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Short communication

Profitability of strawberry (*Fragaria ananassa*) production with biofilmed biofertilizer application

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ABSTRACT

The economic benefits of strawberry production with the application of monocultures of *Aspergillus* sp. and *Enterobactor* sp. and their mixed cultures (fungal-bacterial biofilm; BF) were calculated in comparison to the recommended dosage of chemical fertilizers (CFs) in a pot experiment. In terms of productivity, strawberry yield with BF coupled with 39% of CFs was 152% profitable over 100% CFs treatment. *Aspergillus* sp. and *Enterobactor* sp. showed the 102 and 66% of more profits when coupled with 100 and 34% of CFs, respectively. The findings of this study clearly indicate the efficacy of BF as a biofertilizer to reduce the usage of CFs in strawberry cultivation.

In conventional strawberry farming, high doses of chemical fertilizers are applied to obtain better yields. However, long-term use of chemical fertilizers and other agrochemicals have been reported to affect the soil fertility and crop productivity adversely, mainly due to their negative effects on soil fauna and microbes (Hedley et al., 1982; Seneviratne, 2009). These negative effects can eventually disrupt the nutrient cycling in soil. As a result, more pesticides and fertilizers are required to maintain a reasonable crop yield. While the list of environmental problems associated with conventional agriculture extends, scientists have paid attention to reduce the usage of chemical fertilizers (CFs) by coupling the CFs with growth promoting biofertilizers. According to the literature, soya bean showed the best growth performance when using phosphorus solubilizing bacterium, *Bradyrhizobium japonicum* together with 33% of chemical fertilizers (Janagard et al., 2013). The significant growth and yield of maize was observed with the use of bio- and chemical phosphorous combinations (Yosefi et al., 2011). Strawberry has benefited from the application of biofertilizers together with reduced dosage of CFs over application of CFs alone (Zargar et al., 2008; Umar et al., 2010). The application of nitrogen (225 kg ha^{-1}), phosphorus (150 kg ha^{-1}) and biofertilizer (*Azotobacter*) in combination showed the highest average fruit weight (19 g) over the application of biofertilizer or CF alone (Zargar et al., 2008). The application of 25% nitrogen through subabul (green leafy manure of *Leucaena leucocephala*) +75% N in the form of urea augmented with biofertilizer has resulted higher fruit size (38.4 × 28.9 mm) and weight (16.9 g) in strawberry cv. 'Chandler' (Umar et al., 2010). Bio- and chemical fertilizer combinations have been reported to improve the soil health (Patil, 2010). Biofilmed Biofertilizers have been reported to reduce the recommended dosage of CF by 50% in tea, while significantly increasing soil microbial biomass and biological nitrogen fixation (Seneviratne et al., 2011). Therefore, present study focused on evaluating the potential use of biofilmed biofertilizer between *Aspergillus* sp. and *Enterobactor* sp. in comparison with monocultures of *Aspergillus* sp. and *Enterobactor* sp. together with CFs to reduce heavy usage of CFs in strawberry farming with reasonable improvements in yield and economical returns. In the present experiment, the strawberry growth promoting microbial cultures; a fungal strain (*Aspergillus* sp.; F), a bacterial strain (*Enterobactor* sp.; B) and a fungal-bacterial biofilm between *Aspergillus* sp. and *Enterobactor* sp. (BF) were used as biofertilizers. All cultures were introduced in to a Low Cost Medium (LCM) formulated in Microbial Biotechnology Unit (MBU) of the National Institute of Fundamental Studies (NIFS), Kandy and incubated (25–27 °C, 110 rpm) for 7 days. The three types of biofertilizers and, the biofertilizers coupled with 25, 50, and 75% of recommended dosage of CFs were used as the treatments. In reference treatments, the CFs alone (i.e. 25, 50, 75 and 100%) were used. The pot experiment was conducted under glasshouse conditions (20 °C–11.6 °C day and night temperatures, respectively, 77% Relative Humidity and

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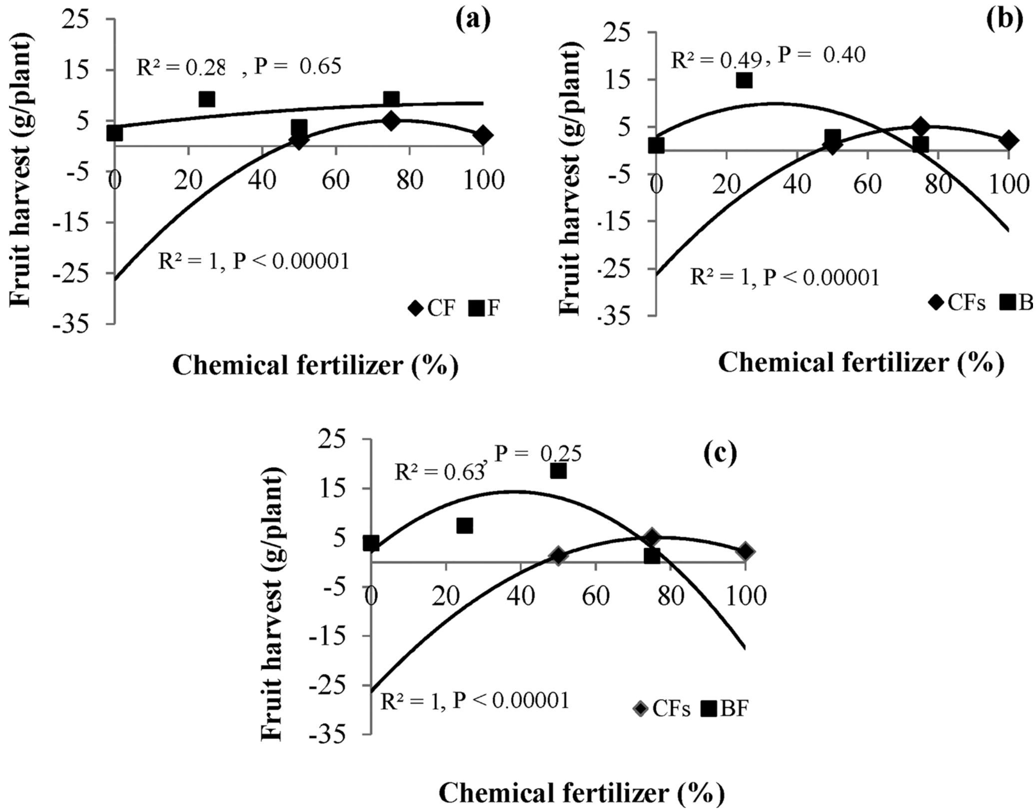

Fig. 1. Estimated yield response of strawberry when applied : a – F (*Aspergillus* sp.), b –B (*Enterobactor* sp.), c – BF (Biofilm between *Aspergillus* sp. and *Enterobactor* sp.) coupled with different levels of chemical fertilizers in comparison to yield response of only chemical fertilizers application.

Table 1
Net profit calculation of strawberry production with biofertilizers application in a 100-pot nursery.

Treatment	Production function (Q)	Percent CFs level (x) to obtain maximum output (Q)[a]	Maximum output (g)	Earning (at a rate of LKR 2500 /kg of Strawberry)	Expenditure - fertilizer and labor cost (LKR)	Net profit (LKR)	Profit increase over the CFs application (%)
CFs	$Q = -0.005x^2 + 0.816x - 26.25$	81.6	600	1,500 (9.66 USD)	195.84 (1.26 USD)	1304.16 (8.4 USD)	–
F	$Q = -0.000x^2 + 0.089x + 3.746$	100.0	1,200	3,000 (19.32 USD)	360.00 (2.32 USD)	2640.00 (17 USD)	102.4
B	$Q = -0.006x^2 + 0.411x + 2.946$	34.3	1,000	2500 (16.10 USD)	302.25 (1.92 USD)	2197.75 (14.15 USD)	66.7
BF	$Q = -0.008x^2 + 0.638x + 2.110$	39.9	1,500	3,750 (24.15 USD)	460.03 (2.96 USD)	3289.97 (21.19 USD)	152.3

F, *Aspergillus* sp., B – *Enterobactor* sp., BF, biofilm between *Aspergillus* sp. and *Enterobactor* sp.
LKR, Sri Lankan Rupees; USD, US dollars.
(USD 1 = 155.09 LKR, as at 20.03.2018).
[a] calculated from dQ /dx = 0.

1600 lx Light Intensity) at Seetha Eliya Agricultural Research Station, Sri Lanka. Strawberry (*Fragaria x ananassa*) var. Chandler runners from G1 generation were potted in black polythene bags (diameter 20 cm, height 15 cm) each filled with 3 kg of forest soil (pH = 6.8, organic C = 32%, total N = 0.51%, total P = 1.7%.). After two weeks, treatments were applied. The 100% CF reference treatment received 0.250 g of urea, 0.500 g of super phosphate and 0.125 g of muriate of potash per pot (as calculated from the recommendations of the Department of Agriculture, Sri Lanka). The control was maintained without addition of biofertilizers or CFs. During the application, the microbial biofertilizers were diluted 20 times by adding water. For each pot, 50 mL of diluted biofertilizers were applied. The treatments were applied once in every two months for a period of 10 months, according to the recommendations of the Department of Agriculture, Sri Lanka. The treated pots in triplicate were arranged according to completely randomized design. All recommended crop maintenance practices were followed throughout the experimental period. Fruits were harvested and weighted to obtain fresh yield. Yield data under different treatments with biofertilizer and biofertilizer coupled with different dosages of CFs were used to assess the economically optimal levels of fertilizer application with or without biofertilizers. Production function (*Q*) graphs were created in Excel [Excel®*2007 (12.0.4518.1014)]*. The 2nd order polynomial functions were fitted for each curve in the graphs. These curves were used to determine the maximum production (output) and the level of chemical fertilizer application at the maximum production of strawberry. The profits of strawberry production with the application of biofertilizers alone and biofertilizer coupled with 25, 50 and 75% CFs were calculated by using *Q*, a fundamental economic concept. *Q* = f (L, K, etc), where L and K are inputs of the strawberry production process (Rasmussen, 2013). The *Q* curves of chemical fertilizers alone and biofertilizers coupled with different chemical fertilizer levels are given in Fig. 1a–c. According to the figures, *Aspergillus* sp. treated plants gave the highest yield when coupled with 100% of CFs (Fig. 1a). Microbial biofertilizers, *Enterobactor* sp. and biofilm between *Aspergillus* sp. and *Enterobactor* sp. gave the highest yields when coupled with lower percentages of chemicals fertilizers than 100% CFs, as given in Table 1 and Fig. 1b and c. According to the net output calculation given in Table 1, ~ 80% CFs alone is sufficient to obtain a maximum yield of strawberry. *Aspergillus* sp. combined with 100% CFs gave a 102% profit increase over the 100% CFs (Fig. 1a, Table 1). Thus, the use of *Aspergillus* sp. as a biofertilizer did not markedly reduce the recommended dosage of CFs. The profit increase over the 100% CFs under *Enterobactor* sp. was 66% (Table 1). However, the maximum profit and the maximum profit increase (152%) over the 100% CFs was obtained in BF biofilm coupled with 39% of CFs. Thus, BF between *Aspergillus* sp. and *Enterobactor* sp. with 40% of CFs can be introduced as the best fertilizer combination for strawberry production in nursery pots. Further, according to the fruit quality analysis, BF + 50% CFs treated fruits showed significantly improved (at $p \leq 0.05$) Total Soluble Solid and Ascorbic Acid contents in comparison to 100% CFs suggesting improved fruit quality in BF + 50% CFs.

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