Design of Drip Irrigation for Cayenne Pepper

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Abstract. Chili is one of the strategic vegetable commodities both red chili and cayenne pepper that farmers in West Sumatra productivity and quality are relatively low when compared to national productivity. Low productivity of chili is caused by physical factors and biotic factors. Water arrangement is one of the factors that determines the success of plant production because water is a basic need for plants. Chili is a sensitive plant to water shortages and excess because the rooting system is shallow. Thus, a more precise water supply system is required. Designing and using drip irrigation is a way of managing the agriculture of cayenne pepper with the rules of precision farming to increase the productivity. Drip irrigation system has a good way of controlling since the water is flowed until absorbed by plants. In addition, the system will reduce evaporation, and nutrients can be directly fed to plants through irrigation. This system is suitable for having high economic value of plants, so that it could cover the cost of development and management. The designed drip irrigation is expected to serve about 1,000 of cayenne pepper, which can be built and managed by farmers and operate in a simple, easy-to-understand and relatively easy-to-obtain material on the market. The result obtained by the design of drip irrigation at a tower height of 2 m, a tank capacity of 180 liters, two filters (10 microns), an adjusted emitter for water output, a flow of 200 l/hour, with an operating time of 8 hours per day, is estimated to be able to serve around 3,000 to 4,000 cayenne pepper plants on maximum water requirements on the plastic mulch soil. The drip irrigation capacity is also determined by the turbidity level of the water from the source. In limited conditions on an experimental area of 300 m² and relatively flat land, a watering uniformity index of 83% was achieved. The capacity of irrigation services can still be increased by increasing the pressure height, increase the water flow range and increase the number of filters and increase operating hours.

Keywords: Chili; Supply System; Flat Land; Productivity

1. Introduction
Chili is a strategic vegetable commodity, both red chili and cayenne pepper. The national chili productivity for the last 5 years is around 6 t / ha [1]. like several types of cultivated horticultural commodities, many farmers in West Sumatra cultivated chili. This can be seen from the production data in 2003 was 39,731 tones chilies with a productivity of about 5.14 t/ha [2]. The productivity and quality of these vegetables are relatively low when compared to national productivity so that they lack market competitiveness and farmers' profits are not optimal. The low productivity of chili is caused by physical factors and biotic factors. The dominant physical factors affecting plant productivity include soil fertility, temperature, humidity and irradiation. Meanwhile, the dominant biotic factors that affect productivity are variety, purity and vigor of seeds and OPT. The low productivity of West Sumatra vegetables is caused by the use of low-quality seeds, inappropriate fertilization and timing of administration and the high attack of pests and diseases. Increasing productivity can be done through...
improving cultivation techniques (land preparation techniques, irrigation, fertilization and pest control) as well as the use of adaptive superior varieties and high productivity [3]. Increasing productivity through improved cultivation techniques alone requires high costs for input and labor requirements. The irrigation determines the success of plant production, both vegetatively and generatively because water is a basic need for plants. Water requirement increases with increasing soil moisture content, but the highest water use efficiency is at soil moisture content between 55–70% of field capacity. Lack or excess of water in plants will affect their growth and production. Chili plants are sensitive to water deficiency and excess water because of their shallow root system. The water requirement at the beginning of growth is lowest and reaches a maximum at the time of flowering or fertilization, then decreases towards the ripening phase. In the phase of maximum plant growth (flowering or fertilization) a sufficient amount of water is needed. Therefore, it is necessary to know the phases of plant growth, the length of each growth phase and the critical growth phase so that the planning of water supply, both in quantity and timing, is more precise. The water requirement for plants is the same as evapotranspiration [4].

This study aims to design a drip irrigation system in order to obtain optimal water supply to obtain maximum production in cayenne pepper plants. Using of super varieties that are adaptive and high productivity will be able to increase productivity without increasing minimum production costs. The output of the research will provide a way of agricultural management of cayenne pepper with precision farming principles, especially in water management by design of drip irrigation, to increase the productivity.

2. Materials and Methods

2.1 Location and Time of Implementation
The research was carried out in 3 stages:
   a) The design and construction of the tools were carried out in the TTA (Soil and Water Engineering) lab and the Fateta Unand workshop.
   b) Seedlings were planted at the plastic house, Faperta Experimental Garden, Unand
   c) Application / field trials were carried out on dry land covering an area of 300 m²
   d) The study was conducted in June - October 2020

2.2 Implementation Procedure

2.2.1 Tool Design Method
Design of drip irrigation, it must be defined for the function of the tool is and to achieve the intended function what is the structure of the tool.

2.2.1.1 Functional Design
   a) The purpose of the function of the tool is to drop water into the root area of the cayenne pepper plant which is measured and dynamic (as needed), the flow rate is slow (droplets) so that it does not interfere with the soil texture around the roots [5].
   b) The drip irrigation capacity is expected to serve around 1000 cayenne pepper plants, which can be built and managed by farmer.
   c) Drip irrigation design it is also necessary to consider: can operate in a simple, easy to understand and manageable manner by farmers with various limitations of tools and field conditions.

2.2.1.2 Structural Design
   a) The form of the design is designed to be as simple as possible while still prioritizing the function of the tool according to the purpose of the study and not taking up a large area.
   b) The capacity is in accordance with the functional design for 1000 cayenne pepper plants.
   c) The power source used is expected to be as minimal as possible but the continues to function according to its designed capacity.
   d) The materials must be relatively easy to find in the market

2.2.1.3. Economical Design
Drip Irrigation Costs must be feasible from an economic calculation point of view. Because the ultimate goal of applying technology within the framework of Precission Farming is the most profitable for farmers.

2.2.2 Design tools
Based on the functional design, structural design and economic design, tools are built according to the predetermined criteria according to the design above.

2.2.3. Tools and Materials Required

2.2.3.1 Tool
- Soil cultivating tools such as plows and hoes,
- Tape meters to measure land area, pipe cutting tools, wood etc.
- Iron meter to measure into the tillage layer,
- Scale capacity of 100 kg to weigh fertilizer,
- Hoes and shovels,
- Sparyer,
- Water pump.

2.2.3.2 Material
- Angle iron for water tower,
- 180 l tank (used drum),
- 1 inch Paralon pipe,
- Water filter,
- 1/2 inch paralon pipe,
- Faucet stop,
- Lateral pipe / hose,
- Emitter,
- Manure (chicken),
- Poly bag for seeds,
- Seed of cayenne pepper.
- Inorganic fertilizers: Urea, TSP,
- Power cables for connection of electricity from the source to the pump,
- Plastic mulch,
- Wood for plant stakes.

2.2.4. Test tools
After designed in the laboratory and workshop, the drip irrigation is ready to be installed in the field and tested. During the trial, the field observation parameters that need to be observed are:
- The capacity. Drip irrigation built must be able to meet optimal water requirements during the chilli planting period.
- Drip irrigation efficiency: water delivery efficiency
- Watering uniformity. It is important to know that the amount of water given is in accordance with the needs of the plants.
- Based on the testing of drip irrigation carried out, improvements were made so that the drip irrigation can be used according to design objectives.
- Observation of performance (plant performance) in the field.

2.2.4. Cost analysis

3. Results and Discussion

3.1 Functional Design

3.1.1 Irrigation water requirements
The water requirement for chillies in the peak period with drip irrigation can be calculated:

\[
\text{Ir.} = (\text{Etc} + \text{P} - \text{Re}) \times \text{Eff. Irrigation}
\]

(1)
\[
\text{ETc} = \text{ETo} \times \text{Kc}
\]

(2)
\[
\text{ETo} = \text{E} \times \text{Kp}
\]

(3)

where, Ir is Irrigation Requirements, ETc is Evapotranspiration, ETo is Evapotranspiration of reference plants, E is daily evaporation, Kp = pan coefficient of class A (0.8), Kc is crop coefficient, Re is Effective Rainfall and Eff = Irrigation efficiency (assume 90%). For the area of West Sumatra the E value is around 5 - 7 mm / day (average 6 mm / day), Kp 0.8, Kc max for chilli 0.45, percolation (P) is assumed to be 0 because watering is on slow flowing and effective rainfall (Re) to be 0 (because the
Irrigation efficiency is around 95%, then:

\[ \text{Ir.} = \frac{(6 \times 0.8) \times 0.45}{0.95} = 2.05 \text{ mm / day.} \]

Because the land uses plastic mulch, the evaporation from the soil is close to 0, so the water needs are only for transpiration. Thus, the water demand is estimated to be only 50% of the irrigation water requirement or 0.5 x 2.05 mm / day = 1.02 mm / day. Irrigation water requirement for 1 hectare of land = 1.02 mm / day x 10,000 m \(^2\) = 10.2 m \(^2\) / day. With a spacing of 1 m x 0.4 m chilies, the population of chilies in 1 hectare is 10,000 m \(^2\) / (0.4 x 1 m) = 25,000 chilies.

Water requirement at peak period for a chili stem per day = 10.2 m \(^2\) / 3: 25,000 stems = 408 ml/stem/day. Thus, the drip irrigation is designed to function to drain irrigation water of 408 ml/day with drops.

### 3.1.2 Drop Test

The result of the drop test shows that the water dropping in the drip tube with a diameter of 3 mm is obtained 300 drops = 17 ml, so for 408 ml is needed: (408 ml / 17 ml) x 300 drops = 7,200 drops.

### 3.2 Design of Drip Irrigation

Based on the functional design, structural design and economic design, Drip irrigation is built according to the predetermined criteria. Several factors considered for build-up Drip Irrigation are:

1. The drip irrigation device for irrigation water for about 1,000 chilies, at peak times it requires 1,000 x 408 ml water/day = 408,000 ml/day or 408 l/day, which is flowed at low pressure.
2. Flow time <8 hours (normal working hours).
3. The materials and tools used are readily available, affordable and relatively easy to mobilize. Based on some of the criteria above, a drip irrigation device was built with a water tank capacity of 180 l, (used a drum available in the market), 2 m tower height (pressure is not too high), filters that are easy to obtain and easy to operate, emitter (drip) from emitter for infusion (easy and cheap) which is easy to regulate drip and a water pump with the same capacity as the water flow capacity of the drip irrigation device. The drip irrigation operation time can be adjusted by calculating the dropping intensity. Thus, it can be calculated the length of operation of the tool and the number of plants that can be watered. From the water drainage test using 2 10 \( \mu \) -sized filters and the use of a 125watt DAAP water pump, the drip irrigation capacity was 212 l/ hour.

### Table 1. Comparison of equipment working hours, irrigation intensity and number of plants that can be served by drip irrigation (with the input capacity of water to the tank is regulated)

| Working time (hours) | Irrigation intensity (1 drop/s) | Number of plants (stem) | Estimated need for planting land (m \(^2\)) at a spacing of 1 m x 0.4 m |
|----------------------|-------------------------------|-------------------------|---------------------------------|
| 2                    | 424 l/2 hours                 | 1.039                   | 450 - 500                       |
| 4                    | 848 l/4 hours                 | 2.078                   | 900 - 1,000                     |
| 6                    | 1,272 l/6 hours               | 3.118                   | 1,350 - 1,500                   |
| 8                    | 1,696 l/8 hours               | 4.157                   | 1,800 - 2,000                   |

Note: It also need area for drain and farm road

In limited land conditions with a few plants, the intensity of watering can be reduced. In conditions of large areas with more plants, the intensity of watering can be increased by adjusting the emitter and by increasing the pump capacity and filtering capacity.

### 3.3 Test Performance

From testing the drip irrigation in the area of 300 m \(^2\), it was found that the drip irrigation capacity for watering with an intensity of 1 drop / second for 535 chilies takes about 64 minutes, or if it is converted into 2 hours for 1,000 chilies. The average watering time, different time between the nearest and farthest points is 35 seconds. The distance of the farthest point from the opening valve is 28.5 meters and the closest point distance from the opening valve is 2.5 m. The efficiency of delivering water for irrigation
is estimated to be close to 99% because there is no visible water leakage during operation. Watering uniformity test obtained an average uniformity of 83%. This uniformity value is quite good [6]. This uniformity can be obtained because the emitter discharge regulation is easier can be locked to the desired flow rate and the effect of the pressure due to the distance and proximity of the emitter from the pressure source can be reduced. In addition, the high pressure of the water tank with a tank capacity of 180 liters and a 2 meters water tank is not too height.

**Figure 1. Drip Irrigation as Designed**

**Figure 2. Lateral Pipe, Drip/Tricle and Hose**
3.4 Cost Analysis

3.4.1 Fixed cost

3.4.1.1 Investment Cost
Drip irrigation for a capacity of 1,000 cayenne pepper, an investment cost is required for a). Tower and water tank Rp. 2,000,000, b). Pipes and networks, hoses and drips Rp. 2,500,000, c). Water Pump (DAAP 125 watts) Rp. 300,000. It is assumed that the useful life of the drip irrigation is 10 years with a final value of 25%. Depreciation cost for equipment for 2 years (cayenne pepper planting cycle period), is \( \frac{\text{IDR} \ 4,800,000 - (0.25 \times \text{IDR} \ 4,800,000)}{2} = \text{IDR} \ 720,000/2 \text{ years} \).

3.4.1.2 Maintenance Cost
Maintenance cost needed to repair leaks and connection systems, filter replacement, replacement of damaged drips and materials due to moving and unloading the drip irrigation. During operation, maintenance cost estimated at 10% per year for 10 years of operation (life time) of the drip irrigation [7] is \( 2 \times 0.10 \times \text{IDR} \ 4,800,000 = \text{IDR} \ 960,000/2 \text{ years} \).

3.4.2 Variable Cost
Variable costs is the operating costs of drip irrigation during operation, especially electricity costs for pump during the plant period. For pump electricity (125 watts), electricity costs per month: 0.125 x 2 hours / day x 30 days / month = 7.5 KWH / month. Pump operation in crop cycle is 22 months (2 months for land preparation and nursery). The electricity requirement for one crop cycle is 22 months x 7.5 KWH / month = 165 KWH. The PLN electricity price for 1300 KWH capacity is IDR 100,000 / 100 KWH or IDR 1,000 / KWH. Thus, the electricity cost for operation during one crop cycle is IDR 1,000 / KWH x 165 KWH = IDR 165,000. Labor costs are assumed to have been calculated in equipment and maintenance costs because in operation, labor is needed to turn on and off drip irrigation.

3.4.3 Drip Irrigation Costs
Based on the calculations above, total cost of drip irrigation for a cycle of cayenne pepper is: IDR 720,000 + IDR 960,000 + IDR 165,000 = IDR 1,845,000. Drip irrigation cost for a cayenne pepper is IDR 1,845 / stem. Drip irrigation costs can be reduced for a larger business scale:

Figure 3. Drip Irrigation and Planting Area
Table 2. Comparison of drip Irrigation Costs for Cayenne Pepper According to Business Scale

| Irrigation scale (stem) | Investation (Rp) | Fixed Cost (Rp) | Variable cost (Rp) | Total cost (Rp) | Drip Irrigation Cost (Rp/stem) |
|------------------------|------------------|----------------|-------------------|----------------|-------------------------------|
|                        | Tower and Pump   | Pipes and Networks | Depreciation | Maintenance |                       |                               |
| 1.000                  | 2,300,000        | 2,500,000       | 720,000          | 960,000       | 165,000                       | 1,845                         |
| 2.000                  | 2,300,000        | 5,000,000       | 1,095,000        | 1,460,000     | 330,000                       | 2,885                         |
| 3.000                  | 2,300,000        | 7,500,000       | 1,470,000        | 1,960,000     | 495,000                       | 3,925                         |
| 4.000                  | 2,300,000        | 10,000,000      | 1,865,000        | 2,460,000     | 660,000                       | 4,965                         |

The increasing in business scale from 1,000 chilies with 2 hours of drip irrigation operating time to 2,000, 3,000 and 4,000 chilies with 4 hours, 6 hours and 8 hours of drip irrigation operation, showed a significant reduction of drip irrigation costs from IDR 1845 / stem to IDR 1,442 / stem, Rp.1,308 / stem and Rp.1,241 / stem or a decrease in drip irrigation costs by 22%, 29% and 33%.

4. Conclusions

Technically, drip irrigation is suitable for cayenne pepper because the technology is simple, easy to assemble, the building materials are available in the market and easy to operate and maintain. The performance of the drip irrigation is quite convincing with a uniformity index reaching 83% on relatively flat land. For further development, this drip irrigation technology can be developed by using a water content level sensor in the soil connected to an on-off valve to start or end watering. With the capacity of the drip irrigation designed, minimal costs are obtained for the use of 3000 and 4,000 chilies, IDR 1,308 and IDR 1,241 per stem in an area of 1,500 m² and 2,000 m² with a spacing of 1 m x 0.4 m. This drip irrigation design device can also be used for other types of plants with operational adjustments of the drip irrigation which is estimated to have almost the same character as cayenne pepper.

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