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Asystasia intrusa: Cover crop and water balance dynamics in oil palm plantation

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Oil palm plantation in Bireuen regency is planted on class 3 (marginally suitable) soil class with land tilt and climate as limiting factors (Fitri and Satriawan 2015) and it has resulted in un-optimum productivity. Climate in Bireuen is marked by uneven rainfall throughout the year which leads to long dry month and excessive wet season. Consequently, soil water deficit during dry season and water loss during wet season have been reported. These conditions have been known to compromise oil palm production sustainability, particularly biomass production (Agusta *et al*. 2019). Water deficit on oil palm plantation will cause disturbance on plant growth, development of flower and fruits and in turn, lower its productivity (Cros *et al*. 2013, Tarigan *et al*. 2016).

It has been previously reported that land vegetation are able to hold more soil water compared to empty land by increasing land infiltration and reducing evaporation (Guswa *et al.* 2002, Zhang and Schilling 2006). Weeds which are generally found in oil palm plantation such as *A. intrusa* and *N. Biserrata* are identified as cover crops and nutrient contributors to the environment. However, *A. intrusa* role on balancing water dynamics in oil palm plantation has not been previously reported.

Therefore, the present study was conducted at Bireuen Regency, Aceh Province, Indonesia during January–Decembe 2020 for obtaining clear information regarding the role of *A. intrusa* in balancing water dynamics in oil palm plantations, especially during the dry and rainy seasons. Experimental plots (4 m × 2 m) were set between rows of oil palm plants (age 8 years) and were arranged in frond stacks and outer discs plantation area. The experiment consisted of two levels treatment namely with cover crop (100% covered by *A. intrusa*) and without cover crop (0% covered). Each treatment was conducted in triplicate. The soil moisture content during the experiment were measured at various depths (10, 20, 30, 40 and 50 cm) using a sensor connected to multimeter. Measurements were carried out every 15 days at pre-determined time in the morning.

Hydrological variables measurement: Hydrological variables observed in each experimental plot were rainfall, water interception by oil palm, water interception by *A. intrusa*, evapotranspiration (ETP) of *A. intrusa* and soil percolation. Data collection was carried out every day and lasted for 12 months (January–December 2020). Data of hydrological variables were then used to calculate water balance according to Ariyanti *et al*. (2016). Interception of oil palm [INTP (OP)] was calculated according to Mira *et al*. (2015) and interception of *A. intrusa* [INTP (Ai)] was calculated according to Purba (2007). Evapotranspiration was calculated based on the average value of daily water content at 30 cm depth on dry season where there was no rain recorded at all. Soil water content (SWC) was recorded using censor connected to multimeter. Soil percolation and surface flow happened when ΔSWC value were higher than total land porosity. All hydrological variables were based on 10 days data and calculated at 30 cm soil depth. Land physical characteristics observed were bulk density which were needed for the calculation of soil water content according to the following formula:

Soil water content (v/v) = bulk density × water content read on multimeter (b/b)

Statistical analysis: The data were analysed for the means and standard deviation. T-tests were performed in order to analyze the difference between two treatments at 5% level of significance.

Rainfall and soil water profile: Month of May, November and December are months with highest rainfall (wet season) recorded in 2020 which were 433.6, 292.9 and 311.5 mm per month, consecutively. April, June and July in 2020 are included in the category of months with moderate rainfall, since the amount of rainfall recorded is between 100–200 mm per month, namely 183, 149 and 137 mm per month. While dry seasons were on January, March, and August as the rainfall are <30 mm per month (1mm per day) .

Table 1 indicated that *A. intrusa* as cover crop positively

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Table 1 Monthly soil water content (SWC) retrieved from various land profile depths at cultivated and uncultivated plots

Month	Soil water content											
	Cultivated with *A. intrusa*						Uncultivated (control)					
	Depth (cm)											
	0–10	10–20	20–30	30–40	40–50	50–60	0–10	10–20	20–30	30–40	40–50	50–60
January	10.4	18.6	23.5	25.8	24.1	15.3	8.9	14.2	18.3	17.9	17.1	9.2
	12.12	19.7	25.2	26.9	24.8	14.6	10.2	14.4	21.2	20.6	19.2	10.6
	13.5	22.4	26.1	28.12	25.6	13.1	13.5	20.5	23.5	26.9	20.3	10.7
	12.0	20.2	24.9	26.9	24.8	14.3	10.9	16.4	21.0	21.8	18.9	10.2
Average	12.01	20.23	24.93	26.94	24.83	14.33	10.87	16.37	21.00	21.80	18.87	10.17
February	30.1	36.3	36.6	39.2	35.3	23.5	20.2	21.7	21.8	19.5	18.9	10.2
	31.4	36.5	39.3	35.9	32.4	20.6	21.1	21.6	22.1	20.8	19.2	10.8
Average	30.75	36.4	37.95	37.55	33.85	22.05	20.65	21.65	21.95	20.15	19.05	10.5
March	20.3	22.8	25.98	29.1	27.6	14.5	11.1	17.3	18.8	20.2	20.1	10.2
April	49.6	58.4	61.3	54.4	51.5	22.9	25.3	28.9	31.2	34.3	31.9	12.7
	45.67	60.7	62.1	65.2	63.2	25.4	32.5	33.4	33.9	35.1	32.2	15.8
Average	47.635	59.55	61.7	59.8	57.35	24.15	28.9	31.15	32.55	34.7	32.05	14.25
May	40.2	65.5	66.6	69.4	67.1	25.2	30.2	30.4	23.6	27.7	22.8	19.4
	60.2	62.1	65.3	69.1	66.3	23.1	30.7	31.1	26.2	25.1	24.5	20.3
	52.7	63.4	66.2	68.6	62.3	21.5	29.9	30.6	28.9	27.5	22.1	21.5
Average	51.0	63.7	66.0	69.0	65.2	23.3	30.3	30.7	26.2	26.8	23.1	20.4
June	45.2	53.9	58.6	63.9	59.7	20.3	25.2	23.9	28.5	23.6	29.8	18.1
	51.2	64.5	69.9	67.1	62.1	23.1	21.1	24.4	27.8	21.7	21.6	13.1
Average	48.2	59.2	64.25	65.5	60.9	21.7	23.15	24.15	28.15	22.65	25.7	15.6
July	40.8	41.9	47.3	35.4	30.6	22.6	33.8	25.9	22.7	24.5	20.6	12.6
	46.5	55.1	60.4	63.7	59.8	20.2	35.6	25.1	24.1	23.7	18.9	12.2
Average	43.65	48.5	53.85	49.55	45.2	21.4	34.7	25.5	23.4	24.1	19.75	12.4
August	24.3	29.7	35.2	39.5	37.1	13.1	14.2	17.9	15.3	15.9	13.2	11.3
September	25.2	34.9	38.7	40.1	38.2	13.8	15.2	24.1	24.7	20.1	18.2	10.3
	25.6	31.7	36.2	38.4	35.3	14.4	15.6	21.7	26.2	28.4	23.3	11.4
Average	25.4	33.3	37.5	39.3	36.8	14.1	15.4	22.9	25.5	24.3	20.8	10.9
October	14.8	20.3	31.4	36.2	32.9	10.9	11.2	18.3	21.4	16.2	12.9	10.1
	25.4	36.5	43.8	45.1	40.7	15.7	22.5	25.6	28.1	21.5	17.4	11.7
	30.1	33.3	34.6	38.1	42.6	12.6	12.4	19.1	16.9	18.1	16.8	13.6
Average	23.4	30.0	36.6	39.8	38.7	13.1	15.4	21.0	22.1	18.6	15.7	11.8
November	47.4	64.8	68.3	67.2	65.2	42.3	46.4	59.9	58.1	57.2	55.6	32.2
	49.5	51.1	60.9	62.3	60.4	40.1	48.1	50.1	50.9	62.2	60.5	30.2
	49.2	53.6	55.7	58.2	50.6	36.5	47.9	43.3	49.2	48.1	45.6	29.8
Average	48.7	56.5	61.6	62.6	58.7	39.6	47.5	51.1	52.7	55.8	53.9	30.7
December	50.4	61.8	67.4	66.5	65.1	42.4	49.7	51.9	57.6	60.1	61.5	32.4
	55.7	59.3	65.3	66.1	62.5	40.2	44.2	59.1	63.5	66.2	59.9	37.2
Average	53.05	60.55	66.35	66.3	63.8	41.3	46.95	55.5	60.55	63.15	60.7	34.8

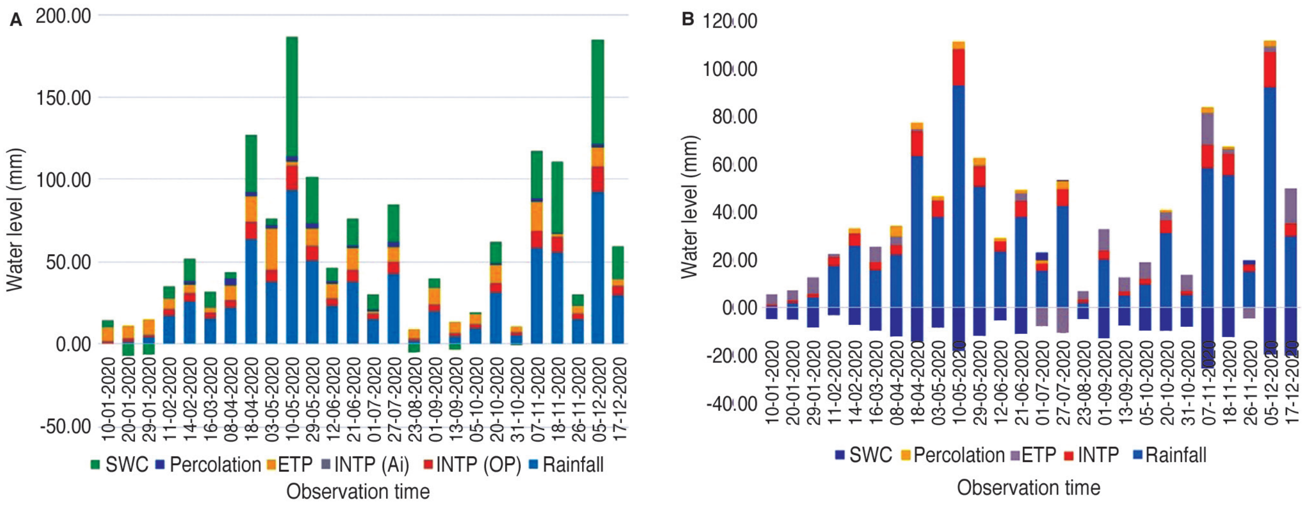

Fig 1 Soil water balance on (a), cultivated and (b), uncultivated plots.

affected SWC especially during dry season and on months when rainfall is moderate. Study on *A. gangetica* (Ariyanti *et al*. 2017) reported its beneficial contribution to water supply on oil palm plantation particularly during dry months (rainfall <60 mm per month).

It is suggested that cover crops might exhibit competition with the intended crop (Kaur *et al.* 2017). However, plant might interact differently to water balance dynamics in the plantation. On uncultivated plots, rainfall will be directly evapotranspired which then leads to loss of soil humidity on soil surface. While in deeper soil depth, soil percolation will happen which then leads to SWC reduction. On plots cultivated with *A. intrusa*, rainfall was intercepted by *A. intrusa* which then infiltrated and stored in root system of *A. intrusa*; thus, higher SWC on cultivated plots (Fig 1). On wet season, SWC on cultivated plots are higher than those of uncultivated plots even though the rainfall is considerably high. Soil store water through soil pores and *A. intrusa* play its role on storing soil water on its root system. *A. intrusa* plays an important role in keeping soil humidity so that the SWC is always higher at the end of wet season as anticipation of dry condition during dry months of dry season.

SWC profile patterns on cultivated plots are varied and affected by soil physical characteristics on every soil layer's observed and months of observation (wet, normal or dry season). The effect of cultivation of *A. intrusa* on changes of SWC daily average (ΔSWC) on study plots at different depth recorded were varied during research period (January–December 2020) (Table 1). However, it is observed that SWC deficit is markedly lower on cultivated plots compared to uncultivated plots. Exemption was observed on 40–50 cm depth as there was no SWC deficit observed both on cultivated and uncultivated plots. At 10–20 cm soil depth, *A. intrusa* significantly affected ΔSWC as soil water binds to root system of *A. intrusa*. Similar pattern as January is observed on August. On February–December, ΔSWC deficit recorded at 10 cm depth on uncultivated plot. In general, daily average of deficit reduction during August–September was 36.71% and could be recorded up to 50 cm soil depth. The role of cover crop is more visible during dry seasons in which ΔSWC on plots cultivated with *A. intrusa* were higher compared to uncultivated plots. To maintain soil water condition on dry season, shade condition of 80% and land covered with litter as much as 100% were suggested (Suhardi *et al*. 2012). It is reported that *A. intrusa* as land coverage thrives to increase soil water availability to 33–66% (Junaedi 2014).

On April–July and November–December ΔSWC were increased (Table 1), largely due to high rain intensity during these months. *A. intrusa*'s effect can be observed on March at all measurement level (0–50 cm) and ΔSWC daily average were increased in the range of 414.6–625% compared to dry season due to the presence of cover crop. During dry season, *A. intrusa* can maintain ΔSWC daily average at 30 cm depth particularly during January and August as growth and spread of the roots which is more effective at 30 cm depth enables rainfall to be detained on the zone during wet season.

At January and August 2020, deficit ΔSWC was recorded at 10–30 cm soil depth on both cultivated and uncultivated plots. Moreover, ΔSWC deficit happens consistently at 0–10 cm soil depth on uncultivated plots during February–June, September–December. This is due to water entering the ground mostly flows as percolated water and is not retained inside soil profiles. *A. intrusa* roots are able to reduce percolations rate as indicated by lower water deficit on 30 cm soil depth compared to uncultivated plots. Similar conditions reported on March with the highest rainfall compared to other months, but the effect of *A. intrusa* only reduced rainfall on soil surface through plant interception and holding the water until 30 cm soil depth according to roots depth even though the effect was not different to SWC both on cultivated and uncultivated plots.

Effect of cultivation of A. intrusa to water balance: Intervention on land water availability to conserving land water will be beneficial for crop intensification, productivity, and resilience (Garg *et al*. 2020).

Plots cultivated with *A. intrusa* have more water surplus days (200 days) compared to uncultivated plots (30 days) during January–December 2020. This can serve as an evidence to support the practice of cultivation of *A. intrusa* as cover crops on oil palm plantation. In contrary, uncultivated plots experienced 230 deficit days in total, in which the highest deficit was recorded on November 2020 (25.25 mm). This proves that *A. intrusa* was able to reduce the daily water deficit for >90% on highest water deficit condition. Apart from playing the role on reducing soil water deficit, *A. intrusa* plays the role in increasing soil ability to save ground water with single root system of *A. intrusa*.

Moreover, *A. intrusa* as cover crop able to reduce water deficit on both number of days or amount of water deficit. This is also supported by high soil percolation of *A. intrusa* cultivated plots. Percolation enables water deposit after infiltration to the soil profiles. This is indicated by consistent water balance at 30–50 cm depth.

On dry season (January–March), total rainfall on the mentioned period was as much as 83.4 mm and on cultivated plots recorded of SWC deficit as much as 63.26%. This shows that cultivation of *A. intrusa* plays a role in reducing SWC deficit especially on months with low rainfalls (January–March and August–October). The reason behind lower SWC on uncultivated plots were lower porosity and lower water holding capacity due to lower organic content compared to cultivated plots. This is supported by Satriawan *et al*. (2021) which reported that on the same study location, organic matter on land covered with *A. intrusa* which grow naturally at 0–20 cm depth was 3.29% and at 20–50 cm was 2.72%.

SUMMARY

Cultivation of *A. intrusa* as cover crops in oil palm plantation plays a role in reducing water deficit as much as 90% on condition of higher water deficit occurred. The present study aimed to examine the roles of *A. intrusa* as land cover crop on water balance in oil palm plantation in Bireuen Regency, Aceh Province, Indonesia during the year of 2020. The initial soil moisture content during the experiment were measured at various depths and conducted using a sensor connected to multimeter. The hydrological variables observed were included rainfall, interception of oil palm plants, water interception of *A. intrusa*, *A. intrusa* evapotranspiration, initial soil water content, soil water content during the experiment at each predetermined soil depth and percolation. This study showed that with *A. intrusa* as cover crop, positively affected soil water content especially during dry season and on months when rainfall are moderate. *A. intrusa* as cover crops in oil palm plantation played an important role in affecting water balance by reducing ground water deficit during dry season or months with lower rainfall.

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