Techno-economic comparison of hydroponic cultivation system under polyhouse in Maharashtra.

by

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January 21th 2020,

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Preface

I am following a European Engineer degree in plant production and high-tech horticulture. I worked for four months in the Centre of Excellence of KVK Baramati in the state of Maharashtra, India. I worked under the wings of HollandDoor, which is an independent company that aims to share agricultural knowledge between India and the Netherlands. KVK is a school farmer that links scientific field with the practical by providing training and lecture to local farmers. My objective was to bring solutions to the KVK's high-tech polyhouse which is facing challenges. I wanted to focus my work on water management in semi-arid climate, thanks to my previous work experience in the Nile Delta dealing with Climate Smart Agriculture and salinity. My objectives were to find the best irrigation systems in polyhouse, adapted to the needs and the abilities of local farmers, but I decided to change my objectives to a more realistic project, a techno-economic comparison between two Indian hydroponic system. This rapport was written to bring advices to governmental instances and farm school advisors in order for them to help farmers to build adapted and sustainable agricultural systems.

Acknowledgements

My great thanks to the Indian people and the member of the Center of Excellence of KVK, I worked with, who have led my thinking on the Indian farmer interest.

I would like to express my thank to Mrs Ineke Van Meggelen for her help and coaching all along my work, as well as for giving time and showing interest on my project.

A special thank goes to Mrs Chloé Durot and Mr Ganesh from Jain Irrigation, for helping me out to complete the project, by exchanging ideas and opinions and making it possible by sharing accurate information.

At last but not least, I want to thank my family who treasured me for my work and encouraged me and finally to God who made all the things possible for me till the end.

Summary

India is facing issues with the availability of vegetables and with water quality and availability especially in Maharashtra where the availability of water depends on the season. Drought years can have a severe impact on the agriculture production. The polyhouse can be a solution to increase the production of vegetable while decreasing the use of land and water. In Maharashtra, there are two main types of fertigation systems for soil-less cultivation under crop protection: the high-tech automated irrigation system and the low-tech dosing pump system which is a manual way to fertigate accurately the cultivation. The objectives of this study were to find which one of these systems, dosing pump or automation, is the most adapted to the local context of Maharashtra in terms of investment and efficiency. The topic deals with a comparison between two soil-less system, automated irrigation system and dosing pump technology. A simulation of the installation of the two systems was carried out in order to compare costs. The automated system was found more expensive than the dosing pump system, but allowing an automatic control of the EC and pH of the nutrient solution and irrigating a larger area. Automated fertigation is ten times more expensive than dosing pump so it is required for higher productivity high added value vegetable production and large production on monoculture, when dosing pump, less expensive is more adapted to smaller field crops and poly-culture systems. As it is less expensive, it is possible to use more than one pump on the same farm. In order to obtain an inclusive development in agriculture and to limit the risks, it is required to enhance a dynamic of cooperative work between farmers.

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Chapter 1: Introduction

India contributes to about 13% of the world vegetable production (Samantaray, Prusty, & Raj, 2016) and nearly 70% of the total vegetable production is consumed by the urban and the semi-urban market (Sahu, 2004). The main consumers are from the upper and middle-income group, which indicates a sporadic vegetable consumption in India (Attavar, 2000).

The cultivation of vegetables in India is mainly restricted to open field. The summer cultivation in open fields in Maharashtra is possible due to the absence of pests and diseases. However, the incidence of disease is higher during the rainy season (Singh, Kumar, & Sirohi, 2007). It is why the trend is to grow vegetable under crop protection.

With the increase of the word population, from 7.0 billion to 9.5 billion (Tembe, Khan, & Acharekar, 2018), attention is being given to reduce land and water use and to produce more sustainably. Availability of total renewable water per Indian is going to decline from 2,133 m^3 in 1998 to 1,289 m^3 in 2050, and today about 83% of the freshwater resources in India are currently being used for agriculture (Pandey et al cited by Gupta, Chattoo, & Singh, 2015). Between 1901 and 2010, more than 17 years have been recorded as drought years (Udmale, Ichikawa, Kiem, & Panda, 2014). Udmale (2014) declares that the 2012 drought is responsible of the 0.5% decrease of the Indian gross domestic product. Baramati city receives about 400 to 430 millimetres of rain and 85% from the 4-month-rain season (June-September) till October (Murumkar & Arya, 2014), which it is not enough to allow a year-round vegetable cropping without efficient irrigation system.

Hydroponic cultivation saves 20 times more water than soil cultivation (Sardare & Admane, 2013). Cultivation in polyhouse in closed hydroponic systems can reduce the pollution of water resources, and contributes to a reduction in water and fertilizer consumption (Carmassi et al.; Bar-Yosef cited by Grewal, Maheshwari, & Parks, 2011). In 2011, only 2 000 ha of vegetable crops were produced under polyhouse (Sabir & Singh, 2013). Crop protection under hydroponic cultivation is an opportunity to increase the Indian vegetable production thanks to its high productivity, its better quality and its all the year-round production.

In Maharashtra, soil-less system is usually made on coco-peats substrate with stack dripper, and some time with a more or less high-tech drain system. Two main systems are currently in used in India for the fertigation part, first system is the automated irrigation and the second is the dosing pump.

Automation

Nutricare© is an Indian Automated Irrigation System (AIS) *(schema appendix 1)* which allows to control the fertigation according to the plant requirement. This system is the most common in India and is designed by an Indian company. It allows adjusting:

– a sustainable irrigation for the crop (max 2 ha) with a pressure sustaining valves and specific drippers; an accurate fertigation concentration using adjustable flow meter,

– pH and electric conductivity sensors;

– and the timing of fertigation using a computer according to the plant requirement.

The operating system follows two main steps. Water is pumped from the well by the first pump and go through the filter, then it is mixed with a diluted nutrition solution, a part of the flow is going directly on the crop, while the other part is up-taken by the mixing booster pump to be mixed with high concentration solution from A and B tanks with mean of adjustable flowmeter. The mixing booster pump uptakes the concentrated solution and adds it in the water flow. EC/pH measurements are taken from irrigation water and from up-taken water of the booster pump to avoid any fluctuation of irrigation fertigation. This system is monitored by computer by the mean of a controller. It determines the time of irrigation and the concentration of the nutrients in the irrigation system.

This technology uses two fertilizer tanks named A and B, the most common in India and allows a more accurate fertigation than a 5-tank irrigation system. Some fertilizers are known to interact together and make salt deposit in the mother solutions, it is why they are separated into two classes in A and B, because salt can damage the irrigation system and clogged the drippers. However, in low concentration level there is no interaction with ions; this system is designed to keep the salt in the soluble state.

The acid tank aims to control the pH and to avoid the increase more than required. If the solution is not enough acid, the controller will relay the information to the computer and actions will be taken in order to balance the pH.

Dosing pump

The dosing pump is a simpler system which could be set up by an Indian farmer on his own with accurate explanations. Dosing pump *(Schema Appendix 2)*, the most common system in India, is a low-cost system that allows having an accurate amount of fertilizer in the irrigation water. It uses water pressure from the pump to dose a proportional amount of fertilizer. Water from the well is up-taken by the pump (A). If B valve is open and C valve is closed the water will go to the cultivation without any fertilizer. In the opposite situation, the water will go to the dosing pump (D) which will dose a precise amount of fertilizer (orange) from the tank (F) using the water pressure from the A pump. The potentiometer (E) will adjust the dosage of fertilizer solution up-taken from the fertilizer tank. It needs a filter unit (screen and sand filter for Baramati) and one regular tank adapted for low concentration fertilizer.

Due to the fact that it is not an AIS, the dosing pump system has to be started and stopped manually. The mother solution inside the fertilizer tank will be less concentrated to avoid salt deposit therefore the tank will be bigger. Other technologies which are not in used in India allow to synchronise more than one dosing pump to use the A & B tank technology.

It would be also possible to consider the use of more than one dosing pump in a farm to fertigate more than one crop as the cost is less expensive than the AIS and the size of facility is reduced.

In both systems, the proportion of each nutrient in the solution depends on the mother solution made by the farmer. However, the concentration of the nutrient solution in the irrigation water depends on the setting of the fertigation system. In the case of the dosing pump, there is no automatic control to regulate the concentration of nutrient inside the irrigation water, and the accuracy depends on how the farmer adjusted the dosing pump and made the proper nutrient solution. The dosing pump system is very sensitive and needs to be checked each time the farmer is changing the solution. However, the pH is sustainable, which is why no acid tank is required for the dosing pump. In the automated system, the EC will give to the farmer the ability to have a sustainable concentration of solution for all the plant. The pH will also be regulated to avoid any fluctuation of acidity on the irrigation water which will improve the crop's quality and the yield.

The efficiency and accuracy of the irrigation technology under crop protection are key factors of the growing process. However, due to the lack of development of soil-less cultivation in Maharashtra, it is not known which irrigation system is the most adapted to Maharashtrian farmers in terms of economy and technics. This is why the following question has been formulated:

- ➔ **Which one of these models, dosing pump and automation, is the most adapted to the Maharashtrian context in terms of investment and efficiency?**

The investment and efficiency of these soil-less technologies have to be economically compared in Maharashtra. This information is required to know if these systems are adapted to the Maharashtrian context. This study aims to make a techno-economic comparison between two soil-less irrigation technologies: AIS and dosing pump. The analysis will only consider the system installation, the irrigation labour, the amortisation, the maintenance, and the depreciation of each system. It is assumed that the running cost of the crop cultivation will be the same.

To be able to answer these objectives, the following questions have been formulated:

What are the technical characteristics to be considered when installing each system?

What is the investment amount required for each irrigation system?

What is the depreciation and maintenance cost of each system?

What are the differences in efficiency for the irrigation system?

Chapter 2: Methodology

1 Technical characteristics of the two systems

All the technical elements required for the installation of the two systems were listed with the help of irrigation professionals in order to build two coherent systems that can be adapted to different production areas. Schemas of the two systems have been made to visualize the irrigation system.

2 Investment costs

The initial cost of each irrigation system was calculated based on the commercial available price. Company representative, farmers and staff from KVK’s Centre of Excellence (CoE) were interviewed to find information on the installation, the different elements required for the implementation of the systems and the price of both systems. The current irrigation system of the CoE was analysed to have a better overview of the irrigation technology. A 12% Maharashtrian VAT has been added to the price of all items. The Government of India is providing subsidies on the drip pipe at the rate of 75%.

3 Maintenance & depreciation costs

The maintenance costs of the models have been estimated. The objective was to base the economic analysis on accurate and complete data to obtain a clear standard of investment for Indian farmers. Depreciation has been estimated according to the selling price of the different items and their lifespan with the help from irrigation experts from local companies and the CoE.

4 Analysis of efficiency

• Energy efficiency

Electricity and Internet are required for the use of the *Nutricare©* technology. Information about Internet cost has been found on the base of the market price with the references of AIS. The electricity cost was taken from an example of an AIS used in the CoE.

Chapter 3: Results

The research aims to compare the two systems in term of cost and efficiency. Initial investment was calculated, by considering all the necessary elements of each system. Energy, internet and labour requirement were also compared by taking into consideration both system' specificities and requirements. Labour fertilizer and water were not comparable.

1 Technical characteristics of the two systems

The AIS was built according to the following schema. A room is required to protect the electronic component of the system. In this room should be gathered, the computer and the controller while the other items can remain outside with a protection against the weather.

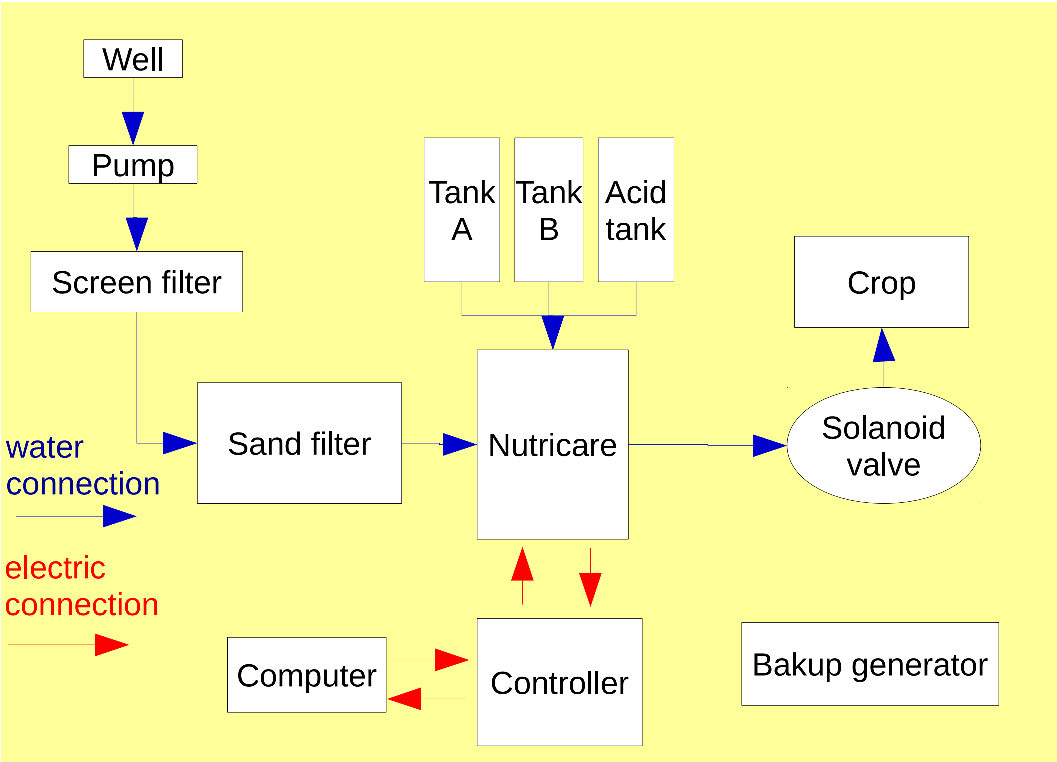

Figure 1: Schema of elements required for the AIS

A generator is needed for the irrigation because it insures electricity at any moment during possible electricity cuts.

The following scheme illustrate the different elements that were considered in the cost calculation of the dosing pump system. No room, nor electric device are required for this installation, only protections are required.

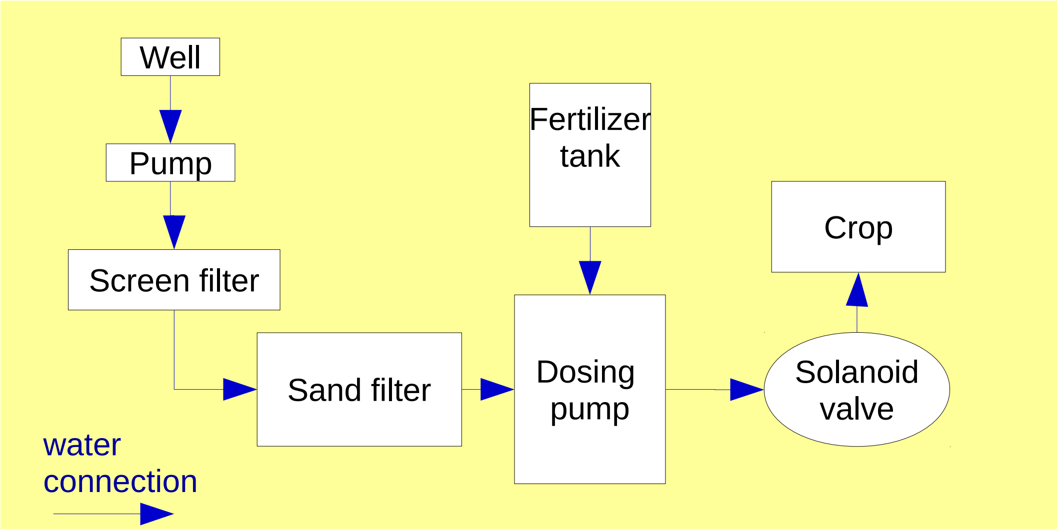

Figure 2: Schema of the element used for the dosing pump system

2 Cost of installing

The following table shows the initial investment for irrigation unit on both systems (*cost details on appendix III-V, p. 18-20*), taking into account the installing cost and the costs of irrigation elements. It takes into consideration the subsidies which are available on the drip holes and all the taxes that are 12% of VAT.

Table 1: Installing cost of both irrigation systems in rupees

Initial investment name	AIS	Dosing pump
Cost independent of growing area	₹1 026 222	₹94 270
Cost dependent of growing area rps/m²	₹73	₹73

The filtration unit cost was calculated based on the requirement on the specificity of the unit, according to the local quality of irrigation water in the Baramati area. It is composed of a screen filter and a sand filter adapted to the capacity requirement of the pumping system. The screen filter is needed in Maharashtra, due to the presence of elements in the irrigation water that can damage the irrigation system. Water in Maharashtra is mainly brought by the irrigation canal, this water can be unclear.

The cost of the AIS was calculated on the base of the economical context of Maharashtra. The calculation of the Investment cost was based on 4 plants per line meter and every bed separated by

1,5 meter which give a plant density of about 2,7 plant/m² as commonly done by Maharashtrian farmers. The same drip and drain system is used for both models, and it includes stack drippers, and plastic gutter over a soil bed with an underground irrigation water evacuation. The cost of the well was not taken into account as it is not specific to the soil-less cropping system in a farm.

3 Depreciation and maintenance cost of each system

For the depreciation, the salvage of each cost was taken at zero as it is assumed that the Indian farmers will use the components of the irrigation system until it has to be replaced. The maintenance has been determined according to the complexity and the life span of each part of the irrigation system. The maintenance was calculated mainly on the irrigation unit. The cleaning of salt residue was not taken into account.

Table 2: Depreciation and maintenance of the systems in rupees

Yearly irrigation fix costs	AIS	Dosing pump
Depreciation	₹111 883	₹22 894
Yearly maintenance	₹4 551	₹421
Total	₹ 62 323	₹ 23 316

4 Efficiency of both systems

Electricity & Internet

Electricity was determined with the help of CoE’s polyhouse manager who use Nutricare technology while Internet cost has been calculated by taking in account the yearly cost of an Indian internet subscription.

Table 3: Electricity and Internet cost for the systems in rupees

Name of expenditure	Nutricare	Dosing pump
Energy*	₹22 000	₹11000
Internet	₹2 000	₹0
Total	₹20 000	₹11000

* based of the example of tomato production

Water and nutrient

The two irrigation systems used on the same type of polyhouse with the same soil-less system and the same drip system required similar nutrient and water as the climate condition are similar. Nutricare allows a more accurate fertigation on plant, which can in practice reduce the waste of water and nutrients. The cost of water is difficult to determine as there is no clear legislation in Baramati, some farmers do not use water meter which make impossible the calculation of water used on field.

Labour

According to an Indian representative from crop protection company, there is no difference in the need of labour for the two systems, but the organisation of the labour is different. In this example labours related to irrigation was not taken into account as it was not possible to establish accurately the number of hours spent only on the irrigation process. It can be assumed that the irrigation management is made by the owner himself as it needs experience and qualifications. The preparation of the nutrient solution needs to be adjusted according to the requirements of the crop.

Chapter 4: Discussion of results

The aim of this study was to make a techno economic comparison between two types of irrigation and fertigation systems available for soil-less cultivation and to determine in which context they can be adapted.

Technical characteristics

All systems were set-up according to the Maharashtrian context, using local technologies with advises from Maharashtrian experts.

The system was selected for Baramati and its region with the help of agronomists from the same region who know the context of Maharashtrian farming under crop protection. It would have given some more extra information to compare the different irrigation system first by visiting different farms to have a clear overview of the situation and to see what are the specific challenges and to collect feedbacks and point of view from the different farmers.

Investment cost

All costs were available for the study. All the elements required were given. The cost of installation is based on Indian irrigation companies, which means that the total cost can vary according to the context.

To have a better view of the system, it would have been better to compare with farmer invoices. It was possible to compare the different investment made by the CoE of KVK but the invoices were not complete and did not give a clear overview of the installation and its cost.

The Nutricare system was 1,5 time more expensive than expected. It could be due to the estimation of the installation which can have fluctuation or it can be due to the fact that the installation is done by a company and family labour is not deducted.

Depreciation and maintenance

The main point is the lifespan of each items which was estimated by irrigation expert. It is assumed in the study, that all elements are used until the end of their estimated lifespan because Maharashtrian are more likely to use as much as possible elements from the irrigation system to reduce expenses. The maintenance has been calculated as 0,5% of the cost of items for all the irrigation unit (pump automation, and filter unit) but the maintenance on items on the field has not been taken in account because of its short life.

As it is difficult to estimate the irrigation maintenance, for each system the rate of 0,5% of the total cost the important items such as the *Nutricare* module or pumps were used, to estimate the maintenance cost. However, maintenance fees were not completely taken into account by Maharashtrian which makes more complicated to estimate it.

Efficiency

Due to a lack of practical example and due to the difficulties to estimate the labour cost, it was not possible to determine the difference of labour between the two systems. However, it can be assumed that the use of automated system is more efficient for the labour as the irrigation can easily be schedule and the concentration of solution inside the tank is higher which save time from refilling it. Electricity has been estimated on the base of what is currently facing the Centre of Excellence of Baramati and not on irrigation company data. For now, no study has been made to compare the fertilizer and the water used efficiency in India between both systems.

Most of the economic data are from the same company. The irrigation set-up is theoretical, huge fluctuation of cost can occur in the setting of the system due to the different context of the local environment. The absence of labour information regarding the two system shows one limit of the economic study.

Chapter 5: Conclusions and recommendations

1 Conclusion

This study aimed at making an techno-economic comparison between two fertigation/irrigation technology available in India on soil-less cultivation to find in which context they are the most adapted.

The AIS is the most complex system as it is automated and need the use of power sources, computer and facility. The amount of investment is part due to the technical component of the irrigation system and part due to the price of unit installation which it is more technical and take more time than dosing pump. Dosing pump is a simple system that needs less investment than automation system. The AIS monitors and regulates EC, pH, and pressure in the irrigation system.

The automated irrigation system is 10 time more expensive than dosing pump due to the complexity of system and the time of settlement.

Depreciation and maintenance are more expensive in the AIS (3 time more expensive than dosing pump) because the AIS is more complex and need more knowledge and time to maintain it. The cost of depreciation is mainly due to the initial cost being expensive even if the lifespan is longer. The dosing pump is a simpler system and is more likely to be maintain by the farmer himself which can decrease the amount of the maintenance and will give more autonomy to the farmer.

No studies have shown, for now, difference on water and fertilizer use efficiency between both systems. However, it can be expected some differences in it as well as labour due to the difference of accuracy of each system and due to the difference of operating autonomy of each system.

The AIS should be used on high value-added crop or large area of cultivation to increase the gross return and decrease the cost per square meter of the initial cost, because of its high initial and operating cost. However, most of the polyhouse in Maharashtra are about one thousand square meter which is not enough for growing with an AIS. The dosing pump system required less investment conducing the farmer to use it in a smaller polyhouse area. The risk of investing in dosing pump is reduce compared to automated irrigation systems because the time of amortisation is reduced and so is the risk of over production. The technicity of each system needs a different level of understanding of the irrigation system. The automated irrigation system is designed to control the irrigation system and to schedule it, however it needs knowledge to use the computer and to understand the irrigation system, on the other hand the dosing pump is easier to use but needs from the farmer, rigour on the schedule and on the settings. The farmer will have to do his own pH and EC measurement for the water irrigation control. The Maharashtrian agriculture is in development and most of the farmers who are growing vegetable under crop protection are cultivating them on soil as it requires less investment. So, the dosing pump system might be the most adapted system for the production of vegetable in a soil-hydroponic system in Maharashtra.

2 Recommendations

It is recommended to start soil-less cultivation fertigation by dosing pump system in order to gain skills and experience before investing for AIS. The farmer who wants to use an AIS, needs a bigger polyhouse than the current Maharashtrian one. He needs to have already worked on polyhouse and hydroponic system and experienced the drip irrigation which represent 5% of the Maharashtrian farmer (Centre of Excellence of KVK, 2019)

To sell the production in an efficient way, farmers need to live in a specific region next to the markets and the consumers (process food factory, big market or big city) and to reduce the risk of post-harvest which is about 7% for the whole agriculture production in India (Sahu, 2004).

The AIS needs larger areas. A farmer can cultivate on field to have a larger area of production and decrease the cost of its production. By that way, he will have different quality of product and will be able to have more volume during the main growing season and still having production in the off season.

Cooperative work between farmers and in family is solution to decrease the cost of repayment and to enhance a dynamic of inclusive development for Maharashtrian farms. It will give them more power on the market.

To keep the water quality healthy for Maharashtrian farmer, it would be more environmentally friendly to bring solution in order to reuse the draining water, either by making an affordable disinfected unit to make a close hydroponic system or to reuse it on field crop.

To have a better overview of the efficiency of both systems, it would be interesting to set-up a comparison on both systems (AIS and dosing Pump) to calculate more accurately all the costs by taking into account, the spendings on each cultivation system and know which one is the most adapted to the irrigation system. This way, it would be possible to calculate the minimum area required for the cultivation according to the crop and the irrigation system.

The Indian farmer are facing constraints such as lack of post-harvest technologies, absence of storage facilities, inadequate training programmes and inadequate demonstrations (Samantaray et al., 2016).

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Appendix I: Schema of the Nutricare system

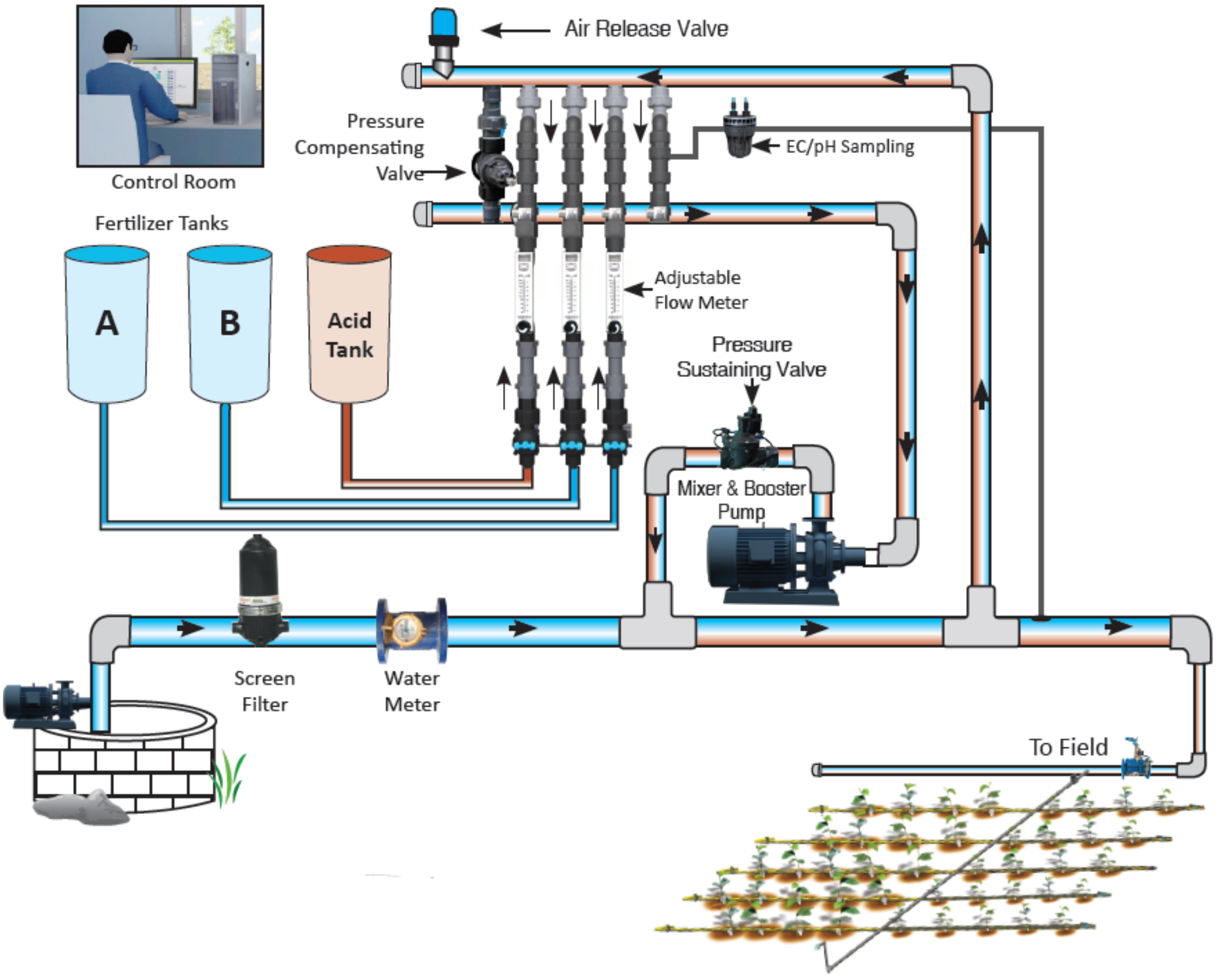

Figure 3: Schema of the Nutricare system (Jain Irrigation Ltd, n.d.)

Appendix II: Schema of the dosing pump system

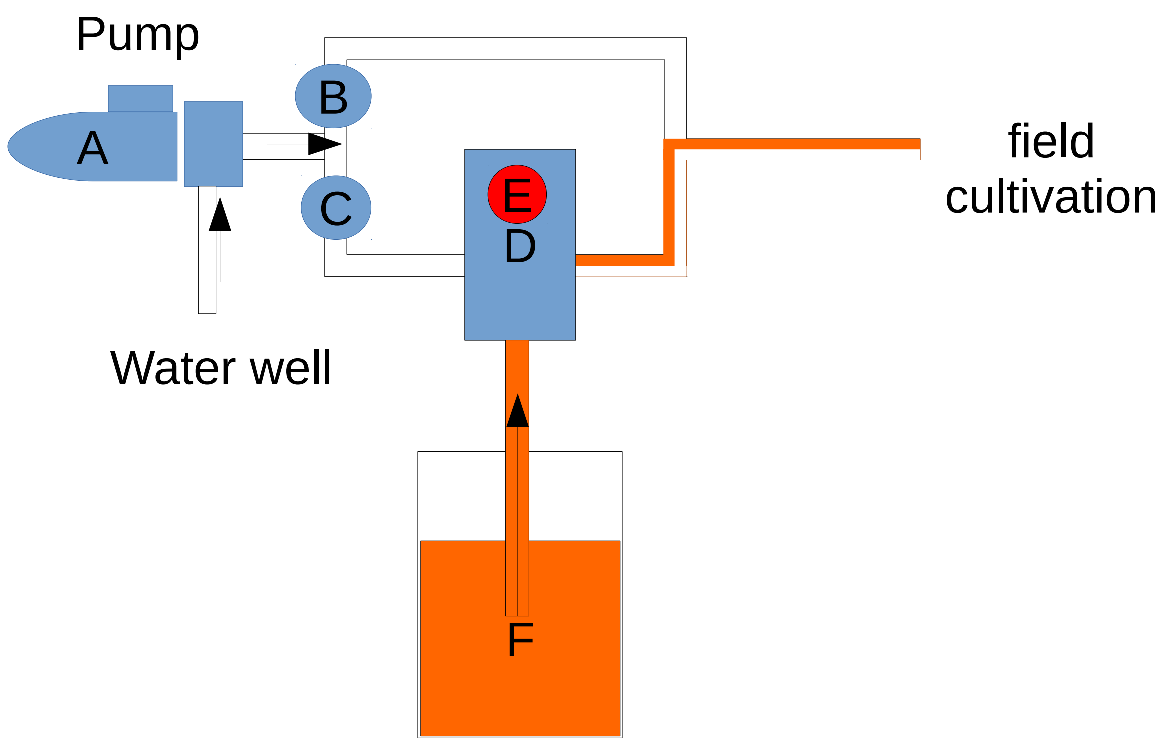

Figure 4: Schema of the dosing pump system

Appendix III: Cost detail of Nutricare system

Table 4: Detail cost of the Nutricare system

Name of the expenditure	Cost
Nutricare 3hp	₹367 000
Tanks	₹6 000
Fertigation and computer room	₹100 000
Computer	₹20 000
Jain Controller/ software	₹234 000
Bakup generator	₹80 000
Filter unit basic	₹65 270
Wire	₹3 000
Screen filter	₹3 000
Pump	₹22 000
Solanid volve	₹16 000
Total	₹916 270
After taxes	₹1 026 222
After subsidies	₹1 026 222

Appendix IV: Cost detail of line irrigation

Table 5: Cost detail of lines irrigation

Name of the expenditure	**Cost/m^2**
Drain	₹0,92
Drip/m	₹8,50
Maine line+pipe/m	₹13,76
Lateral line+pipe/feet	₹50,40
Sub-maine line	₹4,62
Stack driper	₹5,91
Total	₹75
After taxes	₹84
After subsidies	₹73

Appendix V: Cost detail of the dosing pump system

Table 6: Cost detail of the dosing pump system

Name of the expenditure	Cost
Dosing pump	₹10 000
Filter unit sand	₹65 270
Screen filter unit	₹3 000
Solanid volve	₹16 000
Total	₹94 270
After taxes	₹105 582
After subsidies	₹105 582