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Trial on Supplemental Irrigation Technology during Rainy Season in Semi-Arid Area of Ethiopia

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Abstract: To stabilize and increase crop yield in semi-arid area, where rainfall is insufficient and unreliable even during rainy season, supplemental irrigation is essential. A verification experiment was carried out in the field located in Zway, Oromia Region, Ethiopia to examine the effect of supplemental irrigation on yield of cabbage and tomato. Application of irrigation was decided based on either effective rainfall (5 mm/day) or soil moisture content (25% at 20 cm depth, volume %). Two levels of water amount (5.6, 11.2 mm/day) were applied as supplemental irrigation. The effects of Furrow and Watering Can irrigation were also compared. Cabbage yield was increased by supplemental irrigation, however, no substantial increase was observed in tomato yield. Two levels of water amount for irrigation gave no consistent effect on yield of cabbage and tomato. Decision of irrigation application based on soil moisture content was more effective compared to effective rainfall when water was applied to the cabbage plots with the amount of 5.6 mm/day. Irrigation efficiency in terms of crop yield was relatively higher with Furrow irrigation compared to Watering Can irrigation. This result was consistent with our previous one during dry season that showed Watering Can and drip irrigation were less effective compared to basin and Furrow irrigation if irrigation was not applied frequently. Together with the improvement in water harvesting technologies, such as spate irrigation and farming pond, supplemental irrigation will become a more important technology in semi-arid agriculture.

Key Words: Crop yield, Irrigation efficiency, Soil moisture, Supplemental irrigation, Water use efficiency

1. Introduction

Ethiopia has great agricultural potential based on its vast areas of fertile land, diverse climate, generally adequate rainfall, and large labor pool. Despite this potential, however, Ethiopian agriculture has remained underdeveloped. The agricultural sector suffers from frequent drought and poor cultivation practices. Some of the very precious rainfall in the dry lands is wasted through evaporation and runoff. Insufficient and unreliable rainfall, drought, and low diversification of crops have resulted in natural resources degradation, low production, and low water use efficiency. Improving water use efficiency through the implementation of appropriate technologies may lead to poverty mitigation through the increased crop productivity. Although this can be achieved through different agronomic practices, irrigation development has a great and decisive role to play.

Based on this background, after conducting several development studies, Japan International Cooperation Agency (JICA) conducted "The project for irrigation farming improvement" for three years from September 2005 to September 2008. Its objective was that water utilization technology is improved by the farmers in the project target area, which will make small holder farmers to increase their production using the available moisture in those areas.

To maximize crop yield, irrigation will be applied according to crop water requirement shown by FAO (1998). A verification experiment was carried out during dry season in the field located in Zway, Oromia Region to examine suitable irrigation type and optimum irrigation amount that can be easily applicable by farmers (Inada *et al.*, 2009). However, even during rainy season, rainfall is not sufficient in this area for crop optimum growth. Therefore, supplemental irrigation should be applied to fulfill crop water requirement.

Necessity of irrigation application can be judged by available water such as rainfall pattern and soil moisture content, or crop state such as wilting and stomatal behavior. To examine when and what amount irrigation should apply, a verification experiment was carried out during rainy season in the same field as the previous dry season experiment.

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2. Materials and Methods

Experiment was carried out during rainy season in Zway (N08°01', E38°43', 1622 masl.). Cabbage (Variety: Copenhagen) and tomato (Variety: RomaVF) seedlings were transplanted to the experimental field (Farmer Training Center demonstration field) on 9 and 10 August 2008. Plot size was 3 m × 3 m, and planting density was 40 cm × 60 cm for cabbage and 40 cm × 75 cm for tomato.

Soil type was sandy loam. Ten and twenty g/m^2 of diammonium phosphate was applied to cabbage and tomato, respectively, on the day of transplanting. Twenty g/m^2 of urea was applied on the day of the initiation of irrigation treatment. Weeding was made manually as needed. Fungicide and insecticide were applied once during vegetative stage.

Daily rainfall was recorded manually with a rain gauge installed by the experimental field.

Soil moisture content at 10, 20, 30 cm depth, 10 cm apart from the plant grown center of the plot was measured with soil moisture sensor (Profile probe, PR2/4, Delta-T) during 7 to 9 a.m. every day before irrigation.

The timing to apply irrigation was decided based on the following conditions. 1) Rain-based irrigation treatment: Irrigation was applied every day except the following day of effective rainfall (more than 5 mm/day). 2) Moisture-based irrigation treatment: Irrigation was applied when soil moisture content at 10cm depth was below 25% (volume). Two levels of water amount were applied (50 liter/plot/day and 100 liter/plot/day, equal to 5.6 and 11.2 mm/day, respectively)

To compare the effects of irrigation type on crop growth and yield, irrigation was applied as furrow and watering can. Water was applied to a furrow plot from the bottom of a barrel through a hose. Irrigated water was not so clear with some silt and its pH was around 8.

For yield analysis of cabbage, five average plants were harvested from mid area of each plot on November 9 to determine mean fresh weight. For tomato, the whole products during harvesting period (from 9 to 29 November) were taken from each plot for yield analysis.

There were three replication plots, however, due to the limitation in number of the tubes, soil moisture was measured without replications.

3. Results and Discussion

Rainfall pattern during experiment is shown in **Figure 1**. Days with effective rainfall were observed constantly but with certain intervals until 50 days after transplanting (DAT, late September). After this period, there was a dry spell for one month until 80 DAT (late October). After that, considerable amount of rainfall was concentrated in a short period until harvest (90 DAT for cabbage, 110 DAT for tomato).

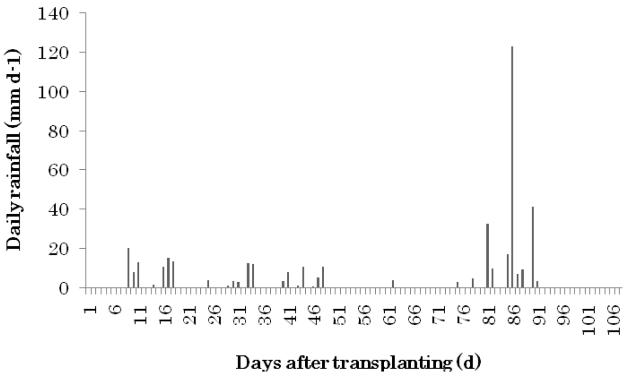

Fig. 1. Pattern of rainfall during experimental period. Transplanting date was 10 August 2008.

Table 1. Number of days with irrigation during experimental period.

Treatment	Cabbage		Tomato	
	Furrow	Watering Can	Furrow	Watering Can
Control	0	0	0	0
R50	65	65	71	71
R100	65	65	71	71
M50	48	31	36	39
M100	22	27	14	13

Table 2. Cabbage yield (kg Fresh Weight/head).

Treatment	Furrow	Watering Can
Control	1.28±0.39	1.08±0.36
R50	1.46±0.25	1.57±0.20
R100	1.72±0.14	1.21±0.21
M50	2.00±0.31	1.57±0.33
M100	1.10±0.47	1.47±0.10

Data are shown as means of three replications±SE.

According to the decision based on rainfall pattern and soil moisture content, number of days with irrigation varied by treatment (**Table 1**). Rain-based irrigation with 100 liter (R100) treatment received the largest irrigation amount during the experimental period, followed by Rain-based irrigation with 50 liter (R50) treatment, Moisture-based irrigation with 50 liter (M50) treatment, and Moisture-based irrigation with 100 liter (M100), in this order.

Cabbage yield tended to increase with supplemental irrigation in both cases applied by furrow and watering can (**Table 2**). Furrow irrigation showed slightly higher yield compared with Watering Can irrigation, which suggests that water use efficiency or irrigation efficiency in terms of crop yield is higher with Furrow irrigation compared to Watering can irrigation. Similar result had been obtained in our previous experiment carried out during dry season (Inada *et al.*, 2009). It was considered that R50 treatment would have brought the highest yield, because our previous results recommended 5 mm/day of irrigation was optimum for yield of cabbage (Inada *et al.*, 2009). However, the highest yield

Table 3. Tomato fruits yield (kg Fresh Weight/m^2).

Treatment	Furrow	Watering Can
Control	0.92±0.13	0.90±0.22
R50	1.08±0.04	0.76±0.14
R100	0.94±0.10	0.74±0.12
M50	0.98±0.14	0.80±0.11
M100	1.07±0.19	0.90±0.30

Data are shown as means of three replications±SE.

was shown by M50 treatment with smaller amount of supplemental irrigation compared with R50 treatment, which suggests the possibility of water saving with monitoring of soil moisture. Yield in M100 treatment with Furrow irrigation was relatively low probably because it received smallest amount of water by irrigation.

Different from cabbage, no substantial yield increase was observed with supplemental irrigation in tomato (**Table 3**). Similar to cabbage, Furrow irrigation showed slightly higher yield compared with Watering Can irrigation.

Soil moisture content at 10 cm depth with cabbage was more affected by rainfall and irrigation than those at 20 cm and at 30 cm depths (**Figs. 2 and 3**). That in control plot at 10 cm depth reflected rainfall pattern, showing a considerable decline during dry spell period and a subsequent increase with rainfall after the period (Figs. 1, 2 and 3). Decision for irrigation application based on the soil moisture content at 10 cm depth was effective to maintain soil moisture content higher in M50 and M100 treatment plots compared to control plot, although M100 treatment plot received irrigation with longer interval and less frequency than M50 plots as is shown in Table 1. R50 and R100 irrigation treatments made soil moisture content higher than M50 and M100 treatments at 10cm depth. It is presumably because of larger amount of water applied more frequently to those treatments (Table 1).

In our previous experiment during dry season, soil moisture contents at 20cm and 30cm depths also declined as crop grew (Inada *et al.*, 2009), however, those in this experiment were maintained almost constant. This difference by season may suggest that optimum irrigation amount during rainy season should be smaller than that during dry season when atmosphere is extremely dry without any rainfall. This fact may explain why R50 treatment that received 5.6 mm/day water constantly during the experimental period did not show the highest yield in cabbage (Table 2).

Trend of soil moisture content with tomato was similar to that with cabbage (data not shown for tomato). However, soil moisture content at 20cm depth with tomato showed a decline during dry spell period, which was not observed with cabbage in this experiment. Maynard (1997) reported that effective rooting depth is deeper in tomato than in cabbage. This may be one of the possible reasons why tomato did not respond to supplemental irrigation.

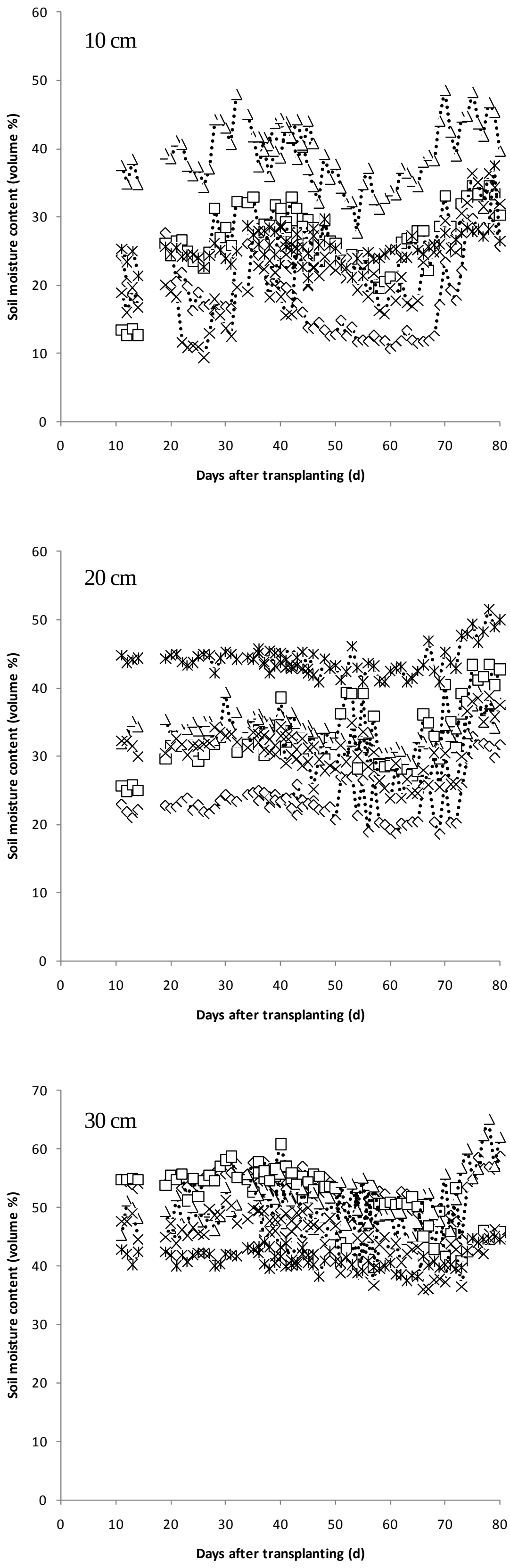

Fig. 2. Change in soil moisture content in Furrow irrigation plot during experimental period. ◇:Control, □:R50, △:R100, ×:M50, ∗:M100.

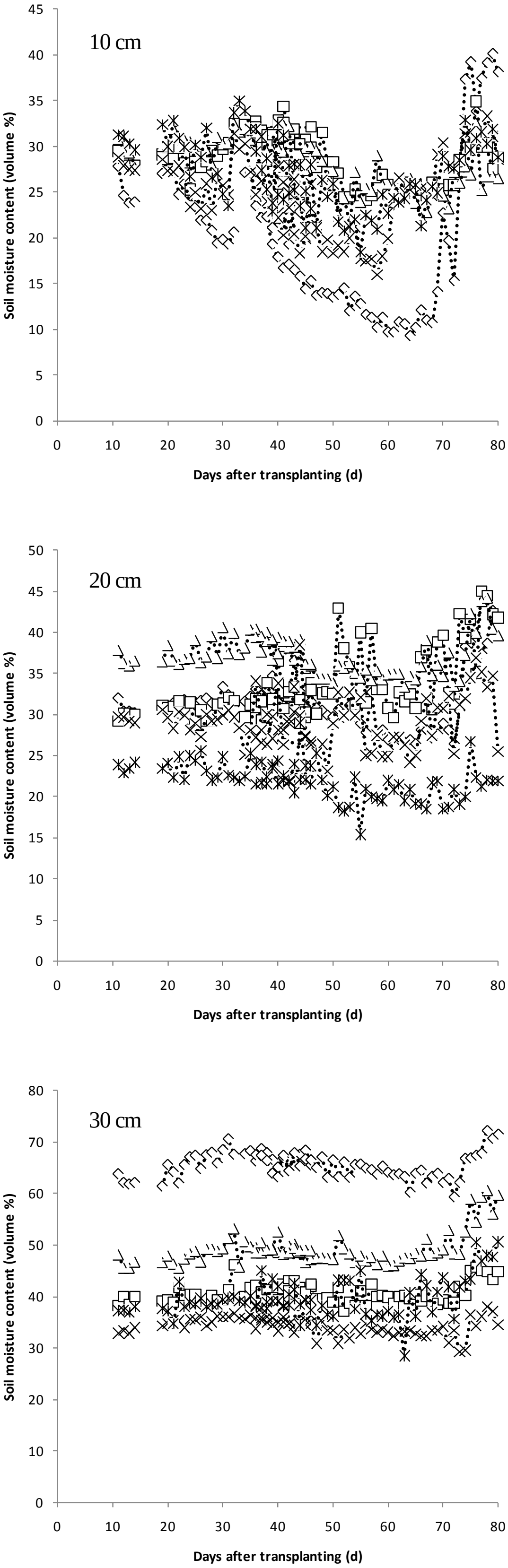

Fig. 3. Change in soil moisture content in Watering Can irrigation plot during experimental period. ◇:Control, □:R50, △:R100, ×:M50, ∗:M100.

This experiment was conducted in the final year of the project, that is, only in one rainy season. Further repeated experiments may be necessary to confirm the obtained results.

4. Conclusion

It is considered that supplemental irrigation is effective to increase cabbage yield during rainy season. Decision made for irrigation by soil moisture content will be more effective and efficient than by rainfall pattern, which will be more water saving technology in semi-arid area of Ethiopia. Simple index for farmers that shows critical soil moisture content should be developed. Therefore, a trial should be done further on farmers' field with their management as a process of extension like Yusuf and Muluken (2008) to make them more confident of its practical applicability.

Without water source, supplemental irrigation will not be applicable. Water harvesting pond that collects runoff from roads or other water ways may be a good source. Besides it, spate irrigation system that utilizes unused floods to irrigate fields will be also a good source in Ethiopia (Geleta *et al.*, 2009, Negussie *et al.*, 2009).

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