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Optimizing Agricultural Sustainability: Integrating Solar-Powered Drip Irrigation in the Onion-Corn Cropping System for Climate-Resilient Farming in Magsaysay, Occidental Mindoro

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ABSTRACT

The study aims to determine the comparison of the yield response of bulb onion and Magenta corn using solar-powered automated drip irrigation and farmers' practice (furrow) irrigation as a response to the deficit water supply brought by climate change. The experiment was conducted last December 2022 to August 2023 at Sitio Cabag, Brgy. Poblacion, Magsaysay, Occidental Mindoro. The Complete Randomized Design (CRD) of the experiment was adopted consisting of two treatments and five replicates. This was done by following the simple random sampling of assigning the treatments on the experimental plots (1000 sq meters). The Philippine National Standard for onion and corn production was followed. The same care and management practices were employed except for the type of irrigation used. Results show that drip irrigation resulted in reduced water consumption when irrigating an area of 1000 square meters, in comparison to furrow irrigation. Furthermore, the bulb onions, and magenta corn that were subjected to solar-powered drip irrigation exhibited greater fresh and dry weight, highest number of corn cob and grain weight. The T-test reveals a statistically significant difference between the treatments. Although, solar irrigation systems often entail more initial investment compared to furrow irrigation systems, it still offers greater advantage of lower maintenance and operation expenses. Lastly, this climate smart technology can minimize the cost on fuel expenditure and effectively maximize water scarce resources that could help mitigate climate change.

Keywords: bulb size, dry weight, drip irrigation, SDG: 13-Climate Action, 2-Zero Hunger.

INTRODUCTION

The strain on agricultural productivity has been exacerbated by the harsh impacts of climate change and a growing population, necessitating the identification and promotion of sustainable practices. Fortunately, agricultural output can be incrementally enhanced through the application of fertilizers, irrigation, high-yielding seed varieties, and additional methods. Nevertheless, it is critical to acknowledge that an overabundance of these inputs may result in adverse environmental and social consequences. As an illustration, excessive application of nitrogen fertilizers may give rise to unfavorable ecological consequences, including contamination of groundwater, eutrophication of freshwater bodies, and tropospheric pollution due to the release of nitrogen oxides and ammonia gas (Steffen et al., 2015). Irrigated agriculture, constituting the largest water consumer sector, depletes 70% of available water resources (FAO, 2023). In order to mitigate the economic and climate risk associated with farming operations, it is crucial to exercise prudence in choosing an irrigation system tailored to a certain crop, such as opting for automated drip irrigation. Drip irrigation is a crucial and cutting-edge type of irrigation that surpasses surface irrigation in terms of innovation and effectiveness (Bhasker et al., 2017).

Drip irrigation is clearly more efficient in terms of unit water productivity than alternative irrigation methods, given that it reduces water loss via evaporation and seepage (Flores et al., 2021). Furthermore, it facilitated improved fertilizer management and nutrient distribution, which led to decreased plant stress, earlier harvests, enhanced crop quality, and greater uniformity in yield (Gebremeskel et al., 2018). In the same way, Pourgholam-Amiji et al. (2020) proposed that a rise in water productivity served as an efficient approach to prevent the depletion of nonrenewable water resources by indirectly causing a rise in crop productivity. After rice, farmers in Occidental Mindoro cultivate onions as a secondary commodity. Typically, onions are at their height of production from March to May; subsequent to this, the rainy season resumes and rice is once more planted. The onion industry is one of the province's lucrative enterprises. Nevertheless, the industry continues to face numerous challenges in its production process, including drought, pests, and diseases (Calitang and Orfiano, 2011); inadequate post-harvest facilities; fluctuating product prices; and a lack of quality control protocols (Ruedas and Ruedas, 2012). Further, due to a lack of irrigation facilities, droughts during the second crop often led to water shortages that lower the number of hectares that can be irrigated, which affects farming's profits and output. That is why, crops that needs lesser water is planted for second crop like onion, garlic, corn and vegetables as a supplementary source of income prior to the start of the rice growing season.

This project involves the provision of automated drip irrigation facilities to improve the farming system of the farmers in planting High Valued Crops like onion, vegetables and grains. The project was handled by the Magsaysay First Christian Multi-Purpose Cooperative with the supervision of Occidental Mindoro State College (OMSC) in cooperation with the DOST MIMAROPA-PSTC Occ. Mindoro. DOST-MIMAROPA, thru PTSC-Occidental Mindoro, had provided the technological assistance for the improvement of farming system through drip irrigation. While, the Occidental Mindoro State College (OMSC) was responsible in the research aspect of the project.

The study aims to determine the comparison of the yield response of bulb onion and Magenta corn using solar-powered automated drip irrigation and farmers' practice (furrow) irrigation as a response to the deficit water supply brought by climate change.

MATERIALS AND METHODS

Materials

Table 1 presents the drip irrigation materials used in this study. It includes quantity, unit and description of materials based on a company that specialized in irrigation visitation. The experiment was conducted last December 2022 to August 2023 at Sitio Cabag, Brgy. Poblacion, Magsaysay, Occidental Mindoro. Final write up and data analysis was done from September 2023 to February 2024.

Table 1: Materials.

Components	Description	Farm size (1 ha)
Solar Pumping Unit	Engine-driven pump with flexible suction hose and accessories with housing	75,000.00
Solar Panel for the pumps	12 panels with stand	200,000.00
Water storage	3 drums with stand	14,962.00
Head Control System	2" AMIAD T Tagline Disc Filter Check valve 2" Spring threaded one side NAVd PP Kint ¾" BSP PN10 Pressure Gauge 250 GLZ BAR ¼" BSP	51,894.86
Mainlines, infield valve and distribution line	Layflat hose 2 ½ " x 100 M Angle sear Valve 2"2 Plasson Fittings and accessories	177,460.92
Lateral networks	FXN ring strat 16 Aries 16150 0.951/H 0.30M 1000M Fittings and accessories	10,985.52
Installation fee		50,000.00
Delivery fee		50,000.00
		630,303.30

Fig 1: Experimental layout.
Legend: T_1-Furrow irrigation; T_2- Drip Irrigation

Methods for The Experiment

Onion Cultural Practices and Management:

The Philippine National Standard for onion production was followed. The same care and management practices was used to each replication to produce healthy onions. The treatment varies in the use of irrigation. The plants must be watered 10-15 days based on the wetness of soil. Flooding irrigation was be the utilized. Watering frequency is reduced once the bulb is near to maturity. Watering has to be stopped completely one week prior to harvesting. For the drip irrigation, onion plots were irrigated depending on the soil moisture.

Corn Cultural Practices and Management:

The recommended production management by the private company that developed Magenta Corn Variety was followed. The treatment varies in the use of irrigation method.

Research Design

The Complete Randomized Design (CRD) of experiment was adopted consisting of four treatments and five replicates. These experimental plots were 1,000 square meters for drip irrigation and 1,000 square meters for furrow irrigation, divided into five 200-square-meter replications.

Onion:

T1R5	T2R5
T1R3	T2R3
T1R1	T2R4
T1R2	T2R2
T1R4	T2R1

Corn (Planted After Onion):

T1R5	T2R5
T1R3	T2R3
T1R1	T2R4
T1R2	T2R2
T1R4	T2R1

Fig 2: Drip irrigation and furrow irrigation for onion and corn.

Statistical Tool

Various data gathered was be analyzed and interpreted using T-test following the layout in Complete Randomized Design (CRD) set at 5% level of significance.

RESULTS

Water Saving Capacity

Table 2 shows that drip irrigation with a mean amount of water amounting to 900,00 liters used is lower amount of water for irrigation 1000 sq meter of land as compared to the furrow irrigation with a mean of 1.8 M liters. While, for Magenta corn there is a difference of 120,000 L between furrow and drip irrigation system. The results are corroborated by Enchalew et al. (2016), who demonstrated that farmers achieved a 30% to 60% reduction in water consumption and a concurrent increase in crop growth by transitioning from surface irrigation to drip irrigation. In a comparative analysis of the drip and surface methods, Tagar et al. (2012) observed that the drip method yielded a 22% higher return and conserved 56.4% of water. According to Jain Irrigation Systems Ltd. (2023), maize only needs 3642 m3 to 4342 m3 of water per hectare to grow for 65 to 100 days and produce 10 to 12 t/ha of grain when drip-fertigation is used with precision farming. Using water in the amounts shown above can only be done with the drip way of irrigation. The average farmer uses 5,000 to 6,000 m^3 of irrigation water over the course of a season that lasts 115 to 120 days, and the crops they grow produce between 7 and 8.5 t/ha.

Table 2: Water consumption (based on the container liter capacity).

Treatments	Number of irrigation schedule	Water consumption (L)
Onion		
T1 (Furrow)	12	1.8 M
T2 (Drip)	12	900,000
Magenta Corn		
T1 (Furrow)	6	420,000
T2 (Drip)	6	300,000

Further, irrigation water may be required 4-6 times throughout the growing season of corn at an interval of 10-14 days, starting the first irrigation one day after planting and ending at about

15-21 days before harvest, depending on the climatic condition, soil type, corn variety and maturity of the crop. For onion, there were 12 irrigation schedule and six irrigation schedule for Magenta cormn

Yield Response of Red Pinoy Onion:

Fresh Weight of Bulb:

Fresh weight of bulb refers to the weight of the bulb at harvest. Result of the study shows that bulbs in Treatment 2 obtained the heaviest weight with a mean 3.20 kg as compared to Treatment 1 with mean weight of 2.50 kg.

Onions need a lot of water, and the amount of water in the top 12 inches of the soil has a big effect on how well they grow and how much they produce (Shock et al., 2013). Most of the time, regular irrigation is needed to keep the soil's moisture level at the right amount for getting the best yields. To keep onions healthy, the FAO says that the water level that plants can use should not drop below 75%. The reason for this is that onions soak up less water when the water level drops below this point. According to Al-Jamal et al. (2000), enough water in the soil helps bulbs grow instead of roots, which leads to more selling produce. When onions aren't watered enough, they experience water stress, which slows leaf growth, lowers the bulbing ratio, lowers bulb fresh weight, smaller bulbs, and lower marketable crops.

Table 3a: Fresh weight of the bulb.

Treatments		**Weight (kg)**				**Treatment Total (T)**	**Treatment Mean**
	R1	**R2**	**R3**	**R4**	**R5**		
Treatment 1 (Furrow)	2.30	2.20	2.60	2.70	2.70	12.50	2.50
Treatment 2 (Drip)	3.20	3.30	3.20	3.30	3.20	16.20	3.20
Replication Total (R)	5.50	5.50	5.80	6.00	5.90		
Grand Total						**28.70**	
Grand Mean							**2.87**

The T-test shows that the p-value of 0.00137116130352916 is lower than the 0.05 (typically ≤ 0.05), which means that there is significant difference among the treatments.

Table 3b: T-test result on the fresh weight of bulb.

df	4
t Stat	-6.59244396717314
P(T<=t) one-tail	0.00137116130352916

Dry Weight of Bulbs:

Dry weight refers to the weight of bulbs after curing for 6-10 days (Bautista,2000). Treatment 2 obtained the heaviest weight with a mean 2.88 kg as compared to Treatment 1 with mean weight of 2.06 kg. Curing reduces bulb weight. The acceptable weight loss of 3-5% is normal under ambient drying conditions and up to 10 % with artificial drying (Thompson, 1982). However, estimated loss in bulb onion crop is high and can reach 16-35% (Steppe, 1976).

Table 4a: Dry weight of the bulb.

Treatments		_Weight (kg)				Treatment Total (T)	Treatment Mean
	R1	**R2**	**R3**	**R4**	**R5**		
Treatment 1 (Furrow)	1.80	1.80	2.10	2.20	2.40	10.30	2.06
Treatment 2 (Drip)	2.90	3.00	2.80	3.00	2.70	14.40	2.88
Replication Total (R)	4.70	4.80	4.90	5.20	5.10		
Grand Total						**24.70**	
Grand Mean							**2.47**

The T-test shows that the p-value of 0.00338358787672032 is lower than the 0.05 (typically ≤ 0.05), which means that there is significant difference among the treatments.

Table 4b: T-test result on the dry weight of bulb.

df	4
t Stat	-5.1451376021329
P(T<=t) one-tail	0.00338358787672032

Yield Response of Magenta Corn:

Number of Corn Cobs:

The number of corn cobs were done per replication. There were 30 corn plots selected for each replication. The total corn cobs for Treatment 2 is 200, which is higher than Treatment to with 168 corn cobs.

Table 5a: Number of corn cobs.

Treatments		_Weight (kg)				Treatment Total (T)	Treatment Mean
	R1	**R2**	**R3**	**R4**	**R5**		
Treatment 1 (Furrow)	32	34	36	32	34	168	33.60
Treatment 2 (Drip)	38	45	43	38	36	200	40.00
Replication Total (R)	70	79	79	70	70		
Grand Total						368	
Grand Mean							36.80

The T-test shows that the p-value of 0.005584059 is lower than the 0.05 (typically ≤ 0.05), which means that there is significant difference among the treatments.

Table 5b: T-test result on the number of corn cobs.

df	4
t Stat	-4.459091291
P(T<=t) one-tail	0.005584059

Grain Weight of Corn:

Result shows that corn irrigated using the drip irrigation system got the highest grain weight in five replications with a mean of 10.00.

Table 6a: Grain weight of the corn.

Treatments		Weight (kg)				Treatment Total (T)	Treatment Mean
	R1	R2	R3	R4	R5		
Treatment 1 (Furrow)	8.00	8.50	9.00	8.00	8.50	42	8.40
Treatment 2 (Drip)	9.50	11.25	10.75	9.50	9.00	50	10.00
Replication Total (R)	17.50	19.75	19.75	17.50	17.50		
Grand Total						**92**	
Grand Mean							**9.20**

The T-test shows that the p-value of 0.005584059 is lower than the 0.05 (typically ≤ 0.05), which means that there is significant difference among the treatments.

Table 6b: T-test result on the grain weight of corn.

df	4
t Stat	-4.459091291
P(T<=t) one-tail	0.005584059

Costs and Fuel Consumption Using Drip and Furrow Irrigation System

Based on the existing experimental site, Table 7 shows how much it costs to grow onions and how much fuel is used using a furrow irrigation method. The traditional irrigation system costs an average of PhP 411,275.00 fpr onion-corn production system per hectare. This includes the cost of the diesel engine, water pump, drilling of the water source, installation costs, hose, and the housing that protects the machinery from harsh weather. The amount of fuel used depends on how many times the veggies need to be watered. Compared to furrow, a solar-powered drip irrigation system costs PhP 198,720 for onion and PhP 58, 600.00 for corn per hectare to set up. This includes the cost of solar PV panels, a pump and controller, accessories, grounding, PV cable, installation, and mounting work.

Table 7: Summary of costs and fuel consumption using drip and furrow irrigation system in one onion production.

Parameter	Unit of Measurement	Furrow Irrigation		Drip Irrigation (5-10 years)
		Onion	Corn	
Investment cost (panel, wire, engine, pump, drilling, hose & accessories)	Set	109,400.00		630,303.30
Diesel consumption	Liter/ha/cropping	2880 Liters	850 Liters	-
Oil and Lubricants	Ha/cropping	12,000.00	2,500.00	
Fuel cost (PhP 69/L)	Liter/ha/cropping	198,720.00	58,600.00	-
Maintenance and other operational costs	Ha/cropping	25,000.00	5,000.00	-
	Total	345,125.00	66,150.00	**630,303.30**
		411,275.00		

The solar irrigation system has no fixed operating costs since it uses no fuel and operates on solar energy. In contrast, the fixed maintenance cost includes labor and transportation costs, in addition to the replacement costs of a submersible water pump that must be replaced every 8 to 12 years, depending on the siltation in the water source. Solar panels require no maintenance other than routine cleaning to capture the optimum amount of sunlight.

Even though this study shows that this technology is two times more expensive than furrow irrigation, its cost to operate and maintain is zero per hectare per year, which is way less than its contemporary. Considering the value of money over time, this means that a farmer can save an average of PhP 30,000.00/ha and up to PhP 300,000.00/ha on maintenance costs over the next 10 years. Moreover, if the price of diesel will not change, could be lessened in the production cost.

Costs and Return Analysis (Onion & Corn)

The dynamics of supply and demand within the local market resulted in fluctuations in the farmgate price of onion harvests. Additionally, the pricing was susceptible to manipulation by some merchants. In 2022, onion producers experienced the highest farm-gate prices for their produce, while the lowest prices were recorded in 2020. Middlemen played a critical role in the aggregation of onion yields, which subsequently facilitated sales to Chinese merchants, by acting as intermediaries.

The price of onion in the analysis is based on the current farm gate price. The ROI shows the difference between the utilization of furrow and drip irrigation system. There is a higher ROI when using furrow irrigation (78.23%) in onion production but in corn using drip irrigation (86.20%) yield higher ROI.

Table 8: Costs and Return Analysis (Onion & Corn).

Particulars	Furrow Irrigation		Drip Irrigation	
	Onion	**Corn**	**Onion**	**Corn**
Gross Return (Php/ha)	1,470,000.00	100,000.00	1,596,000.00	108,000.00
Total Costs (PhP/ha)	320,000.00	74,000.00	750,000.00*	58,000.00
Net Returns (PhP/ha)	1,150,00.00	26,000.00	846,000.00	50,000.00
Cost per kilogram (PhP)	22.85	2.85	49.342	1.16
Yield per hectare (kg/ha)	14,000.00	2500.00	15,200.00	2700.00
Farmgate Price (PhP/kg)	105.00	40.00	105.00	40.00
Return on Investments (NR/GR*100%)	78.23%	26%	53%	86.20%

*Solar set up investment

DISCUSSION

The findings was supported by the study of Halvorson et al. (2008) that drip irrigation obtained higher fresh onion yields, irrigation water use efficiency, and economic returns with SDI compared to furrow irrigation systems. Their study demonstrated that drip irrigation used at least 57% less water than the furrow system and its yields were 15% higher.ased on the results of the study of Villaroman et al (2018) in Central Luzon, the following conclusions were drawn: 1) more uniform - sized bulb can be produced under drip irrigation system,2) the use of treatment 1 increase water savings without sacrificing the crop quality; and, 3) atmometer can be a substitute for automatic weather station in managing irrigation scheme based on crop evapotranspiration and it can be used in large scale irrigation system.

It is also mentioned that the onion crop is going to be managed through drip system in many advance countries with the result of high yield. Ishfaq (2002) also found in his study that drip irrigations system create stability and improve the irrigation water in crop.Moreover, Sammis (1980) reported that, the irrigation water could be preserved through drip irrigation system up to 90%, and subsurface soil irrigation also improve the soil moisture and penetrate water in direction of root zone, and labor cast categorically decreased more than 70%, and reduction of weed was assessed up to 70% and increased in yield become obsessed up to 76.6 %. Drip irrigation systems enhance the stability of water efficiency and reduce the loss of water.

Hanson et al. (2003), reported that the less interval between the irrigations helps to keep active root zone moist which leads to proper growth of onion plant. Irrespective of the irrigation treatments, the plant height, bulb diameter and bulb weight was measured at the time of harvesting under fertigation treatment and was found highest The statistical analysis revealed that the fertigation strategies have significant effect on the growth parameters of the onion crop. The combined effect of irrigation interval and fertigation strategies was also investigated on the onion crop growth parameters.

Kadayifci et al., (2005) reported that bulb and dry matter production were highly dependent on appropriate water supply. Mermoud et al., (2005) showed that irrigation frequency plays an important role on the development and yield of the onion crop. Irrigating twice a week instead of once a day (and thus increasing the irrigation depth) was found to cause an increase of the water storage through the whole root zone, a better crop water availability and higher yield. Bekele and Tilahun (2007) observed that water deficit at first and fourth growth stages had insignificantly effect on yield as compared to optimum application. In the study of Camp (1998) yields of horticultural crop irrigated with SDI were equal to or greater than those obtained for other irrigation systems in most cases. For cantaloupes, onions, and carrot grown in Arizona, crop yields were very similar for SDI and furrow irrigation systems.

In contrast to traditional irrigation techniques such as flood or furrow irrigation, drip irrigation presents a range of benefits. These advantages encompass notable reductions in water usage and enhanced water efficiency, achieved through the direct delivery of water to the root zone of plants (Lv, et al., 2019). The advantages can be ascribed to the capacity of drip irrigation to provide water with precision and control, hence minimizing water losses resulting from runoff, evaporation, and deep percolation. Drip irrigation, a technique that enables the application of tiny and frequent amounts of water, is well recognized as an efficient approach for water saving and enhancing the water productivity of onions (Wu et al., 2023). However, this study reveals that this method is 4 times more expensive than furrow irrigation, but it costs nothing per hectare per year to operate and maintain. Over 20 years, a farmer can save an average of PhP 15,000.00/ha and up to PhP 375,000.00/ha on maintenance costs due to the value of money. If diesel prices stay the same, production costs might drop by PhP 16,560.00/ha/cropping or PhP 331,200.00 over 20 years.

CONCLUSIONS

Drip irrigation system used a lower amount of water in irrigating 1000 sq meters of land as compared to furrow irrigation. The bulb onions, and magenta corn that were subjected to solar-powered drip irrigation exhibited greater fresh and dry weight, highest number of corn cob and grain weight. The T-test shows that there is a significant difference among the treatments. Although, solar irrigation systems often entail more initial investment compared to furrow irrigation systems, it still offers greater advantage of lower maintenance and operation expenses. Lastly, this climate smart technology can minimize the cost on fuel expenditure and effectively maximize water scarce resources that could help mitigate climate change.

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RECOMMENDATION

Additional research is needed to look into the economic and environmental implications of implementing the furrow irrigation system compared to the drip irrigation method in onion cultivation. In addition, the research could explore the incorporation of demographic characteristics to assess the level of acceptance of the technology.

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