Impact of weather changes on the potato cultivation quality with the LEISA system

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Abstract. The aspect of potato cultivation well known to most farmers is closely related to the climatology of the cultivated site. Therefore, this study aims to obtain the basic information on climatic change in potato cultivation quality using the LEISA system or in potato cultivation, compost is used as fertilizer at a dose of 10–30 tonnes/ha. The experiment was designed based on four treatments namely, (1) cultivation in normal weather conditions from April - June 2019, (2) in foggy air conditions from July to September 2019, (3) in extremely hot conditions from October to December 2019, and (4) in extremely rainy conditions from January to March 2020. The parameters observed were (1) microclimates around the plants, (2) the condition of the growing media depth 0-30 cm, (3) plant growth, and (4) productivity. The changes from normal to foggy, extremely rainy, and hot weather had impacts on soil temperature by 22.1±5.2%, 8.6±2.2%, and 10.3±5.9% respectively. In extremely hot and rainy weather, the cation exchange capacity (CEC) value was low by 22.1±0.16 and 23.8±0.21 meq/100g of dry soil. The extremely hot, rainy, and foggy weather reduced the productivity of potato plants by 32.13–60.2%, 19.5–43.0%, and 16.7–18.0% respectively. In addition, they also reduced the quality of potato tubers by 19.9–94.7%, 26.0–62.9%, and 8.8–15.9% respectively.

1. Introduction

Potatoes are the fourth basic food material needed by the community since they contain lots of carbohydrates [1]. The productivity and quality of potatoes depending on the interaction between the genetic and the environmental factors such as soil type, topography, management, climatic patterns, and cultivation technology [2][3][4]. Most potato farmers have made efforts in optimizing their products, however, weather or climate changes always occur, which result in obstacles such as, the occurrence of long drought or rain exceeding the forecast [3][5][6].

An increase in environmental temperature or a long dry season has a significant impact on increasing plant evaporation, therefore, irrigation, soil moisture, and temperature play important roles in potato production [7]. The cultivation of potatoes in conditions of limited water irrigation causes crop yields to decline, as a result of nutrients inhibition [8]. An altitude of more than 1000 masl has a risk of fogging on potato cultivations, while thick fog and even hail arise due to extreme weather below 10 degrees Celsius. Therefore, cold temperatures make farmers experience crop failure due to stems and leaves freeze in the morning [9].
The optimal yields of most commercial potato varieties are produced on average daytime of 14–22°C, while higher temperatures lead to a sharp decrease of yield, for example, at 27°C, the yield of Spunta variety is reduced to about 15% of the maximum yield [10]. Therefore, this study aims to obtain the basic information of climatic change on potato cultivation quality using the LEISA system.

2. Research methods
A factorial design with two factors was used in this study, the first was the cultivation period, while the second was the site feature. The first factor included (1) cultivation from April to June 2019, (2) from July to September 2019, (3) from October to December 2019, and (4) from January to March 2020. Each experimental unit occupied a land area of 10 acres and was divided into 4 blocks for test replications. The potato seed for cultivation was fertilized with NPK 250 kg/ha and compost of 20 tons/ha, then maintained to control pests and diseases by spraying insecticides and fungicides once a week, and twice if the rainy season [11]. Meanwhile, other plants were maintained using supplementary fertilization and nutrient addition.

The land for potato cultivation is processed to a depth of 30 cm until the soil structure is crumbly. Potato cultivation was carried out on the farm bed of 1 m wide, 10 m long, and 30 cm high, while the drainage channel was 40 cm wide. On each bed, there were 3 potato plant grooves with a distance of 40 cm between them and spacing of 30 cm, which were covered with black plastic mulch [11]. The observation of climatic micro parameters was carried out every 2 weeks. The temperature around the plant was assessed with a digital thermometer, while the air humidity was measured with a hygrometer, then light intensity was assessed with a lux meter, and length of daily exposure was taken from the nearest meteorological station. Analysis of the data is graphed for the relationship between several variables and averaged and the standard deviation is sought.

Determination of the amount of soil organic matter using the 1995 AOAC method. Parameters of soil physical properties (porosity, mass density, and moisture content) were measured by the gravimetric method from 5 soil samples taken randomly. Parameters of plant height and total biomass were observed from 20 samples of potato plants taken randomly every 2 weeks. Zero plant age - eight weeks is the vegetative phase and 9-12 weeks is the generative phase.

Plant height is measured by the meter, while total biomass is measured by weighing the biomass of potato plants. Plant productivity is measured by observing the total production per unit area (1 m²) and total tubers per tree. The number of samples for the observation of the total number of tubers was 20 for each plot, while for the observation of the total production, 5 samples were taken for each plot.

3. Results

3.1. Microclimate in potato cultivation
The weather changes had a direct impact on potato plants [12][13]. In extremely hot weather conditions, sunlight intensity increased from 14–115% or to an average of 53.1%, while potatoes at normal conditions received an exposure intensity of 491–1114 lux. The average sunlight intensity captured by potato plants to support photosynthesis in foggy and rainy weather were 576.13 ± 227 lux and 403.3 ± 159 lux, while the length of irradiation in these weather conditions reduced to 5.5 ± 0.1 hours/day and 7.8 ± 0.2 hours/day (Figure 1).

The foggy and rainy weather indirectly affected the air temperature around the plant [13]. Figure 2 showed that air the temperature around the potato plants at the cultivation location with a location of the field experiment range of altitude of location 900–1300 masl, decreased with increased plant age. The rate of temperature reduction in normal, foggy, extremely rainy and hot weather were 0.65 ± 0.2°C, 0.96 ± 0.3°C, 0.77 ± 0.2°C, and 1.55 ± 0.3°C respectively. The humidity around the potato plants in foggy and extremely rainy were 83.1 ± 2.2% and 85.7 ± 2.5%. Meanwhile, the relative humidity around the potato plants in normal and extremely hot weather was 79.3 ± 0.7% and 76.4 ± 0.7% (Figure 3).
Figure 1. The intensity of exposure received by potato plants.

Figure 2. The air temperature around the potato crop

3.2. Soil conditions in the root zone
The temperature changes around the plant had a direct impact on the soil in the root zone (Figure 4). The changes from normal to foggy, extreme rain and hot weather had an impact on soil temperature changes by 22.1 ± 5.2%, 8.6 ± 2.2%, and 10.3 ± 5.9% respectively. The chemical and physical properties of soil in the root zone were shown in Table 1. The soil moisture content did not support organic matter absorption in extremely hot weather, which was indicated by the CEC value of 22.1 ± 0.16 meg/100g of dry soil. While the organic matter leached in rainy weather was 12.1 ± 1.2% with the CEC value of 23.8 ± 0.21 meg/100g of dry soil. The content of organic matter in the soil in the dry season is more than in the rainy season because: (1) there is a process of washing organic matter in the rainy season, (2) the amount of organic matter absorbed by plants in the rainy season is more than in the dry season (CEC value is bigger)

As a result of rain, small soil particles (dust and clay) are carried to the deeper layers of the soil, this results in changes in porosity, in addition, due to the blow of rainwater there is soil compaction. Meanwhile, in the dry season, changes in porosity are due to soil compaction only. Changes in soil porosity directly result in changes in soil mass density in reverse.
Figure 3. Humidity.

Figure 4. Soil temperature in the root zone of potato plants.

Table 1. Physical and chemical properties of soil in the root zone of potato plants.

|                          | Normal weather | World weather | Extreme dry weather | Extreme Rain weather |
|--------------------------|----------------|---------------|---------------------|----------------------|
| **Physic characteristic of the soil** |                |               |                     |                      |
| Bulk density, g/cc       | 0.62 ± 0.1     | 0.71 ± 0.1    | 0.67 ± 0.1          | 0.68 ± 0.15          |
| Soil porosity, %         | 55.8 ± 2.1     | 50.4 ± 1.7    | 45.2 ± 1.2          | 35.5 ± 2.2           |
| Moisture content, % w.b  | 29.6 ± 1.7     | 34.1 ± 1.8    | 24.5 ± 2.2          | 35.5 ± 2.2           |
| **Chemical characteristic of the soil** |                |               |                     |                      |
| Content of organic material, % | 29.29 ± 2.2 | 23.25 ± 1.8 | 38.76 ± 2.6 | 17.16 ± 3.2 |
| Soil pH                  | 6.92 ± 0.3     | 6.81 ± 0.2    | 6.79 ± 0.2          | 6.73 ± 0.2           |
| Cat-ion Exchange Capacity, me/100g | 27.2 ± 0.3 | 25.3 ± 0.2 | 22.1 ± 0.16 | 23.8 ± 0.21 |
3.3. The potato plants quality

Generally, potato plant growth in the vegetative and generative phases was normal, due to nutrients availability in the root zone. However, the intensity of sunlight (Figure 1), air temperature (Figure 2), and the duration of exposure to inhibit the growth of potato plants. The direct result of changes in sunlight intensity, air temperature, and long exposure is the process of photosynthesis. The growth rate of the vegetative phase from normal to foggy, extremely rainy, and hot weather were $8.2 \pm 1.1$, $5.7 \pm 1.3$, $7.5 \pm 1.1$, and $5.2 \pm 1.3$ cm/week.

![Figure 5. Potato plant height.](image)

The relationship between plant age and total biomass in the vegetative phase increased and conversely decreased in the generative phase. Furthermore, the total increase rate of biomass in the plant phase of normal, foggy, extremely rainy, and hot weather were $28.6 \pm 2.3$, $16.2 \pm 2.1$, $14.0 \pm 2.0$, and $15.3 \pm 2.3$ g/week respectively. While the reduction in biomass weight in the generative phase of these weather conditions were $56.3 \pm 2.0$, $21.7 \pm 2.1$, $31.8 \pm 2.2$, and $33.3 \pm 2.3$ g/week respectively.

![Figure 6. Total biomass of potato plants.](image)
3.4. Productivity and quality of potato tubers

The cultivation treatment in normal weather, foggy, extremely rainy and hot produced potatoes with the number and weight of tubers per tree and unit area as shown in Table 2. The extremely hot, rainy, and foggy weather reduced potato crop productivity by 32.13–60.2\%, 19.5–43.0\%, and 16.7–18.0\% respectively. The number of tubers produced per tree in normal weather was 1232.32–1245.12 g or 32.5–34.3 tons/ha. This met the production target of the National Development Planning Agency or BAPPENAS of 30 tons/ha.

Meanwhile, tuber production decreased in extremely rainy and hot weather by 50\% with an average weight of 80 g per tree, which was categorized into class A/B. Extremely hot, rainy, and foggy weather reduced potato tubers' quality by 19.9–94.7\%, 26.0–62.9\%, and 8.8–15.9\%. In normal weather conditions, potato tubers had an average weight and number of 100.19 ± 3.2 g, and 12.3 ± 1.4\%, while the weight and number of superclass potatoes were 200 g and 25.2–30.1\% [14]. The number of superclass tubers in foggy, extremely hot, and rainy weather were 18–21.6\%, 1.13–2.5\%, and 9.34–10.2\% respectively.

4. Discussion

4.1. Impact of weather change on microclimate

The heat absorbed by plants to support the photosynthesis process in normal, foggy, rainy, and hot weather were 809.58 ± 2.1lux, 654.48 ± 2.5lux, 409.33 ± 3.2lux, and 1302.98 ± 2.6lux respectively. The heat for this process in the early stages of growth, generative phase, and for all types of treatment varied between 174.41–1624.65lux.

The weather changes had a direct impact on the soil temperature at a depth of 0–30 cm, therefore, the amount of heat required to change soil temperature from normal to foggy, extremely rainy, and hot weather were 4.45 ± 0.8lux, 2.4 ± 0.3lux, and -1.59 ± 0.4lux respectively. The extremely hot weather changed the ambient temperature of 4.07–6.55°C, 0.54–4.21°C, and -2.39–3.32°C. The heat transferred from the environment to the root zone of plants in extreme, foggy weather is greater than in extreme hot and rainy extremes, this has an impact on the number of plants affected by the disease.
The temperature in the root zone greatly affects the productivity and quality of the potato tubers produced. Because the effect of temperature was in carbon assimilation between the leaf and tuber. At high-temperature carbon was assimilated into the vegetative part, while at low temperature it was assimilated into the tubers [15].

Furthermore, the results showed that the soil temperature for normal treatment, foggy air, rainy season, and dry season were respectively: 24.3 °C - 27.8 °C, 17.8 °C - 23.1 °C, 20.6 °C - 27.2 °C, and 27.6 °C - 29.9 °C. From experiments conducted in growth chambers, it is known that haulm growth is fastest in the temperature range of 20–25 °C whereas the optimal range for tuberization and tuber growth is 15–20 °C [5]. Therefore, the potato tubers cultivated in this study varied widely in shape and size, because the soil temperature was not optimal in the root zone.

The changes in the environment air and heat, due to exposure intensity had a direct impact on the evapotranspiration rate of potato plants and indirectly affected the amount of water vapour in the air. The amount of heat that aided water evaporation in foggy, extremely rainy, and hot weather were 33.6kJ, 64.2kJ, and 139.2kJ respectively, while the amount of heat and the exposure period increased potato productivity [16]. But, in the cultivation of potatoes, during the extreme dry season, the heat received by the plants resulted in (1) high water evaporation, and (2) the quality and productivity of potatoes decreased.

4.2. Productivity and quality of tubers in normal weather

The growth of potato plants and their tuber production was mainly determined by the exposure period, sun intensity, ambient temperature, and the duration of vegetative and generative phases [17]. The metabolic process of potato plants had a direct effect on (1) plant growth rate, (2) their health, (3) productivity, and (4) the potato tubers' quality. Their yields were increased by 10-15% using nitrogen fertilizers with unlimited water supply [8].

The effect of the application of LEISA continuously and consistently on potato cultivation in normal or optimum weather conditions, strongly correlated with the productivity and quality of potato tubers. The number of super and A-class potatoes was 25.20 ± 1.1% and 41.70 ± 1.8%, this number is better than the previous research results [9][18]. In normal weather, the metabolic process and the absorption of the nutrients from soil was effective, as indicated by the CEC value of 27.2 ± 0.3 meg/100 g of dry soil.

4.3. Productivity and quality of tubers in hot extreme weather

The increased temperature caused increased transpiration and water demand in the plant. Furthermore, high temperature inhibited carbon acquisition in the plant photosynthesis process and threatened productivity [19]. The nutrient inhibition by plants was supported by the remaining organic matter in the soil after harvesting 38.76 ± 2.6% potato's tubers.

Temperatures above 30°C had various negative effects on potatoes' tubers including, slowing down their initiation and development, lessen their starch assimilation, causing physiological damages, shortening their dormancy, and making them grow early. Therefore, the number and weight of tubers per tree only reached 7.20 ± 1.2 % and 489.53 ± 1.6 g with an average weight per tuber of 67.99 ± 1.7 g, these results are by the research conducted by Kim and Lee [18]. The number of tubers decreased by 41% and their weight per tree also reduced by 60.2%, compared to the cultivation in normal weather.

High temperatures during the growing season caused a series of changes to the crops, which affected their development, leading to a decrease in tubers' production and quality. Furthermore, the high temperature under drought conditions negatively affected the photosynthetic activity in the plant and this effect depended on the stress period in the cultivar [5]. The number of superclass potatoes produced in extremely hot weather was only 1.33 ± 1.7, while in normal weather it was 25.20 ± 1.1%. The decrease in tubers' quality was the effect of the potato plant not being optimal in absorbing nutrients and processing them into food reserves stored in the tubers because the limited soil water content becomes an inhibiting factor [7].
4.4. Productivity and quality of tubers in foggy and rainy weather

The potato plants that were cultivated physiologically in foggy and rainy weather, experienced the stress of cold ambient temperature below 25°C, which resulted in decreased physiological activities. Therefore, plant growth in foggy and rainy weather caused a decrease in plant height by 20.28 ± 2.7% and 24.29 ± 3.2%, while the total biomass reduced by 29.4 ± 2.7% and 33.76 ± 3.2%.

The result of weather changes showed that soil pH from 6.92 ± 0.3 to 6.73 - 6.81 were acidic, therefore, nutrients became more unavailable to plants. Furthermore, potato cultivation in rainy weather caused soil organic matter to be lost or leached by rainwater, therefore the organic matter content in the root zone became 17.16 ± 3.2%. Schulz et al. [17] showed that the number and weight produced by each tree decreased by 53% and 69% when the sun intensity was reduced by 50%. In this study, the weight of potato tubers per tree cultivated in the rainy and foggy seasons decreased by 43% and 18%, while the number of tubers reduced by 29% and 12%. The total biomass, tuber weight, and the number decreased, since the period and intensity of sun exposure decreased by 30-50% and 28-49% respectively [8].

5. Conclusion

The average sunlight intensity received by the potato plant in foggy and rainy weather conditions were decreased to 5.5 ± 0.1 hours/day and 7.8 ± 0.2 hours/day. The soil water content in extremely hot weather did not support the absorption of or organic matter by plants as indicated by the CEC value and the organic matter leached in extremely rainy weather The extremely hot, rainy, and foggy weather decreased potato crop productivity, which was consistent with the BAPPENAS production target of 30 tonnes/ha.

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