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A Preliminary Study to Estimate Supplementary Water Requirement of Ginger (*Zingiber officinale* L.) under Coconut in Low Country Intermediate Zone (IL_{1a})

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ABSTRACT

Ginger is mainly cultivated in Central, Western and North Western Provinces in Sri Lanka and requires about 1500 mm or more rainfall per *annum* preferably with a short dry season. In Low Country Intermediate Zone in the middle of ginger growing season plants are subjected to water stress due to depletion of soil water storage beyond stress point. This study was conducted to establish the effective root zone depth of ginger in IL_{1a}, to study the dynamic field capacity of the ginger field and to run a decision support model by using rainfall data during ginger growing season. Soil sampling was done from the root sphere of ginger for root measurements. Moisture content was recorded for ginger field and Kuliyapitiya series reference sight. Ginger roots were found to be concentrated in 5-10 cm soil depth within the ginger bed. The effective root zone depth was found as 20 cm. The readily available water storage capacity for ginger was estimated to be 11 mm of soil water for root zone of ginger. Supplementary irrigation requirement would be 720 mm as a height and a farmer can commence irrigation whenever any short dry spell exceed beyond 4 consecutive dry days with application of 12 mm height of irrigation on 5th day and continue until rain to avoid water stress in IL_{1a}.

KEYWORDS: Dynamic field capacity, Effective root zone depth, Ginger, Readily available water.

INTRODUCTION

Ginger (*Zingiber officinale*) is one of the important cash crops grown in Sri Lanka for its underground rhizome which is used as a spice and for its medicinal value. It probably originated in Asia and grows in the humid tropics with at least 1500 mm of rain yearly and a short dry season (William *et al.*, 1980). Ginger is mainly cultivated in Central, Western and North Western Provinces in Sri Lanka (Balasuriya and Kelaniyangoda, 2010). In the year 2008/2009 Maha season, ginger was cultivated in 1890 ha of Sri Lanka and the yield obtained was 10,780 tones (Anon, 2012).

Ginger is grown as an intercrop with coconut and as a home garden crop. The production of ginger can be increased with the application of supplementary irrigation during growing season in the intermediate zone.

Soil water availability refers to retain water available to plants. After heavy rainfall or irrigation, downward water movement is taken place due to the gravity until soil is reached to its field capacity level. In the absence of water supply, the water content in the root zone decreases as a result of water uptake by the crop (Anon, 2013).The purpose of irrigation is to supply water to the soil so as to meet the deficit and return the root zone to field capacity. The amount of irrigation to be applied at any time is based on the deficit from the field capacity of the root zone to be wetted (Sumanasena, 2003).

Yellowing and disease outbreak of ginger plots during the middle of growing season have been reported at the Intercropping and Betel Research Station during recent past and that may be attributed to the occurrence of extreme weather events. Therefore it seems to be necessary to investigate the requirement of supplementary irrigation in the middle of ginger growing season on preliminary step for decision making. The time has come for agricultural modelers to conduct sensitivity experiments on productivity to be done as a measure of climate change adaptation method.

The objectives of this study were to establish effective root zone depth of ginger in IL_{1a}, to study the dynamic field capacity of ginger beds and to run a decision support model using rainfall data during ginger growing season.

MATERIALS AND METHODS

Location

The study was carried out at the Intercropping and Betel Research Station, Dampalassa, Narammala. Laboratory works were carried out at the Department of Plantation Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka during the period from January to April 2013.

Soil Sampling

Soil samples were collected from field of Intercropping and Betel Research Station and famer fields of Kuliyapitiya area. For the current recommended spacing for ginger plant in a bed is 25×25 cm (Ariyathilake *et al.*, 2010). Therefore for soil and root sampling from the root sphere of ginger bush a square was marked at 12.5 cm length for each direction away from base of a ginger bush as representative area for each bush. Soil samples containing roots were taken at 5 depth classes from the marked area through neat excavations of the ginger rhizosphere of the soil. Samples depth intervals were 0-5, 5-10, 10-15, 15-20 and 20-25 cm. Replications were made four times from each location.

Separation of Roots from the Soil

Soil samples were stored for a maximum of 72 hr at 4 ^{0}C until washing to separate the roots from soil. The soil of each samples were thoroughly mixed with approximately two liters of water in a plastic container and drain the container through a 250 µm sieve and root fragments were retained on the seive. Fine root fragments were further separated from adhering silt and sand particles by directing a gentle flow of water through sieve using a wash bottle (Sumanasena, 2003).

Measuring the Root Samples

Samples were collected and stored in ethyl alcohol for root measurements of total root length, total root volume, root dry weight and root mean diameter (Sumanasena, 2003).

Total Root Length

Root samples were separated with the minimum overlap possible, over a regular 1 cm grid Newmans method as discribed by Tennat (1975).

Total root length = $\pi/4$ × number of intersection × grid unit

Total Root Volume

Pycnometer method was used to determine the Total root volume (Sumanasena, 2003).

Root Dry Weight

Each root samples were oven dried at 70 ^{0}C for 24 hr and weighed (Sumanasena, 2003).

Root Mean Diameter

Root mean diameter = [4 × Total root volume/π × Total root length] $^{1/2}$ (Sumanasena, 2003).

Determination of Moisture Content

Soil samples were taken from Kuliyapitiya series reference sight and ginger fields. Soil samples were oven dried at 105 ^{0}C until the dry weight of the samples become constant. Moisture content was calculated by using following equation (Fernandopulle, 2010).

$$\text{Moisture content} = \frac{W1-W2}{W2}$$

Where,

W_1= fresh weight of soil sample

W_2= Oven dry weight of soil sample

Determination of Bulk Density

Bulk density was estimated by using the standard sampling auger with guard ring and 100 cm^3 stainless steel core. Soil samples were oven dried for 72 hr at 105 ^{0}C until the dry weight become constant. Bulk density was calculated by following equation.

Bulk Density = Dry weight of soil sample/Volume of soil core (Fernandopulle, 2010).

Determination of Readily Available Water Content

Readily available water content (RAW) was calculated using the equation suggested by Sumanasena (2003).

RAW = 2/3 × Total available water (TAW)

Total available water is the difference between soil water content at the field capacity and the permanent wilting point.

Determination of Readily Available Water Storage Capacity

The Readily available water storage capacity was estimated by following equation suggested by Sumanasena and Chandana (2005).

$$Wr = (\theta_{fc}-\theta_{sp})\, Zr$$

Where,

Wr = The Readily available water storage capacity of a root zone

θ_{fc} = The volumetric water content at field capacity

θ_{sp} = The volumetric water content in the root zone at stress point

Zr = The effective depth of the root zone

Determination of Irrigation Interval

Irrigation interval was calculated using the equation suggested by Sumanasena *et al.* (2011).

$$\text{Irrigation interval} = \frac{Wr}{E}$$

Where,

Wr = The readily available water storage capacity

E = Daily evaporation

Statistical Analysis

Data were converted into log 10 based values and statistically analyzed using GLM followed by Duncan New Multiple Range Test ($p < 0.05$) using SAS 9.1 software.

RESULTS AND DISSCUSSION

Effective Root Zone Depth

The highest total root length density was observed in depth class of 5-10 cm from the surface. The difference among soil depth classes of 0-5 cm, 5-10 cm and 10-15 cm were not significant for root length density. The root length density dropped by 3 fold from depth class of 10-15 cm to 15-20 cm and it was significantly different ($p<0.05$). Root length density value was further reduced significantly from 15-20 cm to 20-25 cm depth class. Therefore, it can be considered that effective root zone is only up to 20 cm from the surface for ginger under this condition (Figure 1).

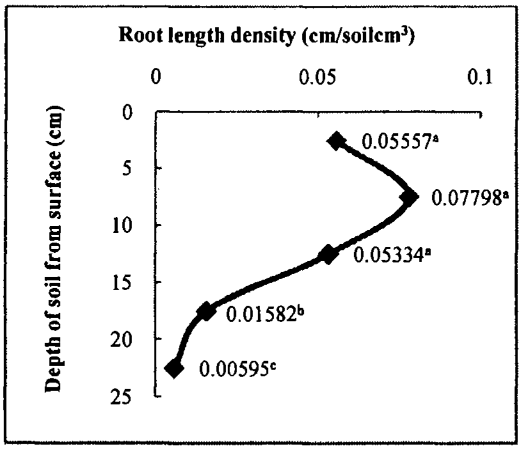

Figure 1. Root length density of ginger bed on depth of soil surface

Means with the same letters represent non-significant differences (p<0.05)

Root Mean Diameter

Results revealed that root mean diameter (RMD) varied from 0.1016 cm to 0.2046 cm and the effect of depth classes were significantly different ($p<0.05$). The maximum RMD was observed at 0-5 cm depth class and it was significantly higher than each RMD of depth class 15-20 cm as well as RMD of 20-25 cm depth class (Table 1). Greater RMD at 0-5 cm depth is an indication of the presence of large roots of ginger near the surface and it seems to be a characteristic of a rhizome bearing crop. According to Jackson *et al.* (1997) fine roots ($\leq$ 0.2 cm diameter) are primary pathway for water and nutrient uptake by the plants.

Table 1. Root Mean Diameter

Depth level (cm)	Root mean diameter (cm)
0-5	0.2046^{a}
5-10	0.1691^{ab}
10-15	0.1674^{ab}
15-20	0.1084^{b}
20-25	0.1016^{b}

Means with same letters represent non- significant differences (p<0.05).

Root Dry Weight

The root dry weight values were not significantly different among depth classes except 20-25 cm depth class for ginger in this study (Table 2). Negligibly smaller root dry weight observation for depth class 20-25 cm affirmed the decision drawn for effective root zone depth as top 20 cm from the surface.

Table 2. Mean root dry weight

Depth level (cm)	Root dry weight (g/soilcm^{3})
0-5	0.00016^{a}
5-10	0.00025^{a}
10-15	0.00018^{a}
15-20	0.000062^{a}
20-25	0.0000047^{b}

Means with same letters represent non- significant differences (p<0.05).

Moisture Content

The soil water content of 0.1904 w/w following natural drainage of soil after 24 mm of rainfall on 24th January 2013 was considered as the near equilibrium dynamic field capacity value for the sight as suggested by Sumanasena *et al.* (2011).

Readily Available Water Content

Soil water content of 0.1904 w/w can be considered as field capacity for ginger bed at Intercropping and Betel Research Station. Moreover soil bulk density of ginger bed was found to be 1.39 gcm^{-3}. This is in agreement with reference value of 1.6 gcm^{-3} in surface soil of Kuliyapitiya series soils (Mapa *et al.* 2005). Readily available water content of ginger field was found to be 56.66 mm/m.

Readily Available Water Storage Capacity

According to Mapa *et al.* (2005) total available water content for Kuliyapitiya series soils is 85mm/m depth of profile. As root zone of ginger is 20 cm, total available water storage capacity would be calculated as 17 mm. Therefore when soil water depleted to first 17 mm (-17 mm) from top 20 cm depth of profile, ginger plant would approach permanent wilting point. If 66.66 % of total available water is equivalent to RAW as described above, then ginger root zone would approach stress point at -11.33 mm depletion.

According to the decision support model suggested by Sumanasena *et al.* (2011) there were 180 stress days and 91 rainy days in the 10 month growing season of ginger from 20th April 2012 to 28th February 2013. The mean daily evaporation for stress days was 4 mm. Therefore, supplementary irrigation would have to be provided for 180 days in which ginger root zone depth was drier than RAW capacity (-11 mm). Supplementary irrigation requirement would be 720 mm as a height. As a practice of supplementary irrigation, a farmer can commence irrigation whenever any short intermittent dry spell exceed beyond 4 consecutive dry days with application of 12 mm height of irrigation on 5th day to avoid water stress. Then continue the supplementary irrigation by application of 12 mm each time at 4 day interval if the dry spells continue further until rain come. The estimated irrigation quantity for one event for 100 square meter ginger plot would be equivalent to 1200 l. Need of this supplementary irrigation indicated that inability to irrigate ginger during intermittent dry spells may course stress related complications and subsequent yield loss.

CONCLUSIONS

Overall observations of ginger root parameters suggested that root zone depth could be considered as 20 cm deep for the purpose of tabulation of supplementary irrigation requirements.

The Readily available water storage capacity for ginger was estimated to be 11 mm of soil water for root zone of 20 cm from the surface. Supplementary irrigation requirement would be 720 mm as a height. A farmer can commence whenever any short dry spell exceed beyond 4 consecutive dry days with application of 12 mm height of irrigation on 5th day and continue the supplementary irrigation by application of 12 mm each time at 4 day interval if the dry spells continue further until rain come to avoid water stress in IL_{1a}.

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