nigrum*). Indian Journal of Agricultural Science. 75:735-737.

Hamza, S. and Sadanandan, A.K. (2005b). Effect of source and method of application of zinc on yield and quality of black pepper (*Piper nigrum* L.). Journal of Spices and Aromatic Crops. 14:117-121.

Hatch, T. (1981). Preliminary Results of Soil Erosion and Conservation Trials under Pepper (*Piper nigrum*) in Sarawak, Malaysia. Wiley-Interscience, Chichester.

Ishaq, U.M., Umara, B., Edi Armanto, H.M., Adzemi, M.A. (2014). Assessment and evaluation of Bris soil and its implication on maize crop in Merang-Terengganu Region of Malaysia. Biology, Agriculture and Healthcare. 4:69-76.

Izzah, A.H. and Wan Asrina, W.Y. (2018). Spatial variability of nitrogen, phosphorus, and potassium using geospatial techniques on black pepper farms. Azarian Journal of Agriculture. 5:76-85.

Kifelew, H. and Adugna, G. (2018). Study on Phytophthora capsici cause of foot rot disease on black pepper (*Piper nigrum* L.), Tepi, Ethiopia. International Journal of Research Studies in Agricultural Sciences. 4:1-7.

Laha, M.K.C., Nordina, M.N., Isaa, M.M., Khanif, Y.M., Jahana, M.S. (2011). Composting increases BRIS soil health and sustains rice production. Science Asia. 37:291-295.

Malaysia's Open Data Portal (2019). Information on Black Pepper Industry. Department of Statistics Malaysia.

Malaysian Pepper Board (2018a). World Pepper Production. Malaysian Pepper Board.

Malaysian Pepper Board (2018b). Statistics of Pepper Commodity. Malaysian Pepper Board.

Mousavi, S.R., Shahsavari, M., Rezaei, M. (2011). A general overview on manganese (Mn) importance for crops production. Australian Journal of Basic and Applied Sciences. 5:1799-1803.

Nalina, C.N., Kumar, K.S., Chandrakala, M., Rani, S.S., Sujata, K., Shree, K.G., Hegde, R., Singh, S.K. (2016). Soil nutrient status mapping of Nagenahalli micro-watershed under Eastern Dry Zone of Karnataka by remote sensing, detailed soil survey and GIS techniques. Indian Journal of Agricultural Research. 50:389-397.

Nguyen, V.L. (2015). Spread of Phytophthora capsici in black pepper (*Piper nigrum*) in Vietnam. Engineering, 7: 506-513.

Niranjana, K.S., Yogendra, K., Mahadevan, K.M. (2018). Physico-chemical characterisation and fertility rating of maize growing soils from hilly zone of Shivamogga district, Karnataka. Indian Journal of Agricultural Research. 52:56-60.

Pal, S. and Marschner, P. (2016). Influence of clay concentration, residue C/N and particle size on microbial activity and nutrient availability in clay-amended sandy soil. Soil Science and Plant Nutrition. 16:350-361.

Partelli, F.L. (2009). Nutrition of black pepper (*Piper nigrum* L.)-a Brazilian experience. Spices and Aromatic Crops. 18:73-83.

Paulus, A.D., Sim, S.L., Eng, L., Megir, G., Rosmah, J. (2011a). Pepper Production Technology in Malaysia. Malaysian Pepper Board and Department of Agriculture Sarawak, Sarawak.

Paulus, A.D., Sim, S.L., Eng, L., Megir, G., Rosmah, J. (2011b). Malaysian Pepper Production Technology Manual. Malaysian Pepper Board, Sarawak.

Pooja, C. and Sarawad, I.M. (2019). Influence of iron and zinc on yield, quality of chickpea and status of iron and zinc in post harvest soil. Agricultural Science Digest. 39:31-35.

Prabhakaran Nair, K.P. (2011). The Agronomy and Economy of Black Pepper and Cardamom -The "King" and "Queen" of Spice. Elsevier, London.

Rao, N.K.S., Shivashankara, K.S., Laxman, R.H. (2016). Abiotic Stress Physiology of Horticultural Crops. Springer India, New Delhi.

Ravindran, P.N. (2000). Black Pepper *Piper nigrum*. Harwood Academic Publishers, Amsterdam.

Roslan, I., Shamshuddin, J., Fauziah, C. I., Anuar, A.R. (2011). Fertility and suitability of the Spodosols formed on sandy beach ridges interspersed with swales in the Kelantan-Terengganu Plains of Malaysia for kenaf production. Malaysian Journal of Soil Science. 15:1-24.

Sa'adi, Z., Shahid, S., Ismail, T., Chung, E.S., Wang, X.J. (2017). Distributional changes in rainfall and river flow in Sarawak, Malaysia. Asia-Pacific Journal of Atmospheric Sciences. 53:489-500.

Samndi, M.A. and Mahmud, A.T. (2014). Distribution of potassium forms along a hillslope positions of newer basalt on the Jos Plateau Nigeria. International Journal of Soil Science. 9:90-100.

Sarker, M.A.Z., Hossain, A., da Silva, J.A.T. (2015). Timing of first irrigation and split application of nitrogen for improved grain yield of wheat in Old Himalayan Piedmont Plain of Bangladesh. British Journal of Applied Science & Technology. 6:497-507.

Satyagopal, K., Sushil, S.N., Jeyakumar, P., Shankar, G., Sharma, O.P., Boina, D.R., Sain, S.K., Reddy, M.N., Rao, N.S., Sunanda, B.S. (2014). AESA based IPM package for small cardamom. Ministry of Agriculture, Government of India, India.

Shamshuddin, J., Elisa Azura, A., Shazana, M.A.R.S., Fauziah, C.I., Panhwar, Q.A., Naher, U.A. (2014). Properties and Management of Acid Sulfate Soils in Southeast Asia for Sustainable Cultivation of Rice, Oil Palm, and Cocoa. Advances in Agronomy. Academic Press, Amsterdam.

Singh, B. (2018). Are nitrogen fertilizers deleterious to soil health? Agronomy. 8: 1-19.

Sivaraman, K., Kandiannan, K., Peter, K.V., Thankamani, C.K. (1999). Agronomy of black pepper (*Piper nigrum* L.) - a review. Spices and Aromatic Crops. 8:1-18.

Sruthi, D., Zachariah, T.J., Leela, N., Jayarajan, K. (2013). Correlation between chemical profiles of black pepper (*Piper nigrum* L.) var. Panniyur-1 collected from different locations. Medicinal Plants Research. 7:2349-2357.

Sun, W., Shao, Q., Liu, J., Zhai, J. (2014). Assessing the effects of land use and topography on soil erosion on the Loess Plateau in China. Catena. 121:151-163.

Tahir, S. and Marschner, P. (2016). Clay amendment to sandy soil—effect of clay concentration and ped size on nutrient dynamics after residue addition. Soils and Sediments. 16:2072-2080.

Tahir, S. and Marschner, P. (2017). Clay addition to sandy soil—influence of clay type and size on nutrient availability in sandy soils amended with residues differing in C/N ratio. Pedosphere. 27: 293-305.

Tanaka, S., Tachibe, S., Wasli, M.E.B., Lat, J., Seman, L., Kendawang, J.J., Iwasaki, K., Sakurai, K. (2009). Soil characteristics under cash crop farming in upland areas of Sarawak, Malaysia. Agriculture, Ecosystems & Environment. 129: 293-301.

Thankamani, C.K., Srinivasan, V., Hamza, S., Kandiannan, K., Mathew, P.A. (2007). Evaluation of nursery mixture for planting material production in black pepper (*Piper nigrum* L.). Spices and Aromatic Crops. 16: 111-114.

Tuan, V.D., Hilger, T., MacDonald, L., Clemens, G., Shiraishi, E., Vien, T.D., Stahr, K., Cadisch, G. (2014). Mitigation potential of soil conservation in maize cropping on steep slopes. Field Crops Research. 156: 91-102.

Uzoho, B.U., Ihem, E.E., Ogueri, E.I., Igwe, C.A., Effiong, J.A.I., Njoku, G.U. (2016). Potassium forms in particle size fractions of soils on a toposequence in Mbano, southeastern Nigeria. International Journal of Environment and Pollution Research. 4: 1-11.

Yanai, J., Nakata, S., Funakawa, S., Nawata, E., Katawatin, R., Tulaphitak, T., Kosaki, T. (2007). Evaluation of nutrient availability of sandy soil in northeast Thailand with reference to growth, yield and nutrient uptake by maize. Japanese Journal of Tropical Agriculture. 51: 169-176.

Yulnafatmawita, Y., Aprisal, A., Hakim, N. (2017). Role of alley cropping system with cultivated Tithonia (*Tithonia diversifolia*) on soil erosion and soybean (*Glycine max Merr* L) production at ultisol under wet tropical area. International Journal of Civil Engineering and Technology. 8: 1237-1248.

Zhang, X., Zhang, D., Sun, W., Wang, T. (2019). The adaptive mechanism of plants to iron deficiency via iron uptake, transport and homeostasis. International Journal of Molecular Sciences. 20: 1-14.

Zingore, S., Delve, R.J., Nyamangara, J., Giller, K.E. (2008). Multiple benefits of manure: the key to maintenance of soil fertility and restoration of depleted sandy soils on African smallholder farms. Nutrient Cycling in Agroecosystems. 80: 267-282.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit http://creativecommons.org/ licenses/by/4.0/.© The Author(s)

ISSN: 0976-0539 (Online), 0253-1496 (Print), Naas Rating: 4.37