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# Determination of Optimal Soil Moisture Depletion Level for Cardamom (*Elletaria cardamomum*)

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**Abstract:** The study was conducted at Tepi National Spices Research Centerto determine optimal soil moisture depletion level for Cardamom (Elettaria cardamomum). Six level of soil moisture depletion level (20, 30, 40, 50, 60 and 100% of total available water of the soil (TAW)) were used as treatments to evaluate the vegetative, yield, and yield component of cardamom arranged in randomized complete block design. Different levels of soil moisture depletion level has significantly ($p<0.05$) affected leaf area, canopy cover, capsule per panicle, fresh and dry yield of capsule. The highest number of leaf area, canopy cover, and capsules per panicle, fresh and dry yield of capsule were obtained when the soil moisture depletion levels were 30% to40% of TAW and refilled to its field capacity level. On the other hand, minimum result was obtained in the ranges of 50% to 100% of TAW. In this study, the soil moisture depletion levels of 40% and 30% of TAW are recommended to cardamom grown in Tepi, South-West Ethiopia. In addition, the yield data is recorded from only one year, validating the finding at farmers circumstances will strengthen the information identified.

**Keywords:** Depletion level, Cardamom, Irrigation

## 1. Introduction

Cardamom (*Elettaria cardamomum*) belongs to the family Zingiberaceae is a perennial spice crop. The crop grows mainly in tropical regions of India, Indonesia, Srilanka, Tanzania, Guatemala, and Latin America, South West Ethiopia. Green cardamom is one of the most expensive spices and stored in its pod in order to keep its flavor. Cardamom is a common ingredient in baking and used as spice in traditional flavoring for coffee and tea. It also used for its cool, minty aroma, and flavor used as flavoring and cooking spice in food and drink(Ohny et.al, 2002). In addition, it has beneficial use for digestion system, promoting clear breathing and respiratory health(Rajagopal and Padamanabham, 1999).

Cultivation of cardamom in Ethiopia has started in 1972 and currently the crop has expanded in tropical humid and forest part of South Western Ethiopia. *Gene* variety of cardamom, released by Tepi National Spices Research Center (TNSRC), has currently being cultivated in Tepi, Bebeka, and Bonga areas. The crop prefers to grow in an altitude of 760 to 1400meters above sea level (masl) and precipitation greater than 1500mm for prolonged months. The temperature ranges of 26 to 32$^0$C and fertile soil conditions are required for better production. The productivity of the crop ranges from 140 to 180 Kilograms per hectare of dry capsule yield. Cardamom's root depth is shallow (0.3 meters) but its height may reach two to four meter. It has herbaceous stem and uniform primary leaves. It produce tiller throughout the year. Once the plant grows, it can stay for 10-15 years on the field with production. It is also known as "Queen of Spices".

In South west Ethiopia cardamom is cultivated with rainfall but climate change is the most limiting factor to gain highest production. The existing rainfall pattern has become erratic and provides unreliable moisture when needed. Ratnam and Korikanthimath (1985) claimed that irregular rainfall pattern with increased degradation of forests can adversely affect cardamom production. Similarly, the dry spell in the growing areas has extended to half of the growing season and the temperature is very high when the crop reaches its moisture sensitive stage. The crop is sensitive to moisture stress due to its false stem and shallow root system. Since cardamom is one of the most expensive crops in the world market, providing sufficient production inputs for proper cultivation will result better economical return. For this reason, supplying irrigation water during critical period has improved yield and water productivity of cardamom (Madan et.al, 2005).

Irrigation will not be beneficial unless the right amount of water supplied to the crop root zone in the soil. In order to apply proper irrigation water to the crop; the soil, crop, and climatic characteristics should be well identified. Among the factor that determine the amount of water to deliver, the allowable soil moisture depletion level for the cardamom crop is not identified like other crops presented in the FAO publications or else.

Irrigation water should be applied to the effective crop root zone, defined as 80 percent of the total water intake takes place (Dastane, 1978), otherwise water will create saturation or water logging problem and leads to percolate excess water beyond the crop root zone. Crop root zone needs identification of allowable soil depletion level to apply water to the effective root zone that can be untaken by the crop roots without exerting excess energy by the plant. It is, therefore, relevant to identify optimum soil moisture depletion level of cardamom for better cardamom production at Tepi area.

## 2. Materials and Methods

### 2.1. Description of the experimental site

A Field experiment was carried out at TNSRC. It is found South West of Ethiopia located at 7.180 N latitude and 35.420 longitudes E. It is 611Km far from Addis Ababa and have an altitude of 1200masl.

The soil texture in the experimental site was deep clay and clay loam. The soil has deep clay loam texture, and 7.3 mm/hr intake rate. The moisture content test at field capacity and permanent wilting point was 37.66% and 26%, respectively. Consequently, the available soil water per unit meter depth was 147.96mm. The area receives mean annual rainfall of 1500mm.As shown in Figure (1),the rainfall concentrates between May to September but during October to April the drying spell occurs in which most crops exposed tohigher moisture demand in order to facilitate their flowering and seed setting processes.

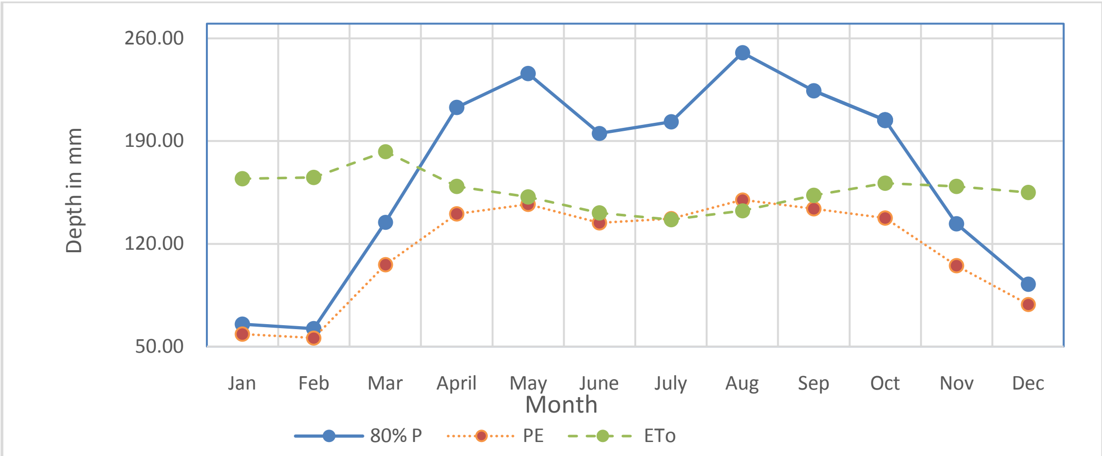



**Figure1.** Water Deficit graph

Note:

- 80%P: is 80 percent probability occurrences of precipitation at Teppi area estimated from long term precipitation data.
- PE: is effective rainfall
- ETo: is reference evapotranspiration.

### 2.2. Experimental design and material used

The field experiment was carried out using randomized complete block design with three replications following the procedure of Gomez and Gomez (1984). The plot size was 3m by 3m and the spacing between block and plots used was 2.5m and 1.5m respectively. Six treatments of soil moisture depletion levels (20, 30, 40, 50, 60 and 100% of TAW) were used.

One year old cardamom, *Gene* Variety, seedling stem raised from the recommended nursery media at the TNSRC was transplanted at the experimental field. All agronomic practices were applied uniformly for all plots. Irrigation water was applied to refill the soil moisture to field capacity level by measuring the designed soil moisture depletion levelsviaTensiometer installed at the required root depth. The soil moisture depletion levels more than 50% of TAW was measured gravimetrically.

**Table 1.** Monthly Reference Evapotranspiration of Teppi, Southwest of Ethiopia

| Month | Jan | Feb | Mar | April | May | June | July | Aug | Sep | Oct | Nov | Dec | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ETo(mm/day)** | 5.3 | 5.9 | 5.9 | 5.3 | 4.9 | 4.7 | 4.4 | 4.6 | 5.1 | 5.2 | 5.3 | 5.0 | **5.1** |

(Source: Muktar and Yigezu, 2016)

### 2.3. Data collection and analysis

**Data collection**

Data representing vegetative, yield and yield components of cardamom plant was collected. Vegetative data includes data on number of tiller, plant height, canopy cover and leaf area. It is known that cardamom crop starts to yield fresh capsule after finishing its vegetative growth for two years. The yield and yield component includes total number of panicle per clump, panicle length, number of capsules per panicle, fresh capsule yield, and dry yield of capsule.

**Data Analysis**

The data collected were analyzed using statistical analysis system (SAS) software using the general linear model (GLM). Mean separation was carried out using F-test at 5% probability level to compare the differences among the treatments mean.

## 3. Result and Discussion

### 3.1. Vegetative parameter

**Number of tiller (NT) and Plantheight (Ph)**

The number of tiller per clump did not show statistical response for different soil moisture depletion levels. An average of seven tillers per clump was grown and the minimum was recorded from 60% of TAW. As shown in Table (2), the mean plant height was 151.2cm and different levels of soil moisture depletion levels did not result statistically variation on the plantheight. The maximum pooled plant height was 169.4cm from 30% TAW but 60% TAW raised a relatively short plant height (136.2cm).

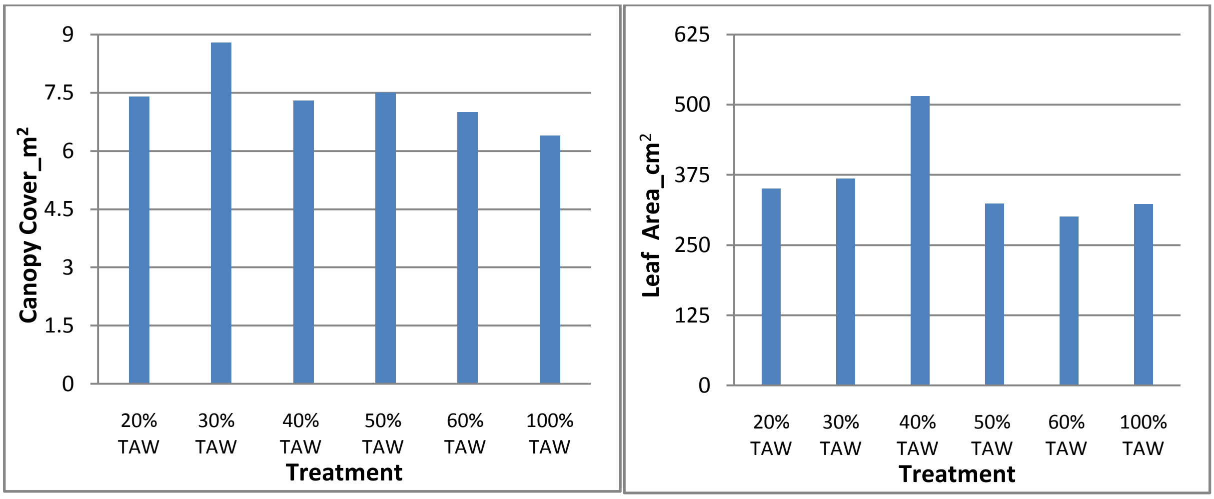
**Leaf area (LA) and Canopy cover (CC)**

There was a significant variation of leaf area due to soil moisture depletion effect as shown in Table (2). The maximum and minimum leaf area was 515.4cm$^2$and 300.4cm$^2$ measured from 40%TAW and 60%TAW respectively. Canopy cover did not have significant variation between treatment means (P=0.05). The smallest canopy cover recorded from100%TAW (6.4m$^2$) was not statistically different with the other soil moisture depletion levels except the treatment that had result the maximum canopy cover (8.6m$^2$). As shown in Figure 2(b), the cardamom leaf area has responded positive where the depletion level increased from 20% to 40%TAW and turns decreased towards 100%TAW which implied that the plant leaf responds negative to withstand the moisture stress developed in the soil.

**Table 2.** Data collected for vegetative parameters

| Treatment | NT | Ph_cm | LA_cm$^2$ | CC_m$^2$ |
|---|---|---|---|---|
| 20% TAW | 7.0 | 152.4 | 350.8b | 7.4 |
| 30% TAW | 8.5 | 169.4 | 368.2b | 8.8 |
| 40% TAW | 7.0 | 147.9 | 515.4a | 7.3 |
| 50% TAW | 7.4 | 151.6 | 323.5b | 7.5 |
| 60% TAW | 5.5 | 136.2 | 300.4b | 7.0 |
| 100% TAW | 7.8 | 149.8 | 323.4b | 6.4 |
| Mean | 7.2 | 151.2 | 363.6b | 7.4 |
| LSD at 5% | NS | NS | 116.1 | NS |
| CV | 46.2 | 13.9 | 26.96 | 21 |

**Note:** *Means followed by the same letters with in same columns are not different p≤ 5%*




a) b)

**Figure2.** Soil moisture Depletion level effect on Canopy cover (a) and Leaf area (b)

### 3.2. Yield and yield component

**Number of panicle per clump (NPC) and Panicle length (PL)**

The mean number of panicle per clump and panicle length was 9.75 and 24.1cm respectively. As shown in Table(3), significant difference was not be seen on both quantity of panicle per clump and panicle length due to soil moisture depletion variation at p≤0.05.

**Number of capsule per panicle (NCP), Fresh capsule yield (FCY), and Dry capsule yield (DCY)**

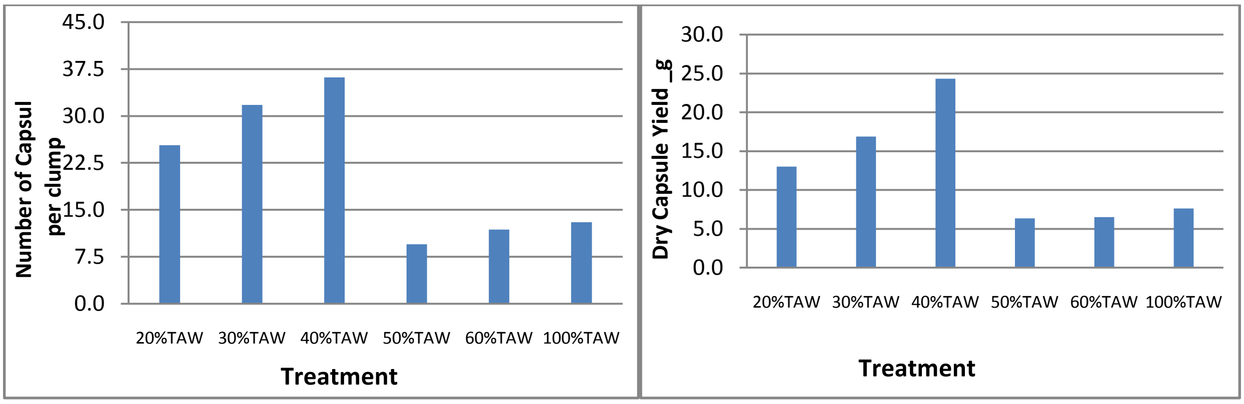
As shown in Table(3), the mean number of capsule per panicle was 21.3 and was affected by the soil moisture depletion variation at p=0.05. NCP was at increasing trend with respect to soil moisture depletion levels but the trend turns down after the peak value attained by 40%TAW (36.2), as shown in figure 3(a). There was no statistical difference between 40%TAW and 30%TAW on NCP. The minimum NCP was attained at 50%TAW (9.5)though there is no statistically difference between 60% of TAW and 100% of TAW.

FCY was highly affected by soil moisture depletion level at p=0.05. The mean FCY was 35.4gram as shown in Table(3). The maximum FCY was gained from 40%TAW though it is statistical similar with 30%TAW. The minimum FCY was gained from both 50% TAW and 100%TAW. There was no statistical variation shown in FCY among 50% TAW, 60% TAW, 100% TAW, and 20%TAW.

The effect of soil moisture depletion levels on DCY was statistically similar with FCY as shown in Table (3). The maximum DCY was 24.33gram (40%TAW) but there was a statistical difference between 40% and 30%TAW unlike to FCY. The reason behind the lesser DCY of 30%TAW will be due to the frequency of irrigation application that might have increased the moisture content of FCY. The minimum and mean DCY was 6.33gram and 12.44gram respectively. The DCY has shown increasing trend with FCY and NCP, as shown in Figure3(b). Hence,40%TAW gave the highest mass of dry capsule yield as a result of more quantity of FCY and NCP.

**Table 3.**Yield and yield component data

| Treatment | NPC | PL(cm) | NCP | FCY(g) | DCY(g) |
|---|---|---|---|---|---|
| 20% TAW (1) | 13.3 | 25.09 | 25.3b | 28.83bc | 13.00bc |
| 30% TAW (2) | 8.5 | 25.63 | 31.8ab | 53.69ab | 16.88b |
| 40% TAW (3) | 16.5 | 34.24 | 36.2a | 74.44a | 24.33a |
| 50% TAW (4) | 7.5 | 22.59 | 9.5c | 18.00c | 6.33c |
| 60% TAW (5) | 5.8 | 18.95 | 11.9c | 19.17c | 6.50c |
| 100% TAW (6) | 6.8 | 18.43 | 13.0c | 18.00c | 7.61c |
| Means | 9.75 | 24.1 | 21.3 | 35.4 | 12.44 |
| LSD at 5% | NS | NS | 10.4 | 32.4 | 7.2 |
| CV | 57 | 36.0 | 26.9 | 50 | 32 |




a) b)

**Figure3.** Soil moisture Depletion level versus NCP (a) and DCY (b)

## 4. Summary and Conclusion

Cardamom crop is high value, economical and cultivated mostly in South-West Ethiopia through rain-fed system. The crop needs sufficient shade, sensitive to moisture stress and favors good soil fertility conditions. Irrigating cardamom will enhance crop production and water productivity. In order to apply proper irrigation water, soil moisture depletion level should be identified. The study aimed to identify best soil moisture depletion level from 20%, 30%, 40%, 50%, 70%, and 100%of TAW. Some vegetative and yield parameters were collected and analyzed using SAS. The study showed that number of tillers, plant height, panicle per clump and panicle length did not show statistical difference. However, Leaf area, canopy cover, capsule per panicle, fresh and dry yield of capsule was significantly improved by the soil moisture depletion levels. Increasing the soil moisture depletion level from 20% to 40%TAW has changed the leaf area, capsule per clump and capsule yield positively. However, the trend has changed inversely when the soil moisture depletion level increased from 40% to 100%TAW for the rest of parameters. There are rare or no research work has done on irrigated cardamom in Ethiopia.

Since cardamom has herbaceous stem and very short rooting system, it will be difficult for the crop to withstand moisture stress condition for up taking deeper soil moisture. Allen et al. (1998) has provided the soil moisture depletion fraction for herbaceous plant ranging from 0.30 to 0.50 of the total available soil water. It indicates that herbaceous plants need frequent application of irrigation water with lesser depth of irrigation due to their shallow root depth. In this study, depletion levels of 40% (0.40) and 30%TAW(0.3) has shown very promising result and it is in line with the recommended given by Allen et al. (1998). The depletion levels ranging 0.3 to 0.4 is relevant to replenish the soil moisture lost in irrigated cardamom production. Since the yield data is recorded from a single year, validating this result at farmers' field will strengthen the information gained.

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