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# APPLICATION OF BIOSTIMULANTS BASED ON PADDY STRAW COMPOST AND INORGANIC FERTILIZER IN INCREASING SOIL FERTILITY AND RED CHILLI YIELD

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## ABSTRACT

Salinity due to abiotic stress can reduce the yield and productivity of agricultural crops. The negative effects of salinity stress can be overcome by adding soil organic matter that is enriched with beneficial microbes. The aim of this research is to evaluate the application of a combination of straw compost with biostimulant microbes and doses of N, P, K fertilizer which can increase soil fertility and red chili yields and can reduce the use of inorganic fertilizer doses on Inceptisols saline and non-saline soils. The research was designed using the Randomized Block Design with 14 treatments combination and three replications, namely control treatment, as well as a combination of rice straw compost without or with added biostimulants with reduced doses of N, P, K fertilizer on non-saline and saline soils (4 dS /m). The research results showed that the combination of straw compost treated with biostimulants with various levels of N, P, K fertilizer doses was able to increase plant N content, Phosphate Solubilizing Bacteria (PSB) population and red chili plant yields in both saline and non-saline Inceptisols. Biostimulants applied to straw compost can reduce the use of N, P and K fertilizer doses by up to ¼ of the recommended dose for the fruit weight of chili plants planted in saline Inceptisols soil.

**Keywords:** Azotobacter, Phosphate Solubilizing Bacteria, Biostimulants, Inceptisols.

## 1. INTRODUCTION

Soil salinity greatly influences plant growth and microbial life processes by inhibiting cell enlargement and division, protein production, and the addition of plant biomass [1]. The accumulation of $Na^+$ and $Cl^-$ in saline soil can cause a decrease in available nutrients such as $K^+$, $Ca^{2+}$, $Fe^{2+}$, and $Mg^{2+}$, due to competition between each element in binding nutrients by plant roots [2]. The main problem with salinity is the increase in capillarity of the groundwater table so that salts that have been leached can re-enter the root area. Apart from that, the highly intensive use of inorganic fertilizers has also had an impact on reducing soil quality and fertility by decreasing the C-organic content in the soil [3], so that the soil becomes hard, less able to store water, lowers the pH, and affects growth and plant productivity [4].

Efforts that can be made to overcome this problem include using rice straw compost, which contains a total of 1.92% N nutrients, 2.51% P, 4.8% K, 11.43% organic C. and C/N 6 [5]. The advantages of using straw compost include being able to reduce the use of chemical fertilizers by up to 50%, especially the nutrients K and Si [6]. Besides that, alternative technology that can be applied to reduce the impact of salinity is to use Plant Growth Promoting

Rhizobacteria (PGPR) from the type of Nitrogen Fixing Bacteria (*Azotobacter* sp.) and Phosphate Solubilizing Bacteria (PSB) which are able to stimulate nutrition and ion transport systems in plant roots [7]. PGPR has a role as a biostimulant, biofertilizer and bioprotectant for plant growth [8].

Nitrogen-fixing bacteria and phosphate-solubilizing bacteria (PSB) are microbes that are known to be able to increase plant growth through bio-stimulation mechanisms. The addition of organic matter can stimulate indigenous microbes to improve degraded soil by helping plant roots to produce root exudates which can help soil microbes in producing protein compounds, organic acids, or other compounds required by soil microbial activity [9]. Application of PGPR at a dose of 300 mL/plant and 7.5-ton $ha^{-1}$ of compost gave a better effect in increasing the growth and production of red chili plants with an average value of 58.56 kg per plant [10]. The PGPR group of bacteria can be developed to facilitate plant growth in saline soil [11,12] and can develop molecular mechanisms to survive and grow with increasing salinity [13] and help plant resistance to dry environments, salinity, nutritional deficiencies, and other environmental stresses [14,15].

Red chilies (*Capsicum annum* L.) are an important commodity in Indonesia. Red chili production in 2015-2019 increased by 0.63%. Population growth which continues to increase every year, as well as the high level of agricultural land conversion activities, has caused the land to become degraded, increasing the osmotic potential of the soil, as well as increasing soil salinity, so that plants experience physiological drought [16]. Planting horticultural commodities using straw compost and biostimulant microbes on saline soil has not been widely practiced. The aim of this research is to evaluate the application of a combination of straw compost with biostimulant microbes and doses of N, P, K fertilizer which can increase soil fertility and red chili yields and can reduce the use of N, P, K fertilizer doses on Inceptisol saline and non-saline soils.

## 2. MATERIALS AND METHODS

### Research Implementation

This research was carried out at the screen house of the Faculty of Agriculture, Unpad, in Ciparanje, Jatinangor District, Sumedang Regency, West Java. The soil used in this research was Inceptisols from the Ciparanje experimental garden, Faculty of Agriculture, Universitas Padjadjaran, Jatinangor, Sumedang, West Java. The preliminary chemical analysis of Inceptisols soil from Jatinangor carried out before the experiment showed that had pH of 6.71 (slightly acidic); C-organic 1.67% (low); N-total 0.18% (low); C/N ratio 9 (low), salinity level 1.2 dS/m. Based on the results of the soil analysis, the soil at the experimental location was in low fertility soil category. The initial soil biological analysis on Inceptisols Jatinangor had a population of *Azotobacter* sp. 1.02 x $10^5$ $CFUg^{-1}$ and PSB 0.85 x $10^5$ $CFUg^{-1}$. Inceptisols 4 dS/m saline soil is made by adding NaCl salt to adjust the salinity level.

This research used an experimental Randomized Block Design (RBD), consisting of 14 treatment combinations. Inceptisols soil was treated without and with rice straw compost combined with or without the addition of biostimulant *Azotobacter* sp. and PSB (called straw compost plus) with different doses of N, P, K fertilizer on non-saline and saline Inceptisols soil. The treatment combination can be seen in Table 1.

**Table 1. Treatment combination of straw compost dosage + N, P, K dosage and soil salinity level on red chili plants (*Capsicum annum* L.)**

| Code | Treatments |
|---|---|
| A | Control (non-saline Inceptisols soil and no straw compost) |
| B | Straw Compost + 1 N, P, K fertilizer recommended dose |
| C | Straw Compost + ¾ N, P, K fertilizer recommended dose |
| D | Straw Compost + ½ recommended dose of N, P, K fertilizer |
| E | Straw Compost Plus + 1 recommended dose of N, P, K fertilizer |
| F | Straw Compost Plus + ¾ recommended dose of N, P, K fertilizer |
| G | Straw Compost Plus + ½ recommended dose of N, P, K fertilizer |
| H | Soil Inceptisols supplemented with NaCl salt (4 dS/m), no straw compost |
| I | Straw Compost + 1 recommended dose of N, P, K fertilizer (4 dS/m) |
| J | Straw Compost + ¾ recommended dose of N, P, K fertilizer (4 dS/m) |
| K | Straw Compost + ½ recommended dose of N, P, K fertilizer (4 dS/m) |
| L | Straw Compost Plus + 1 recommended dose of N, P, K fertilizer (4 dS/m) |
| M | Straw Compost Plus + ¾ recommended dose of N, P, K fertilizer (4 dS/m) |
| N | Straw Compost Plus + ½ recommended dose of N, P, K fertilizer (4 dS/m) |

Note : Straw compost plus is straw compost that has been treated with the biostimulant *Azotobacter* sp. and PSB 10% (v/w) one week before application to the planting medium. The recommended doses of N, P, K for chili plants is 300kg/ha Urea, 300kg/ha SP-36, and 250 kg/ha KCl.

Each treatment was repeated three times. The planting distance used was 75 cm x 50 cm so that the area of the experimental plot used in this research was around 3 m x 6 m.

**Observation and Sampling**

Soil samples used for microbial population analysis, initial soil analysis, and organic C were taken by purposive sampling at three soil sampling points around the root area, which were then homogenized. Plant tissue samples were taken when the chili plants were 45 DAP.

C-Organic analysis was using the Walkey and Black method. Analysis of plant N content using the Kjeldahl method. The plant tissue taken for analysis of plant N content was the third to fourth leaves from the shoots of plants that were 45 days after planting (DAP) with the characteristic that the plants were starting to show flowers.

The total bacterial population was analyzed using the pour method at 0 DAP and 45 DAP after application. A total of 10 g of soil sample was put into a test tube then 90 mL of 0.85% NaCl solution was added as the first serial dilution then homogenized using a vortex and dilution carried out. Selective media was used to calculate the population of *Azotobacter* sp. are Ashbys medium and Pikovskaya medium for calculating the PSB population. Next, it was incubated for 48 hours in an incubator at 28ºC. Growing colonies were counted based on the Total Plate Count (TPC) method.

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The results of the rice straw compost analysis were C-organic 20.54% and N-total 0.8% with a C/N of 26. The C/N of ready-to-use compost is in the range of 11-30 [17]. The rice straw compost used in this research was incubated for a week in Inceptisols soil planting medium. Apart from that, rice straw compost has an alkaline pH, namely 7.5. Rice straw compost also contains $P_2O_5$ of 0.37% and $K_2O$ of 0.29%. The population biological analysis of rice straw compost showed that *Azotobacter* sp. of 11.3 x $10^6$ $CFUg^{-1}$ and PSB 8.25 x $10^6$ $CFUg^{-1}$. This proves that the initial population of bacteria in rice straw compost was greater than in soil media.

**Statistical analysis**

Statistical Product and Service Solutions (SPSS) version 15.0 was used to analyze experimental data. An analysis of variance (ANOVA) was performed, and significant differences were assessed with Least Significance Difference (LSD) at a 5% significance level ($p< 0.05$).

## 3. RESULTS AND DISCUSSION

### Soil Organic-C

The organic-C content in the soil is greatly influenced by several factors such as soil pH and EC, climate (temperature and soil humidity), nutrients available in the soil, and the presence of microorganisms to fulfill their metabolic capabilities [18].

**Table 2. Soil C-Organic content in chili planting media after application of straw compost and N, P, K fertilizer**

| Code | Treatments | Organic-C (%) |
|---|---|---|
| A | Control (non-saline Inceptisols soil and no straw compost) | 1,96 a |
| B | Straw Compost + 1 N, P, K fertilizer recommended dose | 2,08 a |
| C | Straw Compost + ¾ N, P, K fertilizer recommended dose | 2.13 a |
| D | Straw Compost + ½ recommended dose of N, P, K fertilizer | 2,20 a |
| E | Straw Compost Plus + 1 recommended dose of N, P, K fertilizer | 2,22 a |
| F | Straw Compost Plus + ¾ recommended dose of N, P, K fertilizer | 2,14 a |
| G | Straw Compost Plus + ½ recommended dose of N, P, K fertilizer | 2,15 a |
| H | Soil Inceptisols supplemented with NaCl salt (4 dS/m), no straw compost | 2,14 a |
| I | Straw Compost + 1 recommended dose of N, P, K fertilizer (4 dS/m) | 2,10 a |
| J | Straw Compost + ¾ recommended dose of N, P, K fertilizer (4 dS/m) | 2,01 a |
| K | Straw Compost + ½ recommended dose of N, P, K fertilizer (4 dS/m) | 2,23 a |
| L | Straw Compost Plus + 1 recommended dose of N, P, K fertilizer (4 dS/m) | 2,16 a |
| M | Straw Compost Plus + ¾ recommended dose of N, P, K fertilizer (4 dS/m) | 1,96 a |
| N | Straw Compost Plus + ½ recommended dose of N, P, K fertilizer (4 dS/m) | 2,09 a |

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Note: Numbers followed by the same letters in the column for the same age of observation and treatment are not significantly different based on the 5% LSD test.

In Table 3, the application of straw compost without biostimulants and those treated with biostimulants (straw plus compost) with different doses of N, P, K fertilizer did not have a different effect on soil organic C in saline (4 dS/m) and non-saline soils. However, soil organic C tends to increase compared to the organic C content in the initial soil (1.67%). The increase in soil organic C is thought to occur because during biostimulation the weathering process of soil organic matter continues to progress, stimulated by soil microbes. The process of fixing $N_2$ carried out by microbes in biostimulants can contribute N available to plants, so that plant growth and development increases, including plant roots. The impact of increasing and developing plant roots causes an increase in soil organic-C [19] although it is not statistically different. According to Rochmah and Sugiyanta [20], the nutrients contained in straw compost are available slowly and take longer to be absorbed by plants so that for a long time residual organic-C is still present in the soil.

Planting red chilies in the dry season causes the evaporation process to occur more quickly. This condition causes the water in the chili planting medium to evaporate easily, so the soil dries out quickly, this causes organic matter to be decomposed more quickly by bacteria using dissolved oxygen. Apart from bacteria in the soil, aerobic bacteria derived from biostimulants will speed up the decomposition process. This is in line with the opinion of Hanafiah [21] who states that adding organic fertilizer to the soil will increase soil organic-C.

**Plant N Content**

Soil nitrogen exists in several organic and inorganic forms which affect its availability for plant uptake. Rapid nitrogen uptake in red chili plants is generally observed between phases V10-V14 [22].

**Table 3. Plant N Content in Chili Planting Media after Application of Straw Compost and N, P, K Fertilizer**

| Code | Treatments | Plant-N Uptake (%) |
|---|---|---|
| A | Control (non-saline Inceptisols soil and no straw compost) | 5,14 ab |
| B | Straw Compost + 1 N, P, K fertilizer recommended dose | 5,13 ab |
| C | Straw Compost + ¾ N, P, K fertilizer recommended dose | 4,88 b |
| D | Straw Compost + ½ recommended dose of N, P, K fertilizer | 5,37 ab |
| E | Straw Compost Plus + 1 recommended dose of N, P, K fertilizer | 5,37 ab |
| F | Straw Compost Plus + ¾ recommended dose of N, P, K fertilizer | 5,52 a |
| G | Straw Compost Plus + ½ recommended dose of N, P, K fertilizer | 5,36 ab |
| H | Soil Inceptisols supplemented with NaCl salt (4 dS/m), no straw compost | 5,03 ab |

| | | |
|---|---|---|
| I | Straw Compost + 1 recommended dose of N, P, K fertilizer (4 dS/m) | 5,25 ab |
| J | Straw Compost + ¾ recommended dose of N, P, K fertilizer (4 dS/m) | 5,37 ab |
| K | Straw Compost + ½ recommended dose of N, P, K fertilizer (4 dS/m) | 5,14 ab |
| L | Straw Compost Plus + 1 recommended dose of N, P, K fertilizer (4 dS/m) | 5,22 ab |
| M | Straw Compost Plus + ¾ recommended dose of N, P, K fertilizer (4 dS/m) | 5,08 ab |
| N | Straw Compost Plus + ½ recommended dose of N, P, K fertilizer (4 dS/m) | 5,63 a |

Note: Numbers followed by the same letters in the column for the same age of observation and treatment are not significantly different based on the 5% LSD test.

Providing biostimulants to straw compost and ½ the recommended dose of N,P,K fertilizer at a salinity of 4 dS/m (N) and treatment of straw compost + ¾ recommended dose of N,P,K fertilizer on non-saline soil (F) shows that the plant N content is higher compared to straw compost without biostimulants + ¾ of the recommended dose of N, P, K fertilizer (C). Based on these data, the addition of biostimulants greatly influences the efficiency of using inorganic fertilizers in both saline and non-saline soils in increasing the N content in plants.

The amount of plant nutrient uptake is influenced by several factors such as the amount of nutrient availability in the soil and the ability of the roots to absorb nitrogen elements [23]. The biostimulant used contains the N-fixing bacteria *Azotobacter* sp. reduced N in the soil affects plant N uptake. Loss of N from the soil can be caused by use of N in the soil by microorganisms, leaching of N in the form of $NO_3^-$ by rainwater (leaching) or volatilization [24]. Diazotroph bacteria in the rhizosphere of red chili plant roots play an important role in providing N elements for plants. The bacteria applied as biostimulants can play a role in stimulating the growth of soil bacteria that benefit plants.

Rice straw compost has lower nitrogen levels than inorganic fertilizer, but the nature of organic fertilizer can act as a buffer for nutrients in the soil or inorganic fertilizer added to the soil, so the application of rice straw compost can increase the nitrogen content of plants. Application of organic fertilizer can increase nutrient uptake, especially nitrogen by reducing mineral leaching [25].

**Azotobacter and PSB Populations**

The aspect of soil fertility is characterized by the good biological properties of the soil. One of the important elements of the biological properties of soil is the population of bacteria contained in it. The bacterial growth process depends on the cell's ability to form new protoplasm from nutrients available in the environment. The activity of organisms in the soil will also influence plant growth which will ultimately determine the productivity of the land where the microbes live [26].

**Table 4. Microbial Population at 45 DAP on Chili Planting Media after Application of Straw Compost and N, P, K Fertilizer**

| Code | Treatments | Microbes Population ($x10^8$) | |
|---|---|---|---|
| | | *Azotobacter* sp. | PSB |
| A | Control (non-saline Inceptisols soil and no straw compost) | 4,07 a | 2,61 bc |
| B | Straw Compost + 1 N, P, K fertilizer recommended dose | 5,47 a | 2,99 abc |
| C | Straw Compost + ¾ N, P, K fertilizer recommended dose | 5,54 a | 4,38 ab |
| D | Straw Compost + ½ recommended dose of N, P, K fertilizer | 5,93 a | 4,44 ab |
| E | Straw Compost Plus + 1 recommended dose of N, P, K fertilizer | 9,45 a | 4,14 abc |
| F | Straw Compost Plus + ¾ recommended dose of N, P, K fertilizer | 9,11 a | 2,57 bc |
| G | Straw Compost Plus + ½ recommended dose of N, P, K fertilizer | 6,61 a | 1,80 bc |
| H | Soil Inceptisols supplemented with NaCl salt (4 dS/m), no straw compost | 6,01 a | 3,98 abc |
| I | Straw Compost + 1 recommended dose of N, P, K fertilizer (4 dS/m) | 7,87 a | 5,53 a |
| J | Straw Compost + ¾ recommended dose of N, P, K fertilizer (4 dS/m) | 7,97 a | 4,35 abc |
| K | Straw Compost + ½ recommended dose of N, P, K fertilizer (4 dS/m) | 7,49 a | 3,50 abc |
| L | Straw Compost Plus + 1 recommended dose of N, P, K fertilizer (4 dS/m) | 6,25 a | 4,00 abc |
| M | Straw Compost Plus + ¾ recommended dose of N, P, K fertilizer (4 dS/m) | 6,04 a | 3,00 abc |
| N | Straw Compost Plus + ½ recommended dose of N, P, K fertilizer (4 dS/m) | 5,80 a | 1,55 c |

Note: Numbers followed by the same letters in the column for the same age of observation and treatment are not significantly different based on the 5% LSD test.

Based on Table 4, it is known that the total population of *Azotobacter* sp. showed that the effect was not significantly different for each treatment at 45 DAP but tended to increase in the treatment with the addition of straw compost accompanied by biostimulants and 1 recommended dose of N, P, K fertilizer on non-saline soil. This is different from the PSB population which has significantly different effects on several treatments.

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The best total PSB population at 45 DAP was found in the treatment with the addition of straw compost + 1 recommended dose of N, P, K fertilizer (4 dS/m) which had a population of 5.53 x $10^8$ $CFUg^{-1}$. Decomposed straw compost can act as a source of nutrients for microbes in the soil, both indigenous microbes and those provided as biostimulants. Therefore, the provision of rice straw has a positive effect on the population of PSB bacteria in saline and non-saline soil.

### Weight of Red Chili Fruit

Based on Table 5, it shows that biostimulants (*Azotobacter* sp., and PSB) given to straw compost were able to increase the weight of chili per fruit and the weight of chili fruit planted on non-saline soil and saline soil given the recommended dose of 1 N, P, K fertilizer.

This is in line with research by Rohmawati et al. [27] which stated that the addition of 30 mL of PGPR consortium to 10 tons $ha^{-1}$ of compost on the soil was able to increase the number of fruits, weight per fruit, and total weight per hectare of eggplant plants. This is because the addition of PGPR to the soil can contribute N and P nutrients and helps the decomposition process that occurs in compost so that it can increase the nutrients available in the soil so that they are more easily absorbed by plants. Soesanto [28] found that applying PGPR to tomato plants could increase the weight of tomato fruit planted by 51.44 g, compared to the control treatment of 20.68 g.

**Table 5. Weight of Red Chili Fruit after Application of Straw Compost and N, P, K Fertilizer**

| Code | Treatments | Fruit Weight (g) | Total Weight Fruit per plant (g) |
|---|---|---|---|
| A | Control (non-saline Inceptisols soil and no straw compost) | 8,4 h | 91,40 e |
| B | Straw Compost + 1 N, P, K fertilizer recommended dose | 9,0 gh | 92,33 e |
| C | Straw Compost + ¾ N, P, K fertilizer recommended dose | 9,73 g | 93,00 e |
| D | Straw Compost + ½ recommended dose of N, P, K fertilizer | 11,90 de | 93,30 e |
| E | Straw Compost Plus + 1 recommended dose of N, P, K fertilizer | 14,73 a | 144,67 a |
| F | Straw Compost Plus + ¾ recommended dose of N, P, K fertilizer | 14,5 ab | 137,33 ab |
| G | Straw Compost Plus + ½ recommended dose of N, P, K fertilizer | 13,2 bc | 128,13 bcd |
| H | Soil Inceptisols supplemented with NaCl salt (4 dS/m), no straw compost | 11,9 de | 126,20 cd |
| I | Straw Compost + 1 recommended dose of N, P, K fertilizer (4 dS/m) | 13,77 ab | 137,70 ab |

| | | | |
|---|---|---|---|
| J | Straw Compost + ¾ recommended dose of N, P, K fertilizer (4 dS/m) | 13,33 bc | 130,37 bcd |
| K | Straw Compost + ½ recommended dose of N, P, K fertilizer (4 dS/m) | 13,74 bc | 128,57 bcd |
| L | Straw Compost Plus + 1 recommended dose of N, P, K fertilizer (4 dS/m) | 13,83 ab | 137,86 ab |
| M | Straw Compost Plus + ¾ recommended dose of N, P, K fertilizer (4 dS/m) | 13,36 bc | 134,17 bcd |
| N | Straw Compost Plus + ½ recommended dose of N, P, K fertilizer (4 dS/m) | 11,03 ef | 120,27 d |

Note: Numbers followed by the same letters in the column for the same age of observation and treatment are not significantly different based on the 5% LSD test.

Providing biostimulants on saline soil has been proven to reduce the use of N, P, K fertilizer even though only ¼ of the N, P, K dose is given. This was demonstrated by the application of biostimulants to straw compost treated with ¾ of the recommended dose of N, P, K fertilizer on saline soil (M) resulting in the weight of chili per fruit and the weight of chili per plant being no different from 1 recommended dose on saline soil (L). This is related to the role of N-fixing bacteria and phosphate-solubilizing bacteria contained in biostimulants which help add nutrients for fruit formation in the generative phase of the plant.

Apart from that, organic material from rice straw compost has various functions, including the release of nutrients, as well as creating better soil physical conditions such as increasing soil aeration which allows the $O_2$ cycle to run smoothly, increasing the pH so that phosphate availability increases so that PSB can dissolve phosphate. Biostimulants contained in rice straw compost apart from acting as a facilitator of nutrients available to plants, also function as producers of hormones for plant growth [29]. Indole acetic acid is a very important growth hormone which is an active form of auxin which plays a role in improving the quality and yield of crops, cell development, stimulating the formation of new roots, stimulating growth, stimulating flowering, and increasing enzyme activity.

## 4. CONCLUSION

The combination of straw compost treated with biostimulants with various levels of N, P, K fertilizer doses was able to increase plant N content, PSB population and red chili (*Capsicum annum* L.) plant yields on saline and non-saline Inceptisols soil. Biostimulants applied to straw compost can reduce the use of N, P and K fertilizer doses by up to ¼ of the recommended dose for the fruit weight of chili plants planted in saline Inceptisols soil.

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