Plant biostimulant to improve crops productivity and planters profit

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Abstract. Plant bioestimulants are applied to meet the challenge for sustainability of agriculture production. IRIBB has developed organic-based biostimulant formulas (OBFs) and tested in the field of several crops. OBF-1 improved the vegetative growth and productivity of some annual food crops. Compared with the control plants, the productivity of OBF-1 treated rice, maize, potato and shallot increased by 25%, 31%, 30% and 23%, respectively. In addition, OBF-1 treated crops indicated more tolerant to pests and diseases. OBFs applications on perennial estate crops demonstrated that OBF-2 and OBF-1 combination increased tea yield around 48% and sugarcane yield up to 50%. Whereas foliar sprays of OBF-3 on oil palm increased the CPO yield by up to 32%. The increased CPO yields were contributed to the increase of total FFB (fresh fruit bunches) weight and oil extraction rate in the fruit mesocarp. OBF-3 is a formula enriched with oil-biosynthetic activators. The farmers and planters should gain additional profits from the increased crop yields in response to the OBF application. How much profits gained were depended also on the price of the commodities. In general, the additional profits were much higher than the OBFs and labour costs.

1. Introduction

Within 40 years, the world population was doubling, increased from 3 billion in 1959 to 6 billion by 1999. The US Census Bureau [1] estimated that world population will continue to grow even though at a slower rate. The world population is projected to grow from 6 billion in 1999 to 9 billion by 2042 [1]. The increasing number of the world population is contributed by both the increased number of new births and life expectancy [2]. To support the needs of world growing population for primary food and energy, the supply of agricultural products must be increased. With decreasing area of arable land for agriculture production, an intensification strategy is necessary. The use of plant bioestimulant is considered an innovative approach to increase agriculture production in a sustainable and environmentally friendly way [3].

Plant bioestimulants can be defined as substances or products that contain compounds, microorganisms or formulations stimulating natural process of plant growth. Of the developing definitions, there are five categories of bioestimulants: microbial inoculants, humic acids, fulvic acids, protein hydrolysates and amino acids, and seaweed extracts [4, 5]. The Indonesian Research Institute for Biotechnology and Bioindustry (IRIBB) has developed some formulations of plant bioestimulant
with primary components are extracts of natural organic materials from local sources. The extracts and formula were prepared in such unique ways in both compositions and bioactivities to plant growth and development [6, 7]. The organic-based biostimulant formulas (OBFs) have been tested to stimulate the growth and development of some plants *in vitro*, in the greenhouse, and in the fields.

This paper reported some of the results of those tests. The test at the laboratory level was conducted using tobacco (*Nicotiana tabacum* L.) plantlets grown *in vitro*. The field trials were mainly to evaluate the effects of OBFs on productivities of some perennial estate crops and annual food crops such as rice, maize, potato, and shallot. The perennial estate crops used to test the efficacy of the OBFs were tea (*Camellia sinensis* L.) and oil palm (*Elaeis guineensis* Jacq.) in the plantations, and sugarcane (*Saccharum officinarum* L.) grown in polybags.

2. Materials and Methods

Organic extracts were prepared as described previously [6]. Chemicals for plant tissue culture media were bought from Sigma Chem. Co. or local sources. Biostimulant stock solutions of several formulations were produced and kindly provided by Biostimulant Lab Production of IRIBB. These stocks sent to the fields were prepared with concentrations 10,000 ppm (OBF-1 and OBF-3) and 80,000 ppm (OBF-2). To most crops in the fields, 250 to 1,000 times diluted biostimulant solutions were applied through foliar spraying. For mature oil palm trees taller than 5 meters, there were 2 alternative ways of application, trunk injection or root infusion.

2.1. *In vitro* testing of organic extracts

*In vitro* culture medium for tobacco, plantlet development was prepared using basic MS salt [8] with a half concentration as used for Lilium plant species [9]. The MS salt solution was added with 3% sucrose and 1% Gelrite. After the pH was adjusted to 5.7, sterilization was performed using an autoclave at 121 °C for 30 min. A certain amount (0.5 to 40 ppm) of filter-sterilized organic extracts were added and mixed into warm autoclaved media. After the media were solidified and cooled in some culture tubes, sterile tobacco plantlets were cultured into the tubes and maintained in a culture room. Plantlet development was observed every 2 to 7 days.

2.2. Foliar sprays

For foliar spray application, diluted OBF solution was filled into the tank of a power sprayer. The doses of the sprays were between 200 - 300 L/ha for all crops or 1.5 L per productive oil palm tree. The sprays were performed during the shady time, preferably early in the morning when the stomata were open.

2.3. Trunk injection

Application of the biostimulant through trunk injection used diluted biostimulant solution with smaller volumes but higher concentration, volume 60 - 100 mL per tree and dilution 200 - 500 times. Small holes with diameter 1 – 1.5 cm and depth 10 - 15 cm were made with 30-degree slope into the palm trunk. Using a funnel 30 - 50 mL diluted biostimulant was filled per hole.

2.4. Root infusion

In term of dosage, application of biostimulant through root infusion was more similar to trunk injection than to foliar spray. The volume could be 100 to 200 mL per spot and dilution 400 – 600 times. Roots to be infused were chosen the healthiest ones. The chosen roots were selected by digging carefully the soil at the spotted area approximately 50-cm from the outer side of the trunk. Two healthy roots at the opposite positions on the trunk were cut smoothly with a very sharp cutter. The cut root was inserted into a 500-mL plastic bag with 5 to 8 cm in diameter that contains 100 to 200 mL diluted biostimulant. After insertion of a straw, the open end of the bag was tied loosely together with the cut root and the straw, the construction was dumped loosely with soil and the tip of the straw was
several centimetres above the ground and covered with cotton. The function of the straw was to later normalize air pressure in the bag and refill the bag with biostimulant solution.

3. Results and Discussion

Bioactivities of organic extracts were tested in vitro using tobacco plantlets observed weekly until 10 weeks in culture. Table 1 indicates that the two preparation of organic extracts were strong inducers of the early development of roots. The four treatments induced plantlet rooting to some extent were similar in one week of culture, where the control plantlets had no root yet. The Exalk-4 provided several different types of plant development at different lengths of culture. While the other three extracts were similar, since two weeks in culture stimulating only the vegetative growth and no generative development. In addition to vegetative development and growth, the Exalk-4 strongly stimulated generative development. Only within the two-week culture, Exalk-4 induced flower buds on the top of the tobacco plantlets. Whereas in normal culture condition (without extract), the tobacco plantlets were never flowering. The strength of florigenic properties of the Exalk-4 could be confirmed with a comparison to transgenic tobacco carrying flowering transgene. In transgenic tobacco plantlet ectopically expressing flowering gene TcAP1, the tobacco plantlet was flowering only after 3.5 months or about 14 weeks in culture [10]. These data indicate also that the Exalk tends to work better in a lower concentration. Whereas the Exair to some extent was more effective in a higher concentration.

Table 1. Growth and development responses of tobacco plantlets to the presence of extracts.

| Treatments | 1 week rooting | 2 weeks flowering | 7 weeks buds | 10 weeks |
|------------|----------------|------------------|--------------|----------|
| Control    | None           | none             | none         | none     |
| Exalk 4    | N=23; L 4-7 mm | Flower bud       | Apical flower bud wilted, many axillary buds | A flower bud formed on every axillary bud |
| Exalk 40   | N=16; L 2-7 mm | none             | none         | none     |
| Exair 4    | N=5; L 1-15 mm | none             | none         | none     |
| Exair 40   | N=18; L 3-28 mm| none             | none         | none     |

Note N= number of developing roots per plantlet; L= length of roots.

Considering that the organic extracts contain some kinds of phytohormones, the root-inducing capability of the extracts was likely provided by the cytokinin content in the extracts. Research by de Vries et al. [11] reported that cytokinin induced promotion of root meristem in the fern. Flower induction involves a more complex network of molecular regulation including hormones. In apple trees (Malus domestica) flower formation involved cytokinin, abscisic acid and gibberellic acid pathways [12]. Gibberellic acid promoted the transition from vegetative development to the first inflorescence phase of reproductive development of Arabidopsis [13]. In the case of Exalk 4, strongly induced flower buds of tobacco plantlet could be likely synergistic effect of the composition of flower-promoting hormones in the extract cytokinin and gibberellic acid. Our previous analysis using LCMS indicated that the extract contains GA3 (gibberellic acid-3) and cytokinin.

These in vitro data of the tobacco plantlet development were considered to be the key information useful in formulating OBFs. Type of extract and concentration in the treatments extrapolated to the composition of those in OBFs. There are usually certain conversion factors that can be used to transform composition and concentration from the laboratory level to the field trial level. In general, the dosage needed by the crops in the field is higher than that of the model plants in the laboratory.
3.1. OBFs field trials on annual food crops

Application of OBFs to improve the yield of some annual food crops such as rice, maize, potato and shallot was examined in several different locations in Java. These trials involved directly small farmers own the lands. The results were presented in Table 2. These data show that the increases in those crops productivity were varying from the lowest 23% in shallot to the highest 31% in maize. The most comprehensive data were collected from trials on rice crop. In addition to data on the efficacy, data of surveys were collected from farmers involved directly in this trials. One of the questions of the surveys was “after being experienced using OBF-1 to improve rice productivity, how much satisfied you (the farmers) on the efficacy of OBF-1?”. From 129 farmers of the respondents, 62 farmers gave the highest level of satisfaction (score 5 of 5 choices available), 66 farmers provided score 4, and 1 respondent chose none [14]. These farmers satisfaction could be the reflection of the additional profit gained from the increased yield of the crops.

Table 2. Improved yield of annual food crops by biostimulant OBF-1.

| Crops   | Location in Java | The control yield (ton/ha) | Yield increase (%) |
|---------|------------------|---------------------------|-------------------|
| Rice    | East, Central, West | 7.05                      | 25                |
| Maize   | West             | 9.20                      | 31                |
| Potato  | Central, West    | 18.25                     | 30                |
| Shallot | Central          | 9.67                      | 23                |

Additional profits possibly gained by the farmers from the increased productivity calculated using the selling price of the commodities at the local or neighbouring market. The selling price at the producer level was obtained from the online information service provided by the Indonesian Ministry of Agriculture and can be accessed at http://aplikasi.pertanian.go.id/smshargakab/qrylaprmsayu.asp. Table 3 shows that additional profit by the OBFs application could provide 4- to almost 20-fold additional profits to the additional cost. The lowest additional profit was from OBFs on rice, but it was still more than 4-fold of the additional cost. The highest additional profit was gained from OBFs on potato, it was almost 20-fold of the additional cost.

Table 3. Increased profit of the annual food crops treated with biostimulant OBF-1.

| Crops   | Yield increase (kg/ha) | Selling price (IDR/kg) | Additional cost (IDR/ha) | Additional profit1 (IDR/ha) |
|---------|------------------------|------------------------|--------------------------|-----------------------------|
| Rice    | 1,507                  | 4,500                  | 700,000                  | 6,081,500                   |
| Corn    | 2,852                  | 3,700                  | 900,000                  | 9,752,400                   |
| Potato  | 5,475                  | 7,500                  | 6,000,000                | 35,062,500                  |
| Shallot | 2,224                  | 12,000                 | 2,000,000                | 24,689,200                  |

1Additional cost of OBFs and labours varied from IDR 1,500,000 to 2,000,000

Efficacy of OBFs on three different types of perennial estate crops has been conducted on plantations and on polybags. The range of their productivity increases was comparable with those of the annual crops above (Table 4). The highest increase occurred in OBFs on sugarcane, which was up to 50%. Two conditions were applied on the sugarcanes. The plants were grown in more favourable conditions, controllable polybags and using two other types of plant biostimulants which were humic acid-based plant biostimulant and microbial inoculant of mycorrhiza. Whether the increased productivity of the sugarcane in the field would be similar, a field trial should be conducted with the same treatments. In fact, a field trial is being performed in East Java.
Table 4. Improved yield of estate crops by biostimulant OBF-1.

| Crops         | Location         | The control yield (kg/ha) | Yield increase (%) |
|---------------|------------------|---------------------------|--------------------|
| Tea           | PTPN-8; PTPN-6   | 1,941                     | 48                 |
| Oil palm      | PTPN-6           | 6,805                     | 29                 |
| Sugarcane*    | IRIBB            | 7,800                     | 50                 |

*Grown in polybags

From the data in Table 4 and the listed current selling price of the commodities, the additional profits were calculated. The additional profits gained by the planters are profits obtained from additional production multiplied by the selling price, then are subtracted by additional cost. Table 5 indicates that the most profitable in number is the biostimulants on sugarcane, the lowest profit is OBF on oil palm. Nevertheless, the use of OBFs on oil palm is very attractive because the additional profit is still much higher than the additional cost, more than 3-fold of the cost. Besides, the potential market of the OBFs on oil palm plantations is the biggest. Owned by mostly big companies, the purchasing power of the plantations for OBFs should be attractive for doing business with.

Table 5. Increased profit (IDR) of estate crops by biostimulant OBF-1.

| Commodity | Additional production (kg/ha) | Selling price ( IDR/kg ) | Additional cost ( IDR ) | Additional profit ( IDR ) |
|-----------|--------------------------------|--------------------------|-------------------------|---------------------------|
| Tea       | 932                            | 18,000                   | 2,460,000               | 14,306,860                |
| Oil palm  | 1,983                          | 8,000                    | 3,764,400               | 12,099,600                |
| Sugarcane*| 3,900                          | 11,000                   | 3,500,000               | 39,400,000                |

*Grown in polybags

OBFs have attractive in both scientific and business aspects. That mechanisms by which OBFs regulates plant development has not yet been revealed are interesting objects of further studies. These include more detail composition of the bioactive compounds in each specific extract of the organics used.

The existing formulations the OBF-1 to -3 proven capable of improving the productivity of some trial crops are profitably attractive. Therefore, mutually beneficial involvements of the industries are necessary for commercialization steps. There were indications that the OBFs improve the quality of the harvests needs to be further explored both scientifically and economically. Moreover, new formulations maybe developed with a specific function to a specific crop. Otherwise, new OBFs formulations and combinations that have more general functions to most crops can be alternative targets of development. All of these should be developed in response to farmers and planters needs to get beneficial impacts that supportive to sustainable developments.

4. Conclusions

Organics-based biostimulant formulations (OBFs) were proven to improve the productivity of some annual food crops and perennial estate crops. The yields of OBFs-treated rice, maize, potato and shallot in the fields increased around 25%, 31%, 30% and 23%, respectively. Likewise, OBFs showed good effects on improving the productivity of tea, oil palm and sugarcane by 48%, 30% and 50%. Based on the results, the farmers and planters should gain additional profits from the increased yields of the crops in response to the OBFs application. How much more profits gained were depended also
on the selling prices of the crops. The additional profits were much higher than the OBFs and labour costs, could be 4- to 20-fold of the cost.

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