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# Effect of slope and year of pruning of tea plants on soil water content in Indonesian tea plantations

Restu Wulansari[a]*, Faris Nur Fauzi Athallah[a] , Aloysius Adya Pramudita[b]

[a] Research Institute for Tea and Cinchona, Department of Soil and Plant Nutrition, Desa Mekarsari Kecamatan Pasirjambu Kabupaten Bandung, 40972, Bandung, West Java, Indonesia

[b] Telkom University, Department of Telecommunication Engineering, Jl. Telekomunikasi. 1, Terusan Buahbatu - Bojongsoang, Telkom University, Sukapura, Kec. Dayeuhkolot, Kabupaten Bandung, 40257, Bandung, West Java, Indonesia

* M. Agr, Restu Wulansari, restuwulan_sari@yahoo.com, ORCID iD: https://orcid.org/0000-0001-6982-1307

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**Abstract**

Global climate change that causes drought requires integrated and sustainable crop management through management of soil water content in tea plantations. In dry season in tropical and subtropical climate conditions, there is a decrease in soil water content between 11–28%. To minimize the decline in production, it can be anticipated by knowing the changes in water content in the soil. The purpose of this research was to determine the effect of slope and year pruning tea plant (YP) on soil water content and shoot production in tea plantations. The research was conducted in November 2020 – April 2021, at Research Institute for Tea and Chincona, West Java, Indonesia. The research design used a factorial randomized block design with 2 factors, factor 1 (year of pruning) and factor 2 (slope). The parameters observed were soil water content and shoot production. The results showed that the factor of slope and year of pruning did not show any significant interactions and differences in soil water content a soil water content found at YP-3 at 40.48% and the highest shoot production at YP-2 of 20.06 kg/plot. The effect year of pruning (YP) is highly correlated and has a strong relationship to soil water content. The results of this study can be used to predict the actual situation the tea leaf growing period, which can improve the management of tea production plantations and also provide a scientific basis for accurate timing of effective fertilization of tea planting, as well as providing technical support for the future of farming technology.

## 1. Introduction

Plants need water for survival such as digestion, photosynthesis, mineral transport, supporting the body growth and transpiration. The growth of crops is influenced by soil conditions and presents in different growth characteristics (Huang et al., 2022). The tea plant is a plant that requires a large amount of water because the tea plant is sensitive to drought, so it is only suitable in areas that have fairly high and evenly distributed rainfall throughout the year. Tea plants in Indonesia which are cultivated on dry land depend on rainwater for their water needs. The minimum amount of rainfall for tea plant growth is 1150–1400 mm/year, evenly distributed throughout the year (Carr, 1972; Eden, 1965). Soil conditions for tea plantation are generally Andisols with soil pH between 4.5 and 5.6 and organic matter content of more than 1% (Effendi et al., 2010; Athallah et al., 2022).

Various factors such as rainfall intensity, duration, slope and cultural practices influence the runoff and soil loss behavior in new tea plantation (Sahoo et al., 2016). Water entering through a process of infiltration into the soil will be retained in the unsaturated zone because the soil holding capacity that holds most of the water to not become saturated so the soil pores are filled with air and water (Chandra, 2012). Each soil has different water moisture according to the physical and chemical properties of the soil and is adapted to the type of plant to be developed, tea plants that grow in areas with relatively high elevations (1300–1500 m above sea level) along with environmental parameters (rainfall amount).

Tea plants require large amounts of water or equivalent to 2000–4000 mm/year of rainfall in order to grow optimally (Santoso et al., 2006). This causes the tea plant to be unable to withstand the long dry season. Therefore, the need for water is highly dependent on rainwater. Rainfall that is less than 60 mm/week causes the nutrients provided to tea plants cannot be completely decomposed so that is slows down growth. If the dry period is more than 2 months, there will be growth disturbances and large production losses due to reduced shoot production. In addition, the loss of water content in the leaves by 30% can result in decreased photosynthetic activity. Even photosynthetic activity will stop if the water loss reaches 60% (Griffiths, 1976). According to Keagel (1965), the water content of tea shoots in the dry season is around 70%, while in the rainy season it is around 83%. Wang et al. (2001) regarded topography as the dominant factor influencing soil property variation due to its influence on runoff, drainage, microclimate, and soil erosion.

Tea production is highly dependent on seasons and the impact of climate change is starting to be felt in tea plantations. Increased rainfall, a fairly dry and long dry season due to seasonal shifts, increased anomalous cycles of the dry season, rainy season, and reduced soil moisture will disrupt the agricultural sector, one of which is the tea plantation sub-sector (Anjarsari et al., 2020). Thus, normally every year tea plantations, especially on Java, always experience a deficit in the groundwater balance during a normal dry season, followed by a decrease in shoot production. This is due to the decreasing value of transpiration with reduced total water available in the root zone (Gregory et al., 2000).

Pruning is carried out on mature tea plants with pruning intervals every four years (Athallah et al., 2022). Pruning is the cutting of branches of a tea bush at predetermined height and at a specified interval in order to reinvigorate and bring tea bushes within reach of the pluckers. Pruning rejuvenates the tea bush and brings it to growth of new pluckable shoots (Ahmad et al., 2014; Kumar et al., 2015). The crop distribution in a year depends also on the pruning cycle and time which, in turn, is decided by the prevailing seasonal conditions. Tea cultivation of tea plant are generally carried out on various slopes. Based on this background, it is necessary to know the soil water content as a precise determination of fertilization time. The purpose of this study was to determine the effect of slope and year of pruning on soil moisture content and shoot production in tea plantations and to see the correlation between slope and year of pruning on soil moisture content. This is also the basis for determining the time of fertilization according to the actual conditions of the tea plant.

## 2. Materials and methods

The research was conducted from November 2020 – April 2021, at the Gambung Experimental Garden, Research Institute for Tea and Chincona, West Java at an altitude of 1,350 m above sea level. Soil order Andisols, the plant used was superior tea plant Clone GMB7, plot area 10 m x 10 m (100 $m^2$) with a total population per plot of about 138 shrubs. The research design used a factorial randomized block design with 2 factors with 3 replications. The treatments were as follows:

The factor of 1 year of pruning (YP), i.e:

1. Year of pruning 1 (YP-1)
2. Year of pruning 2 (YP-2)
3. Year of pruning 3 (YP-3)
4. Year of pruning 4 (YP-4)

The factor 2 (slope), i.e:

1. Flat (0–8%)
2. Sloping (8–15%)

Observational parameters observed in this study are:

a) Soil water content (SWC)

Soil samples were taken using a fertility drill at a depth of 20 cm at each location of the research plot. Soil samples used disturbed soil samples. Sampling of soil moisture content was carried out 2 times in December and February in a composite manner on each research plot. Gravimetric method was used to estimate the soil moisture content at 105°C till the constant weight (Hussain et al., 2003). Soil samples were analyzed at the Laboratory of Soil Fertility and Plant Nutrition, Padjadjaran University.

b) Observation of shoot production (kg/plot).

Shoot production was carried out by weighing the shoots in each treatment plot. Shoot production is carried out every one plucking every month.

c) Observation of the shoot ratio

The ratio of the number of peko shoots to the number of dorman shoots is one indicator of plant health. From the shoot production at each observation, 100 g of shoots were taken randomly, then counted and recorded the number of peko shoots and dorman shoots in each plucked.

### 2.1. Data analysis

An ANOVA analysis was performed to see treatment interactions and a simple Pearson correlation analysis was performed to see the correlation between the slope and the year of pruning of tea plants on the soil moisture content with a 95% confidence level using the software SPSS version 26. Normality of the treatment was tested. The type of ANOVA used is a one-way ANOVA. The type of normally test is the Kolmogorov-Smirnov test and post hoc test with Duncan.

## 3. Results and discussion

### 3.1. Soil water content (SWC)

Based on the results of statistical analysis showed the year of pruning (YP) of tea plants with a slope to soil water content did not show significant differences and interactions between the two factors (Table 1).

Overall, the results of soil water content (SWC) were in the optimal range for tea plant growth, which was a minimum of 30%. Soil water content in the research plot is around 36.28–40.48 %. The highest mean soil water content in the 3rd year self-treatment (YP-3) was 40.48%. According to Hermawan (2004) the measured soil water content described the characteristics of groundwater related to the ability of the soil to hold water in very critical conditions. Groundwater from the lower layers generally moves as an unsaturated flow depending on the soil groundwater potential gradient (Wang et al., 2011). The higher the water content value, the greater the ability of the soil to store water for plants when experiencing drought such as during the dry season.

**Table 1**
Average of soil water content of the year pruning and slope

| Treatment | Soil water content 1 (%) | Soil water content 2 (%) | Average Soil water content (%) |
|---|---|---|---|
| **Year of pruning** | | | |
| Year of pruning 1 | 36.83 | 35.73 | 36.28 a |
| Year of pruning 2 | 40.33 | 36.20 | 38.27 a |
| Year of pruning 3 | 41.80 | 39.17 | 40.48 a |
| Year of pruning 4 | 38.87 | 35.10 | 36.98 a |
| **Slope** | | | |
| Flat (0–8%) | 40.22 | 36.57 | 38.39 a |
| Sloping (8–15%) | 38.70 | 36.53 | 37.62a |

**Note:** Numbers followed by the same letter in the same row and column indicate that the treatment is not significantly different based on Duncan's multiple-distance test with a significance level of 0.05%. The treatments replication is 3 (n=3).

The tea plant is characterized by branching roots that are scattered in the soil. The tea root series shows many branches of different diameters. Tea plants have a significant influence on slope stability due to their lighter weight and protection from wind gusts due to their short stems with small leaves. The problem is how the strengthening of tea roots with the contribution of their branching series on the slope can increase the stability of the soil mass. Roots can reduce soil diffusion pressure from rainwater and reduce the risk of landslides from a hydrological aspect. From a mechanical aspect, tea roots increase the tensile stress and shear stress or soil-root cohesion. Tensile stresses from interactions between roots and soil can contribute to increasing shear strength on slope stability (Udeni et al., 2014).

The tea plant is not drought tolerant. Good rainfall for tea plants should be an average of the last ten years showing a dry month with less than 60 mm of rain, no more than two months and no month where there is no rain at all (Santoso et al., 2006). Chang and Wu (1971) stated that the need for one productive tea plant is equivalent to rainfall of 1.24–2.68 mm/day at an air temperature of 10–28°C. Based on the calculation of the annual water demand for tea plants of 917 mm/year which is equivalent to 917 liters/year or 2.51 liters/day (Chapagain and Hoekstra, 2007). Meanwhile, excessive rainfall can result in nutrient leaching, drifting and erosion. Within reasonable limits, rainwater can mobilize nutrients so that it can increase soil absorption. Sunlight directly affects the process of plant photosynthesis and affects the growth phase of tea plants. According to Wulansari *et al.*, (2015) the need for sunlight and water is equally important in the metabolic process, especially during photosynthesis, so as to be able to produce tea shoots of good quality and quantity.

The relationship pattern of slope slope with soil water content (SWC) shows fluctuations that the sloped slope (8–15%) has a higher mean SWC than on flat (Fig. 1). Pruning year 3 (YP-3) has the highest SWC of around 39% where at this stage the growth of tea plants is most productive in producing shoots and the water required is greater for the needs of tea plants. The water continuously transferred between soil, vegetation and atmosphere by phase change, to keep the dynamic balance in the soil–vegetation–atmosphere system (Wang et al., 2011; Chen et al., 2008).

Tea shoots have different water content in each season, namely in the dry season by 70% and the rainy season by 83%. The amount of water needed is not entirely utilized for shoot

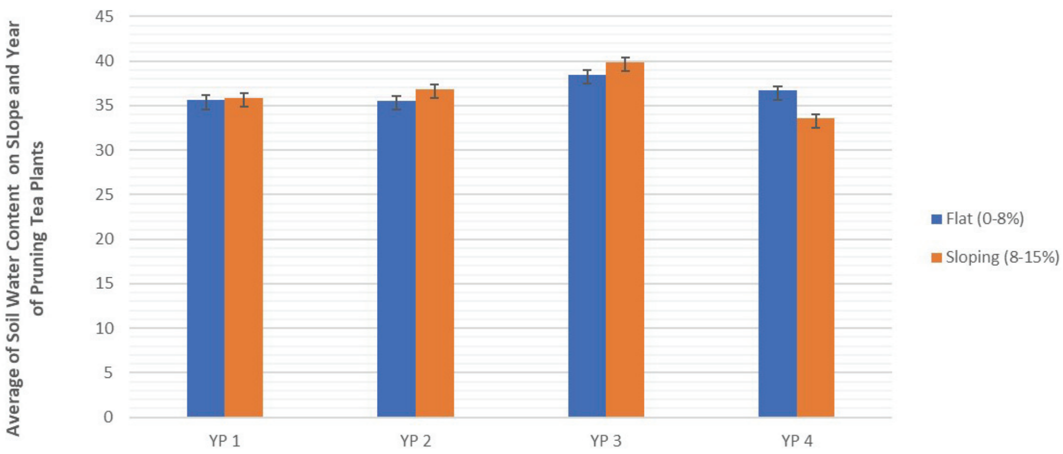


**Fig. 1.** The relationship between the slope and the year of pruning on the soil water content (n=3)

growth, but tea plants require even rainfall to maintain high soil and air humidity, and if in 2 (two) consecutive months the rainfall is less than 50 mm, it can result in reduced shoot production (Eden, 1965). In addition, it is estimated that a productive tea plant with an area of 1 (one) hectare can evaporate water as much as 25,400 liters/day (Eden, 1965). This amount is considered equivalent to rainfall of 930 mm/year, according to Chang and Wu estimates. (1962) that 1 (one) stem of a productive tea plant can consume water equivalent to 1.34–2.66 mm/day at an air temperature of 10–28°C.

### 3.2. Production and Shoot Analysis

Shoot production and plant quality analysis (plucking analysis) with a plucking cycle of 45–60 days from December 2020 to April 2021. The tea pruning cycle is influenced by several factors, including altitude, soil fertility, and plant management, pruning height, and picking system. The higher the place there is tendency for plant productivity to decrease. The results of the statistical analysis of shoot production for 5 times of picking can be seen in Table 2.

Peko shoots are active shoot buds with a pointed shape located at the tip of the shoot. Meanwhile dorman shoots are inactive shoots in the form of a point located at the tip of the shoot. Dorman shoots are often formed when there is insufficient fertilization and water availability. Based on the results of statistical analysis, shoot production and shoot analysis (number of pecco shoots, number of dorman shoots and shoot ratio) did not show significant differences between treatments on all parameters. The highest average production is in the year of pruning 2 (YP-2) and flat (0–8%). This is in according with the condition of YP-2 that in this pruning year the trend of shoot production is highest and will increase to YP-3 and then will decrease at YP-4. Productivity trend was started to decrease after the 3rd year of pruning. This may be due to lower, leaf photosynthesis, leaf water potential, and decreased number of active and increased number of banjhi shoots (Kumar et al., 2015). In addition, decline in crop production occurs at the age of 4-years after pruning, marked by number of accumulative pecco shoots, weight per pecco shoot and length of internode is lower (Dacosta et. al., 2009). Based on research of Battany and Grismer (2000) showed that field slopes within the range of 4–16%, although a statistically significant factor affecting soil losses, had only a minor impact on the amount of soil loss.

In addition to the production of wet shoots, shoot quality is also observed by conducting a plucking analysis which is one of the indicators of plant health. With regard to plants, the state of plant health is a reflection of previous pruning practices, plant nutrition, soil conditions, rainfall distribution, and temperature (TRIT, 2004; Anjarsari, 2021). The observation of the plucking analysis consisted of the number and weight of pecco shoots and dorman shoots. From these data, the ratio of the number of pecco shoots to dorman was calculated, and the percentage of pecco shoots. The comparison value (ratio) of pecco shoots with dorman shoots of tea plants with normal growth is (1.5–2.33), meaning that in every plucking on normal tea plants there are (60–70)% the number of pecco shoots and (40–30)% number of shoots of dorman. From Table 2, it can be seen that all treatments were within the normal criteria for each passage (1.08–3.88). The highest shoot ratio was at YP-1 (3.88) because in year of pruning 1, it was at the stage of forming new shoots after pruning so that the pecco shoots grew more than dorman shoots. According to Sriyadi et al (2009) if the growth of dorman shoots exceeds (40–30)%, it indicates that the plant is experiencing stress caused by nutrients, environment and climate which causes an imbalance in the plant, so that shoot growth experiences dormancy and forms dorman shoots. The ratio of the number of pecco shoots to the number of dorman shoots in each plucking fluctuated.

Based on Figure 2, the average production of shoots (kg/plot) for 5 times plucking show production fluctuations. The highest average production is in February, where this month experiences the highest rain amount compared to other months. The lowest shoot production is in April. The dry season that occurs every year, both normal (<2 months) and long (>3 months), can cause a decrease in production by 40–60% and plant death of 20–40%

**Table 2**
Average shoot production, number of pecco shoots, number of dorman shoots and ratio of shoots to year of pruning and slope

| Treatment | Production (kg/plot) | Pecco Shoot | Dorman Shoot | Shoot Ratio |
|---|---|---|---|---|
| **Year of pruning** | | | | |
| Year of pruning 1 | 16.581 a | 36.269 a | 12.230 a | 3.879 a |
| Year of pruning 2 | 20.052 a | 30.668 a | 23.400 a | 1.689 a |
| Year of pruning 3 | 16.569 a | 34.169 a | 27.230 a | 1.489 a |
| Year of pruning 4 | 16.220 a | 24.868 a | 28.900 a | 1.099 a |
| **Slope** | | | | |
| Flat (0–8%) | 17.869 a | 32.047 a | 22.779 a | 1.969 a |
| Sloping (8–15%) | 16.846 a | 30.930 a | 23.100 a | 2.089 a |

**Note:** Numbers followed by the same letter in the same row and column indicate that the treatment is not significantly different based on Duncan's multiple-distance test with a significance level of 0.05%. The treatments replication is 3 (n=3).

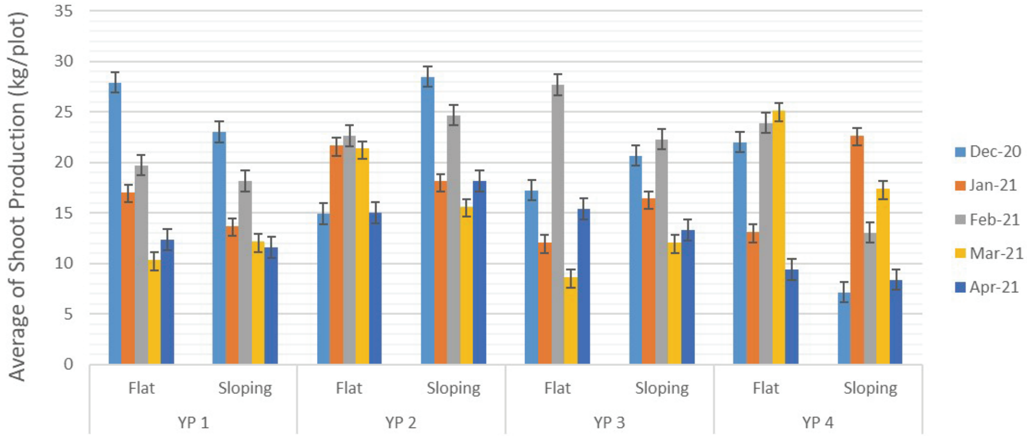


**Fig. 2.** Fluctuations in shoot production for 5 times of plucking (n=3)

in tea plants (Wibowo et al., 1998). This shows that in carrying out its metabolism as a function of production, the need for water as a solvent macro and micronutrients are crucial. During the growth of tea, moderate moisture is especially important for tea growth. Tea will be influenced by too much or too little water (Huang et al., 2022; Zhang et al., 2010).

In addition, important factors that can affect the acceleration of the growth rate of shoots and leaves include climatic conditions, soil, elevation and type of clone (Hajra, 2001). The growth and development of plants are reflected by root growth state, which is mainly concentrated in the development and distribution of roots and physiological characteristics (Wang, 2007; Wang, 2015; Niu, 2017). According to Wudianto (2002), the nutrient that promotes leaf growth, namely nitrogen, is widely available in leaf tissue to support the faster synthesis of carbohydrates into protein and protoplasm, thereby increasing cell size which in turn will result in more leaf growth. One of the causes of the decline in tea production is land degradation due to unfavorable soil conditions, also due to the decrease in the plant (Rachmiati and Salim, 2005).

### 3.3. Correlation Of Slope and Year of Pruning On Soil Water Content

The results of the analysis showed that there was a very significant correlation between the year of pruning and soil water content (Table 3). The effect of the year of pruning has a very significant correlation and has a strong relationship with the yield of soil water content (SWC) both SWC-1 and SWC-2. The age of pruning, tea has been plucked intensively due to its relatively high production potential (Kumar et al., 2015). The parameter of soil water content has a negative correlation with the year of prune, where the higher the YP, the lower the SWC. Likewise, the influence of the slope has a negative correlation but a weak relationship to the SWC value, the more sloping, the SWC will decreased.

Based on the results of research by Banjarnahor et al., (2018), an increase in the slope value will be followed by a decrease in plant height. The contribution of slope value to plant height is 1.8%. Plant height tends to decrease by 0.25 cm for every 1% increase in land slope. Land with a high slope is susceptible to erosion, which is due to poor aggregate stability. Based on research result that there was no significant difference between flat and sloping land on soil nutrients, but there was a correlation between plant nutrients and tea plant nutrient content (Athallah et al., 2021). The results of the study of Murcitro et al. (2005) showed that soils with high stable aggregates will have lower volume weight values with higher porosity and organic carbon values. Therefore, it is natural that an increase in the slope of the land will be followed by a decrease in plant performance. Altitude in the tea plantation effect physiological processes of the tea plants that will affect pruning time of tea plant (Muningsih et al., 2014).

Tea plant is a rainfed crop that requires an even distribution of between 1150–1400 mm per annum. Tea farming is greatly influenced by various environmental conditions among them drought. During drought seasons there is a significant decline in tea production of up to 14–33% and increased mortality of between 6–19% (Maritim et al., 2013; Wijeratne and Fordham, 1996; Cheruiyot et al., 2010). To increase the water holding capacity of the root zone and keep soil water content, several steps can be taken such as mulching, use of organic matter by compost,

**Table 3**
Correlation of slope and year of pruning to soil water content

| Parameter | Slope | Year of Pruning | SWC-2 | SWC-1 |
|---|---|---|---|---|
| Slope | 1 | | | |
| Year of Pruning | 0.00 | 1.00 | | |
| SWC-2 | –0.01 | –.651** | 1.00 | |
| SWC-1 | –0.23 | –.547** | 0.40 | 1 |

** = shows a very significant correlation at = 5%

and shading plants to minimize direct evaporation from the soil surface (Kotze and Joubert, 1992; Hussain et al., 2003). In addition, this can happen because the taproot type of tea plant can penetrate deeper soil layers with relatively broad root branches so that when nutrient leaching occurs at this slope level, nutrients can still be well absorbed (Zuazo and Carmen, 2008).

## 4. Conclusions

The influence of the slope factor with the year of pruning of tea plants did not show any interaction and significant differences in soil water content and shoot production. The average soil water content in the research plot was 38%, with the highest soil water content found in YP-3 at 40.48% and the highest shoot production at YP-2 at 20.06 kg/plot. The tea plant will still be fresh if the total water availability in the soil is more than 30% and the tea plant will die if the water content is less than 15%. The effect of the year of pruning has a very significant correlation and has a strong relationship with the yield of soil water content (SWC). The higher the year of pruning and the more sloping the slope, then the value of the soil water content will decrease.

The results of this study can be used to predict the actual situation during the tea leaf growing period, which can improve the management of tea production plantations and also provide a scientific basis for accurate timing of effective fertilization of tea planting and a decision basis for formulating agricultural policies, as well as providing technical support for the realization of agricultural modernization.

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