Effect of shelter and fertilization on shallot yield, peat properties, and CO$_2$ fluxes in peatlands

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Abstract. Peatlands are potential for cultivating horticultural plants including shallot. This research aims to study the effect of shelter and fertilization on shallots and CO$_2$ emissions in peatlands. This study was conducted on peatlands in Landasan Ulin village, North Banjarbaru District, Banjarbaru, South Kalimantan. We used a split-plot design with main plot was shelter (R1) and without shelter (farmer’s practice) (R2), and subplot was fertilization consist of 100% recommended dosage (P0), 50% recommended dose + Liquid organic fertilizer (P1), 75% recommended dose + Liquid organic fertilizer (P2), 100% recommended dose + Liquid organic fertilizer (P3), and 125% recommended dose + Liquid organic fertilizer (P4). Observations included soil periodic of pH, available P, available K, CO$_2$ emissions, growth and yield of shallot. The results showed that shelter application increased the availability of P and K in peatlands. A combination of shelter and 75% recommended dose+Liquid organic fertilizer could increase the shallot yield in peatlands up to 25.7% compared to P0. The highest cumulative flux CO$_2$ were shown by the treatment without rain shelter (treatment R2PO) reaching 6.2 t CO$_2$/ha/year and the lowest was in the rain shelter application plot (treatment R1P4) reaching 4.7 t CO$_2$/ha/year which was not significantly different from treatment R1P2 (4.7 t CO$_2$/ha/year).

1. Introduction
Climate change has affected many countries indicated by increasing temperature caused by greenhouse gases (GHGs). Fossil fuel has been considered as main source of GHGs. However, GHGs released from peatlands are a major concern recently [1]. Peatland ecosystems are fragile and likely being a net source of GHGs when the ecosystem is disturbed or damaged [2]. Emissions from peatlands are mostly in the form of CO$_2$ from peat decomposition and land fires [3]. Draining peat increases CO$_2$ emissions by more than 2 Gt per year globally [4]. Groundwater level, redox potential, soil pH, and groundwater content can influence CO$_2$ emissions [5]. Peatlands are potential for sustainable horticulture development if influencing factors of CO$_2$ emission are managed properly.

Shallot is a leading commodity with high economic value for a spice in cooking and medicine [6]. According to Aryanta [7] shallots contain many nutrients that are beneficial to humans such as protein, fatty acids, vitamins, calcium, iron, magnesium, phosphorus, potassium, sodium, zinc and selenium. The prospects of Indonesian shallots in the world are quite good considering that Indonesia is one of the exporters of shallot in the world [8].

The conventional use of peatlands for horticulture requires high input, which affects the environment, including GHG emissions. In addition, the use of peat land for shallot development is often constrained by pests and low soil fertility. Yield losses due to pest infestation on shallot ranged
from 20 to 100% [9]. Pest control is vital to succeed shallot cultivation. Rain shade is sometimes applied to create micro-climatic conditions which subsequently affect soil moisture. Rain shading can potentially suppress pest infestation and reduce CO$_2$ emissions.

Moreover, fertilization is critical to succeed shallot cultivation. A high dosage of NPK fertilizer for shallot cultivation on peatlands may enhance peat decomposition and ought to increase CO$_2$ emissions. An improved application and alternative fertilizers are required to increase crop yields while reducing GHG emissions. Previous research had shown that spraying appropriate type and dose of liquid fertilizer on the leaves can increase the efficiency of NPK fertilization and reduce inorganic fertilizers applied through the soil. Nonetheless, limited research explored the effect of rain shelter on GHG emissions. Therefore, this study aims to investigate the use of shelter and fertilization on CO$_2$ emissions, soil properties, growth and production of shallots in peatlands.

2. Materials and methods

2.1. Materials

The materials of this research include onion tubers of Bauji variety, manure, dolomite, NPK fertilizer, Liquid Organic Fertilizer (Brilian), herbicides, insecticides, fungicides, shelter, soil sample kits, and chemicals material for soil analysis and stationery kits.

2.2. Methods

The study was conducted in March-December 2018 on peatlands in Landasan Ulin Village, North Banjarbaru District, Banjarbaru Municipality, South Kalimantan Province, Indonesia. The research site was peatland that has been intensively used for agriculture in the last 15 years. A split-plot design with rain shelter as main plot and fertilization as sub-plot was implemented. The main plot consisted of rain shelter (R1) and without rain shelter (R2), while the subplot of 100% recommended dosage (P0), 50% recommended dose + Liquid organic fertilizer (P1), 75% recommended dose + Liquid organic fertilizer (P2), 100% recommended dose + Liquid organic fertilizer (P3) and 125% recommended dose + Liquid organic fertilizer (P4).

The rain shelter was made of plastic and bamboo for the clamp with a curved lid. The fertilizer dosages being implemented were NPK 200 kg/ha, SP 36 150 kg/ha, supplementary fertilizer I (14 days old) in the form of NPK 200 kg/ha, KCl 100 kg/ha, and supplementary fertilizer 2 (35 days old) in the form of NPK 100 kg/ha and KCl 100 kg/ha. “Brilian” liquid organic fertilizer (LOF) was made from fermented sheep urine having a pH of 7.65, EC 22.9 mS/s, and containing 25% N, 3.7% P, 5.1% Ca, 32.4% Mg, 0.6% K, 2000 ppm Cu and 2500 ppm Zn.

The soil ameliorants (i.e., chicken manure at the rate of 10 t/ha and dolomite at the rate of 5 t/ha) were incorporated into the field 2 weeks before planting. The onion bulbs were planted at an interval of 20x15 cm. Bulbs were planted in the way such as turning a screw to enable the tuber growing over the surface.

Pest control was adapted to the conditions, at 4 days after planting all treatments were sprayed with the pre-growth herbicide at recommended dosage. We cultivated a strain named Bauji. The soil ameliorant material was chicken manure 10 t/ha and dolomite 5 t/ha, that given 2 weeks before planting. Onions was harvested at 65 days old with specific circumstances, i.e. dry soil and sunny weather to prevent tuber blight in the warehouse. Furthermore, the tubers dried in direct sunlight until they are quite dry (1-2 weeks) until they reach a moisture content of approximately 80%.

Soil samples were taken at the beginning and at planting to analyze the H$_2$O pH, KCl pH, EC, available P and exchangeable K. We observed plant height, number of leaves, and the level of pest attack at 3 and 6 week after planting. In addition, in this phase a gas sample was taken for CO$_2$ analysis. At the end of the observation, we observed number of fruit crops, weight of onion tubers, and shallot yields.

Two emissions were measured, i.e. soil emissions and root respiration. A closed chamber having dimension of 30 cm diameter and 20 cm height was used to gage gas emission. Air temperature and
CO₂ concentration were observed every 3 minutes, and simultaneously, soil temperature was observed at a depth of 5 cm using a digital thermometer. CO₂ gases emission gauged in the morning from 6:00 - 8:00 am. The measurement of gas samples used IRGA which has been calibrated in advance with sodalime and CO₂ standard gas. The CO₂ flux was calculated by the following formula:

\[ E = \frac{Bm}{V} \times \frac{\delta Csp}{\delta t} \times \frac{V}{A} \times \frac{273.2}{T+273.2} \]

Where:
- \( E \) = flux CO₂ (mg/m²/day)
- \( V \) = cover volume (m³)
- \( A \) = cover base area (m²)
- \( T \) = average air temperature in the containment (°C)
- \( \delta Csp/\delta t \) = change rate of gas CO₂ concentration (ppm/minute)
- \( Bm \) = CO₂ gas molecule weight in standard condition
- \( V_m \) = gas volume in STP (standard temperature and pressure) condition i.e. 22.41 liter at 23°C

The collected data were then analyzed using analysis of variance followed by the 5% Duncan test.

3. Results and discussion

3.1. Soil characteristics

The research location is peatland in a freshwater swampland which experience an overflow of mud during annual flood. The initial soil characteristics of the research site before planting and just after tillage and ameliorant application are presented in Table 1.

| Soil characteristics       | Before planting | During planting |
|----------------------------|-----------------|-----------------|
| pH (H₂O extract)           | 4.28            | 5.57            |
| pH (KCl extract)           | 3.69            | 4.90            |
| EC (mS/cm)                 | -               | 0.417           |
| Organic C (%)              | 24.10           | -               |
| Available P (mg/kg)        | 32.280          | 179.18          |
| CEC (cmol(+)/kg)           | 33.879          | -               |
| Total P (mg/100g)          | 17.118          | -               |
| Total K (mg/100g)          | 4.939           | -               |
| Exchangeable K (cmol(+)/kg)| -               | 1.230           |
| Ash content (%)            | 24.10           | -               |

Note: - = data is not available

Initially, soil acidity was very high, however after ameliorant material application, the acidity decreased. Soil organic C content was 24.10%, while total soil P and total K were low. Ash content is commonly used as an indicator of the fertility of peat soil as reported by Kurnain [10]. The higher the ash content in peatlands, the better the soil fertility is generally. The ash content in oligotrophic peat soils is normally less than 1%, except for peat soil that experienced fire or intensively cultivated which can reach 2 - 4% [11]. There was an increase in pH from 4.18 to 5.57 and available-P from 32.28 ppm to 179.18 ppm after ameliorant application and basal fertilizer application.
3.2. Shallot growth and yield
Rain shelter treatment has a significant effect on plant height and leave number of shallots. The best effect on the shallot growth was observed on the R1P3 treatment (Figure 1). Rain shelters do not only protect plants from high rainfall, but also from solar thermal and winds, and maintain air temperature to allow a faster growth [12]. The possibility of etiolation due to transparent plastic shade is very small [13]. Rain shelter protects shallots from direct splashing that can damage shallots plant.

Rain shelter enabled better growth than without rain shelter (Figure 2). In the rain shelter treatment, increasing the fertilizer dose up to 125% increased plant performance. However, the improvements did not in line with increasing yield. It needs a balance of nutrient absorption to allow optimal photosynthesis. Excessive N fertilization potentially increase vegetative growth, but possibly suppress generative growth. The LOF “Brilian” contained high N, but the content of other elements such as P (0.03% P₂O₅) and K (0.48% K₂O) were very low. Phosphorous an K are needed for tuber formation [14]. Madjid et al. [15] stated that potassium is needed for starch formation and translocation of photosynthetic products such as sugar. Pest-infestation rate of no shelter was somewhat higher than with a shelter (Figure 3).

Figure 1. The effect of rain shelter and fertilization on plant height (a) and number of leaves (b)
Note: WAP - week after planting

Figure 2. The performance of shallot plants as affected by shelter and fertilization.
Figure 3. Effect of rain shelter and fertilization on the intensity of pest attacks on shallots.

Sheltering and fertilization affect shallot yield (Figure 4). The highest shallots yield was shown by R1P2 treatment (rain shelter treatment + 75% NPK + LOF) which was able to increase the yield up to 25.7% compared to 100% NPK fertilization without LOF treatment (R1P0). In addition to increasing the yield by 25%, LOF applications reduced the use of NPK fertilizers by 25-50%. Giving sheep urine on the shallot tuber weight depends on the dose given [14].

Figure 4. Effect of rain shelter and fertilization on shallot yield.

The yield of these shallots may be improved by balancing nutrient uptake. Increasing N uptake should be accompanied by increasing K uptake to positively improve crop yields. Fertilization increases the availability of K leading to improving K uptake. The K element plays a role to improve plant resistance towards pests and plant diseases. Increasing the dosage of K fertilizer may anticipate pest infestation on shallot in the rainy season to complement pesticide application.

3.3. CO₂ emissions
The CO₂ flux at 3 WAP of no rain shelter was higher than with the rain shelter, while at 6 WAP it is relatively similar (Figure 5). From the start of transplanting until 3 WAP, the rainfall was somewhat little, so that the shelter played a role in reducing soil temperature. Decreasing temperature can reduce the decomposition and CO₂ emissions of peat soils. Putri et al. [14] explained that CO₂ generated from
the decomposition of peat material is influenced by temperature, hydrological conditions, soil properties and agricultural cultivation techniques. At high temperatures, CO$_2$ is in form of gas in large quantities.

![CO$_2$ flux (mg/m$^2$/day)](image)

**Figure 5.** Effect of rain shelter and fertilization on CO$_2$ flux.

The highest cumulative emission was indicated by R2PO and R2P3 treatment (7.11 t/ha/year) and the lowest was at R1P4 (4.5 t CO$_2$/ha/year) which was similar to R1P2 (4.7 t CO$_2$/ha/year). The R1P2 treatment reduced CO$_2$ emissions by 24% compared to R1P0, while R1P4 reduced CO$_2$ emissions by 27% compared to R1PO (Figure 6).
Since the research site is situated in a freshwater swampland, the water level is totally determined by rainfall. Increasing rainfall was observed during cultivation from the start at September until November (Figure 7). The rainfall rose the groundwater level and CO₂ emissions. Whilst, CO₂ emissions observed in November were much lower than the one in October. The rainfall also greatly increased the likelihood of pest infestation, especially fungi, as shown in Figure 7, which reduced crop yields.

Figure 6. Effect of rain shelter and fertilization on cumulative CO₂ emissions.

Figure 7. Rainfall at the research location (BMKG Banjarbaru).
4. Conclusion
A combination of shelter and NPK fertilization at 75% of the recommended dose + liquid organic fertilizer “Brilian” could increase the shallot yield in peatlands up to 25.7% as compared to 100% NPK fertilization without liquid organic fertilizer. The highest CO$_2$ cumulative emissions were shown by the treatment without shelter (R2PO) reaching 6.2 t CO$_2$/ha/year and the lowest was treatment R1P4 (4.5 t CO$_2$/ha/year) followed with R1P2 (4.7 t/ha/year). Rain shelter can be potentially applied for planting cash crops.

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