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Peanut production through innovative water management strategies

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Abstract

Background/Objectives: A study on enhancing peanut production through drip irrigation (DI) technology was conducted to increase the productivity and profitability of peanut production in the Ilocos region, Philippines. It sought to develop irrigation management strategies suitable for peanut. **Methods/Statistical analysis**: Decision Support System for Agrotechnology Transfer (DSSAT) simulation was done, and field validation was conducted to achieve the objectives. The simulation activity led to the determination of the top three promising drip irrigation management schemes suitable for peanut production, which were then field validated through actual field set-up in three different locations. The best scheme (DI S9 410mm) was then pilot-tested at the farmers' field and compared with Farmers' Practice (FP) d using t-test. **Findings:** Using the DI scheme, dry pod yield was increased from 1.59Tha^{-1} to 2.09Tha^{-1} or 31.45% increase as compared to the farmer's practice. This result is a little higher than the target increase in yield of 30%. Findings indicate that the DI is a much better method than FP, increasing the dry pod yield to as much as 70.21% during the dry season. Yield increase could be attributed to more even application of water and less water stress. On the other hand, water productivity was only increased by around 16% due to farmers' limited water application. In terms of seed quality based on seed size, DI and FP are comparable. Results the economic analysis showed that yield of peanut under DI were higher by about 0.84Tha^{-1} to 1.16Tha^{-1} as compared to FP with a Return of Investment (ROI) of 0.25. In the long run, the profitability of DI could be improved through water productivity and yield improvements. Water savings was not a factor in profitability due to under-irrigation by farmers. **Novelty/Applications:** The use of DI technology with the developed irrigation scheme substantially contributed to the goal of increasing the productivity of and profitability of peanut. It is especially useful for areas with limited water supply for irrigation.

Keywords: Drip irrigation; peanut; water productivity; water savings; DSSAT simulation

1 Introduction

Peanut (Arachis hypoqaea L.) is not a new crop in the Philippines but it was not given much importance like that of corn. Data from the Bureau of Agricultural Statistics (BAS) have shown that the volume of peanut production has been declining from 31,377 MT to 29, 400 MT in 1991 to 2018, respectively. The total area of production likewise decreased from 38,924 ha to about 26,000 ha in the same observation period. This scenario has resulted in the importation of peanuts in order to meet the high demands by the processors, who in turn export their products to the United States (1). At present, Ilocos Region is the primary producer of peanuts in the Philippines. Based on BAS data from 2011 to 2018, this region accounted for 39% of the national production areas, followed by Cagayan (15%) and Northern Mindanao (10%). Pangasinan produced 55% of the region's peanut production, followed by La Union (25%), Ilocos Norte (10%), and Ilocos Sur (10%) (2).

Generally, peanut production in the country is still below the potential yield levels of 3-4 $MTha^{-1}$. The national average yield only range from 800 to1,000 kilograms per hectare (3). The top ten peanut producing provinces are Ilocos Sur, Pangasinan, La Union, Aurora, Albay, Ilocos Norte, Quirino, Iloilo, Isabela, and Cagayan with average yield ($MTha^{-1}$) of 1.97, 1.67, 1.37, 1.23, 1.08, 1.02, 0.92, 0.62, 0.60, and 0.45, respectively. Peanut yield is a product of a complex cascade of reproductive processes both above and below ground, starting at approximately three weeks after seed germination.

Irrigation is important factor in achieving high yield and seed quality of peanuts. Water deficit on peanut can decrease seed weight and percentage of extra-large kernels that reduce market quality (4). Pre-harvest aflatoxin contamination of peanut is common when peanut is deprived of water, and soil temperature is high during the last 3 to 6 weeks of the pod maturation period (5). Furthermore, insufficient water during the growing season may reduce germination, normal root expansion, pod growth, and fruit development. Excess water can cause excessive vegetative growth and a greater leaf area index, but restricts root growth and development, resulting in decreased pod yield (6).

Irrigation at appropriate times is essential to stabilize and ensure peanut production with high quality and yield. In many peanut production areas in the country today, the usual irrigation practice of farmers is still by flooding. The main drawback of this method is its low irrigation efficiency and low distribution efficiency, which may adversely impact both on the quality and yield of peanut. Moreover, with the declining amount of surface and groundwater supply for irrigation, which can be attributed to climate change, water conservation or saving water is very important.

Due to its high water efficiency compared to other irrigation methods, drip irrigation has been used to irrigate vegetables and high-value crops for many years. It can precisely deliver water, nutrients, and chemicals to the crop's root zone, resulting in yield increases and improved water conservation. One of the most significant advantages of using surface drip irrigation is that the system can be installed easily in small fields with low initial investment and can provide flexible irrigation schedules without using large pumps and wells. It also offered the best method of supplying soil moisture uniformly in the root zone throughout the growing season (7).

Drip irrigation (DI) has the potential to provide consistently high yields while conserving soil, water, and energy. Other benefits include precise placement of water and chemicals, low labor requirements, and reduced runoff and erosion. These DI systems have the capability of frequently supplying water to the root zone thereby reducing the risk of cyclic water stress typical of other irrigation systems. Moreover, these DI systems are adaptable to various field sizes and shapes (8).

It is envisaged in this project that developing water management strategies and employing water-saving techniques would play an important role in improving quality and yield of peanut. Surface drip irrigation has increased profits for farmers growing many types of crops. However, little research has been done on the use of surface drip irrigation to increase peanut yield and quality. No information is available to transfer this technology to peanut production and improve the grower's profit (9). The project generally aims to increase the productivity and profitability of peanut production in the Ilocos region through the adoption of drip irrigation technology. Specifically, the project was geared towards the following: 1) to simulate the effects of irrigation depth and frequency on the yield and yield components of peanut using Decision Support System for Agrotechnology Transfer (DSSAT) to serve as basis in coming up top three promising irrigation management strategies suitable for peanut production; 2) to validate the top three promising irrigation management strategies under field condition; 3) to establish peanut pilot-test farms showcasing drip irrigation (DI) technology using the best irrigation management strategy along with other packaged of technologies developed for peanut production; and 4) to evaluate the comparative advantage of DI in improving profitability of peanut production through improved seed quality, yield increase, water savings, and water productivity.

2 Methodology

2.1 Conceptual Framework

Better management of water and other inputs is possible through effective and appropriate conservation tactics and technologies. Efficient water use is the key to sustainability, and tactical management of it is the key to resource conservation [10]. Relative hereto, despite of the importance of appropriate irrigation schemes in ensuring peanut production with high quality yield, appropriate water management schemes for peanut production has not been fully adopted by peanut farmer growers. As such, the volume of peanut production in the country today is declining. The low quality of seed produced and high irrigation costs caused by inappropriate amount and timing of irrigation has aggravated the situation.

The project utilized the concept of science/technology innovation to advance the promotion and adoption of drip irrigation technology to efficiently apply the needed amount of water and nutrients to the crop. The scientific basis of this undertakings lies on the principle that irrigation water when applied to the crop at the right amount at the right time and delivered most efficiently will result in improving irrigation efficiency, better crop stand and ultimately increase in yield and quality.

Figure 1 shows the project's conceptual framework, which served as guide in the utilization of drip irrigation system for more profitable peanut production. As shown in the figure, irrigation management strategies suitable for peanut were developed using DSSAT simulation and field validation at station scale. This step was important for determining the top three promising drip irrigation management strategies suitable for peanut production. The most promising drip irrigation (DI) management package was then pilot-tested at the farmers' field. It was compared with the usual furrow irrigation method presently being adopted by farmers in a nearby field. The comparative advantage of the aforementioned irrigation system over the farmers' practice (FP) was then showcased via on-site pilot-test farms.

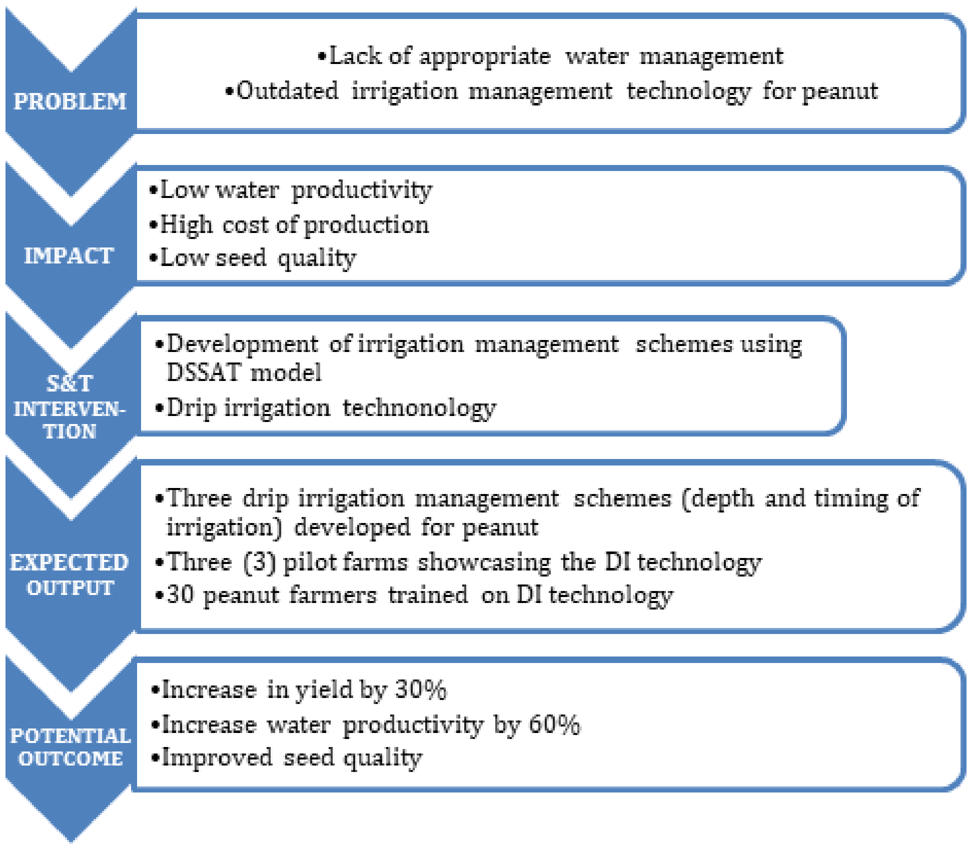

Fig 1. Conceptual framework of the study.

2.2 Location and Description of the Study Areas

The identified study sites (Figure 2) are suitable for peanut production. Soils were characterized as medium to light texture (clay loam to sandy loam) with good internal drainage.

Fig 2. Location of the study areas.

2.3 Simulation of Different Irrigation Management Schemes Suitable for Peanut using DSSAT Model

Models are useful because they are simplified simulations of reality [11]. Hence, in order to reduce the cost and time of evaluating different irrigation management strategies for peanut production, they were first evaluated using the DSSAT model. It was used to simulate effects of different irrigation management strategies. This activity was intended to develop irrigation management strategies suitable for peanut as well as to verify and update existing irrigation schemes already developed for peanut. Predetermined soil type (sandy to loamy soils) was used for the simulation and actual field conditions. Evaluation was based on the depth of irrigation and frequency of irrigation.

The genetic coefficient was generated based on actual field experiment. The ten irrigation schemes shown above were implemented within the DSSAT model. Local climate data from the MMSU PAGASA Agrometeorological station was used in the model. All pertinent data were inputted to parameterized the DSSAT model in order to simulate the 14 irrigation schemes.

The cost and return analysis were done to come up with the top three promising irrigation schemes for peanut. The cost of production per irrigation scheme was computed based on the actual cost of production when done in the field. Using the simulated yield per irrigation scheme, the following were computed as follows:

Gross income per ha = Yield x Price/kg

Net Income = Gross Income – Total Cost of Production

Benefit Costs Ratio (BCR) = Net Income / Total Cost of Production

Cost/kg Fruits = Total Cost of Production / Yield

Top three irrigation schemes that gave the highest yield and BCR were selected.

A controlled experiment was setup at the MMSU experimental station to calibrate the DSSAT model. After calibration, different irrigation schemes were simulated and evaluated based on their potential of increasing peanut productivity as well as reducing the cost of production. In particular, the simulated yield, plant biomass, phenological growth pattern, and soil water balance parameters were analyzed and compared. The top three promising irrigation schemes were selected for further evaluation under field condition.

2.4 Field validation of top three promising management irrigation strategies

The top three promising irrigation schemes for peanut production were evaluated under field conditions using the simulated results. It ensured that the simulated results hold under real field conditions and likewise evaluate other equally essential parameters that are not possible using the DSSAT model.

All plots were laid out with surface drip irrigation system. Validated yield were gathered for comparison with the DSSAT simulated yield.

2.5 Pilot testing of DI technology

The best irrigation scheme developed in this study for peanut (MPn 12 / PN 9 — Ilocos Red) was test piloted in Brgy. Bago, Vintar, Ilocos Norte and Brgy. Lanna, Enrile, Cagayan. The Municipal Agricultural Officers (MAO) in each of the study sites were tapped for the identification of pilot fields and farmer-cooperators. The pilot fields were selected based on accessibility, presence of water source, and receptiveness of the farmers in the area. Each field size was 500m^2. On the other hand, selection of farmer-cooperators was based on farming performance, commitment, and capability to share technologies with other farmers.

The drip irrigation systems for Vintar, Ilocos Norte and Enrile Cagayan were designed to capture actual field conditions such as distance of planting and distance of furrows. Moreover, the systems were designed to efficiently apply irrigation water at the right time (time of application) and amount (depth of application).

Each pilot field was laid out side by side with a field managed (Figure 3) with standard farmer's practice (FP) for irrigating peanut. Except for the irrigation scheme/method, all cultural management practices and inputs such as peanut seeds, fertilizers and chemicals were applied to both fields. The farmer-cooperators were provided the day-to-day management of the fields, as well as the labor and power for land preparation, crop establishment, and weeding, spraying, harvesting, and post-harvesting processes. Designated Project staff has coordinated every activity to the farmer-cooperators including monitoring and evaluation.

Fig 3. Layout of the (a) Drip irrigated field. and (b) Farmer's practice.

2.6 Determination of the comparative advantage of DI

DI has the potential to increase the productivity and quality of peanut produce. Hence, the potential increase in the income of peanut farmers. The perceived comparative advantage of DI over FP was determined and evaluated based on the following parameters which were statistically analyzed.

2.6.1 Pod Yield per Hectare (Tha^{-1})

Pod yield per hectare was obtained by multiplying the plant population per hectare to the pod yield per plant. Pod yield per plant was obtained from the harvest area of 100m^2 and was translated into kilogram ha^{-1} basis. Pods were cleaned and washed with water and the fresh weight was obtained by weighing with a scale. Dry pod yield was obtained after drying the pods to appropriate moisture content.

2.6.2 Seed Quality

Seed quality was assessed through determination of seed size, shelling percentage, percentage classification of pods, and pod-fill.

2.6.2.1 Seeds size or 100 Seed Weight (g). This was obtained by getting the average weight of 100 peas repeated 4 times.

2.7 Water productivity

Productivity is a ratio between a unit of output and a unit of input. Here, the term water productivity was used exclusively to denote the value of the total peanut produce (fresh or dry) over the total volume of water used for the duration of the cropping season.

2.8 Statistical analysis

Simple t-test and analysis of variance were used to analyze data using Statistical Package for the Social Sciences (SPSS).

3 Results and Discussion

3.1 Experiment for the generation of genetic coefficient for peanut

At MMSU, a peanut experiment was established for the generation of crop coefficient of peanut. The experiment has an area of 1,500m^2 consisting of variables, 3-row spacing and 9 planting dates arranged in a strip-plot design with two replications. Data on phenological stages were gathered to determine the number of days after emergence required per growth stage of peanut such as vegetative, flower induction, flowering and maturity. Plant biomass per growth stage was also gathered. The automatic weather station installed at the experimental area was used to monitor the climatic variability and determine their effect on the different growth stages of the test crop.

Using the data set collected from the experimental setup, the DSSAT model was used to determine the PN9 peanut cultivar's genetic coefficient. The genetic coefficients derived are shown in Table 1 . The observed and simulated phenological stages of peanut were compared and found to be comparable. The observed and simulated yield however did not agree much. Differences in the observed and simulated yield could be due to the severe rainfall that occurred during the flowering and pegging stages of the crop which could have affected the yield. Despite of this, the derived cultivar coefficient for PN9 may be considered adequate considering the congruence of the simulated and observed phenological stages. This cultivar coefficient, however, may be adjusted in the succeeding experiments particularly using the drip irrigation system.

3.2 Simulation of different irrigation schemes

Using DSSAT, different irrigation schemes were simulated. This was done to streamline potential irrigation schemes for peanut. The output of the DSSAT model was further validated using the drip irrigation system.

Different irrigation schemes, frequency and amount of irrigation applied at different growth stages were simulated using DSSAT. Fourteen irrigation schemes as described in Table 1 were used in the simulation. These irrigation schemes were done to determine the optimum amount, frequency and timing of irrigation that could be adopted in the field. Irrigation Scheme 1 is the control wherein the frequency and amount are set to the automatic depending on the crop water requirements. This setting means that irrigation is not a limiting factor in the growth and yield of peanut. The other 13 irrigation schemes use different combinations of amount, frequency and timing of irrigation which could be applied using drip irrigation system.

Table 1. Result of simulation of the different irrigation schemes using DSSAT.

Scheme	Frequency (DAS)	Amount (mm)	Growth Stage	Total Irrigation Applied (mm)	Yield (Tha-1)	Rank
1 (Control)	Unlimited	Unlimited	Applied when needed	Unlimited	6.13	
2	0	100	Sowing	500	2.92	11
	30	200	Flowering			
	50	200	Pod development			
3	0	100	Sowing	600	2.95	10
	30	300	Flowering			
	50	200	Pod development			
4	0	150	Sowing	550	2.22	13
5	0	25	Sowing	260	2.73	12
	10	25	End Juvenile			
	20	25	Unifoliate			
	30	25	First flower			
	40	50	First peg			
	50	50	First Pod			
	60	60	First Seed			
6	0	25	Sowing	385	5.24	7
	10	25	End Juvenile			
	20	25	Unifoliate			
	30	50	First flower			
	40	100	First peg			
	50	100	First Pod			
	60	60	First Seed			
7	0	25	Sowing	385	5.64	3
	10	25	End Juvenile			
	20	25	Unifoliate			
	30	100	First flower			
	40	100	First peg			
	50	50	First Pod			
	60	60	First Seed			
8	0	25	Sowing	430	4.05	9
	10	50	End Juvenile			
	20	25	Unifoliate			
	30	120	First flower			
	40	100	First peg			
	50	50	First Pod			
	60	60	First Seed			
9	0	25	Sowing	410	5.72	1
	10	50	End Juvenile			
	20	25	Unifoliate			
	30	100	First flower			
	40	50	First peg			
	50	100	First Pod			
	60	60	First Seed			
10	0	25	Sowing	455	5.59	4
	10	75	End Juvenile			
	20	25	Unifoliate			
	30	120	First flower			
	40	50	First peg			
	50	100	First Pod			
	60	60	First Seed			
11	0	25	Sowing	400	5.67	2
	10	50	End Juvenile			
	20	25	Unifoliate			

Continued on next page

Table 1 continued

Scheme	Frequency (DAS)	Amount (mm)	Growth Stage	Total Irrigation Applied (mm)	Yield (Tha-1)	Rank
	30	100	First flower			
	40	50	First peg			
	50	100	First Pod			
	60	50	First Seed			
12	0	25	Sowing	375	4.84	8
	10	50	End Juvenile			
	20	50	Unifoliate			
	30	75	First flower			
	40	50	First peg			
	50	75	First Pod			
	60	50	First Seed			
13	0	25	Sowing	425	5.56	6
	10	50	End Juvenile			
	20	50	Unifoliate			
	30	100	First flower			
	40	50	First peg			
	50	100	First Pod			
	60	50	First Seed			
14	0	25	Sowing	435	5.57	5
	10	50	End Juvenile			
	20	50	Unifoliate			
	30	100	First flower			
	40	50	First peg			
	50	100	First Pod			

Results of simulation showed the peanut has potential yield of 6.13Tha^{-1} when irrigation is not limiting. Thus, this is the maximum potential yield of PN9 that can be obtained in MMSU Experimental Farm considering the soil and climatic conditions in the area. To determine the optimum irrigation schemes that can be adopted by farmers, 13 irrigation schemes were simulated using same parameters as that of Scheme 1. The numerical ranks of the different schemes in terms of pod yield were considered to come up with the top 3 irrigation schemes as shown in Table 2. Among the top 3 irrigation schemes, S9 gave the highest yield of 5.72Tha^{-1} while the lowest was S7 with a yield of 5.64Tha^{-1}. Results showed that peanut needs a total amount of irrigation ranging from 385mm to 410mm to obtain desirable level of yield..

Table 2. Top three irrigation schemes developed for peanut.

DAYS AFTER SOWING	GROWTH STAGE	IRRIGATION SCHEME AND AMOUNT (mm)		
		S9	**S11**	**S7**
0	Sowing	25	25	25
10	End Juvenile	50	50	25
20	Unifoliate	25	25	25
30	First flower	100	100	100
40	First peg	50	50	100
50	First Pod	100	100	50
60	First Seed	60	50	60
Total Irrigation (mm)		410	400	385
			ns	
Yield (MT ha^{-1})		**5.72**	**5.67**	**5.64**

The best timing of irrigation is very important to ensure optimum yield from the crop. The result showed that appropriate amount of irrigation is needed during the critical stages of plant growth, particularly during the origination (onset) of the first flower and pod development. It should be noted, however, that all the top three irrigation schemes require every 10-day irrigation interval up to 60DAS or with a total frequency of 7 applications.

The top three irrigation schemes (9, 11, and 7) were then validated in actual field condition at the MMSU Peanut experiment station. The resulting most promising irrigation scheme was then test piloted at MMSU peanut experiment station and in selected farms at Brgy. Bago, Vintar, Ilocos Norte and Brgy. Lanna, Enrile, Cagayan.

3.3 Field validation of the simulation work using the top three promising irrigation schemes

The top three promising irrigation schemes generated from the simulation work were field validated through actual field set-up at the MMSU peanut experiment station (Figure 4). The three schemes (S7, S11, and S9) were laid-out in Randomized Complete Block Design (RCBD) with three replications. Pod yield and seed quality (seed size) were the main parameters that were used to determine the best irrigation scheme. Data were analyzed using analysis of variance.

Fig 4. Field validation set-up.

3.4 Mean pod yield (Tha^{-1}) and seed quality comparison among the three promising irrigation schemes

The mean dry pod yield and seed size of peanut for the top three promising schemes are shown in Table 3 . The application of 410mm (S9) of irrigation water all through the growing season resulted in an average pod yield of 2.49 Tha^{-1} with a seed size of 33.65g. Peanut plants irrigated with 400mm of water (S11) produced a slightly lower pod yield of 2.35Tha^{-1}. On the other hand, peanut plants under S7 (385mm) produced a pod yield 2.30Tha^{-1} with a seed size of 32.20g. The trend indicates that the lower the amount of irrigation applied, the lower the pod yield and seed size. Analysis of variance at a 5% level of significance, however, revealed that there is no significant difference among the three schemes in terms of pod yield and seed size. This may be attributed to the small gap in the amount of irrigation applied per scheme. Results indicate any of the top three schemes may be adopted for field piloting. Nonetheless, having numerically produced the highest yield and highest seed size, S9 was selected for pilot testing at selected farmer's field.

It can be noted in Table 3 that the validated pod yield is about half lower than the simulated yield for all the 3 schemes. For S9, for example, the simulated yield is 5.72Tha^{-1}and the validated yield is 2.49 Tha^{-1}. The yield gap maybe primarily attributed to the ideal and optimized settings of the DSSAT (e.g., fertilization and planting options). The validated yield was affected by weather variability and slight diversion from the recommended peanut production options such as date of planting and fertilization, due to late procurement of materials. The result of the validation suggests a simple guide that the expected actual yield of peanut is half the simulated yield.

In general, appropriate amount of Irrigation is indeed important factor in achieving high yield and seed quality of peanuts. Water deficit on peanut can decrease seed weight and percentage of extra-large kernels which reduces market quality. It is also interesting to note that seven times application of irrigation water based on S9 may be practical when drip irrigation is being used. However, when using furrow or flood irrigation, this may become cumbersome to farmers due to the added cost incurred.

Table 3. Validated mean pod yield (Tha^{-1}) and seed size (g) of the top three promising irrigation schemes.

SCHEME	DRY POD YIELD (Tha^{-1})		SEED SIZE (g)
	Simulated	**Validated**	
		ns	ns
S9 (410mm)	5.72	2.49	33.75
S11 (400mm)	5.67	2.35	32.86
S7 (385mm)	5.64	2.30	32.20

3.5 Pilot testing of the best drip irrigation management schemes

3.5.1 Evaluation of the comparative advantage of DI

The comparative advantage of DI over FP was evaluated based on the following parameters: dry pod yield, seed size, water savings, water productivity, and economic viability. The pilot areas in this study were planted with peanut using the S9 scheme (Figure 5). Two dry seasons and two wet seasons of data were gathered from the study sites.

Fig 5. Harvesting, recording, and analysis of pod yield.

3.5.2 Dry pod yield

Data on dry pod yield which was collected over four seasons (2-DS and 2-WS). Table 4 shows the mean pod yield (Tha^{-1} @ 15%MC) comparison between Drip Irrigation (DI) and Farmers Practice (FP) in the study areas during the wet and dry seasons. For the dry season, the dry pod yield obtained using the DI in Vintar, MMSU, and Enrile were 2.46 Tha^{-1}, 1.94Tha^{-1}, and 2.70Tha^{-1}, respectively. On the other hand, the dry pod yield obtained using the FP on the same season and pilot areas were 1.55Tha^{-1}, 1.14Tha^{-1}, and 1.55Tha^{-1}, respectively. Using a t-test at 5% level of significance, the DI produced a significantly higher mean dry pod yield of 2.40Tha^{-1} as compared to the FP which gave a mean pod yield of 1.41Tha^{-1}. The obtained yield of 1.41Tha^{-1} in using FP is in close agreement with the average production of Ilocos Region which is 1.5Tha^{-1}. Findings indicate that the DI is a much better method than FP, increasing the dry pod yield to as much as 70.21% during the dry season. With this, the study was able to double the expected output of increasing the yield by 30%. Yield increase could be attributed to more even application of water, less water stress, more efficient application of nutrients (e.g., Borax/Solubor).

Table 4. Meanpod yield (Tha^{-1} @ 15%MC) comparison between Drip Irrigation (DI)and Farmers Practice (FP) in the study areas during the wet and dry seasons.

	MEANPOD YIELD (Tha^{-1}) 2-Dry Season and 2-Wet Season			
PILOT SITE	**DRY SEASON**		**WET SEASON**	
	DI	FP	DI	FP
Vintar, Ilocos Norte	2.46	1.55	0.93	0.89
MMSU	1.94	1.14	0.82	0.72
Enrile, Cagayan	2.70	1.55	0.81	0.76
	*		ns	
MEAN	2.40	1.41	0.85	0.79
PERCENT INCREASE(%)	70.21		7.59	

* — significant using a t-test at 5% level of significance
ns — not significant using a t-test at 5% level of significance

Meanwhile, during the wet season, results revealed that the dry pod yield was low in both method with a mean yield of 0.85$Tha^{-1}$and 0.79Tha^{-1}, for the DI and FP, respectively. T-test at a 5% level of significance indicates that there is no significant difference between DI and FP in terms of the mean dry pod yield during the wet season. The availability of moisture from rainfall may explain this. Mean pod yield obtained from using the DI was numerically higher, which may be due to the application of appropriate amount of moisture during the critical growth period of peanut in the absence of rainfall for that stage. The low mean pod yield may generally attribute to high moisture brought about by rainfall. Excess water can cause excessive vegetative growth and a greater leaf area index, but restricts root growth and development, resulting in decreased pod yield. This corroborates the action of peanut farmers not venturing into off-season peanut production. According to them, many pods do not produce seeds and rotten due to high moisture.

It is also worth mentioning that the slightly higher yield which was obtained in Vintar, Ilocos Norte (0.93Tha^{-1}) was due to better drainage of the area. Moreover, the application of Borax (Solubor) before the flowering stage may have slightly contributed to the overall increase of yield in using the DI.

3.5.3 Seed size

Seed size matters because this will help farmers in planning the amount of seeds to plant. It gives us the idea how many kilograms we will need to plant per hectare.

The seed size (100-seed weight) in grams of peanut produce in using the DI and FP is reflected in Table 5. The seed size ranges from 35.25g to 36.46g for the DI and 34.17g to 35.05g for the FP, during the dry season. Likewise, the seed size ranges from 34.35g to 35.30g for the DI and 34.25g to 34.55g for the FP, during the wet season. On the Statistical analysis using t-test at 5% level of significance indicate no significant difference between the seed size obtained in using the DI and FP for both seasons. Numerically, the mean seed size of DI (35.70g) is higher as compared to the FP (34.51g) for the dry season. Likewise, the DI gave slightly higher mean seed size (34.70g) in contrast with the FB which is 34.22g, during the wet season. A heavier weight of the seeds for the DI may be attributed to the timely application of irrigation water when needed. Proper soil moisture improves the effectiveness of fertilizers, herbicides, fungicides, insecticides, and healthier seeds.

Table 5. Seedsize (100-seed weight in g @ 15%MC) comparison between Drip Irrigation (DI) andFarmers Practice (FP) in the study areas.

PILOT SITE	SEED SIZE (g) 2-Dry Season and 2-Wet Season			
	DRY SEA-SON		**WET SEA-SON**	
	DI	FP	DI	FP
Vintar, Ilocos Norte	36.46	35.05	35.30	34.25
MMSU	35.40	34.31	34.45	33.85
Enrile, Cagayan	35.25	34.17	34.35	34.55
	ns		ns	
MEAN	35.70	34.51	34.70	34.22

ns – not significant using a t-test at 5% level of significance

3.6 Water savings and water productivity

Water input (mm), water savings (mm), water productivity (kg/m^3), and percentage increase in water productivity are shown in Table 6. As shown in the table, water input in using the DI was constant (410mm) for the three pilot sites, based on the S9 scheme. The results of the farmers' interview reveal that the average water input for Vintar, MMSU-Batac, and Enrile were 368.2mm, 365.00mm, and 367.80mm, respectively. With this data, the water savings is negative for all the pilot sites. This is primarily due to the existing practice of peanut farmers that they only irrigate once or up to three times irrigation throughout the growing season of peanut. Some farmers do not even irrigate. The FP water input range (365.00mm – 368.20mm), though applied 1-3 times only, maybe due to over-irrigation during the time of application.

Table 6. Water input (mm), water savings (mm), water productivity (kg/m^3) comparison between the DI and FP, including percentage increase in water productivity.

PILOT SITE	POD YIELD (MT ha^{-1}) Dry Season		WATER INPUT (mm)		WATER SAVINGS (mm)	WATER PRODUCTIVITY (kg/m3)		% INCREASE IN WATER PRODUCTIVITY
	DI	FP	DI	FP		DI	FP	
Vintar, Ilocos Nort	2.46	1.55	410.00	368.20	(41.80)	0.60	0.42	42.86
MMSU	1.94	1.14	410.00	365.00	(45.00)	0.47	0.31	51.61
Enrile, Cagayan	2.70	1.54	410.00	367.80	(42.20)	0.66	0.42	57.14
							*	
						0.58	0.38	50.54

*significant using a t-test at 5% level of significance

The limited irrigation application may explain why peanut farmers attained lower yield as compared to DI.

Results of the t-test between the water productivity between the DI and FP indicates a significant difference at 5% level of significance. Although water savings does not favor the DI, it is still more advantageous in terms of water productivity. The mean water productivity of DI was significantly higher (0.58 kg/m^3) as compared to the FP which was only 0.38 kg/m^3. On the average, the percentage increase in water productivity was 50.54%. This is little bit lower as compared to the target water productivity increase of 60% of this study. The mean pod yield of DI is higher than the FP. However, FP water input is lower than DI. This condition substantially affects the percentage increase in water productivity.

3.7 Comparative economics of drip and furrow irrigation systems

The study on the economics of drip irrigation versus furrow irrigation showed that the yield of peanut under DI was higher by about 0.84Tha^{-1} to 1.16 Tha^{-1}compared to the furrow irrigation (Table 7). However, DI is higher in fixed and operating costs by about 58.75% to 75.32%. Based on the computed ROI, production of peanut using farmers practice and DI system at Batac, Ilocos Norte is not economically feasible. This could be attributed to the soil texture, i.e., San Fernando Clay, which is not favorable for peanut production. For the other two pilot areas, using farmers, practice, municipality of Enrile (0.25) has higher computed ROI compared to Vintar (0.17). Using drip irrigation system, Enrile (0.26) has higher ROI compared to Vintar (0.17). In the long run, the profitability of DI could be improved through water savings and yield improvements. Yield increase could be attributed to more even application of water and less water stress.

Table 7. Cost and return analysis of producing peanut using DI and FP.

PARTICULARS	COST (PHP)					
	BATAC		ENRILE		VINTAR	
	FARMERS PRACTICE	DRIP IRRIGATION	FARMERS PRACTICE	DRIP IRRIGATION	FARMERS PRACTICE	DRIP IRRIGATION
A. Materials						
Seeds	11,200.00	11,200.00	11,200.00	11,200.00	11,200.00	11200.00
Organic fertilizers	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20000.00
Complete fertilizer	4,800.00	4,800.00	4,800.00	4,800.00	4,800.00	4800.00
Soluborax	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3000.00
Gasoline & oil	6,000.00		6,000.00		6,000.00	
Water pump	9,000.00		9,000.00		9,000.00	
Irrigation hose	940.00		940.00		940.00	
Electricity		2,000.00		2,000.00		2000.00
DI System		112,500.00		112,500.00		112,500.00
B. Labor						
Land Preparation	5,000.00	5,000.00	5,000.00	5,000.00	5,000.00	5000.00
Sowing/Fertilizer Application	5,000.00	5,000.00	6,800.00	6,800.00	5,000.00	5000.00
Spraying	250.00	250.00	340.00	340.00	250.00	250.00
Weeding	25,000.00	0.00	34,000.00	0.00	25,000.00	0.00
Irrigation	3,750.00	0.00	5,100.00	0.00	3,750.00	0.00
Harvesting	5,000.00	5,000.00	6,000.00	6,000.00	5,000.00	5000.00
Total Cost	98,940.00	168,750.00	112,180.00	171,640.00	98,940.00	168,750.00
C. Return						
Gross Income	90,800.00	155,120.00	123,200.00	216,000.00	123,920.00	196720.00
Net Income	-8,140.00	-13,630.00	11,02.00	44,360.00	24,980.00	27,970.00
ROI	-0.08	-0.08	0.10	0.26	0.25	0.17
Cost/ kg fruits	87.17	86.98	60.31	63.57	63.87	70.31

4 Conclusion

The study was able to generate and develop the best irrigation scheme (S9 @ 410mm) for peanut (PN 9) using drip irrigation technology through DSSAT simulation and field validation. Three pilot test farms showcasing the DI technology was established in (1) Brgy. Bago, Vintar, Ilocos Norte; (2) MMSU, Batac, Ilocos Norte; and (3) Brgy. Lanna, Enrile, Cagayan. Using the DI scheme, dry pod yield was increased from 1.59 MT ha^{-1} to 2.09 MT ha^{-1} (31.45%). This result is a little higher than the target increase in yield of 30%. On the other hand, water productivity was only increased by around 16% due to farmers' limited water application. In terms of seed quality based on seed size, DI and FP are comparable. Numerically, DI (35.70g) gave a better seed size as compared to FP (34.51g) during the dry season. The wet season seed quality of the two methods is also comparable, which is attributed to the limited use of the DI due to the availability of moisture from rainfall during this period.

Based on the economic analysis results, the use of DI technology was profitable through yield improvement with an ROI of 0.25. Water savings were not a factor in profitability due to under-irrigation by farmers.

It is recommended to evaluate the irrigation scheme developed in upscaled condition.

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