The productivity and sucrose content on dry land sugarcane influenced by inter-row spacing and transplanting seedlings

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Abstract. Planting sugarcane on dry land is susceptible to drought stress during the vegetative phase thereby reducing productivity. The objectives of this study were to examine the growth and yield of sugarcane transplanting seedling and ascertain their physiological-growth-traits to determine the productivity and sucrose content. The experiment design was a completely randomized block design with four replicates. The treatments were: five varieties and four inter-row spacing of single bud chips seedlings. The study was conducted in Gunung Kidul, Yogyakarta. The parameters were evaluated using analysis of variance followed by Duncan's multiple range test and analyzed using step-wise regression. The application of 60cm inter-row spacing increase the yield of millable cane by 101.7 tons/ha and sucrose content compared with control, respectively by 38.8%, 5.8%. The net photosynthesis (Pn) of nine months, leaf area index of four months, specific leaf weight of five months, the proline content of nine months and net assimilation rate at the age of six months determined the productivity. The physiological determinants of sugar content were Pn at the age of nine months, stem brix, even distribution of brix on the stem nodes, and level of chlorophyll.

1. Introduction
Sugarcane cultivation on dry land is faced with the constraints of climate change and environmental pressures. The beginning of the rainy season is difficult to predict, the adequacy of soil moisture from rainwater is an obstacle to support the maximum vegetative growth phase. Also, the level of soil fertility, organic C storage (0.5-1%) and mineralization of soil are low [1]. Drought stress in the tillering and vegetative phase must be avoided because it will reduce the yield of millable cane by 29.0-30.5% even 53% in sandy soil types and reduce sugar content by 31.0-39.7% [2].

Facing these constraints, the innovation of planting cane method is needed for climate change mitigation and increased productivity. The transplanting seedling system will answer the above constraints in increasing sugarcane productivity [3,4]. The single bud chips seeds are germinated and nursed in the nursery, after sufficient rainfall and at the age of 30-40 days after sowing are transplanted to the field [3,5]. Efforts to germinate single-bud chips seeds are important because the source of growth energy is limited thus avoiding the low ability of seed germination. Besides that avoiding the slow of seedling growing when planted directly in the field [6].
In the sugarcane industry, there are two important yield components, namely the weight of millable cane and sucrose content. High sugarcane production is determined by the ability of seedlings to produce more effective tiller which becomes a millable cane per clumps. The content of sugarcane sucrose is determined by a high of Brix value is distributed between nodes evenly [7]. One of the determinants of growth on the affective tiller or millable cane in seedling transplanting systems is inter-row spacing. Therefore, it is necessary to conduct research on inter-row spacing which effects on agronomic and physiological traits that determine the productivity and sucrose content.

The objective of this study was to examine agronomic and physiological traits by inter-row space treatments on bud chips transplanting seedlings and its effect on the production of millable cane per ha and sucrose content. This is useful so that technological innovation on sugarcane cultivation has a high agriculture precise of the results.

2. Methods
The research was conducted in August 2014 to January 2016 in Piyaman village farmer fields of Gunung Kidul Regency in the Special Region of Yogyakarta and according to Koppen's classification, belongs to tropical monsoon climate [8]. The main chemical characteristics of the soil show that soil pH, C total, organic material concentration, N total, available P and available K, C/N are 5.78, 2.96%, 5.1%, 0.27% and 333.99mg g⁻¹ and 1.50 me/100g and 10.95 respectively. Sucrose content analysis was the performer at the Madukismo sugar Factory in Yogyakarta. The physiological analysis was a performer at the Plant Science Laboratory on Agriculture Faculty Universitas Gadjah Mada. Materials in this study are single bud chips of sugarcane, soil media for nursery, polybags (8 x 12 cm size of polybags), fertilizers used were ZA (Zwavelzure Ammoniak: (NH₄)₂SO₄) with 21% of nitrogen content for N and NPK phonska with 15% of nitrogen, phosphate and potassium contents for N, P and K, arbuscular mycorrhizal fungi inoculum was in the form of zeolitic granular media.

The experimental design was a Randomized Complete Block Design (RCBD) arranged in a 4x5 factorial with 4 replications. The first factor was the inter-row spacing of transplanting seedlings consists of 4 levels: 30, 45, 60, 75cm. The second factor was varieties consists of 5 levels: PS864, PS881, KK (Kidang Kencana), BL (Bululawang) and VMC 86-550 (Victoria Milling Company). Observation variables such as plant height, number of tillers per clump, number of stem nodes, leaf area, stem diameter, clump angles, number of millable cane per clump, stem weight, stem Brix, percentage pol, photosynthesis rate (Pn), light capture, chlorophyll content, leaf area index (LAI), specific leaf weight (SLW), net assimilation rate (NAR), crop growth rate, sucrose content. Data analysis was used variance analysis if the real effect continued with Duncan's Multiple Range Test at p ≤ 0.05. To determine the important growth and physiological parameters for productivity and sucrose contents, these parameter data were analyzed by step-wise regression analysis through zero.

3. Results and discussion
3.1. General condition of research
This research was conducted at Piyaman Wonosari of Gunung Kidul Regency in the Special Region of Yogyakarta. The height of the research site was about 150 meters above sea level. The highest and the lowest temperature of research site were 31°C and 21°C, respectively, and according to Koppen's Classification, belongs to tropical monsoon climate [8]. The soil type in the research site was latosol and, textured clay and pH 5.78.

3.2. The effects of inter-row spacing and varieties for sugarcane productivity and sugar crystals
There was an interaction between inter-row spacing and varieties on the productivity of millable cane ha⁻¹ (Table 1). BL varieties with an inter-row spacing of 45 x 100 cm have been shown to have significantly higher productivity (132.10 tons ha⁻¹) compared to BL with wider inter-row spacing. PS881 varieties produce better productivity at wider inter-row spacing namely 75 x 100cm with yields of 123.45 tons ha⁻¹ (Table 1).
Table 1. Influence of inter row spacing and varieties on productivity and sugar crystals

| Inter-row spacing (cm) | Varieties | PS864 | KK | PS881 | BL | VMC | Average |
|------------------------|-----------|-------|----|-------|----|-----|---------|
| **Productivity (ton/ha)** |          |       |    |       |    |     |         |
| 30                     |           | 100.10b-e | 119.63a-c | 115.35a-d | 124.30ab | 100.75b-e | 112.03  |
| 45                     |           | 99.43c-e | 91.75de | 113.98a-d | 132.10a | 123.23ab | 112.09  |
| 60                     |           | 96.68b-e | 106.38b-e | 114.33a-d | 109.69a-e | 119.65a-c | 109.34  |
| 75                     |           | 104.55b-e | 84.58e | 123.45ab | 92.93de | 115.68a-d | 104.23  |
| **average**            |           | 100.18 |       | 100.58 |    |     | 114.82  |

| **Sugar crystals (ton/ha)** |          |       |    |       |    |     |         |
| 30                     |           | 7.69d-e | 9.75ab | 9.19a-d | 9.83a-c | 8.18b-e | 8.92    |
| 45                     |           | 8.16b-e | 7.58a-d | 9.28a-d | 10.10ab | 9.94ab | 9.01    |
| 60                     |           | 7.85b-e | 8.97a-d | 9.15a-d | 9.63a-c | 8.93   |         |
| 75                     |           | 8.11b-e | 6.59e | 10.48a | 7.08de | 8.97a-d | 8.24    |
| **average**            |           | 7.94   | 8.22 | 9.51 | 9.04 | 9.18 | (+) |

The interaction of inter-row spacing with varieties (Table 1) was shown to have a significant influence on the production of sugar crystals. BL varieties with an inter-row spacing of 45 x 100 cm have been shown to have significantly higher sugar crystals compared to BL with 75 x 100cm inter-row spacing. PS881 produced the highest crystal sugar of 10.48 tons.ha⁻¹ at a wide spacing of 75 x 100 cm. The sucrose content was not significantly determined by the treatments of inter-row spacing and varieties.

Table 2. Influence of inter-row spacing and varieties on sucrose content

| Treatments | Inter row spacing (cm) | Sucrose (%) |
|------------|------------------------|-------------|
|            | 30                     | 7.94        |
|            | 45                     | 8.06        |
|            | 60                     | 8.12        |
|            | 75                     | 7.89        |

| Varieties | PS864 | KK | PS881 | BL | VMC |
|-----------|-------|----|-------|----|-----|
|           | 7.92  | 8.10 | 8.14 | 7.85 | 8.01 |

The different in productivity among varieties effect of varieties and inter-row spacing interaction indicated that varieties have different ability to achieve optimal leaf area index (LAI). According to [9] optimal LAI of sugarcane is required to support the capture of sunlight for photosynthesis so that influences the germination of sugarcane seedlings and leads to optimal plants in protein synthesis, CO₂ assimilation and fat synthesis [10].

High productivity of millable cane and sugar crystal due to the effect of the inter-row spacing is caused by an increase in the number of tillers, plant height and weight of the millable cane. Physiologically these achievements are determined by LAI, net assimilation rate (NAR) and crop growth rate (CGR) [11]. CGR is significantly determined by total plant root length [12]. The influence of these root parameters has been known to significantly determine the weight of sugarcane stem, namely the ratio of shoot roots, root diameter and total of roots length [7].
3.3. Physiological-growth-traits determine productivity.

The physiological-growth-parameters with the most decisive of productivity of millable cane ha\(^{-1}\) ware show in Table 3. The effect (%) of each of physiological-growth-parameters played a positive role in increasing the sugarcane productivity (Table 3).

The results of this study (Table 3) show that there is an important role the photosynthesis occurs at the age of 9 months increasing the productivity of sugarcane. This is because the leaves produce photosynthates which are divided into several tissue cells, especially stems for the accumulation of sucrose [13]. The sucrose produced is flowed out of the leaf to stem on parenchyma cells [14]. Thus there is an accumulation of sucrose in the stem and causes the weight of the sugar cane to increase and cause the productivity of sugar cane to increase.

Table 3. Wise factor analysis, the physiological-growth-traits determinant of sugarcane productivity

| Physiological-growth-parameters | Parameter Estimate | Type II SS | Effect (%) | P-Value |
|----------------------------------|--------------------|------------|------------|---------|
| Pn at the age of nine months     | 0.480              | 10814.00   | 63.2       | <.0001  |
| LAI at the age of four months    | 4.435              | 3253.00    | 19.0       | 0.0011  |
| SLW at the age of five months    | 19.333             | 1129.77    | 6.7        | 0.0497  |
| proline content of the age of nine months | -1.001 | 1139.63 | 6.6 | 0.0487 |
| NAR at the age of six months     | 38.307             | 784.17     | 4.6        | 0.1007  |
| Sum of Residuals                 | 4.725              | First Order Autocorrelation | 0.125 |
| Sum of Squared Residuals         | 15726.79           | Durbin-Watson D | 1.715 |
| Sum of Squared Residuals - Error SS | 0.000 | R\(^2\) | 0.984 |

LAI at the age of 4 months after transplanting positively determine sugarcane productivity by 19.0%. The LAI reaches 5.52 at 30x100 cm and 3.08 at 75x100 cm inter-row spacing treatments. This indicates that 3.08–5.52 of LAI value is optimal for LAI to produce high millable cane ha\(^{-1}\). This result is in line with [15] that the highest of LAI of sugarcane was 3.38 in the vegetative phase of plant age 297 days after cutting of clump. The optimal of LAI will maximize sunlight capture for shoot growth, protein synthesis and carbon assimilation [10].

Specific leaf weight (SLW) at the age of 5 months after sowing positively determines sugarcane productivity by 6.6%. Thicker sugarcane leaves show thicker palisade cells so that CO\(_2\) in the palisade tissue as photosynthetic material is higher to support photosynthesis [16]. The differences among cultivars determine differences in the size of sugarcane tissue leaf vessels [17].

The high content of proline negatively affects sugarcane productivity because there is a change in plant protein which is supposed to be for stem growth and the accumulation of sucrose in the stem converted to proline. This is in accordance with the finding reported by [20]. This indicates that the low proline content on sugarcane leaves shown that sugar cane varieties have not been stressed due to drought.

NAR at the age of 6 months after transplanting has a positive role in determining sugarcane productivity by 4.6%. That age is the peak of NAR. The highest NAR causes an increase in LAI and reaches a maximum so that sunlight absorption by leaf area can be optimal for photosynthesis [10]. The resulting photosynthates reach optimal levels and are flowing to the sink’s organs including the stem so that the highest accumulation of dry matter is reflected in the NAR.

3.4. The physiological parameters determinant of sucrose content

The physiological parameters with the most decisive of sucrose content of sugarcane at dry land were shown in Table 4. Each of these physiological parameters played a positive role in increasing the sucrose content (Table 4).
Table 4. Wise factor, physiological parameters determinant of sucrose content

| Physiological parameters                        | Parameter Estimate | Type II SS | Effect (%) | P-Value |
|------------------------------------------------|--------------------|------------|------------|---------|
| Pn at the age of nine months                    | 0.0289             | 5.1321     | 49.30      | 0.0001  |
| Stem brix at the age of nine months             | 0.1332             | 3.1524     | 30.30      | 0.0023  |
| Even distribution of brix on the stem nodes at the age of ten months | 0.0724             | 1.1551     | 11.20      | 0.0598  |
| Chlorophyll content a                           | 1.3291             | 0.9669     | 9.30       | 0.0845  |
| Sum of Residuals                                | 0.1000             | First Order Autocorrelation | -0.0930 |
| Sum of Squared Residuals                        | 22.0341            | Durbin-Watson D | 2.18104 |
| Sum of Squared Residuals - Error SS             | -0.0000            | R²         | 0.99       |         |

The Pn at the age of 9 months determinant sucrose content is related to sucrose synthesis, flow from leaves to the phloem and division of sucrose storage [17, 18]. Brix also determines the sucrose content. The Brix value is significantly affected by the variety. The high brix value shows that the dissolved solids from the photosynthetic activity are stored in the internodes which contain carbohydrate in the form of lignocellulose [19]. Besides, the brix value that is evenly distributed between the stem nodes determines the sucrose content of 11.20%. Brix that is evenly distributed among the stem nodes shows that the distribution of solids including sucrose has been buried evenly between the nodes and is important in the accumulation of sucrose in stems [20].

Chlorophyll a accounts for 9.3% of sucrose content. Chlorophyll a has the function of capturing light at photosystem I and II with wavelengths of 700 and 680 nm respectively to be converted into high energy such as ATP and NADP + H₂ which are useful in carbon metabolism and growth [21].

4. Conclusion
The application of 60 cm inter-row spacing increasing the yield of millable cane. The Pn at the age of nine months, LAI at the age of four months, SLW at the age of five months, the proline content of the age of nine months and NAR at the age of six months determined the productivity. The physiological determinants of sugar content were Pn at the age of nine months, stem brix, even distribution of brix on the stem nodes, and level of chlorophyll.

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