Growth and yield of sugarcane with drip irrigation in an Ultisol in Indonesia

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Abstract Irrigation is a key to growing sugarcane well in tropical Ultisol soils in Indonesia and sprinkler irrigation has been commonly used for supplementary water supply. This project evaluated drip tape placement as an alternative irrigation system in terms of growth and yield of some commercial varieties grown at Gunung Madu sugarcane plantation. The experiment was carried out in plant cane (July 2013 to June 2014) and first-ratoon crops (June 2014 to May 2015). The field trial was laid out as a complete randomized design with three replications, four drip tape placement treatments (control or without drip irrigation; in the furrow surface (Sf); parallel with the row at 10 cm depth (SbS); and 20 cm under the row (SbD)), and five cultivars (GMP3, GMP4, GM21, GP11 and TC15). Stalk height was retarded and tiller population lowest in the control treatment (without drip irrigation) for all varieties. The highest cane yields for GMP3, GMP4 and GM21 were with SbD: 103.97, 119.15, and 119.37 t/ha, respectively. GP11 and TC15 had the highest cane yields in SbS: 108.49 and 118.77 t/ha, respectively. The high yields were associated with improved water-use efficiency (WUE). The SbS and SbD drip tape placements were able to improve the growth and yield of sugarcane on a commercial scale.

Key words Drip irrigation, drip tape placement, water use efficiency, sugarcane, tropical Ultisol

INTRODUCTION

Productivity of sugarcane cropping in the dry tropical Ultisol regions of Indonesia, such as Gunung Madu sugarcane plantation, has been maintained due to supplementary irrigation. Until recently, sprinkler irrigation was the most common method of applying water to sugarcane in Gunung Madu. Crop water demand has been met through a technically well-run sprinkler irrigation system. However, during the dry season every year, the sources and amount of water have become more limiting.

Megersa and Abdulahi (2015) reported that irrigation efficiency in surface irrigation was only 40%, whereas drip irrigation achieved 70-80%. Therefore, drip irrigation was identified as an alternative irrigation method to save water and supply water to additional areas during the dry season. Olivier and Singels (2003) and Silva et al. (2015), who studied the impact of drip irrigation on the yield and water use efficiency (WUE) of several sugarcane cultivars, found that different varieties often responded differently to drip irrigation. Overall there is an absence of information about this subject in relation to tropical Ultisol soils. Hence, the purpose of our study was to report the effect of drip-tape irrigation on the growth and yield of several local varieties during plant and first ratoon crops of a sugarcane crop cycle at Gunung Madu.

MATERIALS AND METHODS

The trial was conducted between July 2013 and May 2015 in a sugarcane field located on a Typic Plinthudult soil with a sandy clay loam texture. The trial was carried out in a complete randomized design with three replications. Plots measured 40 m x 11 rows, with a 1.5 m inter-row spacing. Drip-tape placement treatments were: control (without drip irrigation); on the soil surface in the planting furrow (Sf); at a 10 cm depth beside the row (SbS); and 20 cm under the row (SbD) (Fig. 1). Five local varieties were planted in the trial plots: GP11, GMP3, GMP4, GM21 and TC15. Varieties GP11 and TC15 are reported to be relatively tolerant to water stress, and have narrow leaves and erect stalks (R & D-GMP 2014).

After land preparation, drip-tape with 0.5 m emitter-spacing was installed according to the experimental design. A water flow rate of 1.01 L/h was used across the trial. The irrigation of the plots was controlled automatically using weather data during the sugarcane vegetative phase. An amount of 40 mm of water from a sprinkler irrigation was applied twice in the control plots. The first at the beginning of plant growth, and the second 2 months after planting (plant crop) and 2 months after harvesting of the plant crop for the ratoon crop.
Phosphorus (P) fertilizer was applied at 92 kg P$_2$O$_5$/ha/year concurrently with ridging-up in the plant crop and 1 week after harvesting the ratoon crop. Nitrogen (N) was applied at 138 kg N/ha/year, and potassium (K) at 180 kg K$_2$O/ha/year. The N and K fertilizer was injected into the secondary pipes of the irrigation system as 40 individual doses 2 days apart during the vegetative phase beginning 2 months after planting/harvesting. In the control plots, N, P and K were applied at the same rate as the drip-irrigated plots but with 92 kg P$_2$O$_5$/ha, 92 kg N/ha and 120 kg K$_2$O/ha buried during planting, and the remaining 46 kg N/ha and 60 kg K$_2$O/ha applied 2 months after planting. In the ratoon crop, the control plots received their full fertilizer application within 2 weeks after harvesting.

All water-use and supply details were recorded daily during the plant and ratoon crops. Plant population and stalk height data were recorded at 4 and 10 months after planting. The plots were harvested at 12 months and WUE of each plot was determined by yield per unit of water use (Olivier & Singels 2003).

**RESULTS AND DISCUSSION**

The total water supply in the drip irrigation plots from irrigation and rainfall was 2485 mm in the plant cane and 2783 mm in the ratoon crop (Fig. 2). In the control, both plant cane and ratoon crops received less water in total. Only 80 mm was added from sprinkler irrigation as the amount of rainfall was the same as the drip irrigation plots. Total evaporation and number of rain days during the growing period in the ratoon crop was 50 days less than the plant crop. Thus, the ratoon crop endured a longer drought period and produced a lower sugarcane biomass (Figs 3 and 4).

![Fig. 1. Layout of drip-tape placement.](image_url)
Despite similar amounts of water being applied to the different drip tape placement treatment plots, water distribution patterns varied according to the treatment. During the longer period of dry conditions in the ratoon crops, plant height was higher in Sf treatments than SbS and SbD (Fig. 3). One explanation is that the wetted zone created by the Sf water distribution pattern reached more young roots that grow extensively and enable increased water uptake. In comparison, the water supplied from SbS and SbD reached further down the profile, and it is assumed that the old roots within the wetted zone were less effective in water uptake.

Treatment SbS resulted in the highest average biomass for GP11 and TC15 (Table 1). Biomass was about 12% and 21% higher than the control for GP11 and TC15, respectively. The biomass of GMP3, GMP4 and GM21 was respectively 6.7, 15.4, and 28.9% higher than the control for SbD. The WUE value of GP11 and TC15 was higher in SbS. This implies that GP11 and TC15 are more responsive to soil moisture and make more efficient use of water. Similar findings were reported by Silva et al. (2015) who found that high yield had a positive relationship with high WUE in cultivars where drip irrigation was used. On the other hand, Olivier et al. (2013) reported that biomass achieved WUE of 6.29-8.13 kg/m\(^3\) up to 50\% sugarcane water demand and 5.48-6.90 kg/m\(^3\) at 100\% water supply. In our study, the water stress conditions of the control resulted in higher WUE than the irrigated treatments but the yield was lower (Table 1).


Table 1. Average sugarcane biomass (t/ha) and water use efficiency (WUE) for the different drip tape placement treatments and sugarcane varieties.

<table>
<thead>
<tr>
<th>Drip tape placement</th>
<th>Variety</th>
<th>GP11</th>
<th>GMP3</th>
<th>GMP4</th>
<th>GM21</th>
<th>TC15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average yield (t/ha)*</td>
<td></td>
<td>107.76</td>
<td>100.34</td>
<td>114.81</td>
<td>103.56</td>
<td>115.16</td>
</tr>
<tr>
<td>Surface</td>
<td></td>
<td>108.49</td>
<td>101.07</td>
<td>112.91</td>
<td>109.47</td>
<td>118.77</td>
</tr>
<tr>
<td>Subsurface-shallow</td>
<td></td>
<td>104.98</td>
<td>103.97</td>
<td>119.15</td>
<td>119.38</td>
<td>109.99</td>
</tr>
<tr>
<td>Subsurface-deep</td>
<td></td>
<td>96.95</td>
<td>97.45</td>
<td>103.23</td>
<td>92.55</td>
<td>98.13</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>4.76</td>
<td>4.57</td>
<td>4.43</td>
<td>5.07</td>
<td>5.08</td>
</tr>
<tr>
<td>Water-use efficiency (WUE) (kg/m²)</td>
<td></td>
<td>4.79</td>
<td>4.83</td>
<td>4.96</td>
<td>4.98</td>
<td>5.24</td>
</tr>
<tr>
<td>Surface</td>
<td></td>
<td>4.63</td>
<td>5.27</td>
<td>4.99</td>
<td>5.26</td>
<td>4.86</td>
</tr>
</tbody>
</table>

* F test at P_{0.05} : ns

CONCLUSIONS

We conclude that drip irrigation is effective in increasing sugarcane biomass and improving plant growth. Differences between drip tape placement were seen in the plant and ratoon crops and this was mainly influenced by rainfall and duration of the dry season. We conclude that each variety showed different responses to drip-tape placement and this is related to differences in varietal water-stress tolerances. Dripper tape placed subsurface-shallow and subsurface-deep could be useful in commercially grown sugarcane if the results remain consistent throughout the crop cycle.

REFERENCES


Croissance et rendement de la canne à sucre sous irrigation goutte à goutte sur un Ultisol en Indonésie

Résumé. L’irrigation est essentielle pour cultiver correctement la canne sur les Ultisols tropicaux d’Indonésie et l’irrigation par aspersion a été généralement utilisée pour un approvisionnement complémentaire en eau. Ce projet a évalué l’effet de la localisation des lignes de goutteurs, comme plusieurs modes d’irrigation, sur la croissance et le rendement de variétés commerciales de canne à sucre cultivées sur l’exploitation de Gunung Mandu. L’expérimentation a été conduite en année de plantation (Juillet 2013 à Juin 2014) et sur une première repousse (Juin 2014 à Mai 2015). L’essai sur le terrain est un dispositif en randomisation complète, avec trois répétitions, quatre modes de placement des lignes goutteurs (témoin, pas d’irrigation goutte à goutte ; dans le sillon en surface (SI) ; parallèlement au sillon à 10 cm de profondeur (SbS) ; à 20 cm sous le sillon (SbD)), et cinq variétés (GMP3, GMP4, GM21, GP11 et TC15). Les tiges étaient plus petites et le nombre de talles plus faible dans le témoin (sans goutte à goutte) pour toutes les variétés. Les rendements les plus élevés pour GMP3, GMP4 et GM21 ont été obtenus pour la modalité SbD : respectivement 103.97, 119.15 et 119.37 t/ha. GP11 et TC15 ont eu les meilleurs rendements pour la modalité SbS : respectivement 108.49 et 118.77 t/ha. Les rendements les plus élevés étaient associés à une amélioration de l’efficacité d’utilisation de l’eau (WUE). La disposition des goutteurs des modalités SbS et SbD a donc amélioré la croissance et le rendement de la canne à sucre à une échelle commerciale.

Mots-clés: Irrigation goutte à goutte, positionnement des lignes de goutteurs, efficacité d’utilisation de l’eau, canne à sucre, Ultisol tropical

Crecimiento y rendimiento de la caña de azúcar con riego por goteo en un Ultisol en Indonesia

Resumen. El riego es clave para un buen crecimiento de la caña de azúcar en suelos Ultisoles del trópico en Indonesia y el riego por aspersión se ha utilizado tradicionalmente para el suministro suplementario de agua al cultivo. Este trabajo evaluó la ubicación de la cinta
de goteo como un sistema alternativo de riego en términos de crecimiento y rendimiento de algunas variedades comerciales de caña de azúcar cultivadas en Gunung Madu. El experimento fue realizado en caña planta (julio 2013 a junio 2014) y en primera soca (junio 2014 a mayo 2015). La prueba de campo fue establecida en un diseño completamente al azar con tres repeticiones. Se evaluaron cuatro tratamientos de ubicación de la cinta de goteo (control o sin riego por goteo; en el surco sobre la superficie (SS); paralela al surco a 10 cm de profundidad (PDP), y 20 cm debajo del surco (PVP)), y cinco cultivares (GMP3, GMP4, GM21, GP11 y TC15). La altura de tallos fue retrasada y la población de tallos fue más baja en el tratamiento testigo (sin riego por goteo) para todas las variedades. Los rendimientos más altos de caña fueron para las variedades GMP3, GMP4 y GM21 con ubicación de cinta PVP: 103.97, 119.15 y 119.37 t/ha, respectivamente. Las variedades GP11 y TC15 tuvieron los más altos rendimientos de caña con ubicación PDP: 108.49 y 118.77 t/ha, respectivamente. Los altos rendimientos se asociaron con una mayor eficiencia en el uso del agua (EUA). La colocación de la cinta de goteo PDP y PVP fueron capaces de mejorar el crecimiento y rendimiento de la caña de azúcar a escala comercial.

**Palabras clave:** Riego por goteo, colocación de cinta de goteo, eficiencia del uso del agua, caña de azúcar, ultisol tropical