IMPROVING IRRIGATION SYSTEM: PLASTIC BOTTLE DRIP IRRIGATION

EXPERIMENTATION RESULTS

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KOPERNIK

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SUMMARY

Agricultural potential in East Nusa Tenggara is limited by low rainfall and a lack of irrigation systems, where irrigated land makes up only 5 percent of total agricultural land[1]. The majority of farmers in Flores therefore find it difficult to grow crops during the long eight-month dry season and instead take seasonal jobs to support their livelihoods.

We built a simple drip irrigation system using recycled plastic bottles, to explore whether this solution can help farmers to produce food in the dry season where previously they did not grow anything at all. Additionally, we hoped that the associated costs to grow food will be cheaper than what would have been spent on purchasing food at the market.
In this experiment we tested 30 plastic bottle drip irrigation units to grow three different crops (corn, peanuts and chilies) in Maumere, Sikka, East Nusa Tenggara. We set up a control group where we planted similar crops and watered those crops manually with a watering can (manual method).

We measured the following indicators:

- the survival rate of the plants;
- their yield;
- the volume of water used for irrigation; and
- the average cost of production using the plastic bottle drip irrigation system.

The experiment proved that the plastic bottle drip irrigation system could be used to grow peanuts during the dry season, but the results with corn and chilies were inconclusive. Results from the drip method for peanuts showed a 90 percent survival rate with an average yield of 18g per plant.

In addition, we also compared the cost of growing crops using the plastic bottle drip irrigation versus purchasing the same product in the market. We found that growing peanuts using the plastic bottle drip irrigation system was 21 times more expensive than buying the same amount of peanuts from the market. Even with a higher yield per plant such as corn where the cost of the irrigation system is minimal, this still remains the case.

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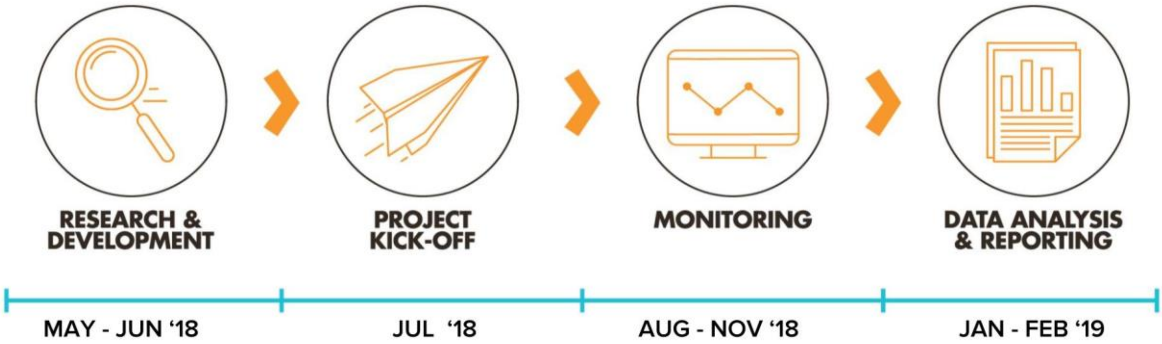
[1] "Saatnya NTT berpaling dari pertanian lahan kering". Chief of agriculture department (NTT). 2014

TIMELINE



CONTEXT

East Nusa Tenggara is an arid region in Indonesia with a four-month rainy season and an average rainfall of 1,500 - 3,000 mm/year. Land with proper irrigation systems accounts for only 5 percent of the total 2.3 million hectares of agricultural land[2]. Consequently, the majority of farmers in this region have difficulty growing enough food for their daily needs during the long eight-month dry season.

Farmer households in Flores depend on subsistence farming. During the rainy season, they cultivate their land to plant staple crops such as corn and rice, using rainwater as the main source of irrigation. During the dry season, the same plot of land becomes idle land and they switch to other income generation activities, to earn money to buy food.

Researchers have studied the use of advanced drip irrigation technology for agricultural practices in arid and semi-arid regions in countries such as Morocco and India[3] [4]. Findings have shown that these systems are quite complex, requiring continuous technical support and major capital investment, a major challenge for farmers in remote locations.

To combat this, Kopernik tested a different approach using a simple irrigation system made from used plastic bottles, a "do-it-yourself" or "DIY" system that is more affordable and accessible. This system was based on the same principles of other drip irrigation technologies, allowing water to drip slowly onto the roots of plants, minimizing evaporation and reducing the amount of water needed for irrigation.

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[2] "Saatnya NTT berpaling dari pertanian lahan kering". Chief of agriculture department (NTT). 2014
[3] "Water saving in arid regions- comparisons of innovative techniques". International Journal of Environmental and Ecological. 2014.
[4] Management of micro irrigation system in arid areas of India. International Journal of Applied Engineering Research. 2015

HYPOTHESIS

We hypothesized that if farmers use the plastic bottle drip irrigation system, they can produce food during the dry season during which previously they didn't grow anything at all. Additionally, we also calculated the average cost of production using the plastic bottle drip irrigation system to determine if it is a viable product for low-resource farmers.

METHODOLOGY

The plastic bottle drip irrigation system is built using a 1.5liter plastic bottle that is connected with a hose and flow regulator, repurposed from an intravenous (IV) set. We built 30 units and tested those in three experimental plots in Maumere, Sikka, East Nusa Tenggara. One plot consisted of ten plastic bottle units watering one plant each, and for the control group, ten similar plants being watered by hand using a watering can (manual method). The manual method described here is not actually carried out by the farmers in practice as they usually don't grow anything at all during the dry season. Its purpose was to act as a control group to obtain comparison data on the amount of water used for alternative irrigation practices.

Three different crops were selected for each plot fulfilling the following criteria:

1. Corn, because it is familiar to farmers and what they are used to growing and eating;
2. Sorghum, because it is suited to rocky, sandy soil conditions (however this was later replaced with chilies as the sorghum seeds did not germinate); and.
3. Peanuts, because they are known as a drought resistant crop.

The experiment setup is illustrated in Figure 1 below. The drip rate from the plastic bottle drip irrigation system was set to be every two to four seconds, and the total amount of water used was calculated at the end of the experiment. The amount of water given using the manual method was 0.5 liters per plant per day.

Figure 1. Experiment setup with plastic bottle drip irrigation system in Maumere, Sikka, East Nusa Tenggara.

During a three-month period in the dry season (July-October), we recorded the following data:

- the survival rate of the plants;
- their yield;
- the volume of water used for irrigation; and
- the average cost of production using the drip irrigation system.

FINDINGS

SURVIVAL RATE, YIELD, AND WATER USAGE

While we succeeded in obtaining results from the peanut and the corn test groups, the sorghum group did not grow at all under both treatments (plastic bottle drip irrigation and manual watering method). In week 5 we replaced the sorghum with chili but only two chili plants grew and subsequently died. We suspect that this particular plot might not have been fertile enough to grow any plants.

The corn group did not survive either and dried out in week 11, resulting in a 0% survival rate for both drip and the manual watering methods. From our investigation, we believe that week 11 was the beginning of the pollination process, where a corn plant is sensitive to heat stress. A research study stated that the water requirement for corn during that particular stage (week 10-12) is seven times higher than the initial vegetative stage[5]. Thus the amount of water given by the plastic bottle drip irrigation system and the manual method were most likely not enough to support the corn's development during the pollination stage.

Detailed figures for survival rates, water usage and plant yields from the experiment are summarized in table 1 below.

Indicator Measurement	**CORN**		**PEANUT**		**CHILI**	
	Drip	Manual	Drip	Manual	Drip	Manual
Plant Survival Rate	**0%**	**0%**	**90%**	**100%**	N/A	N/A
Water Usage (Liter/plant)	**12L** (72 planting days	**36L** (72 planting days	**18L** (98 planting days)	**49L** (98 planting days)	N/A	N/A
Average Yields (grams/plant)	N/A	N/A	**18g** (with skin)	**25g** (with skin)	N/A	N/A

Table 1. Survival rate, water usage and yields from three different plants

For peanuts, the total amount of water used for irrigation with the drip method was 63 percent less than with the manual method (18L versus 49L). The drip method recorded nine surviving plants out of ten, while all ten plants survived with the manual method. The yield from the drip method was 28 percent lower than the manual method (18g versus 25g per plant). In addition, the plant's growth rate plotted in Figure 2 shows that the plastic bottle drip irrigation method resulted in shorter plants as compared to the manual method (17cm versus 19cm). These results suggested that the drip rate

[5] Irrigation Management for Corn. University of Nebraska-Lincoln. Accessed on March 2019.

applied was too low and by increasing the water provision rate in the drip system (while still keeping it lower than the manual method), we may be able to achieve similar yields to the manual method while still using less water.

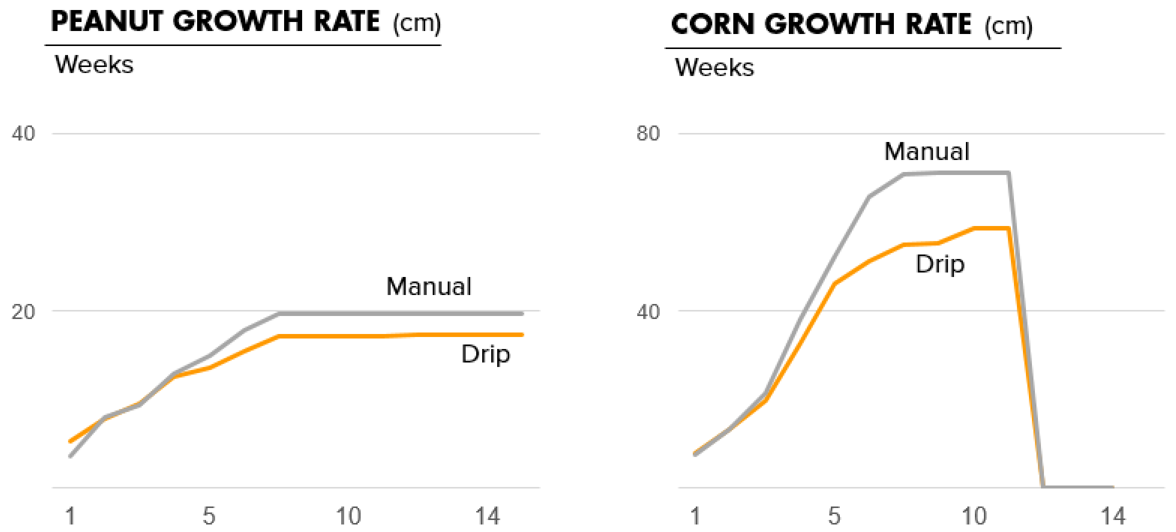

Figure 2. Plant growth rate with the plastic bottle drip irrigation method versus the manual method

PRODUCTION COST

We calculated the cost of growing one kilogram of peanuts with the plastic bottle drip irrigation method. Based on our findings, to grow one kilogram of peanuts using the plastic bottle drip irrigation method requires 56 plants (1000g divided by an 18g yield per plant). The amount of water required for the entire harvest season would be 18 liters per plant. We also assumed that labor cost is free since the farmer usually did not pay himself to water his crops. The breakdown of production cost for peanut is then summarized in table 2 below.

Cost Item	Cost description	Cost per plant	Cost to grow one kilogram of peanut
Technology (plastic bottle drip irrigation)	Materials, consist of: ● Recycled plastic bottle (free) ● IV set (US$0.35 per unit, amortized over five times harvest seasons) ● Tape and sealant (US$2.73, spread over to make around 30 units) Labour time Time required to create one unit plastic bottle drip irrigation is 10 minutes, which is equal to labour cost IDR1,441	US$0.26	US$14.70
Water	Water is purchased from the water truck service, with the cost of IDR50 per liter	US$0.06	US$3.86
	Total		**US$18.24**

Table 2. The cost to grow one kilogram of peanut with plastic bottle drip irrigation

We used a similar approach to calculate the production cost for corn, even though we did not succeed in obtaining viable results from the experiment. We made an assumption that if we were to increase the drip's water provision rate to two third of the corn's water requirement, estimated by the University Nebraska-Lincoln[6], we will able to produce two corn cobs per plant, each weighing around 300 grams. Therefore, we would only need two units of plastic bottle drip irrigation in order to produce one kilogram of corn and the overall cost of the technology is reduced significantly.

We then compared the cost of growing one kilogram of produce with the plastic bottle drip irrigation versus the cost of buying one kilogram of the same product at the market. The price of peanuts (with skin) per kilogram is IDR12,000 (US$0.84) while corn cobs can be bought for IDR4,200 (US$0.30) per kilogram in Maumere market. For this scenario, other fixed costs such as transport is being omitted as it is assumed that the household would be going to the market anyway to buy other groceries.

Figure 3 below illustrates the cost comparison to purchase/grow one kilogram of peanuts and corn, as calculated above.

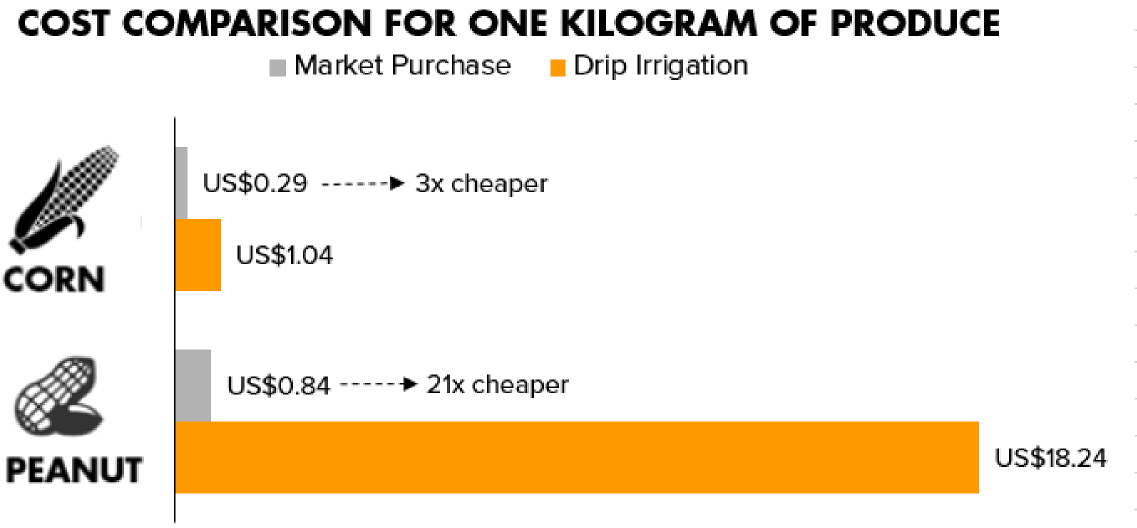

Figure 3. Cost to obtain one kilogram of each product by purchasing at the market versus growing with the plastic bottle drip irrigation method.

Our findings suggest that there is a large cost difference between growing one kilogram of peanuts and growing one kilogram of corn, particularly in terms of the technology costs. This is because the current drip irrigation design requires one unit per plant. Hence its cost-effectiveness depends on the yield per plant. In this case, the peanuts' yield per plant is 24 times lower than corn (25g yield for one peanut plant versus 600g for one corn plant).

In addition, our cost comparison showed that growing one kilogram of produce with the plastic bottle drip irrigation system was much more expensive than buying the same amount of produce from the market. Even in the case of high yield plant such as corn where the cost of the technology can be reduced significantly, the actual time spent to grow the crops and the cost to purchase the water needed for the crops during the dry season is much more expensive than purchasing the product in the market.

[6] Irrigation Management for Corn. University of Nebraska-Lincoln. Accessed on March 2019.

CONCLUSION

Based on these results, we proved that the plastic bottle drip irrigation system enabled farmers to grow peanuts during the dry season where normally they did not grow anything at all. The drip method recorded a lower plant survival rate and yield than the manual method, with 90 percent survival rate and an average yield of 18g per plant, by using 63 percent less water for irrigation. This result indicated that the drip rate applied was too low and could be increased (with the total volume of water still kept lower than the manual method) to produce an equal yield with the manual method and still use less water.

While we could grow peanuts with our drip irrigation technology, we were not successful in doing so with corn, chilies or sorghum. For these three plants however, given they died with both the manual method and the plastic bottle drip irrigation method, it is likely that the drip irrigation mechanism was not the main issue, rather it was more likely that the fertility of the land or that the amount of water provided during the late vegetative stage (for corn) was insufficient.

Regarding the cost analysis, we also found that the cost from growing crops using the plastic bottle drip irrigation technique was 21 times more expensive for buying the same amount of peanuts from the market. Even with a higher yield per plant such as corn where the cost of the technology is minimal, it is still more expensive to grow the crops. than to buy the same amount of produce from the market, rendering this solution unviable in this scenario.

TESTIMONIAL

"It's good that Kopernik dares to try new things to help farmers to grow food during the dry season. This drip irrigation system has potential as a low-cost technology but I wish the design could be improved as for now it takes so much of my time to fill up each bottle." - Yan Piterson, Data Collector

RECOMMENDATION

Based on the results from this experiment, Kopernik recommends that:

- Kopernik with other organizations, modify the design of plastic bottle drip irrigation system so that one unit can provide irrigation for several plants, therefore reducing the cost of technology;
- Kopernik with other organizations, continue experimenting to grow plants that have a higher yield and are more appropriate with the drip irrigation system;
- Kopernik with other organizations, research more appropriate places for plastic bottle drip irrigation experiments where the people have very limited options to purchase produce from the market, or where fresh produce is very difficult to access to explore whether growing food can be a cheaper option than buying the equivalent produce from the market in certain remote areas.