Sugarcane fertilization package with double row system to increase yield of first ratoon cane

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Abstract. The purpose of this study was to obtain a package of compound fertilization on a double row system on growth, cane yield, sugar content, and sugar yield on first ratoon cane (RC1) in dry land. The research was conducted from January to October 2016 at Asembagus Research Station, Situbondo, East Java. Six treatments of fertilizer packages were arranged in a Randomized Block Design with four replications, consisting of standard fertilizer packages for a single row (6 quintal compound fertilizer NPK (15-15-15) + 5 quintals ZA) per ha, 1.2, 1.4, 1.6, 1.8, and 2.0 times the standard fertilizer package. The results showed that the highest RC1 sugarcane yield (138.57 t/ha) was achieved by fertilizing 8.4 compound fertilizer + 7 ZA (quintal/ha) or 1.4 times the standard dose, resulting in a 25.52% increase in sugarcane yield compared to standard fertilizer (110.40 t/ha). The sugar content did not differ among the treatments ranging from 9.2 to 10%. The highest sugar yield was 12.97 t/ha in line with sugarcane yield. This finding suggested the recommendation of a fertilizer package for a double row system in sugarcane.

Keywords: fertilizer dosages, compound fertilizer, sugar yield, sugar content

1. Introduction
Sugarcane cultivation generally uses a single row planting system. A single row planting system does not efficiently manage light energy per unit area of land. According to Waclawosky et al [1], sugarcane plantations receive 11.923 MJ/ha/day of light energy and uses 5.803 MJ/ha/day as dry matter. It is necessary to implement a double row planting system to increase energy efficiency. A double row planting system can increase light penetration in the plant canopy [2] and increase land availability. Single row, dual rows, and three rows, cropping systems affect crop performance [3]. The double row planting system works more effectively on sugarcane plantations because it increases productivity and yields [4]. Many kinds of research on sugarcane multiple row cropping systems but the results did not relate to each other. Randhawa et al. [5, 6] reported that the planting system double row, increased stem weight and productivity. However, double rows planting system did not increase the stem population per meter, length, and diameter. Maqsood et al. [7]Mahmood et al.[8] also reported that the double row planting system increased the stem population per meter, weight, diameter, productivity, sugar content, and harvest index. Different spacing between rows may cause different yields. Zimmerman [9] revealed that double row cropping system spacing affected the crop performance of papaya plantations. The double row planting system spacing needs to suit plant needs, and failure to do so will decrease crop productivity [10]. Furthermore, considering to plant needs may increase crop productivity [11]. The recommended plant spacing in a single row planting system is 1.3 m with a total row length per ha of
7692 m. In practice, however, the row spacing is 1.0 - 1.2 m with an average total row length per ha of 9090 m [12].

Increasing plant population without adequate fertilizer cannot increase crop productivity per land area [13]. Meanwhile, Nurhidayati [14] reported that an increase in the number of sugarcane plant populations must be followed by increasing the dose of fertilizer, otherwise reducing the weight of the sugarcane stalks. According to Kadarwati et al. [15], farmers may increase ratoon crop productivity by improving nursery patterns, ratooning plant cane, applying leaf analysis techniques, and implementing root management. Replanting dead plants in ratoon will stabilize ratoon cane (RC) productivity. NPK fertilization at 1.4 times the normal dose or equivalent to 840 kg Phonska + 700 kg ZA per ha in a double row planting system produced 65.68 tons/ha of sugarcane [16]. The dry condition of the plantation caused a low production level. This research aimed to determine fertilizer dosage for first ratoon cane 1 (RC1) using a double row planting system.

2. Materials and methods
The field research in RC1 was conducted at the Asembagus Research Station, Situbondo, East Java from January to October 2016. The soil type at the research site was Entisols. The soil properties are presented in Table 1.

| No | Soil Parameters | Unit | Result | Criteria* |
|----|----------------|------|--------|-----------|
| 1  | pH 1:1 H₂O     |      | 6.5    | Moderate Acid |
| 2  | pH 1:1 KCl     |      | 6.05   |           |
| 3  | C. Organic     | %    | 0.25   | Very Low |
| 4  | N. total       | %    | 0.05   | Very Low |
| 5  | C/N            |      | 4.5    | Very Low |
| 6  | P. Bray        | mg kg⁻¹ | 30.46 | High |
| 7  | K              | me 100 g⁻¹ | 1.32 | Very Low |
| 8  | Na             | me 100 g⁻¹ | 2.22 | Very High |
| 9  | Ca             | me 100 g⁻¹ | 4.77 | Low |
| 10 | Mg             | me 100 g⁻¹ | 1.59 | Moderate |
| 11 | CEC            | me 100 g⁻¹ | 13.18 | Low |
| 12 | Total Base     | %    | 9.90   |           |
| 13 | Dase saturation|      | 76     | Very High |
| 14 | Sand           | %    | 91.50  |           |
| 15 | Silt           | %    | 7      | Sandy |
| 16 | Clay           | %    | 1.5    |           |

*Sooil chemical assessment according to the Center for Soil Research, (2009)

Sugarcane in Plant Cane (PC) was planted in 2015. The research used a Randomized Block Design and with six treatments and four replications as presented in Table 2.

| No | Fertilizer Dosage (qu ha⁻¹) | Equivalent nutrient level (qu ha⁻¹) |
|----|-----------------------------|-----------------------------------|
| 1  | 6 Phonska + 5 ZA (standard) | 190 90 90 |
| 2  | 7.2 Phonska + 6 ZA (1.2 x) | 228 108 108 |
| 3  | 8.4 Phonska + 7 ZA (1.4 x) | 266 126 126 |
| 4  | 9.6 Phonska + 8 ZA (1.6 x) | 304 144 144 |
| 5  | 10.8 Phonska + 9 ZA (1.8 x) | 342 162 162 |
| 6  | 12 Phonska + 10 ZA (2.0 x) | 380 180 180 |
The research used 50/170 row spacing on a double row planting system. Stubble shaving was done 15 days after harvesting, and off barring two months later. At the same period, first fertilization (Phonska fertilizer) was applied. ZA was applied at second fertilization two months after first fertilization. Fertilizer was applied to each row at a 10 cm distance from the sugarcane row. Earthing up by pulling up the soil at the base of plants. Irrigations were applied at first fertilization, before second fertilization, and during crop growth.

As many as 5 tons/ha manure were applied after ratooning sugarcane. Then, three (3) rows of Crotalaria juncea (Crj) were planted between sugarcane rows (170 cm) during first fertilization. The distance between Crj and sugarcane was 40 cm. At the age of 45 days after planting, Crj was harvested and used as mulch. Crj mulch was placed on each sugarcane row. The height and population of sugarcane plants were observed at 5, 6, 7, 8, and 9 months after ratoon (MAR). Furthermore, production components such as stem length, stem diameter, stem weight, and brix were measured at harvest. Sugarcane production includes stem yields and sugar yields were also observed at harvest. Data were analyzed using analysis of variance and Least Significant Difference (LSD 5%) test.

3. Result and discussion
3.1. Sugarcane growth components
Table 3 presents the observation result of plant height growth. The sugarcane growth was in line with the age of the plant. However, treatment 6 (2x standard dosages) did not significantly increase plant height. Treatment 3 (8.4 Phonska + 7 ZA quintals per ha or 1.4x standard dosages) produced 3 meters (303.98 cm) sugarcane. However, higher dosage treatments did not increase plant height due to infertile soil. The research site had low to very low organic C, N, K, and CEC (Table 1). Due to the infertile soil, increasing fertilizer dosage produced improved responses. At the early growth phase, treatment 3 promoted a faster growth rate of plant height. However, treatment 3 produced a similar response to other treatments at the grand growth phase. Treatment 6 (2x of standard amount) showed a low growth rate of plant height. Fertilizer treatment should follow the nutrition balance. Balanced treatment favored plants to absorb nutrition optimally. Treatment 5 (10.8 Phonska + 9 ZA) showed a lower growth rate of plant height compared to other treatments. Treatment 1 (6 Phonska + 5 ZA) and 2 (7.2 Phonska + 6 ZA) showed a lower growth rate of plant height compared to treatment 3 (8.4 Phonska + 8 ZA).

| Fertilizer Dosages (qu ha⁻¹) | 5 MAR *) | 6 MAR | 7 MAR | 8 MAR | 9 MAR |
|-----------------------------|----------|-------|-------|-------|-------|
| 1). 6 Phonska + 5 ZA (standard) | 182.13 | 220.56 | 221.49 | 258.80 | 285.35 |
| 2). 7.2 Phonska + 6 ZA (1.2 x) | 182.20 | 214.69 | 243.38 | 257.33 | 288.41 |
| 3). 8.4 Phonska + 7 ZA (1.4 x) | 187.11 | 223.03 | 252.14 | 281.70 | 303.98 |
| 4). 9.6 Phonska + 8 ZA (1.6 x) | 184.06 | 222.81 | 241.08 | 271.90 | 298.49 |
| 5). 10.8 Phonska + 9 ZA (1.8 x) | 181.35 | 220.36 | 244.61 | 262.61 | 298.11 |
| 6). 12 Phonska + 10 ZA (2.0 x) | 167.41 | 206.54 | 232.33 | 250.31 | 288.93 |
| LSD 5% | ns **) | ns | ns | Ns | ns |
| CV (%) | 11.73 | 11.16 | 12.05 | 7.94 | 6.29 |

*) MAR: Month After Ratooning
**) ns: Non Significant

Ghube [17] stated that N (150 – 350 kg ha⁻¹), P₂O₅ (65 – 165 kg ha⁻¹), and K₂O (65-165 kg ha⁻¹) fertilizer did not produce different plant heights. The treatment produced 301-365 cm plant height. Khan et. al. [18] found 200N:120P:150 K fertilizer compound produced a maximum sugarcane height of 230.6 cm. Dev [19] stated that N 210 kg ha⁻¹ has a higher influence on plant height than P and K. The average fertilizer dosage is presented in Table 2.
Table 4. The influence dosages of fertilizer on plant population in RC1.

| Fertilizer Dosages (qu ha⁻¹) | Sugarcane population per meter |
|-----------------------------|--------------------------------|
|                             | 6 MAR(*) | 7 MAR | 8 MAR | 9 MAR |
| 1). 6 Phonska + 5 ZA (standard) | 14.46 | 14.57 | 14.34 | 14.33 b*** |
| 2). 7.2 Phonska + 6 ZA (1.2 x) | 14.41 | 14.57 | 14.43 | 13.29 bc |
| 3). 8.4 Phonska + 7 ZA (1.4 x) | 14.19 | 14.33 | 14.88 | 15.25 a |
| 4). 9.6 Phonska + 8 ZA (1.6 x) | 14.77 | 14.65 | 14.64 | 13.79 bc |
| 5). 10.8 Phonska + 9 ZA (1.8 x) | 14.68 | 14.84 | 14.27 | 13.50 c |
| 6). 12 Phonska + 10 ZA (2.0 x) | 14.72 | 14.79 | 14.79 | 14.22 bc |
| LSD 5% | ns** | ns | ns | 1.54 |
| CV (%) | 6.29 | 4.51 | 5.35 | 14.20 |

*) MAR: Month After Ratooning  
**) Non Significant  
***Numbers in the same column followed by the same letter are not significantly different from the LSD test 5%

Table 4 presents plant population per meter. Treatment 3 increased total plant in 9 MAR. However, the total population significantly decreased after 9 MAR. The highest plant population was 15.25 plants per meter (high category) Dev [19]. Seema et al [20] mentioned that the combination of irrigation and high application of NPK fertilizer (250-160-200 NPK kg⁻¹) produced 18.67 plants per meter. Periodically applying N fertilizer during the growth phase was necessary to increase sugarcane production in sandy soil. In general, sandy soil has low organic content [21]. The research site had infertile sandy soil (Table 1).

3.2. Components of sugarcane production, productivity, and sugar yield

Increasing fertilizer dosage significantly influences stem diameter. However, increasing fertilizer dosage did not significantly influence stem length and weight. Increasing fertilizer dosage affected brix value (Table 5). Treatment 3 showed the highest stem diameter at 30.49mm. Increasing fertilizer dosage reduced stem diameter to 26.99 and 28.43 mm (Table 5). Increasing fertilizer dosage did not influence stem length and weight per meter. The average stem length was 2.46 - 2.98 m. The average stem weight was 0.60 - 0.67 kg/m (Sime et al.). However, treatment 3 tended to produce the best result (Table 5). Furthermore, treatment 3 produced the highest stem length and brix value (Table 5). The double row planting system required high nutrient content and only needs a 1.4x standard fertilizer dosage. Nawaz [22] stated increasing fertilizer dosage influenced brix value. The 168:112:112 NPK ha⁻¹ fertilizer dosage obtained a 20.46% brix value. Nitrogen mainly contributes to brix value and stem diameter. Achieng [23] study in Pakistan concluded that the soil needed 208 kg N, 53 kg P, 280 kg K, 30 kg S, 3.4 kg Fe, 1.2 kg Mn, and 0.6 Cu to produce 100 tons/ha sugarcane.

Treatment 3 showed the highest productivity level at 138.57 t/ha (Tabel 6). There was an increased productivity level (25.52%) compared to standard dosage treatment (110.40 tons/ha). The sugarcane yield was 9.2% - 10%. The highest sugar yield was 12.97 t/ha, in line with the sugarcane productivity level. Therefore, the sugarcane productivity level was not necessarily linear with increasing fertilizer dosage (N).
Table 5. The Influence of fertilizer treatment on RC1 production components and brix value.

| Fertilizer Dosages          | Sugarcane Production Components |
|-----------------------------|---------------------------------|
|                             | Stem Length (m) | Stem Diameter (mm) | Weight per meter (kg) | Brix (%) |
| 1). 6 Phonska + 5 ZA (std)  | 2.46            | 28.65 b**          | 0.60                  | 19.41 ab |
| 2). 7.2 Phonska + 6 ZA (1.2x)| 2.47            | 27.58 bc           | 0.62                  | 19.35 ab |
| 3). 8.4 Phonska + 7 ZA (1.4x)| 2.98            | 30.49 a            | 0.67                  | 19.71 a  |
| 4). 9.6 Phonska + 8 ZA (1.6x)| 2.49            | 27.58 bc           | 0.65                  | 19.28 ab |
| 5). 10.8 Phonska + 9 ZA (1.8x)| 2.48            | 26.99 c            | 0.63                  | 18.15 e  |
| 6). 12 Phonska + 10 ZA (2 x)| 2.50            | 28.43 bc           | 0.64                  | 18.63 bc |
| LSD 5%                      | ns**             | 1.55               | ns                    | 0.89     |
| CV (%)                      | 10.40            | 13.26              | 9.09                  | 7.35     |

*) Non Significant
**) Numbers in one column followed by the same letter are not significantly different from the LSD test 5%

Table 6. The influence of fertilizer dosages on RC1 parameter productivity.

| No  | Fertilizer Dosages (qu ha⁻¹) | Sugarcane Production (t ha⁻¹) | Rendemen (%) | Sugar yield (t ha⁻¹) |
|-----|------------------------------|-------------------------------|--------------|----------------------|
| 1.  | 6 Phonska + 5 ZA (standard)  | 110.40 c*)                    | 9.99         | 10.78 bc             |
| 2.  | 7.2 Phonska + 6 ZA (1.2 x)   | 113.24 bc                     | 9.98         | 10.78 bc             |
| 3.  | 8.4 Phonska + 7 ZA (1.4 x)   | 138.57 a                      | 10.00        | 12.97 a              |
| 4.  | 9.6 Phonska + 8 ZA (1.6 x)   | 128.28 ab                     | 9.99         | 11.38 ab             |
| 5.  | 10.8 Phonska + 9 ZA (1.8 x)  | 115.83 bc                     | 9.39         | 10.88 bc             |
| 6.  | 12 Phonska + 10 ZA (2.0 x)   | 111.11 c                      | 9.2          | 10.22 c              |
| LSD (5%) |                             | 10.71                       | ns**)        | 1.24                 |
| CV (%) |                              | 8.36                        | 7.05         | 10.20                |

*) Numbers in the same column followed by the same letter are not significantly different from the LSD test 5%
**) Non Significant

Nitrogen dose for RC1 in Entisol soil is 180 - 220 kg N/ha. The sugarcane production was 109.4 – 112.26 t/ha. Nitrogen dose for RC1 in Alfisol soil was 180 kg N/ha. The sugarcane production was 127.17 t/ha. Nitrogen dose needed for RC1 in Vertisol soil was 180 kg N/ha. The sugarcane production was 111.76 tons/ha. Therefore, the research site has low - very low N content [24]. Applying 180 kg N/ha produced a high yield. Indonesian Sugar Research Institute mentioned that soil with very low N content requires 180 – 200 kg N/ha [25]. Achien et al (2013) [23] stated that light soil requires 120 kg N/ha. Furthermore, RC1 requires twice N fertilizer application. The fertilization significantly increased the productivity level of CO 421 Variety. Ghube (2017) [17] stated that increasing superphosphate from 50 kg/ha to 150 kg/ha did not influence the total population. However, it can produce 30% higher than control (without P fertilizer). The sugar yield is in line with the sugarcane productivity level, as presented in Figure 1. Sugar yield was the multiplication of sugar content and yield.
The other related study revealed that the economic optimum level of NPK (90-50-40) content was at 50% of nitrogen and whole P and K applied at planting, and the remaining N was split and applied at 5-6 and 10-12 weeks after the first application [26].

4. Conclusions
The highest sugarcane productivity of RC1 was 138.57 t/ha, which required 8.4 Phonska + 7 ZA (qsu/ha) or 1.4x standard fertilizer dosage. The sugarcane productivity level increased by 25.52% compared to standard fertilizer (110.40 t/ha). The sugar content was 9.2% - 10%. The highest sugar yield was 12.97 t/ha, in line with the sugarcane productivity level. This finding suggested the recommendation of a fertilizer package for a double row system in sugarcane.

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