Combined Proceedings IPPS 68:48-52. 2018.

Effect of Soil Moisture on The Yield and Quality of Rhizome In Turmeric (*Curcuma longa*)

Arisa Noguchi, Yuta Ito and Hiroko Nakatsuka
Department of Agriculture, Tokyo University of Agriculture
1737 Funako, Atsugi, Kanagawa 246-0034, Japan

a3noguch@nodai.ac.jp

Keywords: Moisture level, irrigation, rhizome.

Abstract

Turmeric (*Curucuma longa* L.) includes many functional components in the rhizome, and the most important ingredient is curcumin, a yellow pigment, which has anti-oxidant and anti-bacterial properties. Plant growth, rhizome yield and curcumin content change depending on various environmental factors. We examined to evaluate the effects of relative soil moisture on the yield and curcumin content of turmeric rhizome. The average soil moisture of the control plot during the cultivation period was 19.5%. The values in the high and the low moisture plots were 23.4 % and 18.8 % respectively. As a result of measuring at 225days after planting, values of total leaf area and the rhizome growth rate in the high moisture plot were 1.8 times compared with the control plot. Curcumin content per rhizome dry weight was highest in the control plot, though the difference was statistically non-significant. On the other hand, the curcumin content per plant was significantly higher in the high moisture plot, 267.9 mg/plant.

INTRODUCTION

Turmeric (*Curcuma longa* L.) is a perennial herb from the ginger family (Zingiberaceae) cultivated throughout tropical and subtropical Asia. It is using in many countries as spice, dye and indigenous medicine. Turmeric is one of the key ingredients in many Asian dishes, imparting a mustard-like, earthy aroma and pungent, slightly bitter flavor to foods. Turmeric includes many functional components in the rhizome, and the most important ingredient is curcumin, a yellow pigment, which has anti-oxidant and anti-bacterial properties. In Japan, almost all raw materials of indigenous medicines are covered by import from overseas. Thus, studies on the domestic production of indigenous medicinal plants have flourished in recent years. Most of indigenous medicines use underground part of plants. Therefore, technique to increase the underground part with high content of functional ingredients is demanded.

Plant growth, rhizome yield and curcumin content change depending on the soil type, fertilization and light intensity, showed in previous studies (Hossain and Ishimine, 2005; Akamine et al., 2007; Hossain et al., 2009). Besides, irrigation method affects the growth and development of many tuber crops, e.g., potato (Deblonde and Ledent, 2001) and sweet potato (Gomes and Carr, 2001). In this present, we described the effects of relative soil moisture on the rhizome yield and curcumin content in turmeric.

MATERIALS AND METHODS

One seed-rhizome (ca. 30 g fresh weight (FW)) of turmeric was planted in a 30 L plastic pot on April 21, 2017. In this experiment, we set up three experimental treatment plots, such as the control plot (C plot): a mixture of akadama soil (small granule; ca. 3 mm in diameter) and humus (2:1, v/v)), the low soil moisture plot (L plot): a mixture of akadama soil (large granule; ca. 10 mm in diameter) and humus (2:1, v/v)), and the high soil moisture plot (H plot): a mixture of akadama soil (small granule), humus and vermiculite (1:1:1, v/v). For fertilization, Nitrogen, P_2O_5 and K_2O were given in the following substantial amounts at 3, 3, 2.5g per pot (Kobayashi et al., 2010), and after then no fertilizer was applied.

This experiment was carried out in the open field at Tokyo University of Agriculture, Kanagawa, Japan. Irrigation was given only twice after planting for the initial healthy growth of seed rhizomes and not after that. Soil moisture contents were measured it every month. The soil moisture sensor (EC-20, METER Group, Inc., USA) was inserted to the depth of 15 cm from topsoil and the soil moisture values (nominal volumetric water content percentage) displayed on a handheld reader (ECH$_2$O Check, METER Group, Inc., USA).

After planting at 120 and 225 days, measurements of plant height, total leaf area and rhizome FW were carried out. For curcumin analysis, rhizomes were sliced and dried, and then the slices were ground to a fine powder.

Curcumin was extracted from those powders in 80% methanol, all samples were filtered through 0.22 μm membrane filters before the injections. Curcumin content was determined by HPLC. Column (Sinergi Hydro-RP 150×4.6 mm, 4μm, Phenomenex, USA) was run at 40°C with a flow rate of 0.8 mL/min and monitoring at 425 nm. The eluent was used acetonitrile and ultrapure water at the ratio of 1:1. All the data are presented in triplicate. The means values were compared using ANOVA followed by Tukey's multiple range tests at the 5% level.

RESULTS AND DISCUSSION

The changes in the daily mean air temperature and the relative soil moisture content during the experimental period are shown in Figures 1 and 2, respectively. The average air temperature during the experimental period was 21.9 °C. From June to October in 2017, the temperature remained above 20 °C, and in July and August it was mostly over 25 °C (Fig. 1). The mean soil moisture content of the C plot during the cultivation period was 19.5%. The values in the H and L plots were 23.4 % and 18.8 % respectively. In the H plot, the value always showed higher compared with other treatment plots. Table 1 shows the results of the measurements conducted on the 120th day after the planting which is about half of the experimental period. Plant height, rhizome FW and rhizome growth rate were statistically non-significant. The total leaf area in the H plot was significantly larger compared with others.

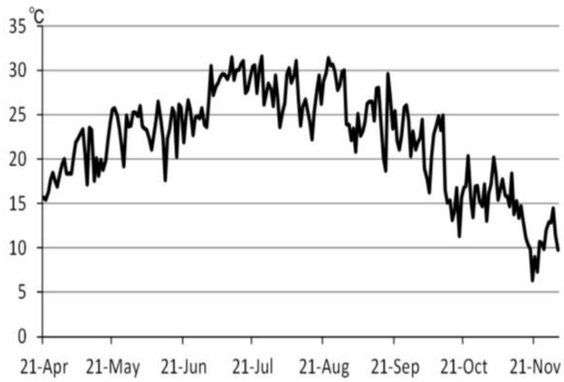

Figure 1. Daily mean of air temperature during the experimental period.

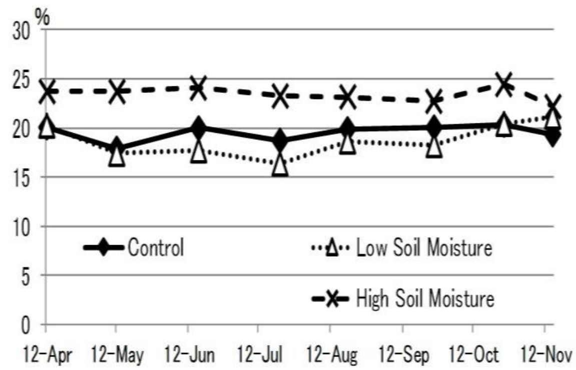

Figure 2. Soil moisture content (%) of each experiment plot during the experimental period.

Table 2 and 3 show the results of the final measurements conducted on the 225th day after the planting. Rhizome growth rate in the H plot was about 1.8 times, and the rhizome FW was doubled compared with the C plot (Table 2). Curcumin content per rhizome dry weigh was highest in the C plot, though the difference was statistically non-significant (Table 3). On the other hand, the content per plant was significantly higher in the H plot, 267.9 mg/plant.

Table 1. Effect of soil moisture content on the growth of turmeric (at 120 days after planting).

Treatment	Plant height (cm)	Total leaf area (m^2/plant)	Rhizome FW (g/plant)	Rhizome growth rate (%)*
Control	78.3	0.14 b	39.6	147.1
Low soil moisture	84.0	0.17 ab	40.6	128.3
High soil moisture	94.7	0.28 a	41.4	128.2

n=3,*The basis of the rhizome fresh weight at planting

Different letters indicate a significant difference at the 5% level by Tukey's test.

Table 2. Effect of soil moisture content on the growth of turmeric (at 225 days after planting).

Treatment	Plant height (cm)	Total leaf area (m^2/plant)	Rhizome FW (g/plant)	Rhizome growth rate (%)*
Control	98.0 b	0.30	305.5 b	1054.4 b
Low soil moisture	108.7 ab	0.33	401.9 b	1219.9 b
High soil moisture	114.3 a	0.53	601.2 a	1854.7 a

n=3 *The basis of the rhizome fresh weight at planting

Different letters indicate a significant difference at the 5% level by Tukey's test.

Root rot and enlargement suppression of underground part showed a tendency to occur in the field which is drainage failure or the high groundwater level. However, high soil moisture was the highest plant height and rhizome yield in this experiment (Table 2). We guess that it is most suitable for photosynthesis in the H plot, though the curcumin content (concentration or accumulation; mg /g DW) in rhizome was not affect by the soil moisture content (Table 3). Gill et al. (1999) showed that application of wheat straw mulch improved growth and yield of turmeric significantly but did not affect curcumin content. In addition, rhizome yield of turmeric increased shading and fertilizer application (Ferreira et al., 2016; Hossain et al., 2009; Akamine et al., 2007), but the curcumin content was almost the same. The differences in curcumin contents were caused by species and strains (Miyazaki et al., 2014). Anandaraj et al. (2014) also reported that the curcumin content was affected by the genetic background rather than environment factors. From these reports, it is thought that it is necessary to combine the soil moisture adjustment with high curcumin accumulation strains to increase the yield of turmeric rhizome and curcumin.

Table 3. Effect of soil moisture content on the content of curcumin in the rhizome (at 225 days after planting).

Treatment	Content(mg)		
	(/g DW)	(/plant)	
Control	3.01	158.2	ab
Low soil moisture	2.43	134.3	b
High soil moisture	2.52	267.9	a

n=3, Different letters indicate a significant difference at the 5% level by Tukey's test.

Literature Cited

Akamine, H., M.A. Hossain, Y. Ishimine, Y. Aniya, K. Yogi, K. Hokama and Y. Iraha. (2007). Effects of Application of N, P and K Alone or in Combination on Growth, Yield and Curcumin Content of Turmeric (*Curcuma longa* L.). Plant Prod. Sci. *10*:151-154. https://doi.org/10.1626/pps.10.151

Anandaraj, M., D. Prasath, K. Kandiannan, T.J. Zachariah, V. Srinivasan, A.K. Jha, B.K. Singh, A.K. Singh, V.P. Pandey, S.P. Singh, N. Shoba, J.C. Jana, K.R. Kumar and K.U. Maheswari. (2014). Genotype by environment interaction effects on yield and curcumin in turmeric (*Curcuma longa* L.). Ind. Crop Prod. 53:358-364. https://doi.org/0.1016/j.indcrop.2014.01.005

Deblonde, P.M.K. and J.F. Ledent. (2001). Effects of moderate drought conditions on green leaf number, stem height, leaf length and tuber yield of potato cultivars. J. Agron. *14*:31-41. https://doi.org/10.1016/S1161-301(00)00081-2

Ferreira, M.I., C.S. Marques, L.G.P. Pereira, U.M. Rodrigues, M. Massimiliano, V. Fabio and M.L. Chau. (2016). Exclusion of solar UV radiation increases the yield of curcuminoid in *Curcuma longa* L. Ind. Crops Prod. *89*:188-194. https://doi.org/10.1016/j.indcrop.2016.05.009

Gill, B.S., R.S. Randhawa, G.S. Randhawa and J. Singh. (1999). Response of turmeric (*Curcuma longa* L.) to nitrogen in relation to application of farmyard manure and straw mulch. J. Spices and Aromatic Crops. *8*:211-214. http://updatepublishing.com/journals/index.php/josac/article/view/296

Gomes, F. and M.K.V. Carr. (2001). Effects of water availability and vine harvesting frequency on the productivity of sweet potato in southern Mozambique. I. Storage root and vine yields. Exp. Agr. *37*:523-537. https://doi.org/10.1017/S0014479702001047

Hossain, M.A., H. Akamine, Y. Ishimine, K. Yamawaki, R. Teruya and Y. Aniya. (2009). Effects of Relative Light Intensity on the Growth, Yield and Curcumin Content of Turmeric (*Curcuma longa* L.) in Okinawa, Japan. Plant Prod. Sci. *12*:29-36. https://doi.org/10.1626/pps.12.29

Hossain, M.A. and Y. Ishimine. (2005). Growth, Yield and Quality of Turmeric (*Curcuma longa* L.) Cultivated on Dark-red Soil, Gray Soil and Red Soil in Okinawa, Japan. Plant Prod. Sci. 8:482-486. https://doi.org/10.1626/pps.8.482

Kobayashi, T., A. Miyazaki, A. matsuzawa, Y. Kuroki, T. Shimazaki, T. Yoshida and Y. Yamamoto. (2010). Change in Curcumin Content of Rhizome in Turmeric and Yellow Zedoary. Jpn. J. crop sci. *79*:10-15. https://doi.org/10.1626/jcs.79.10. (in Japanese)

Miyazaki, A., T. Kobayashi, Y. Aoki, S. Kurita, T. Kashiwagi, Y. Yamamoto and H. Hayakawa. (2014). Effects of Rhizome Yield and Curcumin Content on Curcumin Yield from Curcuma. Trop. Agric. Dev. *58*:163-168. https://doi.org/10.11248/jsta.58.163