Crop water productivity of cash crops under drip irrigation combined with soil mulching

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Abstract. Drip irrigation is one of important technique of watering especially during unstable and uneven distributed rainfall due to global climate change. It minimizes water loss hence may increase the CWP (Crop Water Productivity). The purpose of this study was to evaluate the drip irrigation combined with soil mulching to CWP of cash crops. This research was conducted from October 2020 to February 2021 at Jumantono, Karanganyar Regency, Indonesia. The experiment was arranged in the Strip Plot design with 3 factors, namely type of irrigation (drip and conventional) as main plot; mulch (control, silver black mulch, and straw mulch) also commodities (paddy and chili) as the sub-plot with 3 replications. Parameters observed were biomass and Crop Water Productivity (CWP). The results showed drip irrigation combined with soil mulching resulted in higher CWP at both chili and paddy.

1. Introduction
Climate change in Indonesia brings decreasing water availability, degradation of soil moisture and fertility, also increasing the evaporation followed by augmentation of rainfall. It gives negative impact to agriculture industry in Indonesia which dependent to weather and other elements of climate [1]. Earth temperature’s rising about 0.8 °C which effect on global warming and caused the negative impact to Indonesia [2]. Especially, this country has 75% marine territory from total area so that it easily provides high evaporation and rainfall. Indonesia is a part of Asia, which is a continent with 63% resident from total population in the world and 67% contribution of agriculture productivity [3]. That’s why, climate change issue might be gives serious affect to Indonesia economic, due to the climate change impact on cash crops productivity.

Cash crop production is still using a large amount of fertilizers and irrigation water to achieve high yield. In Indonesia, surface irrigation by farmers still irrigating their land from water source until it spread to all-rounder area [4], hence more water are wasted because not all of the water volume could be absorbed by the plant root. Moreover, residue of fertilizers can pollute to environment. Therefore, the agriculture system is not yet suitable [5]. One of way to solve this problem is by applying the drip irrigation method. This system minimizes water loss because water is slowly released and only applied surrounding the root zone [6]. Drip irrigation is also suitable for rice cultivation too because rice water productivity was the highest with less or limited irrigation [7]. In another study, drip irrigation under soil mulching increased crop water productivity of chili from 50 to 65%, which was significantly higher than control [8].

Drip irrigation usage with mulching can suppress weed growth so as it can minimizing the impact of competition to growing and nutrition absorb [9]. This irrigation system can save water usage from 50 to
80% in compare to conventional irrigation which oftentimes over-irrigated [10]. This system will be more beneficial if the utilization is in dry land such as mostly land characteristic in Indonesia [11]. Drip irrigation combined with plastic mulching can increase Crop Water Productivity (CWP) because it keeps the optimization of water consume from rainfall or irrigation [12]. CWP value can be enhanced by the same input to once production using less volume of water given, or using same water volume with different irrigation system but produce more yield [13].

Till date, few studies are still found regarding CWP of rice and chili under drip irrigation combined with soil mulching. Hence, this study aimed at investigating the CWP of rice and chili under drip irrigation management and soil mulching.

2. Materials and methods
This research was conducted from October 2020 to February 2021 at Jumantono, Karanganyar Regency, Indonesia. The study site located at 7.63° S; 110.95° E, with alfisols of soil type. The experiment was arranged in the Strip Plot design with 3 factors, namely type of irrigation (control/manual and drip) as main plot; mulch (control, black-silver and rice straw mulch); also commodities (paddy and chili) as the sub-plots. Parameters observed were climate (air temperature, solar radiation, wind speed and photoperiodicity), total biomass and Crop Water Productivity (CWP) of each plant. Chili and rice cultivars used were Capsicum annuum L. cv Beautiful and Oryza sativa L. cv. Situ Bagendit (upland rice), respectively. Climate parameters to calculate evapotranspiration were measured using Automatic Weather Station (AWS). Total volume of applied water at each crop type was calculated using ET₀ (potential evapotranspiration) Penman Monteith in Cropwat 8.0 [14] using 10 years of climatic data from Jumantono Climate Station of Sebelas Maret University.

The total volume of applied irrigation based on crop coefficient (kc) and potential evapotranspiration (ET₀) is presented in Table 1. It can be seen in Table 1 applied irrigation volume of chili was smaller (96.9 liter) than paddy (121.7 liter) because the crop evapotranspiration of paddy (rice) is higher than chili [14].

Table 1. Total volume of applied irrigation water.

| Crop  | Planting duration (days) | kc-value | ET₀ (mm) | Irrigated Water |
|-------|--------------------------|----------|----------|-----------------|
|       | kc-in | kc-mid | kc-late | Oct  | Nov  | Dec  | Jan  | Feb  | mm  | liter |
| Chili | 124   | 0.6    | 1.05    | 5.23 | 4.57 | 4    | 3.66 | 3.98 | 459.3 | 96.9 |
| Paddy | 119   | 1.05   | 1.2     | 0.9  | 4    | 3.66 | 4    | 3.98 | 495.6 | 121.7 |

Notes: kc-value from FAO [14]; ET₀ was calculated using Cropwat 8.0 software.

Dry biomass, which is the outcome from stack of CO₂ assimilation [16] was measured using gravimetric method after dry-oven process for approximately 48 hours in 60°C. Crop Water Productivity (CWP) is the ratio of output (yield or biomass) and total water input. CWP (kg l⁻¹) is calculated using equation (1) [15, 16].

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CWP = \frac{Y}{ET_c}
\]

where \(Y\) is yield or biomass (kg ha⁻¹) and \(ET_c\) is total volume of irrigation water applied (mm or liter).

Data analysis used software SPSS 26.0 to find the significance value of each factor using Analysis of Variance (ANOVA) with 95% significance level (\(\alpha = 0.05\)).

3. Results and discussion
Biomass (dry) of each plant is shown in Figure 1. Figure 1 indicates drip irrigation resulted in higher dry biomass than conventional but not significant among chili and paddy, respectively. It means, somehow plants under drip irrigation resulted in bigger header and root, because drip irrigation plays important role on earl stage of plant growth [17].
The effects of soil mulching on dry biomass is presented in Figure 2. Despite insignificant, Figure 2 shows that regardless with irrigation type, soil mulching produced high biomass in general. When combined with drip irrigation, soil mulching resulted in higher dry biomass than control. Under chili, straw mulch resulted the highest biomass (80.6 g plant$^{-1}$), then silver-black plastic mulch (76.46 g plant$^{-1}$). The similar trend is also shown at paddy, where drip irrigation resulted in higher dry biomass, but the combination with black-silver plastic mulch contributed the highest biomass which were 182 and 229 g plant$^{-1}$ under conventional and drip irrigation, respectively. Soil mulch can keep the soil temperature and moisture stable [18], as well as minimizes the evapotranspiration and conserves soil moisture [19]. Drip irrigation under mulch could evenly distributes water to soil and provides less risk of water percolation [20]. Organic amendment, including organic mulch application may contributes to the availability of soil nutrient especially phosphorus to plant [21], hence promotes plant biomass.

Figure 1. Irrigation types on biomass.
(Note: 1= control, conventional irrigation; 2= drip irrigation)

Figure 2. Irrigation and soil mulching on dry biomass.
(Notes: 1= control (no mulch); 2= silver-black plastic mulch; 3= straw mulch; $\alpha=0.05$)
Figure 3. Irrigation method and soil mulching on biomass CWP of chili and paddy.

Figure 3 presents the CWP based on total dry biomass of both chili and paddy as affected by irrigation method and soil mulching. It is indicated in Figure 3 that generally the dry biomass-based CWP of paddy was higher than chili. That is due to higher crop water requirement of paddy than chili [14]. Soil mulching also resulted in higher biomass, that is because mulching helps drip irrigation to provide efficiency and maintain the quality of water given [20]. In chili, the straw mulching resulted higher CWP (29.9 and 35.1 kg ha\(^{-1}\) l\(^{-1}\)) than silver-black plastic mulch (24.6 and 33.2 kg ha\(^{-1}\) l\(^{-1}\)) at both conventional and drip irrigation, respectively. On the other hand, plastic mulch resulted higher biomass (62.3 and 78.2 kg ha\(^{-1}\) l\(^{-1}\)) than straw mulch (52.5 and 72.5 kg ha\(^{-1}\) l\(^{-1}\)) in paddy under conventional and drip irrigation, respectively. Higher biomass with straw mulch in chili probably due to the root of chili needs oxygen by good soil respiration than just availability of soil moisture, it is less tolerant to salinity and acidity [22]. Meanwhile, soil moisture contributes more to paddy’s growth and more tolerant to soil acidity [23].

4. Conclusion
Drip irrigation tended to result in higher CWP at both chili and paddy. However, straw mulch contributed in higher CWP at chili, but it was silver-black plastic mulch at paddy. It can be concluded that drip irrigation under soil mulch method is appropriate to use in this climate change situation. Because, it provides higher productivity by optimizing the usage of minimum water availability to minimize exaggerate water wasted. Although this method spends more cost than conventional irrigation, it can be good invest for further application on farming activity. Further study regarding the effective irrigation volume on CWP is required for more some cash crops.

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