Review Article

Introducing Natural Farming in Black Pepper (*Piper nigrum* L.) Cultivation

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This paper reviews the role of Natural Farming as an ecological farming method to produce organically grown food of safe and high quality and at the same time improve soil quality and soil health. Currently, there is a dearth of information on the effects of Natural Farming approach on black pepper farms particularly in Sarawak, Malaysia. Previous studies on other crops had indicated positive outcome using the Natural Farming method. Thus, this paper discusses the essential role of effective microorganisms in Natural Farming and their potential in pepper cultivation. Through the action of effective microorganisms, this approach should be able to transform a degraded soil ecosystem into one that is fertile and has high nutrients availability. The mixed culture of effective microorganisms applied must be mutually compatible and coexist with one another to ensure its favorable establishment and interaction in the soil. Therefore, it is anticipated that introducing Natural Farming in black pepper cultivation can enhance the predominance of effective microorganisms in the soil, which in turn could lead to promising growth and yield of the crop.

1. Introduction

Current trends in pepper cultivation, fertilizers, and wide-scale applications of broad-spectrum organophosphate pesticides could result in a degrading ecological environment besides shortening the lifespan of pepper vines [1]. Therefore, as part of the National Commodity Policy of Malaysia heads towards an environment-friendly industry, introducing Natural Farming in pepper cultivation will be part of an effort by the Malaysian Pepper Board, Malaysia, to support green development. Moreover, as the global demand for organic farm produce increases, there is a need to develop an agricultural practice which is sound and sustainable for the betterment of both the environment and humans living in it.

Natural Farming is a term used to describe an ecological farming approach to produce organic based food crops [2, 3] (Talaat et al., 2017). It is a natural agriculture alternative

which promotes lower production cost and at the same time is able to achieve product of high quality and yield with lower or without the usage of inorganic fertilizers and pesticides [4]. As the approach is closely related to soil fertility, introducing Natural Farming to enhance the predominance of beneficial and effective microorganisms can help to improve and maintain soil biological, chemical, and physical properties (Fukuoka, 2009) [5].

The role of using beneficial microorganisms in Natural Farming is in increase because many people are being aware of the hazards associated with consuming products with chemical substances. Nevertheless, enhancing food security through this approach in Malaysia is still a not well-established option due to lack of technical knowledge in the required subject. The desired effects for applying Natural Farming fertilizers to soils can vary, at least initially. In some soils, a single application may be enough to

produce the expected results, whereas for other soils, repeated applications may be ineffective [6]. The reason for this is that, in some soils, it takes longer time for the introduced microorganisms to adapt to a new set of ecological and environmental conditions and to become well established as a stable, effective, and predominant part of the indigenous soil microflora. Megir and Paulus [1] observed that in most black pepper farms, intense use of farming chemicals causes the ecosystem to be degraded and therefore not suitable for newly introduced microbial communities to live in. Megir and Paulus [1] added that these microbes may not be able to withstand the intolerable pH, moisture, and temperature conditions of degraded soils. Hence, the proper and regular addition of organic amendments is often an important part of any strategy to ensure the survival of newly introduced microorganisms [5]. To this end, there is strong belief that Natural Farming can ensure very productive pepper farming, clean environment, increase profits of pepper growers, and at the same time make healthy and fresh organic produces affordable for everyone. Thus, this paper discusses the essential role of effective microorganisms in Natural Farming and their potential in pepper cultivation.

2. Fertilization Practice in Pepper

Pepper has high demand for nutrients [7]. It requires large quantities of nutrients to maintain significant growth and yield. It has been estimated that the nutrient uptake of a mature stand of pepper amounts to 202 kg N, 13 kg P, 156 kg K, 18 kg Mg, and 68 kg Ca per hectare per year [8]. Studies by the Malaysian Pepper Board [9] and Yap [8] estimated pepper yield by conventional practice was approximately 6 tons per hectare per year, whereas that of the yield associated with organic farming practice resulted in approximately 5 tons per hectare per year [8]. In Malaysia, the costs of buying compound inorganic fertilizers for pepper vines of different maturity stage are shown in Table 1. Mature vines or pepper aged three years and above requires more chemical or inorganic fertilizers than immature vines; therefore, more cost is involved. Hence, it is important to note that naturally cultivated pepper should be able to reduce the dependency on expensive inorganic fertilizers. Natural Farming approach must be able to convert a degraded soil ecosystem full of harmful microbes to one that is productive and contains useful microorganisms which in turn could contribute to high nutrients availability.

3. Sustainable Agriculture through Natural Farming

The term Natural Farming or nature farming is not simply farming without chemical fertilizers and pesticides, but rather it is organic farming with the added dimension of exploiting beneficial microorganisms to enhance soil quality and soil health [10, 11]. Sustainable agriculture can be defined as a set of practices that conserve resources and the environment without compromising human needs. In line with the concept of sustainable agriculture and development, Natural

TABLE 1: Cost of fertilization associated with pepper cultivation.

Pepper vine	Cost per hectare per year
Immature	USD 1,670
Mature	USD 2,131

Farming approach qualifies as one of its main pillars (Talaat et al., 2017). Sun et al. [11] stated that intimate understanding of the local ecology is necessary for successful agriculture, and it may be important to extend this knowledge to the smallest of lifeforms.

4. Soil Microflora Associated with Natural Farming

Microorganisms are effective only when they are presented with suitable and optimum conditions for metabolizing their substrates including available water, oxygen (depending on whether the microorganisms are obligate aerobes or facultative anaerobes), pH, and temperature of their environment. The important consideration here is the careful selection of a mixed culture of compatible, effective microorganisms properly cultured and provided with acceptable organic substrates [12, 13].

In Natural Farming, these beneficial microorganisms can be grown to high populations and then applied to soils that also have a large stable population of beneficial microorganisms, especially facultative anaerobic bacteria [14]. The desired effects appear only after they are established, become dominant, and remain stable and active in the soil. It has been difficult to study the time required for the inoculated microorganisms to be effective due to variable conditions in soils including unanticipated changes in soil pH, temperature, and moisture [1]. However, it will have required at least a year for a conventional black pepper farm to be fully established as a naturally organic farm with wealth of inoculated beneficial microorganisms in soils [2]. Park and DuPont [2] added that repeated monthly applications, especially during the first cropping season, can markedly facilitate early establishment of the introduced beneficial microorganisms.

Van Bruggen and Finckh [15] also reported that even when a beneficial microorganism is isolated from a soil, cultured in the laboratory, and reinoculated into the same soil at a very high population, it is immediately subjected to competitive and antagonistic effects from the indigenous soil microflora and its numbers soon decline. Studies by Van Der Heijden et al. [16] and Rashid et al. [17] mentioned that one of the essential requirements for the inoculated microorganisms to be well established was the introduction of mixed cultures instead of a single inoculum. Zimmerman (2008) and Thies et al. [18] found that amending soil with biochar can also enhance the effectiveness of beneficial or effective microorganisms as it provides conducive environment for the microbes to live in. Thies et al. [18] added that the tiny perforations in the biochar provide shelter for the inoculated microorganisms to house themselves. Thus, the possibility of shifting the “microbiological equilibrium” of a soil and

controlling it to favor the growth, yield, and health of crops is greater if mixed cultures of beneficial microorganisms introduced are physiologically and ecologically compatible. If so, then it is also highly probable that they will exercise considerable control over the indigenous soil microflora which, in due course, would likely be transformed into or replaced by a “new” soil microflora [16].

5. Effective Microorganism (EM)

Effective Microorganism (EM), generally in liquid form, contains a variety of lactic acid bacteria, yeasts, and phototrophic bacteria that can be applied as inoculants to increase the microbial diversity of soil ecosystem [12, 19–21]. Talaat et al. [22] observed that EM contains selected species of microorganisms including predominant populations of lactic acid bacteria and yeasts, smaller numbers of photosynthetic bacteria, actinomycetes, and other types of organisms. All of these microorganisms are mutually compatible with one another and can coexist in liquid culture. Keymer and Lankau [14] added that usually EM shows best results in situations where the natural balance of microorganisms has been severely disrupted or where agricultural farming inputs are in short supply. In situations where natural microorganism populations are reasonably intact, or where a balanced supply of inputs is available, the addition of EM does not make significant difference.

Zuraihah et al. [21] noted that the exact mechanism of how EM acts and interacts in the soil-plant ecosystem is not known. However, there is evidence that supports a number of theories concerning the action of EM. Further studies done by Van Bruggen and Finckh [15] reported the beneficial effects of EM which include suppression of soil-borne pathogens, increased decomposition rate of organic waste, increased availability of mineralized nutrients to plants, enhancement of microbial activities, increased nitrogen fixation, and reduced requirement of chemical fertilizers, pesticides, and fungicides. Shin et al. [5] added that EM helps to speed up the natural composting process, without many of the side effects of foul odours and pests. Figure 1 shows the function of EM in the soil-plant ecosystem which was illustrated by Higa [19].

Sharma et al. [23] reported an increase in humus content of a soil amended with organic materials and inoculated with EM. Although there was little difference in the chemical analyses of the soil among treatments, EM enhanced or improved the growth of plants over those of the control and fertilizer-treated plants. The beneficial effect of EM was attributed to the utilization of plant root exudates and the solubilization and mineralization of certain soil nutrients into plant available forms [23]. In other experiments, pure cultures of lactic acid bacteria were unable to promote significant differences in the humus content or chemical content of the soil.

6. Biochar as Soil Amendment

Biochar is produced with the intent to be applied to soil as a means of improving soil productivity, carbon (C) storage, or

filtration of percolating soil water [24]. Biochar is produced by thermal decomposition of organic material under limited supply of oxygen (O_2) and at relatively low temperatures ($<700^\circ C$) [25]. The potential of biochar to improve plant growth is related to changes in the physicochemical properties of soils that lead to overall increases in microbial activity [26, 27]. When conditioning soils, it is possible to enhance the effectiveness of beneficial or effective microorganisms by adding biochar, or a similar material with tiny perforations, in which the microbes can house themselves (Zimmerman, 2008) [18].

Agegehu et al. [28] listed some extensive scientific evidence demonstrating that additions of low application rates of biochar into bedding plant container media in the greenhouse, or as amendments to field soils, improve plant growth and yields significantly, regardless of nutrient supply. For example, Vaccari et al. [29] reported increases in the rates of germination, growth, and yields of tomato plants grown in a range of concentrations of a soil commercial container medium amended with biochar. Dunlop et al. [30] demonstrated improvements in the germination and growth of petunias, marigolds, bell pepper, and tomatoes in response to similar charcoal activated carbon amendments into bedding plant container media.

7. Composts as Soil Amendment

Beneficial or effective microorganisms (EM) including yeast, mold fungi, lactic acid bacteria (LAB), photosynthetic bacteria, and actinomycetes [19] microbial groups are responsible for decomposing a variety of organic materials for use in agriculture [31]. These microorganisms are very common in composts [31]. Composts inoculated with EM improve yields and nutrient uptake significantly for a variety of crops including wheat [11], soybean [6], rice [23], and cotton [32] more than plants grown with noninoculated composts. Talaat et al. [22] stated that improved productivity in crops treated with EM-inoculated composts compared with untreated composts is related to hastened decomposition of organic compounds into plant available nutrients. Sharma et al. [23] added that EM compost is a good source of nutrients for crops, which can provide favorable conditions for the growth of crops, promoting the mobilization of insoluble nutrients and activating the beneficial microorganisms in soils.

Significant effects of composts on soils depend on the type and rate of compost, soil C, pH, cation exchange capacity (CEC), and other components of soil fertility. The application of composts to soils can alter soil organic matter status [33, 34] as this is associated with the release of nutrients such as N through mineralization [35]. This process improves both the growth and yield of the plant. Besides decreasing soil bulk density, Agegehu et al. [28] added that application of compost can increase soil pH, soil organic content (SOC), N content, available P, K, Ca, Mg, Na, and S. Compost addition to soil has also been shown to increase yield of crops similarly to, or beyond the effects of, mineral fertilizer application [36]. However, annual application of high doses of compost had an inhibitory effect on enzyme activity and crop yields [37].

FIGURE 1: Functions of effective microorganisms in the soil in “Microorganisms for Agriculture and Environmental Preservation”, Higa [19], Nou-bun Kyo (in Japanese).

8. Role of Natural Farming to Improve Pepper Cultivation

Smith et al. [13] opined that the foundation of Natural Farming production lies in the health of the soil. A fertile soil provides essential nutrients to the growing crop and helps support a diverse and active biotic community. The soil in Natural Farming production is often referred to as living soil. There is a wealth of microorganisms including bacteria, fungi, algae, and protozoa as well as macrofauna such as earthworms, snails, slugs, insects, spiders, centipede, and millipede living in it. Fungi such as mycorrhizae and bacteria (*Rhizobia*), *Azotobacter*, and earthworms are known to contribute to the fertility of the soil.

Pepper is a nutrient demanding crop, especially during fruit setting. For optimal growth and yield, it requires sufficient amounts of macronutrients and micronutrients. A

pepper grower who practices Natural Farming must be able to recognise nutrient deficiency symptoms so that remedial measures are timely taken [1, 11, 14]. Hunt et al. [26] reported that fermented plant juice (FPJ) and fermented fruit juice (FFJ) from organic materials incorporated with biochar can provide fertile soil for the vines to grow well and bear fruit. All crop residues and farm wastes available on the farm including branches and leaves from pepper vines can be recycled, so that soil fertility is restored and maintained. It is the process of transforming organic materials of plant origin into humus. The FPJ and FFJ can act as fertilizers as well as a soil conditioners [6]. Although a study by Paulus and Anyi Wan [38] showed that pepper yield obtained from organic farming was lower compared with that of the conventional practice of using chemical based farming input, on the production cost per yield basis, it provides higher benefit-cost ratio of 1.67 compared with that of conventional practice with benefit-cost ratio of 1.44.

9. Conclusion

The proper selection and dosage of Natural Farming liquid fertilizers should be studied and adopted to improve nutrient efficiency. If the microorganisms comprising the mixed culture can coexist and are physiologically compatible and mutually complementary, and if the initial inoculum density is sufficiently high, there is a high probability that these microorganisms will become established in the soil and will be effective as an associative group, whereby such positive interactions would continue. Therefore, it is important to set up and properly sustain pepper cultivation practices under Natural Farming to reduce investment on chemical based inputs and at the same time lower the environmental hazard caused by pesticides, weedicides, fungicides, and inorganic fertilizers.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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