Effect of NPK fertilizer, biofertilizer containing N fixer and P solubilizer, and green manure of \textit{C. juncea} on nutrients uptake and growth of sugarcane

Djajadi*, R Syaputra and S N Hidayati

Indonesian Sweetener and Fiber Crops Research Institute, Jl. Raya Karangploso PO Box 199 Malang

*Email: jaydjajadi61@gmail.com

Abstract. A field experiment was conducted at Karangploso Research Station to investigate the effect of NPK fertilizer added with biofertilizer containing N fixing and P solubilizing bacteria plus green manure of \textit{C. juncea} on nutrient uptake and growth of sugarcane (\textit{Saccharum officinarum} L.). The experiment had 10 treatments: (1) 100% of recommended fertilizer (RF), (2) 100% RF + biofertilizer, (3) 75% RF + biofertilizer, (4) 50% RF + biofertilizer, (5) 100% RF + \textit{C. juncea}, (6) 75% RF + \textit{C. juncea}, (7) 50% RF + \textit{C. juncea}, (8) 100% RF + biofertilizer + \textit{C. juncea}, (9) 75% RF + biofertilizer + \textit{C. juncea}, (10) 50% RF + biofertilizer + \textit{C. juncea}. The ten treatments were arranged in Randomized Block Design with three replications. Results showed that the nutrients uptake attributes (N, P and K) and growth of sugarcane was affected by biofertilizer and \textit{C. juncea}. The best treatment of the results was combination of biofertilizer and \textit{C. juncea} with 100% rate of recommended fertilizer of NPK gave the highest of N uptake and length of stalk.

Keywords: Biofertilizer, green manure, inorganic fertilizer, sugarcane, nutrients

1. Introduction

Sugarcane is categorized as high fertilizer consumption crop that requires a lot amount of nutrients to have good growth and high yield [3]. The nutrients of 135 kg N ha\(^{-1}\), 32 kg P ha\(^{-1}\) and 98 kg K ha\(^{-1}\) were required to produce 80 tons ha\(^{-1}\) of sugarcane in the first cycle [14]. Mostly the source of nutrients added to sugarcane cropping is inorganic fertilizers and continuous addition of inorganic fertilizers may lead to environmental problems due to the leaching of soluble nutrients into deeper soil layers [20], soil degradation, soil acidity and environmental pollution [17].

The integrated nutrient management practice is an important factor for the sustainable and cost-effective management of soil fertility in sugarcane cultivation. Mixed addition of inorganic with organic materials (including biological fertilizers) may have result in rising soil fertility, growth and yield of sugarcane.

Some previous research reported the positive effect of biofertilizer and organic materials either on soil fertility or on plant growth and yield. Previous research found that addition of biofertilizer containing \textit{Acidithiobacillus} bacteria increased nutrient uptake of sugarcane and raised the availability of nutrients in the soil, especially total N, nitrate-N, ammonium-N, and available P and K [14]. The effects of biofertilizer were enhanced by the combination addition with organic fertilizer in the form of...
sugarcane filter cake. The effectiveness of biofertilizer mixed with organic matter has been also reported in research using annual crops, such as sugarcane [21; 14], rice [1; 9; 4]; and Zea mays [8; 12]. However, most of the research was conducted by using single bacteria which has role to increase the availability of a certain nutrient. Mixed inoculant of N2-Fixing, P- and K-Solubilizing bacteria was able to improve available soil N, P, and K and kiwifruit growth [19]. So that there is a chance to use biofertilizer containing mixed inoculant of N2 fixing and P-solubilizing bacteria on nutrients uptake and growth of sugarcane.

The effectiveness of the biofertilizer on soil fertility and plant growth may be raised when the application of biofertilizer is combined together with green manure, such as C. juncea. Some previous studies reported the positive effect of C. juncea on enhancing soil fertility, growth and yield of sugarcane ([; 10; 18]. The objective of the research was to investigate the effect of NPK fertilizer added with mixed inoculant of N fixer and P solubilizer bacteria plus green manure C juncea on nutrients uptake and growth of sugarcane.

2. Materials and methods
The field research was conducted at Karangploso Research Station of Indonesian Sweetener and Fiber Crops Research Institute in 2016. Biofertilizer containing N fixing and P solubilizing bacteria, C. juncea, and inorganic fertilizer were used as treatments. The field soil used in the research is categorized as low in soil nutrients contents as indicated by very low of organic-C, low in total N, P and K contents (Table 1). The texture of the soil is silty clay with sand, silt and clay contents of 6%, 45% and 49% respectively.

| Soil Nutrients         | Content | Category [6] |
|------------------------|---------|--------------|
| Organic-C (%)          | 1.56    | Very low     |
| Total N (%)            | 0.14    | Low          |
| C/N                    | 11      | Low          |
| P2O5 Bray (mg.kg⁻¹)    | 3.05    | Low          |
| K NH₄OAC1N pH:7 (me/100g) | 0.12 | Low          |

The treatments consisted of 10 combination of biofertilizer, inorganic fertilizer, and C juncea, and their composition applications were as follow:
1. 100% recommended fertilizer of sugarcane (RF: NPK 600 kg ha⁻¹+ Ammonium Sulphate 500 kg ha⁻¹)
2. 100% RF + biofertilizer (BF)
3. 75% RF + BF
4. 50% RF + BF
5. 100% RF + C juncea
6. 75% RF + C juncea
7. 50% RF + C juncea
8. 100% RF + BF + C juncea
9. 75% RF + BF + C juncea
10. 50% RF + BF + C juncea

Those treatments were arranged using Randomized Block Design with three replications. Sugarcane var BL was planted in plots size 7.5 m x 7 m with row spaces of 125 cm. Bagal seeds with three buds were planted at rows. Recommended fertilizer (RF) was applied twice, firstly 600 kg NPK fertilizer per hectare (15 N : 15 P₂O₅ : 15 K₂O) was added at one month after planting and secondly 500 kg Ammonium Sulphate (21% N) per hectare was added at 3 months after planting. C juncea was planted at 20 days before planting of sugarcane. The seeds of C juncea were placed along the rows of sugarcane and after 40 days, C juncea was cut and chopped and then finally they were mixed and buried into the
soil at weeding. The microbial inoculants were collection of Indonesian Sweetener and Fiber Crops Research Institute which were isolated from rhizosphere of sugarcane soil. Biofertilizer was applied at 2 months after planting of sugarcane at the rate of 100 kg/ha with bacterial population of 11.3 x 10^8 cfu gram^-1.

Observation was made on nutrients uptake and sugarcane growth parameters. Nutrients uptake was determined after sugarcane was harvested by analyzing the content of N, P and K in dried biomass. Growth of sugarcane parameters that were measured included length of stalk, plant population, diameter of stalk and number of internodes. Collected data were analyzed using Anova and followed by analysis of treatments comparison by using Least Significant Different method at 5% level.

3. Results

3.1. N, P, K Nutrients Uptakes

Significant effect of the treatments (p < 0.001) was occurred in N, P, and K uptake by sugarcane (Figure 1). In general, addition of NPK fertilizer and biofertilizer with or without *C. juncea* raised the uptake of N and P nutrients compared to control (except treatment 3, 6 and 7 for N uptake and treatment 4 and 6 for P uptake). For K uptake, only treatments 4 and 8 were significantly higher than control. The highest absorption of N (41.16 g plant^-1) by sugarcane was found at treatment 8 (100% RF + BF + *C. juncea*), and if compared to the control (100% RF), it can increase N uptake of about 62.56%.

![Figure 1. Effect of inorganic fertilizer (RF), biofertilizer (BF), *C. juncea* on N, P, and K uptakes of sugarcane.](image)

For P uptake, treatment 9 (75% RF + BF + *C. juncea*) caused sugarcane absorbed the highest amount of P (10.87 g plant^-1) and increased P absorption 1.40 times if compared to the control. However, treatment 10 (50 % RF + BF + *C. juncea*), 2 (100% RF + BF), 5 (100% RF + *C. juncea*) and 8 (100% +
BF+C juncet) were not significantly different to the treatment 9. On parameter of K uptake, the highest K content in sugarcane plant (51.90 g plant⁻¹) was found in treatment 4 (50% RF + BF). Comparing to the control, treatment 4 (50% RF + BF + C juncet) increased K uptake by 92.94%, but not significantly different to the treatment 8 (100% RF + BF + C juncet).

3.2. Growth of Sugarcane

As expected, growth of sugarcane was affected by addition of biofertilizer and C juncet together with inorganic fertilizer at different rate. The effect of treatment on length of stalk and plant population of sugarcane was presented in Figure 2. Sugarcane which had the longest of stalk (343 cm) was found when it received 100% recommended inorganic fertilizer with biofertilizer and C juncet (treatment 8), but it was not significantly different with control. Addition of biofertilizer and C juncet with lower rate of inorganic fertilizer significantly decreased the length of stalk, the shortest of stalk length of sugarcane was found at the lowest rate of inorganic fertilizer which was added together with biofertilizer plus C juncet (treatment 10).

For the plant population parameter, the most dense stalk of sugarcane (17.55 stalk m⁻¹) was found at treatment 2 (100% RF + BF) indicating that addition of biofertilizer together with 100% recommended inorganic fertilizer produced the most amount of sugarcane stalk. The treatment increased the number of stalk by 12.06% over the control treatment. However treatment 10 (50% RF + BF + C juncet) was not significantly different to treatment 2.

The effect of treatments on diameter of stalk and number of internodes per stalk were presented in Figure 3. Addition of biofertilizer on the 100% RF with or without C juncet significantly decreased diameter of stalk. Therefore the biggest diameter of sugarcane stalk (25.41 mm) was observed at sugarcane with 100% recommended inorganic fertilizer (control treatment). However the diameter of stalk size was not significantly different to that with addition of biofertilizer with 75% recommended inorganic fertilizer (treatment 3). For the number of internodes per stalk, the highest number of internodes (27.31 internodes) was found at sugarcane plots where biofertilizer added and 75% were added (treatment 3). The number of internodes per stalk of the treatment was 0.64% higher than that of control treatment.

![Figure 2](image_url). Effect of inorganic fertilizer (RF), biofertilizer (BF), C juncet (Cj) on length of stalk and plant population of sugarcane. 1 = 100% RF; 2 = 100% + BF; 3 = 75% RF + BF; 4 = 50% RF + BF; 5 = 100% RF + C juncet; 6 = 75% RF + C juncet; 7 = 50% RF + C juncet; 8 = 100% + BF + C juncet; 9 = 75% RF + BF + C juncet; 10 = 50% RF + BF + C juncet.
Figure 3. Effect of inorganic fertilizer (RF), biofertilizer (BF), C juncea (Cj) on diameter of stalk and number of internode of sugarcane. 1 = 100% RF; 2 = 100% + BF; 3 = 75% RF + BF; 4 = 50% RF + BF; 5 = 100% RF + C juncea; 6 = 75% RF + C juncea; 7 = 50% RF + C juncea; 8 = 100% + BF + C juncea; 9 = 75% RF + BF + C juncea; 10 = 50% RF + BF + C juncea.

4. Discussion
This research demonstrated that addition of biofertilizer with or without C juncea and inorganic fertilizer together raised nutrients uptakes and increased growth of sugarcane to some extent. Addition of biofertilizer with C juncea provided soil nutrients more available to the plant which was indicated by increasing N, P and K uptakes by sugarcane. In our research, addition of biofertilizer plus C juncea together with inorganic fertilizer at different rate caused the highest absorption of N, P and K nutrients. For a comparable research in which Azotobacter inoculant used as biofertilizer, an increase of N, P, and K uptake by Zea mays was associated with addition of biofertilizer and organic matter [13]. Similar finding was reported by previous researcher who observed that N, P, K nutrients uptake by Zea mays were raised by addition of biofertilizer (containing mix of Azotobacter chroococcum and phosphate solubilizing bacteria) together with C juncea.

Nitrogen (N), phosphorus (P) and potassium (K) are macro nutrients which have important role in supporting growth and yield of sugarcane. Nitrogen is an important nutrient in plant metabolism due its function in the synthesis of proteins and other organic compound so that it is essential for vigorous, vegetative growth and yield of sugarcane [5]. Phosphorus nutrient is required in energy metabolism, synthesis of nucleic acids, photosynthesis, respiration and enzyme regulation [16]. Thus, by adding biofertilizer of N fixing and P solubilizing bacteria together with inorganic fertilizer will raise growth of sugarcane.

The growth of sugarcane as it was expressed by length of stalk, plant population and number of internodes parameters was elevated by addition of biofertilizer with or without C juncea. Similar results of positive effect of biofertilizer on growth of sugarcane were reported by some workers [7, 15, 21]. Higher growth of sugarcane due to addition of biofertilizer with or with no C juncea than control (addition of inorganic fertilizer only) might be due to increasing N, P and K nutrition up take. In this current research, there was significant regression between N uptake and length of stalk ($R^2 = 0.56$), increasing in N uptake would increase the length of stalk (Figure 4). In the research, we found that combination of 100% recommended inorganic fertilizer with biofertilizer and C juncea gave the highest of N and length of stalk.
5. Conclusion
Addition of biofertilizer containing N fixer and P solubilizer bacteria and *C juncea* together with recommended fertilizer raised N, P, and K uptakes and growth of sugarcane. The combination of biofertilizer and *C. juncea* with 100% rate of recommended fertilizer of NPK gave the highest of N uptake and length of stalk of sugarcane.

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![Figure 4. Regression between N uptake and length of stalk of sugarcane](image-url)
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