Drip Irrigation and Fertigation prospective:

A case study of cabbage growing at the ATC, Mukono district

Ministry of Water and Environment

APPROPRIATE TECHNOLOGY CENTRE
FOR WATER AND SANITATION

NETWAS Uganda

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Abstract

The Appropriate Technology Centre for water and sanitation carried out a study on cabbage growing using fertigation and drip irrigation. Before actual growing of the cabbages, a reconnaissance survey was carried out to establish the best type of crops to grow since the earlier irrigation trials had failed. The survey indicated that soils at ATC are not good since they were just heaped from the excavations done during construction of the centre. It thus suggested soil conditioning and application of fertilizers for better results. Cabbages and tomatoes were identified as some of the best crops to grow and thus we opted for cabbage.

The study aimed at assessing the feasibility of using urine as a fertilizer and drip irrigation technology to address food scarcity that has hit Uganda as a country of late. It employed a randomized control trial approach where five plots were established and subjected to different treatments and one of them acted as a control plot with no intervention to give a benchmark. Data was analyzed both qualitatively and quantitatively using ANoVA and Least Significant Difference. We sought for expertise of the Production Department, Mukono District who worked as back-steppers to the project.

The study revealed high rates of return for a farmer who chooses to practice drip irrigation and fertigation. This however gives best results with effective disease control. When a farmer chooses to either practice irrigation or apply fertilizers in isolation chances are clear herein that he/she will not maximize yields and might actually incur serious losses and, leaving the plants to the favour of nature is equally bad because it is very hard to break through and get yields that are competitive to the market. The microbial safety analysis indicated that one out of the five cabbages tested had salmonella. It is therefore important that, before taking the results of this study any further, ATC carries out a relatively larger scale study involving some farmers from the model village to be able to concretize the findings.

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1. INTRODUCTION

The Appropriate Technology Centre for water and sanitation (ATC) carried out an investigation on cabbage growing to comparatively examine the effectiveness of fertigation and drip irrigation for small scale farming. In Uganda today malnutrition is rampant yet people would easily access short gestation vegetables for dietary supplement as they make use of their small back yards for agriculture throughout the year. Agriculture has been tagged as unprofitable partly because soils are exhausted and rainfall is unreliable and thus people are resorting to other economic activities such as petty trade. There is urgent need to intervene with research to provide working solutions to boost agriculture as the back born of the country. To revitalize soil fertility, inorganic fertilizers have been on market for long but many farmers have not used them because they are expensive. Similarly, irrigation is not a new phenomenon but people have not taken up the practice because the common options affordable are labor intensive and the automated options are very expensive. ATC thus considered a study into low cost options of drip irrigation and use of organic fertilizers feasible to address the current gap in agriculture.

1.1. Reconnaissance survey

Soils differ in physical and chemical properties, ability to produce crops as well as management practices (Meyer et al, 2011). This therefore necessitates a soil test to find out how much of the nutrient will be plant-available and how much should be additionally applied in the form of mineral fertilizers to reach an expected crop yield (FAO, 2000). A reconnaissance survey was carried out in collaboration with Mukono District Agriculture Department to establish the type of crops that would grow best on the soils at the Appropriate Technology Centre. Samples were taken to NARO for qualitative analysis. The investigation found soils not very suitable to agriculture due to their poor chemistry and low SOM in respect to crop production.

Table 1: General soil conditions

Soil condition	Remark
Soil acidity content (PH)	6.0-6.8, very slightly acidic
Organic matter	High
Nitrogen	Adequate for some crops like tomatoes and water melon but inadequa for crops like cassava and banana,
Phosphorous	High
Potassium	Sufficient

The soil test results pointed to the observed hardness of the soil and were indicative of deviations from the expected natural (normal) proper soil B horizon and characteristics and hence suggestive of management interventions. Management interventions recommended were basically to condition the soils i.e., incorporation of compost in form of soil conditioner and earth boost. These were expected to decrease on the soil bulky density and increase soil particles aggregation. In addition, nitrogen inadequacy be addressed using poultry manure from layers' housing i.e., of at least six months old. The survey also recommended adequate mulching, use of micro nutrients at some experiments and good pests and disease management regimes.

The survey recommended that; high value vegetables such as cabbage and tomatoes that take a short gestation period can be grown given effective management practices.

1.2. Fertigation: using urine as fertilizers

Fertigation relates to application of fertilizers through the irrigation system (FAO, 2000). Herein, urine a form of organic fertilizers was applied to the crops using the fertigation approach. Urine is known to be a high quality and low cost fertilizer. It is rich in nitrogen, phosphorous and potassium (EcosanRes, 2008 & Westnet, 2008). Application of nitrogen rich urine in this experiment had a high potential to address nitrogen inadequacy identified in the reconnaissance survey. Several countries i.e., Japan, China, India, Sweden, Mexico, USA, Guatemal, Zimbabwe, Botswana, Ethiopia and Tanzania use urine as fertilizers and pesticide. Their experience shows that using urine boosts food production and income (Westnet, 2008).

Soils in Uganda have lost their fertility yet use of fertilizers is neglected. The recent in-country agriculture census indicated that farmers are not using inorganic fertilizers because they are too expensive besides lack of knowledge and limited access and only 26% of the farmers use organic fertilizers yet they can be accessed by almost all of them (Mbowa et al 2013). To ensure soil fertility and maximize yields, soils need to be replenished with nutrients and soil improving materials (EcosanRes, 2008). The current practice of just wasting urine ought to change i.e., promoting its use would provide better crop growth because of their potential to restock the environment where crops grow (BalmFord, 2007).

1.3. Drip irrigation using bucket kit system

Uganda's agriculture is largely dependent on the unpredictable rainfall (Gollin et al, 2010 & DWD, 1995). Coupled with soil exhaustion crop production is ultimately affected (NEMA, 2001). Bucket- kit drip- irrigation system can be used to support crop production throughout the year without relying on the uncertain rains. Bucket- kit drip- irrigation system is a micro irrigation system in which water flows by gravity i.e., drips into the soil through installed drip lines connected to the bucket reservoir (Wilson & Baue, 2005 and Sijali, 2001). The bucket is placed at 0.5 to 1 meter to provide the required pressure (ibid, 2001). This system is relatively cheap and easy to adopt by all the farmers regardless of their gender.

2. EXPERIMENTAL DESIGN

A garden was set up at the ATC on a plot size of 15m length and 6m width. The plot was partitioned into five to cater for the planned five experiments. Each experiment had two bands (A & B) subjected to specific conditions (table 2 below). One experiment was set up as a control and thus received no treatment throughout the experimental period.

Table 2: Plot description and treatment administered

Experimental design	Experiment number	Band	Description of Intervention	Time of intervention
Fertigation	1	A	Inorganic fertilizers; side dressing with earth boost, biosulphate , DAP mixed urea and MOP in 8ltrs of water, drip irrigation, DI grow	At transplanting and one week to head formation. At this stage, cabbages were one and two months old respectively.
		B	Organic fertilizers; 3ltrs of urine mixed in 8ltrs of water, DI grow, side dressing of earth boost, biosulphate, DAP	A week to head formation
Irrigation and manual fertilizer	2	A & B	Side dressing with inorganic fertilizers, DI grow	During transplanting and ahead of head formation
Irrigation and no fertilizer	3	A & B	DI grow and irrigation	DI grow at transplanting and every after two weeks and irrigation till two weeks after head formation
Fertilizer and no irrigation	4	A & B	DI grow, MOP, earth boost, DAP and biosulphate	DI at transplanting and every after two weeks, fertilizers at transplanting and one week ahead of head formation
No intervention	5	A & B	DI grow	At transplanting and every after two weeks

As shown in the table 2 above, each experiment had two bands. The two bands under experiment 1 (fertigation) were subjected to different conditions; i.e., in band A inorganic fertilizers were applied where as in band B organic fertilizers were applied. Nitrogen rich human urine rich was used as organic fertilizer.

All plots received DI grow growth booster i.e., an organic foliar. D.I grow is a pesticide as well as a fungicide rich in Nitrogen, Phosphorous, Potassium, Magnesium, Iron, Manganese, Copper, Zinc, Boron, Molybdenum and humic acid.

2.1. Experimental Stager

Stager activities included setting up a nursery bed, land preparation and transplanting.

2.1.1. Nursery bed

A nursery bed was prepared, seeds sown in rows at 1 centimeter spacing and a shallow depth since the seeds were small. The soil was mulched with dry grass and then thirty liters of water applied using a watering can to help in germination. It took 10 days for the seeds to germinate. After germination of the seeds, a shelter was raised to provide warmth and prevent scorching of the seedlings from the sun.

2.1.2. *Land preparation*

Land was prepared by digging to remove the weeds and raising bands for proper flow of water. 10 bands were prepared for the five experimental designs studied. Arrangements for experiments requiring irrigation were done; i.e., buckets fixed with drip lines were installed per respective experiment. The buckets were raised at a height of 1m above the ground to allow water flow by gravity. The drip lines had holes at an interval of 1ft. The entire garden had 10 bands and each experiment was carried out on two bands which were tagged accordingly.

2.1.3. *Transplanting*

After thirty days in the nursery, the seedlings were transplanted to the main garden. Five experiments were laid out each with two bands. The plant population was thirty two plants per experiment with eight plants per drip line for those that were subjected to irrigation.

2.1.4. *Irrigation*

Irrigation for the respective experimental bands was done throughout the growth period. The practice was that; the bucket is filled with water which would drip gradually in the demarcated experiments. At an early stage, irrigation was done twice a day- i.e., in the morning and evening till the plants developed roots after which; the practice was reduced to once in the morning every after two days. Irrigation for all the respective experiments stopped two weeks ahead of head formation. Irrigation was stopped because it was a rainy season. Besides, cabbages at that stage of growth do not require a lot of water.

2.1.5. *Fertilizer application*

As earlier pointed out, DI grow was applied to all experimental bands. 12mililitres of D.I Grow were mixed in 2 liters Knapsack sprayer for spraying in the nursery. DI was applied because the germinating seeds did not look healthy i.e. they were too thin to survive beyond 10days & their leaves were so light. DI grow was applied after germination and after transplanting to help plants easily absorb the required nutrients. This application based on advice from the prior soil testing which indicated that we need to apply fertilizers rich in NPK and other micro nutrients.

For the fertilizer no irrigation plot (experiment 4) and irrigation manual fertilizer plot (experiment 2) side dressing was done. Each cabbage planted was given 6g of DAP, 0.6g of urea, 0.6g of biosulphate, MOP (6g) and 1.2g of earth-boost. These were halved i.e., first dosage given at transplanting (5 weeks of growth) and the other towards head formation and that was around 10 weeks from sowing.

Fertigation plots received treatment at the same time with the rest of the plots that needed fertilizers i.e., at 5 and 10 weeks respectively. For inorganic fertilizers band, Side dressing was done for MOP (6g), earth-boost (1.2g) and biosulphate (0.6g) to avoid blockage of the emitters. The rest of fertilizers; DAP (6g) and urea (0.6g) were mixed in 8liters of water and emitted to soil through the drip irrigation system. The organic plot received urine at transplanting and towards head formation. Each time, 3liters of urine were mixed in 8liters of water and the plants received it through drip irrigation.

2.2. Analysis of result

Analysis of variation (ANoVA) was used to determine which treatment is better and how better. ANoVA was done by computing an F value which was compared to the tabular F values as recommended by Kwanchai and Arturo (1984). F values help in deducing the better treatment.

Table 3: Abbreviations used in ANoVA analysis

Abbreviation	Meaning	Abbreviation	Meaning
T	Number of treatments	R	Number of replication
	Total number of plots	d.o.f(t)	Treatment degree of freedom
d.o.f(r)	Replication degree of freedom	d.o.f(e)	Error degree of freedom
d.o.f(T)	Total degree of freedom	SS	Sum of Squares
Ms	Mean Square	R	Replication total
F Value	tests for significance of a treatment	X	Different yields
C.F	Correction Factor	Cv	Coefficient of Variation

For ANoVA the following equations are used;

$$\mathrm{d.o.f(t)} = \mathrm{t} - 1$$
$$\mathrm{d.o.f(r)} = \mathrm{r} - 1$$
$$\mathrm{d.o.f\,(T)} = \mathrm{n} - 1$$
$$\mathrm{d.o.f(e)} = \mathrm{d.o.f(T)} - \mathrm{d.o.f(t)} - \mathrm{d.o.f(r)}$$
$$\mathrm{Total\,SS} = \sum_{i=1}^{n} X^2 - \mathrm{C.F}$$
$$\mathrm{Replication\,SS} = \sum_{i=1}^{r} \frac{R^2}{t} - \mathrm{c.f}$$
$$\mathrm{Treatment\,SS} = \sum_{i-1}^{T} \frac{T^2}{r} - \mathrm{c.f}$$
$$\mathrm{Error\,SS} = \mathrm{Total\,SS} - \mathrm{Replication\,SS} - \mathrm{Treatment\,SS}$$
$$\mathrm{Treatment\,Ms} = \frac{\mathrm{Treatment\ \ SS}}{\mathrm{d.o.f(t)}}$$
$$\mathrm{Replication\,Ms} = \frac{\mathrm{Replication\ \ SS}}{\mathrm{d.o.f\,(r)}}$$

$$\mathrm{Error\,Ms} = \frac{\mathrm{Error\,SS}}{\mathrm{Error\,d.o.f}}$$

Least Significant Difference (LSD)

These are comparisons where a control was planned for before the start of the experiment. The control experiment was the no irrigation no fertilizer plot. The steps and equations for analysis are illustrated below;

- Compute the difference between the control mean and each of the treatment means. This is done as an absolute value.
- Compute the LSD value at α level of significance as,

$$LSD = t_{\propto}\frac{\sqrt{2S^2}}{r}$$

Where tα is tabular t

s^2 is the error mean square from the analysis of variation table.

2.3. Microbial safety analysis

Five samples i.e., three from organic fertilizer (fertigation –band B) and two from inorganic fertilizer experiment (fertigation Band A) were taken to the College of Agriculture and Environmental Sciences, Food Technology, Nutrition and Bio-Engineering Department Makerere University for laboratory analysis to establish the safety of these cabbages if they are to be eaten without boiling/cooking.

3. DISEASES AND CONTROL

3.1. Caterpillar attack

Cabbages were attacked by caterpillars twice throughout the growing period. The first attack was during the 8th week of growth when the caterpillars ate the leaves. The experimental bands were affected as illustrated in table 4 below.

Table 4: First caterpillar attack

Experimental design	Experiment number	Band	No. of cabbages attacked	Observations
Fertigation	1	A	8	Leaves eaten
		B	5	Leaves eaten
Irrigation and manual fertilizer	2	A	0	Healthy growth with dark green leaves
		B	0	Fair growth with pale green leaves
Irrigation and no fertilizer	3	A	0	Had dark green leaves
		B	5	Leaves had holes
Fertilizer and no irrigation	4	A	8	Had dark green leaves
		B	7	Had dark green leaves
No intervention	5	A	9	Had dark green leaves
		B	0	Pale green leaves

Treatment was administered to all bands. 28mililitres of Troban were applied basing on the defoliating dosage. However, this was an under calculation as 52 milliliters had to be applied. After application, the caterpillars fled but two weeks after, the cabbages got the second caterpillar attack. This necessitated application of rocket EC where ten milliliters were mixed in a five liters knapsack. One day after administering the treatment, 25 milliliters of D.I grow were applied. Since cabbages had many leaves, DI grow was mixed in the knapsack twice.

The second caterpillar attack occurred during the twelfth week of growth. The attack was uneven in the different experiments and mainly affected experiment 4 and 5 (table 5 below).

Table 5: Second caterpillar attack

Experimental design	Experime nt number	Band	No. of cabbages attacked	Completely destroyed cabbages
Fertigation	1	A	0	0
		B	1	0
Irrigation and amnual fertilizer	2	A	0	**0**
		B	0	**0**
Irrigation and no fertilizer	3	A	0	0
		B	0	0
Fertilizer and no irrigation	4	A	5	1
		B	0	0
No intervention	5	A	4	2
		B	0	0

There was easy disease spillover from the control experiment to other experiments due to the fact that plots were located next to each other. Experiment 1 (Fertigation) had the healthiest cabbages and experiment 5 (No intervention) exhibited very slow growth.

3.2. Wilting

Cabbages experienced wilting in the 10th week of growth. One cabbage from experiment 4 (fertilizer no irrigation plot) wilted. The possible causes could have been placing fertilizers too close to the root zone. That one cabbage was uprooted and thrown away. Wilting was only experienced in one experiment.

3.3. Other challenges

Weather invariability posed a challenge whereby upon scheduling, irrigation was to be done for the whole of the growing season apart from the month of April. However, the rains started in late march. This resulted into leaching of the nutrients meaning that the irrigation no fertilizer and the control plants had to develop stronger roots to get the required nutrients. No wonder during the first harvest, the control had only four cabbages that had formed heads with only two close to maturity. These were used for analysis.

4. RESULTS

4.1. Head formation

Head formation varied from one experiment to another with the no intervention experiment having the poorest head formation (Table 6 below).

Table 6: Formation of heads in the respective experiments

Experiment Number	Treatment	Observation
1	Fertigation	Head formation was very good i.e., all the 32 cabbages formed heads by the 11th week and growth was steady.
2	Fertilizer application with irrigation;	Band A had 14 cabbages with heads formed by the 11th week. 2 cabbages in this band took relatively longer to form heads. Band B of the same experiment had all cabbages with heads by the 11th week.
3	Irrigation no fertilizer	Only 8 cabbages out of 16 in band A had formed heads by week 11 and band B had only 6 cabbages. All the remaining cabbages in both bands of the experiment formed heads later after about 13 weeks.
4	Fertilizers and no irrigation	By the 11th week, band A had 10 and band B had 12 cabbages that had successfully formed heads. The rest of the cabbages in both bands of this experiment formed heads after week 13.
5	No intervention	2 cabbages in band A and one in band B had formed heads by the 11th week. The rest took extra three weeks to form the heads. 3 cabbages from band A and 4 from band B completely failed to form heads.

The experiment subjected to fertigation had perfect head formation and were growing fast compared to the rest of the experiments. In experiments 3 and 5, head formation took longer due to the fact that plants were not given fertilizers so they had to first develop deeper roots to get nutrients.

Results in table 6 indicate that irrigation catalyzes faster head formation because, in addition to fertilizers, water is needed for photosynthesis. The experiments 1 and 2 had dark green leaves compared to experiment 4 and 5 that had rather pale green leaves because the former had enough water and fertilizers.

4.1.1. Impact of caterpillar attack on head formation

The study revealed that even the cabbages that are infected by caterpillars if treated on time can form heads though they take relatively longer time. In this study, such cabbages took 2-3 weeks more to form heads. Therefore even when cabbages are infected by caterpillars but sprayed, they can still yield results. There was evidence of disease spill over from control plot to the rest of the plots. Comparably, this greatly affected the fertilizer no irrigation plot which was next to the control plot.

4.1.2. Abnormal head formation

In experiment 3 (irrigation, no fertilizer), there were some anomalies particularly in band A i.e., a cabbage formed seven heads at once. Speculatively, this can be attributed to the fact that somehow some where the middle head got a problem during head formation. To stop other heads from consuming the nutrients, six were removed and the plant was left with only one head.

4.2. Harvesting

The cabbages took about 3.5months to mature. Harvesting was done four times in bits. On 6th May 2013 the first bunch of cabbages was harvested. At most, two cabbages were harvested per band for qualitative analysis except for the control plot where cabbages were not ready for harvesting. The second harvesting was done on 21st May 2013 and still by this time; cabbages in the control plot were not ready for harvesting. The third round of harvesting was done on the 21st June 2013 and still no cabbage was harvested from the control plots. Cabbages from the control plots were harvested in the fourth round on 9thJuly 2013.

Table 7: Harvested cabbage weights per band

Intervention		Weight (grams)																Total harvest (grams)	Average Weight (grams)
Fertigation	Band A	3381	1662	3249	3414	2566	1837	1542	2443	3214	2447	2860	3215	2443	2113	3215	3058	42659	**2666.19**
	Band B	2375	2222	2571	2827	2891	2373	3185	2579	2623	1849	3171	2942	2112			4238	37958	**2593.85**
Irrigation manual fertilizer	Band A	3272	3228	2497	2615	2437	2553	2708	2895	2412							2873	27490	**2735.22**
	Band B	2793	2531	2079	2024	2131	1243	2431									2488	17720	**2176.00**
Irrigation no Fertilizer	Band A	1967	1748	2139	2165	1838	1977										2786	14620	**1972.33**
	Band B	2118	1985	2017	2311	365											1932	10728	**1759.20**
Fertilizer no irrigation	B a n d A	1853	1367	1947	1814	2282	1031	664	458								1180	12596	**1427.00**
	B a n d B	1856	1628	1145	1375	1406											1925	9335	**1482.00**
No intervention	B a n d A	843	720	331	895	906	577	506	714	405							1131	7028	**655.22**
	B a n d B	910	631	552	506	467	1083	572	1135								1257	7113	**732.00**

As observed in table 7 above, missing results are attributed to the fact that the cabbages were not harvested most especially because they never matured. Apparently the inorganic plot had 100% yields, with biggest cabbage weighing 3058g and the smallest 1542g. The organic plot (band B) where urine was used had only two cabbages failing to mature; the heaviest cabbage weighed 4238g and the least weighed 1849g. Compared to the control plot, the biggest cabbage weighed 1083g and the smallest 405g. It is apparent that, despite the fact that the fertigation plot (band B) where urine was used did not register 100% output as was the case with the plot where inorganic fertilizers were used, the yields were very good comparing with the control plot that registered 41% output.

Although table 7 above indicates a big variation between yields as per respective treatment with fertigation plots having the best output, analysis of results was done with ANoVA to scientifically determine the significance of treatment.

Table 8: ANoVA analysis results

Sources of variation	Degree of freedom	Sum of Squares	Mean Square	Computed F	Tabular F	
Treatment	4	1003682939	250920734.9	0.46	0.05	0.01
Replication	1	46392852.1	46392852.1		6.39	15.52
Experimental error	4	2172810481	543202620.4			
Total	9	3222886273				

The ANoVA analysis results indicate that the treatment was not significant. ANoVA could not establish the difference between treatments because it is a general analysis that looks at treatments in lumpsum and not one intervention at a time. Therefore this justified the need for a more detailed analysis using the Least Significant Difference.

Table 9: Least Significance Difference analysis

Intervention		Weight (grams)																Total harvest (grams)	Average Weight (grams)
Fertigation	Band A	3381	1662	3249	3414	2566	1837	1542	2443	3214	2447	2860	3215	2443	2113	3215	3058	42659	**2666.19**
	Band B	2375	2222	2571	2827	2891	2373	3185	2579	2623	1849	3171	2942	2112			4238	37958	**2593.85**
Irrigation manual fertilizer	Band A	3272	3228	2497	2615	2437	2553	2708	2895	2412							2873	27490	**2735.22**
	Band B	2793	2531	2079	2024	2131	1243	2431									2488	17720	**2176.00**
Irrigation no Fertilizer	Band A	1967	1748	2139	2165	1838	1977										2786	14620	**1972.33**
	Band B	2118	1985	2017	2311	365											1932	10728	**1759.20**
Fertilizer no irrigation	Band A	1853	1367	1947	1814	2282	1031	664	458								1180	12596	**1427.00**
	Band B	1856	1628	1145	1375	1406											1925	9335	**1482.00**
No intervention	Band A	843	720	331	895	906	577	506	714	405							1131	7028	**655.22**
	Band B	910	631	552	506	467	1083	572	1135								1257	7113	**732.00**

T values- 1046.13: 735

Comparing deviations in table 9 with the tabular t values which were 1046.13 at 1 % and 735 at 5% level of significance, it is observed that all treatments were significantly different from the control. This implies that intervention by i.e., applying fertilizers whether organic or inorganic and irrigation boosts productivity and eventual crop yields.

4.2.1 Microbial safety of cabbages subjected to fertigation

Table 10: Microbial safety of cabbage subjected to fertigation

Sample No.	Description	Aerobic plate count (CFU/g)*	Total Coliforms (CFU/g)	Faecal Coliforms (CFU/g)	E.Coli (FCU/g)	Salmonella ssp (in 25g)
1	Organic fertilizer	6.5 x 10^4	4.5 x 10^3	2.4 x 10^2	9.0 x 10^1	Negative
2	Organic fertilizer	4.5 x 10^4	2.0 x 10^1	1.0 x 10^1	<10	**Positive**
3	Organic fertilizer	1.2 x 10^4	4 x 10^1	<10	<10	Negative
4	Inorganic fertilizer	1.2 x 10^5	2.5 x 10^3	5.0 x 10^2	5.0 x 10^1	Negative
5	Inorganic fertilizer	1.2 x 10^5	5.5 x 10^1	1.0 x 10^1	1.0 x 10^1	Negative
Remarks (Based on guidelines for ready-to-eat vegetables		Ranges of 10^4 -10^7 were reported	Counts of up to 10^4 CFU/g were reported	<20CFU/g: Satisfactory 20 to <100 CFU/g: Acceptable if >100 CFU/g: Unacceptable	<100 CFU/g: Satisfactory If 2/5 samples are within 100 – 1000 CFU/g: Acceptable If >100 CFU/g: Unacceptable	Satisfactory if absent in 25g

* CFU/g = colony forming units per gram of sample

From table 10 above, aerobic plate counts were in normal range for ready to eat vegetables. Total Coliforms ranged between 2.0 x 101- 4.5 x 103 CFU/g. Total Coliforms were reported at levels of up to 104CFU/g in ready-to-eat vegetable mixes. Count of faecal coliforms was unacceptable for some sampled cabbages (table 10). E.Coli counts were within acceptable limits for ready-to-eat vegetables. One of the cabbages under organic fertilizer application contained Salmonella spp. Presence of Salmonella ssp in 25g of a sample obtained from among 5 units is sufficient to make the batch unacceptable. These results justified the need to repeat the experiment with emphasis on establishing the possible cause of salmonella ssp in one of the cabbage samples.

4.3. Cost analysis

Table 11 and 12 below give a detail analysis of costs that a farmer would incur and the anticipated profits, it is apparent that the farmers would make more profits by apply inorganic fertilizers and drip irrigation. Using urine and drip irrigation is equally good given that urine is acquired free of charge. In plots where fertilizers were applied without irrigation and where irrigation was done without fertilizers, the returns were in negatives implying that the farmer would incur losses. It is important to note however that; expenditure on irrigation systems is a one off investment that would not keep recurring and this would eventually bring the expenditures down to the advantage of the farmer.

Table 11: Farm inputs in Uganda shillings

In put	Fertigation		Irrigation manual		Irrigation no fertilizer		Fertilizer no irrigation		Control	
	Band A	Band B	Band A	Band B	Band A	Band B	Band A	Band B	Band A	Band B
Fertilizers	3,850		3,850	3,850			3,850	3,850		
Labour	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Irrigation systems	26,250	26,250	26,250	26,250	26,250	26,250				
Total expenditure	35,100	31,250	35,100	35,100	31,250	31,250	8,850	8,850	5,000	5,000

Table 12: Projected income and profit in Uganda shillings

Intervention	Planted cabbages	Actual yields	Average weight	Market price	Expenditure	Projected income	Projected profit
Fertigation inorganic	16	16	2666.19	2,962	35,100	47,399	**12,299**
Organic fertigation	16	14	2593.85	2,882	31,250	40,349	**9,099**
Irrigation, manual fertilizer, band 1	16	12	2735.22	3,039	35,100	36,470	**1,370**
Irrigation, manual fertilizer, band 2	16	8	2176	2,418	35,100	19,342	**-15,758**
irrigation, no fertilizer, band 1	16	7	1972.33	2,191	31,250	15,340	**-15,910**
irrigation, no fertilizer, band 2	16	5	1759.2	1,955	31,250	9,773	**-21,477**
Fertilizer, no irrigation, band 1	16	8	1427	1,586	8,850	12,684	**3,834**
Fertilizer, no irrigation, band 2	16	5	1482	1,647	8,850	8,233	**-617**
No irrigation, no fertilizer, band 1	16	10	655.22	728	5,000	7,280	2,280
No irrigation, no fertilizer, band 2	16	9	732	813	5,000	7,320	2,320

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Practically, it is a worth investment for an ordinary Ugandan farmer to carry out farming using drip irrigation technology and urine as a source of manure if he/she is to break through with farming. The technology relies on materials locally available i.e., plastic backets and after set up, it does not require any specialized skills. All that is required is a person manually filling the buckets with water on schedule. Using the technology for the first time, returns might be inadquate because of the costs incured on installing the irrigation system however they can be maximized the following periods keeping in mind that the drip irrigation kit is purchased once and works for a couple of seasons. It is apparent that applying urine in isolation of irrigation or irrigation without fertigation would not guarantee best results. It is thus important that the two i.e., irrigation and fertigation are applied simultaneously. These two interventions are still not enough to stand alone and give best farm results. There is need to control diseases which would attack the plant at any time during growth period as evidenced in this experiment. However, this was a small project to draw conclusive conclusions.

5.2. Recommendations

ATC should carry out a bigger project to concretize the findings to create evidence especially on safety of products and viability of technology for promotion among the local farming communities. Doing the experiment in collaboration with farmers in the model village will give a breadth of results.

ATC should also carry out laboratory tests on urine to ascertain its safety before application as fertilizers.

For subsequent experiments, Plots need not to be located next to each other because in the event of disease attack it easily spread over. There is need to provide for buffer zones between experiments.


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