DEVELOPMENT AND EVALUATION OF SMALL SCALE HYDROPONIC GREEN FODDER PRODUCTION SYSTEM

By

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DECLARATION

I, hereby declare that this thesis entitled "**DEVELOPMENT AND EVALUATION OF SMALL SCALE HYDROPONIC GREEN FODDER PRODUCTION SYSTEM**" is a bonafide record of research work done by myself during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Tavanur

Date: 29/11/2021

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2019-18-001

CERTIFICATE

Certified that this thesis entitled "**DEVELOPMENT AND EVALUATION OF SMALL SCALE HYDROPONIC GREEN FODDER PRODUCTION SYSTEM**" is a bonafide record of research work done independently by **Er. Adarsha Gopalakrishna Bhat (2019-18-001)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Adarsha Gopalakrishna Bhat

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SYMBOLS AND ABBREVIATIONS

°	Degree
^{1}	Minute
/	Per
%	Percentage
±	Plus Or Minus
ANOVA	Analysis of Variance
AOAC	Association of Official Agricultural Chemists
BCR	Benefit Cost Ratio
C	Celsius
cm	Centimetre
CRD	Completely Randomized Design
DC	Direct Current
DM	Dry Matter
et al.	And Others
Fig.	Figure
FMS	Finger Millet Straw
gm	Grams
ha	Hectare
HBF	Hydroponic Barley Straw
HCl	Hydro Chloric Acid
HMF	Hydroponic Maize Fodder
Hp	Horse Power
hr	Hours
ICMR	Indian Council of Medical Research
KCAET	Kelappaji College of Agricultural Engineering and Technology
Kcal	Kilo Calories
km	Kilometre
km^2	Square Kilometre
l	Litre
LED	Light Emitting Diode
lph	Litres Per Hour
M	Molar
m^2	Square Meter
m^3	Cubic Meter
MC	Moisture Content
Mcal	Mega Calories
Mg	Mega grams
MHF	Maize Hydroponic Fodder
ml	Millilitre
PFDC	Precision Farming Development Centre
PPM or ppm	Parts Per Million
PVC	Poly Vinyl Chloride
TDN	Total digestible nutrients
V	Volts
WUE	Water Use Efficiency

INTRODUCTION

CHAPTER I

INTRODUCTION

India with only 2.29% of land area of the world, is keeping nearly 17.4% of world human population and 10.7% of livestock, forming a huge pressure on land, water and other resources (Roy *et al*., 2019). Total livestock in India is 536.76 million where, number of total cattle, buffaloes, sheep and goat are 193.46, 109.85, 74.26 and 148.88 million respectively. The total number of livestock in Kerala is 29.09 million (20th livestock census-2019). Indian breeds of cattle and buffaloes produce less than 1000 kg of milk per lactation as compared to 4500 kg in Europe, more than 7000 kg in the United States and 10,000 kg in Israel (Roy *et al*., 2019). The low productivity of livestock in India is due to several reasons out of which insufficient supplies of quality feeds and fodder are important.

Feed cost accounts for about 70-75% of the total cost of livestock production, particularly in milch animals (Roy *et al*., 2019). In order to increase the margin of profit from livestock/dairy farming, proper feeding plans need to be followed incorporating adequate proportion of green and nutritious fodder. Fodder crops are the plant species that are cultivated and harvested for feeding the animals in the form of green forage, silage, hay or other forms. The three major sources of fodder supply are by-products / residues of crops, fodder grown from arable land (irrigated and rainfed) and fodder from common property resources (like forests, permanent pastures, grazing lands etc.). Fodder is cultivated on approximately 5 per cent of the gross cropped area in India, which has remained nearly the same area over the last few decades. Total green fodder available in India is 734.193 million Mg per year but the requirements of green fodder is 827.189 million Mg causing a deficit of 11.24%, whereas in Kerala total available green fodder is 3.591 million Mg per year against the requirement of 3.761 million Mg per year leading to a green fodder deficit of 4.5%(Roy *et al*., 2019).

Hydroponics technology is a science of growing plants in nutrient rich solutions instead of soil, and can be efficiently used to take pressure off the land to grow green feed-stuff for the livestock. Plants require three things to flourish and those are water, nutrients, and sunlight. Hydroponics is a straight forward way of providing all these factors without the need of soil under controlled environment conditions to optimise the growth of plants. The word hydroponics has been derived from the Greek word, where hydro means 'water' and ponics means 'working' and is a technology of growing plants without soil, but only with water or nutrient rich solution.

Technology advancement has introduced hydroponic technology for green fodder production. The hydroponic green fodder could be a novel way of feeding dairy animals to improve productivity (Joshi *et al*., 2018). Chemical and structural changes take place within the grain through the hydroponic growing process. Activation of enzymes in the grains leads to hydrolysis of proteins, carbohydrates and lipids into their simpler components (Dung *et al.*, 2010). This hydrolysis increases the concentration of amino acids, soluble sugars and fatty acids within the grain and resulting shoot (Chavan *et al*., 2009).

Different types of fodder crops like barley, oats, wheat, sorghum, alfalfa, cowpea and maize can be produced by hydroponic technology. However, the choice of the hydroponic fodder to be produced depends on the geographical and agro-climatic conditions, easy availability of seeds and economics. In India, maize should be the choice as the grain for production of hydroponic fodder due to its easy availability, lower cost, good biomass production and quick growing habit (Kumar *et al*., 2018). Maize is a member of grass family which has higher amounts of vitamins, proteins, fats and carbohydrates. Hence it is used as fodder for animals (Barwant*et al*., 2019). The grain should be clean, sound, undamagedand free from insect infestation, untreated, viable and of good quality for better biomass production.Seed forms the major input for hydroponic cultivation that takes about 90% of the total cost of production of hydroponics. In situations, where conventional green fodder cannot be grown successfully, hydroponic fodder can be produced by the farmers for feeding their dairy animals using low cost devices. The green fodder from hydroponics is highly palatable, easily digested and of better quality as compared to traditional fodder production. In comparison to conventional green fodders, hydroponic green fodder contains more crude protein (13.6% v/s 10.7%) and less crude fibre (14.1% v/s 25.9 %) (Ramteke *et al*., 2019), making the proportion of TDN (Total digestible nutrients) very high.

Hydroponics is one type of best and innovative methods for the efficient utilization of water. Hydroponic fodder gives higher water use efficiency, higher fodder production from limited area and also reducing the requirement of labour and power. Relatively, the cost of cultivation is low with zero weed growth and insect and pest attack is also 1ess. It has shorter growing period and it is highly nutritive to increase milk production from milch animals. There is upsurge in the milk production of 8 to 13 % with the use of hydroponic green fodder (Gunasekaran *et al.*, 2019). This is a best substitute technology in places where conventional green fodder availability is less. Usage of poor quality water is also possible in hydroponics up to a certain limit (Al Ajmi*et al.*, 2009). Green fodder growth mainly depends on the water supply, temperature and humidity which can be easily controlled by automation.

Indian Council of Medical Research (ICMR) recommends an average daily intake of 300 gm of milk but per capita milk available in Kerala according to National Dairy Development Board data (NDDB, 2019) is 189 gm per day only.Milk requirement of Kerala (3.5 crore population) would be 1,08,36,000 l per day whereas milk production in Kerala (2019, NDDB) is 25,48,000 Mg which is equals to 2,62,95,36,000 l per year. Per day milk production is 72,04,208 l. That would lead to a deficit of 36,31,792 l per day.By considering 10.22 l of average milk yield from each cattle, at least 3, 55,361 more cattle are needed to fulfil the milk requirement of the state. That would demand 30,453 Mgof green fodder per day. Since the land available for fodder growth is limited, innovative and efficient techniques like hydroponic fodder production system will help to achieve selfsufficiency in milk production. Not only cattle but poultry, sheep, goats and other animals which is used for meat production also can be fed with hydroponic fodder. There are scientific evidence that hydroponic fodder helps to increase considerable amount of body weight in such animals and birds.

A farmer rearing 4 to 5 cattle cannot afford large and fully automated advanced hydroponic equipment for fodder production. Supplementation of 5 to 10 kg fresh fodder per cow is his daily requirement. Such farmers need a small scale hydroponic fodder production unit and this project mainly focuses on such rural or urban farmers. Constructing an indoor hydroponic structure eliminates the requirement of green house or extra structures for fodder production. As the solar energy is not possible to fully utilise in an indoor production unit, artificial lighting must be done for the growth of plants. Light emitting diodes provide solution for this problem as they consume less energy and very compatible in use. Blue and red colours have been found to be the best blend for plants and vegetables as it promotes good plant growth. Combination of 23% blue and 77% red has been reported to give good results (Kobayashi *et al*., 2013). So, the intended design should provide year-round consistent production because it is not at all subjected to changes in seasonal solar radiation which affects growth in conventional fodder production method.

By considering all these points,the present study entitled "Development and evaluation of small scale hydroponic green fodder production system" focuses on the fulfilment of hydroponic green fodder production with less time and better water use efficiency in the dark room with artificial lighting and also in polyhouse for comparison. The study was undertaken with the following specific objectives:

1. Development of small scale hydroponic green fodder production system
2. Testing of the developed system under different micro climatic conditions

Estimation of water use efficiency for different water application methods

REVIEW OF LITERATURE

CHAPTER II
REVIEW OF LITERATURE

This chapter deals with the review of previous research work carried out by many research workers, scientists and students. It comprises of review on hydroponic technology, hydroponic technology in fodder production, automation, application of artificial lighting for plant growth and evaluation of the fodder production system in terms of yield and water use efficiency.

2.1 HYDROPONIC FODDER PRODUCTION

The word hydroponics has been derived from the Greek word ‘water working’. Hydro means ‘water’ and ponic means ‘working’ and it is a technology of growing plants without soil, but in water or nutrient rich solution for a short duration in an environmentally controlled structure. Hydroponics has advantages over growing in soil due to many reasons. Plants can be cultivated year-round if the climatic conditions are suitably modified. The plants grown are significantly larger because of readily available nutrients and they need not waste time to develop extensive root systems. This makes the system to produce higher yield. The nutrient solution also maintains uniformity all the time, whereas soil tends to wear out as the nutrients are taken away. The combination of all these advantages makes hydroponics plants more productive than conventional soil growing plants (El-Kazzaz and El-Kazzaz, 2017).

Hydroponic fodder can be produced as per the daily requirement and there are zero post-harvest losses. Round the year consistent rich quality green fodder can be produced for the milch animals. It is free from pesticides, herbicides and hormones. This technology is especially important in places where forage production is limited. Above all, it can be grown organically. Hydroponic fodder production system gives very high-water use efficiency as the fodder is grown within a closed chamber, loss of water due to evaporation is very less. Most of the water used by plants goes to animals along with the feed. There is zero leaching of nutrients during growth of the fodder, unlike traditional field grown fodder crops. Hydroponic fodder has high quantity fibre (20.27%), rich metabolizable energy

(2980 Kcal/kg), crude protein (15.56%) and digestibility (El-Morsy *et al*., 2013). All these special features of hydroponic culture make it one of the most important agricultural techniques for green fodder cultivation in many countries, most importantly in arid and semi-arid regions (Al-Karaki and Al-Momani, 2011).

Muela *et al*., (2005) studied on use of green fodder produced in hydroponic system as supplement for lactating cows during the dry season. In their experiment they fed one set of cows with meadow fodder (grass land) and another set with supplementation of hydroponic green fodder. After two months (may 1st to June 26) the average weight of the cows fed with hydroponic fodder was 497.60 kg whereas the cows which are not supplemented with hydroponic fodder gained 459.99 kg showing an 8.18% increased weight gain in hydroponic fodder supplemented cows. After the intensive study they concluded that the hydroponic green fodder is a viable supplement for sustaining the weight of cows.

2.2 HYDROPONICALLY GROWN MAIZE AS A FODDER

Naik *et al*., (2012) concluded that hydroponic green fodder is more nutritious than conventionally grown fodder. In their study nutritional changes during the growth of hydroponic fodder was evaluated. The crude protein had increasing tendency and found highest on 7th day of growth (13.57%), which was higher than the conventionally grown green fodder maize (10.67%). The ether extract content of hydroponics maize fodder on 7th day (3.49%) was found highest. The crude fibre content of the maize seed was 2.50% and increased up to 14.07% on 7th day of growth but was lower than the fodder maize grown under conventional practices (25.92%).

Gebremedhin *et al*., (2015) did experiment to find the nutritional improvement and economic value of hydroponically grown maize fodder. The study was carried out at Instructional livestock farm, Agriculture College, D.B.S.K.K. Vidyapeeth, Dapoli, Ratnagiri district, India. On the 8th day total yield of 8kg hydroponic maize fodder was obtained per kg seed along with 28 cm height. Sample from 6th, 7th and 8th day of fodder growth was taken for proximate analysis. The crude protein content in hydroponic maize fodder was 14.56% compared to conventional maize seed (7.6%) while ether extract was found to be 4.6% on 8^{th}day growth. The crude fibre content of maize seed was 6.5% and increased to 10.0% on 8^{th}day of growth whereas nitrogen free extract was 68.47%. The value of total ash and acid insoluble ash content was highest as 2.83% and 0.32% on 8^{th}day growth stages, respectively.

Kide *et al*., (2015) took eighteen growing male Konkan Kanyal goats of 3-7 months old with initial body weight of 11.01±0.26 kg and divided into six groups (3 animals each) randomly to receive one of the treatment diets, T0-Finger millet straw(FMS)100%, T1- FMS + hydroponic maize fodder (HMF) 80%:20%, T2-FMS + hydroponic barley fodder(HBF) 80%:20%, T3-FMS + HMF 60%:40%, T4-FMS + HBF 60%:40% and T5-FMS + HMF + HBF 60%:20%:20% for 97 days. After adaptation to the experimental feed, digestibility trial of 7 days was conducted individually to know digestibility of experimental feed and estimated body weight gain and feed conversion efficiency of the experimental fodder treatments fed to growing goats. Results showed a significant improvement in dry matter intake in T5 (504.51 gm/day) and T3 (415.36 gm/day) than other treatments. Dry matter digestibility coefficient was the highest in T5 (68.44%) and T3 (67.28%). Feed conversion efficiency in T3 (12.15%) and T5 (10.56%) was higher compared to T0(-0.47%). Average body weight gain in T3 (61.93gm/day) and T5 (56.70gm/day) was significantly higher compared to T0 (-1.17gm/day). They concluded that feeding of hydroponically grown maize and barley fodder to growing Konkan Kanyal goats increased the digestibility of nutrients, body weight gain and feed conversion efficiency significantly.

Nugroho and Permana, (2015) conducted an experiment to study the effect of addition of 7% dry matter maize hydroponic fodder (MHF) in corn silage on digestibility and milk production of dairy cows. Completely randomized block design with two treatments and four replications were used for statistical analysis. Two treatments were selected R1 and R0, where R0 was dairy cows fed with grass (*Pennisetum purpureum*), corn silage, and concentrate and R1 was dairy cows fed with grass, corn silage, concentrate, and maize hydroponic fodder. Supplementation showed higher dry matter intake in R1 (12.99±0.063 kg/head/day) than R0 (11.98±0.295 kg/head/day). The digestibility of nutrients was not affected by the addition of maize hydroponic fodder. Energy consumption in R1 (49.95±0.36 Mcal/kg) was also higher than R0 (46.11±0.54 Mcal/kg). Supplementation of MHF also increased nitrogen consumption in R1 (318.3±2.3 gm/head/day) than in R0 (295.9±3.5 gm/head/day) and could maintain the persistency of milk production at the end of lactation. It was be concluded that supplementation of MHF in corn silage can increase energy consumption, dry matter intake and nitrogen consumption, also can maintain nutrient digestibility and maintain persistency of milk production during lactation of dairy cows.

Rajkumar *et al*., (2018) conducted an experiment to evaluate the effect of maize green fodder produced by hydroponics system on the performance of eighteen crossbred calves. Calves were made three groups T1, T2 and T3 of six each. The T1, T2 and T3 treatments were of 25%, 34% and 41% maize fodder supplement respectively. The results obtained in their study showed higher values inT3 group with dry matter intake (197.17 kg), total body weight gain (48.58 kg) and average daily gain (0.45 kg) compared to T1 and T2. Data on digestibility of nutrients did not reveal any difference among treatment groups. Cost per kg gain was significantly lower in T3 (Rs.102.14) compared to T2 (Rs. 111.64) and T1 (Rs. 119.82). In the end they concluded that, feeding of hydroponics maize fodder as a partial feed substitute of calf starter improves the dry matter intake, total body weight gain, average daily gain and lowers the cost per kg body weight gain (Rs 102.14 in T3).

Adebiyi *et al*., (2018) carried out research to determine the effect of feeding hydroponically grown maize fodder on the performance of weaned pigs. Hydroponic maize fodder was grown under natural illumination in this study. Maize seeds were kept in trays (500 gm per tray) and irrigated manually twice daily (07:30hr and 17:30hr) at a fixed rate of 250 ml/tray/day with a spray gun. The growth period was of 7 days. Samples of the green fodder were taken for dry matter and nutrient content analysis. The crude protein content in HMF was 13.75% with higher crude protein digestibility (65.76%) in pigs. Significantly higher values for final weight (13.83 kg), feed intake (12.79 kg) and weight gain (3.83 kg) were observed. Study showed that supplementing hydroponic maize fodder with concentrate feed can be a feasible idea in piggery.

Rani *et al*., (2019) studied the effect of feeding hydroponic maize fodder on growth performance in cross-bred calves of three months age. Fifteen healthy cross-bred calves were selected and divided into three groups of five each based on their body weight, age and sex. Three experimental treatments T1 (control), T2 (50% of the calf starter replaced by hydroponic maize fodder on dry matter basis), T3 (75% of the calf starter replaced by hydroponic maize fodder on dry matter basis). Feeding was conducted for a period of 90 days. Higher average daily weight gain (52.20 ± 0.02 gm) also higher average daily dry matter consumed (1.88 ± 0.02 kg/animal) was observed in T2 than control. The results of the experiment proved that calf starter can be replaced with hydroponic maize fodder in cross-bred calves.

2.3 AUTOMATION OF THE UNIT

Matos *et al*., (2015) conducted a study on automated system for hydroponic fodder production. They introduced a system having six-story which produces 15 trays of fodder a day. Production of fodder was constant and year-round. This program was designed for small and an intermediate agricultural system that allows for fodder production within ten days, and the results obtained confirm this statement. The system was designed to produce the fodder in vertical system to reduce the occupied area in the greenhouse. By increasing the year-round availability of fodder, operating profit increases. Return of investment including repair and production costs could be five years.

Aruna *et al*., (2018) have done a project on the design and development of a solar powered hydroponics system. A specific type of hydroponics system with a smart solar panel unit was proposed. In this prototype, the system worked in accordance with the model design. Communication module worked as designed.

Sending information from the model can be found in Arduino which shows details in the monitoring display. The model was developed to automatically control pH, nutrient mineral, mineral solution.

Jagtap *et al*., (2018) developed an automated hydroponics system and tested its performance by various electrical sensors. In a period of one week fodder grown up to 27.94 cm. Water demand was 30% of what required in conventional farming. They found that if trays are not having holes, it results in the accumulation of water leading to the growth of mold. Therefore, one should provide 8-10 holes for each tray.

Kamat and Kulkarni, (2018) developed a hydroponic corn fodder gadget assisted by the sun. Project describes the development of a hydroponic system using a solar module to control light and water pump using the default timer. Gadget includes solar panel, battery, micro sprinklers and automatic timer. The collected sun rays are converted into electrical energy and stored in a battery. The average output obtained was 12 volts while the maximum output was 18 volts. The test revealed that protein content of 13.2%, ether extract 3.3%, crude fibre 15.02%, total ash 2.35%, acid insoluble ash 0.33% and moisture content of 83.87% in hydroponically cultivated sample. Improved nutritional content may be due to improved efficiency of conversion. It was found that there was 13% increase in the milk yield by feeding hydroponic maize fodder (Niak *et al*., 2012).

2.4 EFFECT OF SEED RATE AND WATER LEVEL ON YIELD

Islam *et al*., (2016) conducted a study on effect of seed rate and water level on production and chemical analysis of hydroponic fodder. This study was conducted primarily for the production and analysis of the nutrient content of hydroponically grown green fodders of two different grains namely maize and wheat. Green fodders were produced to monitor yields at different seed rates and water treatment. Chemical composition on different days (8, 9, 10th day) were analysed. It was found that the chemical composition on the 9thday was greater than on any other days. On the other hand, in the case of wheat 0.4 kilograms of seed rate and 2.5 l water level and in case of maize 0.6 kg of seed rate and 2.5 l water 1evel were found to be the best treatments.

Naik *et al*., (2017) conducted a study to find out the effect of seed rate (3.8, 5.1, 6.4, 7.6, 8.9 and 10.2 kg/m^2) on the yield and proximate constituents of different parts of the hydroponic maize fodder. The hydroponic maize fodder grown like a mat of 20–30 cm height consisting of roots along with germinated seeds and leaves. The total yields in kg/m² of the hydroponic maize fodder on fresh basis was found to be 4.94, 5.14, 5.02, 5.07, 4.97 and 4.72for the seed rate of 3.8, 5.1, 6.4, 7.6, 8.9 and 10.2 kg/ m^2 respectively. The maximum leaves (% of total yield) was 32.49 % for 5.1 kg /m^2 and minimum 27.43 % for 10.2 kg/m^2.The fresh yield of the roots along with the germinated seeds increased with the increase in the seed rate. The obtained yield of the roots with the germinated seeds on fresh basis remained similar up to seed rate of 8.9 kg/m² and increased at the seed rate of 10.2 kg/m².It can be concluded that the seed rate had no effect on the proximate constituents of different portions i.e. roots with germinated seeds, leaves and plants of the hydroponics maize fodder. The seed rate of 7.6 kg/m² can be recommended for the production of hydroponics maize fodder for optimal output and all parts of the hydroponics maize fodder are nutritious.

Getachew *et al*., (2020) did the work on effect of variety and seed rate on hydroponic maize fodder biomass yield, chemical composition and water use efficiency. Maize varieties BH540, BH661, BH660, and MVFG were analysed at low (5.6 kg/m²), medium (7.6 kg/m²), and high (9.6 kg/m²) seed rate for hydroponic fodder productivity. 3 m × 4 m wide and 3 m height low-cost plastic house made of luminous plastic and a plastic tray made by dividing a 25 l capacity plastic oil container into two equal parts were used for the cultivation of hydroponic fodder. The bottoms of the trays were stabbed to open holes to remove excess water during irrigation and placed on shelves. The BH661 showed significantly ($p< 0.05$) dry mater (DM) fodder yield; but in medium and low-level seed rates, had lower cost per kg dry matter fodder production. WUE was inferior for BH540 as related to other varieties that had alike values. Medium and high seed rates had shown the parallel water use efficiency, and it was higher than the 1ow seed rate. They recommended BH661 maize variety at a medium seed rate for the hydroponic fodder production.

2.5 ARTIFICIAL LIGHTING TO ENHANCE GROWTH

Kobayashi *et al.*, (2013) stated that there are growing concerns about food security, environmental impact, and energy efficiency in agricultural production programs. Producing lettuce under artificial lighting can be a solution to these problems. Light emitting diodes (LEDs) offer the advantages of low light intensity, low power consumption, and low heat production. The aim of this study was to find the effects of different light sources on the growth of the "Tom Thumb" butter head lettuce plant in a non-moving hydroponic system. Lettuce seedlings, which was grown in the Oasis Horticubes, were transferred making net pots with containers containing a hydroponic nutrient solution. Lettuce was grown in the workplace under three types of bright lights - blue LEDs, red LEDs and fluorescent lights. In the end of the study, fluorescent lamps produced a large root dry weight compared to blue LEDs and red LEDs. The total dry weight of the plants grown under fluorescent lamps was greater than that of the red LEDs. There were no much differences in dry weight loss and crop height between treatments. The percentage distribution of dry weight on shoots was significantly higher with red LEDs, followed by blue LEDs, and fluorescent lamps. The separation of dry and root weight was significantly higher with fluorescent lamps, followed by blue LEDs, and red LEDs. The chlorophyll content was significantly lesser than blue LEDs and fluorescent lamps than red LEDs. The pH of the nutrient solution of blue LED and fluorescent light treatment was higher than red LED treatment. In conclusion, LEDs can provide another source of light for the production of small lettuce. Blue and red colours have been found to be the best blend for plants and vegetables. This promotes good plant growth. Combination of 23% blue and 77% red give good results with good plant growth.

Promratrak (2017) did project on effect of artificial lights on crop growth. According to them, plants need a particular range of blue and red-light wavelengths. The experiment was conducted to show the effect of LED light on growth of plant instead of natural light. The results clearly showed that LED help in plant growth. In this study, the ratio is 3:1 for red and blue LED. The experiment was conducted for 10 days and daily 16 hr light was provided, which shows the better yield in vegetable. After 10 days the average hight of the plant grown in LED light was more (7.75 cm and 8 leaves) compared to hight of plant grown in natural sunlight (6.67 cm and 7 leaves) which indicates the higher growth in LED light.

Bian *et al.,* (2018) said that adding light can increase crop yields in nursery by enhancing photosynthesis and plant growth. However, the high energy costs because of light support is a key factor that reduces development and profitability to improve environment friendly agriculture. Light emitting diodes are promising technology with great potential for enhancing irradiance efficiency and modification of conventionally made horticultural lighting. Compared to traditional light sources (like sodium and metal halide lamps) used for crop production, LEDs have advantages, such as their small size and long lifetime. The spectrum of LEDs can be adjusted depending upon the needs of plant growth. The project aims to study energy efficiency, nutritional values, photosynthesis and development of bright light in a protected horticulture system. In the first stage, the effects of LED light on the plant development, energy efficiency and photosynthetic performance were investigated. The end results showed a high dry weight and a very high leaf area with the red and 23 percent blue light. When compared to fluorescent lamps, light intensity increased greatly of combined red and blue LEDs. Effect of light spectrum composition on food lettuce quality was also studied. Continuous light with combined red, green and blue LEDs showed a remarkable decrease in nitrate. Moreover, continuous LED light for 24 hours greatly increased phenolic compound content and free-radical scavenging capacity in lettuce leaf.

2.6 WATER USE EFFICIENCY OF HYDROPONIC FODDER

Al Ajmi *et al*., (2009) conducted a study on the yield and water use efficiency of barley fodder production under hydroponic system in Gulf Cooperation Countries by using tertiary treated sewage water effluents. Barley is a popular fodder in the region with great adaptability to wide range of climate and soil. The laboratory test was conducted to evaluate yield, water use efficiency and quality of the bar1ey fodder irrigated with tertiary treated sewage water effluents under hydroponic condition. Average green forage yield obtained ranged from less than 90 Mg/ha with tap water to about 130 Mg/ha with tertiary treated sewage water. This is equivalent to 50% increase in fodder production. This increase in yield may be attributed to the high nitrogen content (290 ppm) in tertiary treated sewage water. Hydroponic system is a potential technique for barley production with minimum water consumption in gulf cooperation countries where water is the main limiting factor for agricultural production. Tertiary treated sewage effluent found to be feasible source for irrigation of hydroponically produced barley crop with a water use efficiency of 2.1Mg DM/m^3 water used.

Al-Karaki and Al-Momani, (2011) measured different types of barley grains with green fodder production and use of water under hydroponic conditions. This research has shown that bar1ey can be harvested in 10 days from the planting in a hydroponic system. The local cultivars was superior compared to the other two tested cu1tivars with respect to green and dry fodder yie1d, plant height, and conversion of seed elements in green fodder. The yield of raw barley fodder was 222, 236 and 281 Mg / ha of ACSAD176, Rum, and 1ocal cu1tivar respectively. This is higher than 110, 118 and 140 times the green yields obtained in the conventional field grown alfalfa fodder (50 Mg / ha / year). In addition, the 1ocal cultivar showed large water use efficiency to produce raw fodder than other cultivars (1.48 m^3 by 1ocal cultivars 1.76 and 1.87 m^3 per Mg of Rum and ACSAD176 respectively). It is an amazing development of water efficiency compared to 83 m^3 / Mg produced under fie1d condition. The results showed that the hydroponic fodder of the local cu1tivar was higher in the content of crude protein, Nitrogen (N), Phosphorus (P), Zinc (Zn) and Magnesium (Mg). In conclusion, the local bar1ey cultivar was the best choice for fodder production and the quality of hydroponic raw fodder with reduced water consumption. All found were considered very important as the seeds of this cu1tivars are widely available in a local market than others that reduces the cost of producing fodder.

Putra and Henry, (2015) did research on soilless culture system to help water use efficiency and product quality. Mainly soilless production system was carried out by mirroring traditional methods based on cultivation in soil or soil-based systems. Soilless culture may be the effective tool to increase the crop yield and if closed irrigation systems are adopted could enhance the water-use efficiency, also decreases the environmental impact of greenhouses and nurseries. By using the 8 soilless cultivation system, some researchers obtained a better quality of agricultural products, which is expected to meet the consumer needs. These production systems, which can increase water use efficiency while maintaining its quality, should be more intensively adopted in any scale to support eco-friendly agriculture.

MATERIALS AND METHODS

CHAPTER III
MATERIALS AND METHODS

This chapter elaborates about location, materials used for the research work and methodologies adopted for the development and evaluation of small scale hydroponic green fodder production system.

3.1 DETAILS OF EXPERIMENTAL MATERIALS

3.1.1 Experimental location

The experiment was carried out in the Precision Farming Development Centre (PFDC) building, Kelappaji College of Agricultural Engineering and Technology,Tavanur. The place is located at 10˚51'07"N latitude, 75˚59'13" E longitude and 28 meters above mean sea level.

3.1.2 Environmental factors

The average annual rainfall of study area is about 294 centimetres. Average annual maximum and minimum temperature is about 30˚C and 23.5˚C respectively. Hydroponic maize fodder grows well in wide range of temperature (22˚C to 32˚C) and humidity (40 to 80%) (Bakshi*et al*., 2017). Frequent spray of water keeps the system under desirable condition for sprouting and growth.

3.1.3 Experimental set up for different treatments

A room was selected in PFDC building at KCAET campus to conduct study of hydroponic fodder production system and evaluation at indoor condition with artificial lighting arrangements. All the windows were covered to make the room completely dark so that the effect of different wavelength lights on plant growth can be studied using artificial light source. The CAD diagram with original setup is shown in Fig.3.1 and Plate 3.1.

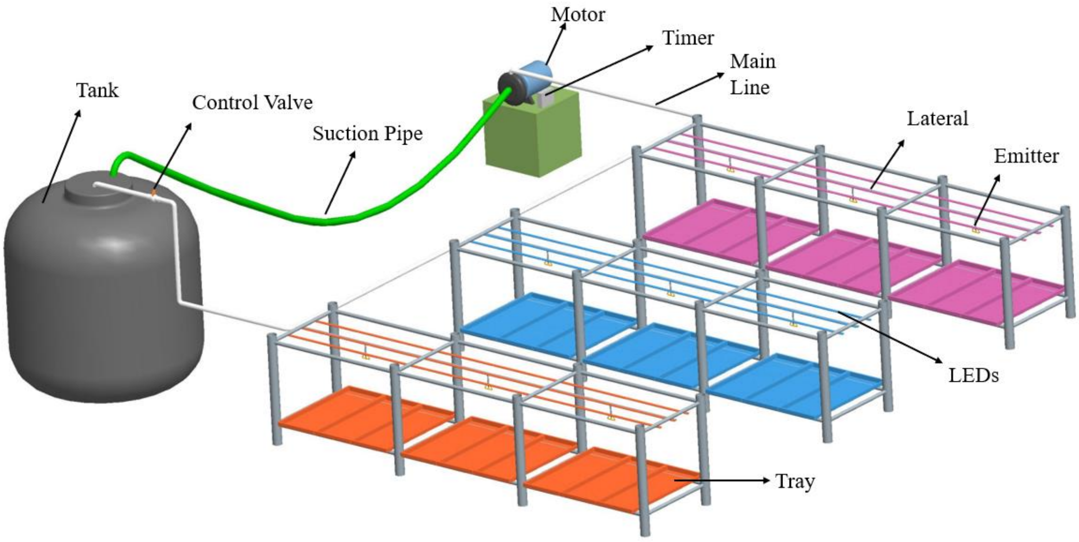


Fig. 3.1 Experimental design in dark room (CAD diagram)

Plate 3.1 Experimental design in dark room

Previously existing polyhouse in the KCAET campus was selected to grow fodder under sunlight for comparison studies. Tray supporting stand was arranged in the polyhouse and irrigation system was placed with storage tank, irrigation pump and timer according to the experimental design and shown in Fig.3.2 and Plate 3.2.

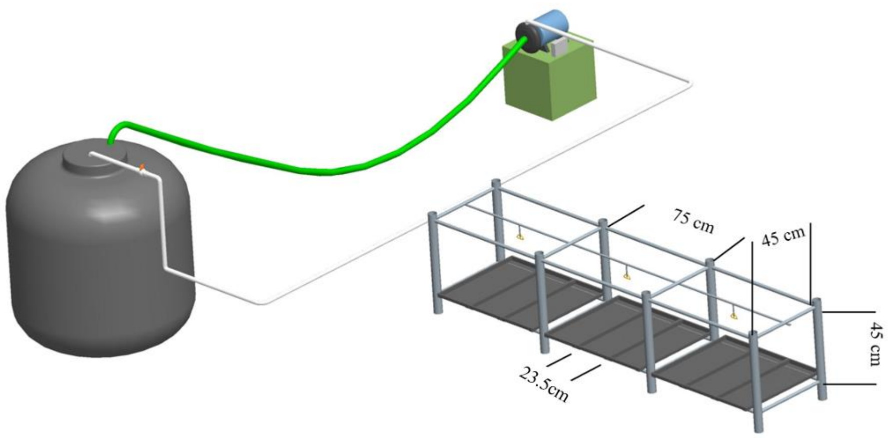


Fig. 3.2 Experimental design in polyhouse (CAD diagram)

Plate 3.2 Experimental design in polyhouse

3.1.4 Hydroponic stand

Pipe framed stand was fabricated for experimenting with different treatments (Plate 3.3). The irrigation laterals and LED lights were fixed to pipe framed stand according to experimental design. Prototype of fodder production system with best treatments obtained from the experiment was built using angle iron.

Plate 3.3 Hydroponic stand for different treatments

3.1.5 Hydroponic trays

The tray used was of plastic and having the size of 58.5 cm x 23.5 cm x 2.5 cm. Downside of the tray had drain holes to drain out the excess water from the trays. Hydroponic trays hold the maize seeds. Tray used is shown in Plate3.4.

Plate 3.4 Hydroponic tray

3.1.6 Water tank

A plastic vertical water tank having capacity of 500 l was used to store the water for the irrigation of hydroponic fodder (Plate3.5). The same water tank was kept inside the polyhouse and dark room.

Plate 3.5 Water tank

3.1.7 Irrigation pump

An irrigation pump of 1 Hp, 240 V was used (Plate3.6). Total head of the pump was 20 meter with discharge of 1 l per second. Excess water in the system was sent back to the tank to utilize the water more efficiently.

Plate 3.6 Irrigation pump

3.1.8 Timer

Timer was used for the automation of the system which is shown in Plate3.7. The irrigation timing and the interval can be easily set by the timer. Multispin UTR 1044 model is a 12V DC digital timer which is very easy to use and it digitally indicates relay status using LED.

Plate 3.7 Timer

3.1.9 Artificial light arrangements

LED was used for artificial light arrangement (Plate3.8). Medium density (60 LED/ meter) requires power of 6 Watt/meter and voltage of 12 Volt (DC) .

Plate 3.8 LED light strip

3.1.10 Irrigation methods

Capacity of the mist, micro sprinkler and fogger is 25lph, 15lph and 16lph respectively. Emitters used in these irrigation methods are shown in Plate3.9.

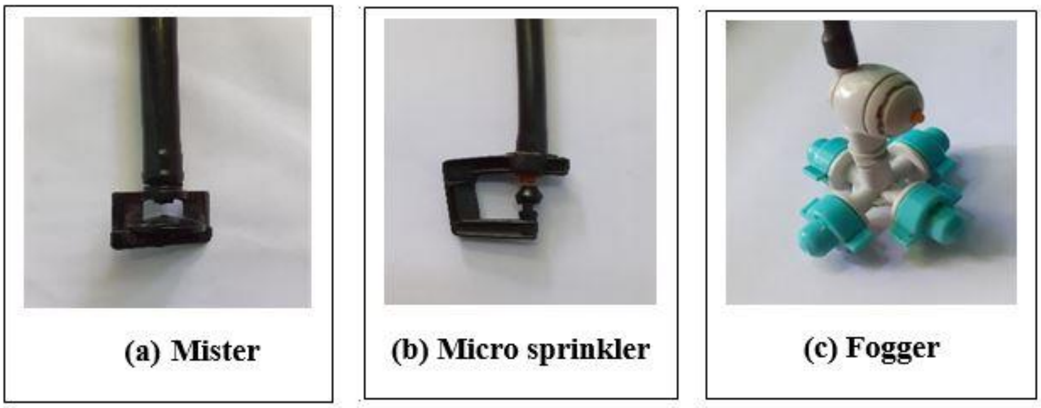


Plate 3.9 Different irrigation methods

3.2 EXPERIMENTAL METHODOLOGIES

3.2.1 Cleaning and washing of maize Seeds

Locally available maize (*Zea mays*) seeds of variety *Ganga 5*was selected for the experiment. Germination percentage of maize seed was more than 80%. The grains were clean, undamaged, viable and of good quality. All the unwanted materials and broken seeds were removed and then good quality seeds were washed with clean water as shown in Plate3.10. The seeds were soaked for 3-5 minutes to remove unwanted dust and lightweight materials which floats on the water.

Plate 3.10 Cleaning the seeds

3.2.2 Soaking and germination of seeds

After cleaning the maize seeds, it was kept for soaking in clean water for 20 hours. Then the water was removed and seeds were kept without water for one hour. This was breathing time and it helps for the proper germination of seeds (Islam *et al*., 2016). Clean gunny bags were dipped in water to make it wet and the soaked seeds were transferred to wet gunny bags, kept 24 hours for germination. Water spray to gunny bag was done periodically (once in 3 to 4 hours) to keep it moist. After 24 hours, germinated seeds were kept in trays and trays were then placed on the hydroponic stand.

3.2.3 Experimental design

The Dependent and independent variables used in the experiment are listed in Table 1

Table 1 Dependant and independent parameters of the experimental design

S.No	Experimental parameters	Particulars
Independent variables		
1	Irrigation method	Mist Micro sprinkler Fogger
2	Light condition	LED Red LED Blue LED Red + LED Blue Sun light
Dependent variables		
1	Total green fodder production	Kg/tray
2	Water use efficiency	Kg fresh fodder /cubic meters of water

The experiment was conducted in statistical design CRD (completely randomized design). Three replications were taken as R1, R2 and R3. After that, twelve treatments with three replications each were also randomly arranged in the equally sized trays of the hydroponic unit. Set of 3 trays were considered as one unit and different treatments were applied on it.

Set of trays were placed such that each unit gets different light condition (LED red, LED blue, LED red + LED blue, Sunlight) with each irrigation method (Mist, Fogger, Micro sprinkler). Each treatment was replicated 3 times and average was considered for the calculation.

Design	Completely randomizes design
No of replications	3
Treatments	12
Total treatments	36

Table 2 Experimental design of the treatments

I_1L_1	I_2L_1	I_3L_1	I_1L_1	I_2L_1	I_3L_1	I_1L_1	I_2L_1	I_3L_1
I_1L_2	I_2L_2	I_3L_2	I_1L_2	I_2L_2	I_3L_2	I_1L_2	I_2L_2	I_3L_2
I_1L_3	I_2L_3	I_3L_3	I_1L_3	I_2L_3	I_3L_3	I_1L_3	I_2L_3	I_3L_3
I_1L_4	I_2L_4	I_3L_4	I_1L_4	I_2L_4	I_3L_4	I_1L_4	I_2L_4	I_3L_4

Where,

I_1 = Mist irrigation

I_2 = Fogger irrigation

I_3 = Micro sprinkler irrigation

L_1 = LED red

L_2 = LED blue

L_3 = LED red + LED blue

L_4 = Sun light

3.2.4Automation Control Unit

Multispin UTR 1044 was used to achieve automatic irrigation. The amount of water to be sprayed on trays per day was fixed (1l per tray per day). The capacity of the different emitters was known, accordingly the time interval between two sprays and spraying time was calculated such that each tray gets 1l of water per day with very little variation. The data was fed into timer. Total irrigation timing was 12 hours. In the dark room the artificial lighting was given for 12 hours.

3.2.5 Irrigation of Hydroponic Maize with Different Methods

Water level of 1 l per tray per day and seed rate of 350 gram per tray was used in the experiment (Naik *et al*., 2017). The capacity and timings used for different irrigation methods is given in table 3 below.

Table 3 Description of different irrigation methods

Irrigation method	Capacity (lph)	Spray interval (minutes)	Spraying time (seconds)
I_1- Mist	25	30	20
I_2- Micro sprinkler	15	20	25
I_3- Fogger	16	20	35

3.2.6 Evaluation of Water Use Efficiency (WUE)

The total water added and drained out of trays throughout the irrigation have to be recorded for each tray on daily basis to compute total water use and water use efficiency (Al-Karaki and Al-Hashem. 2012).

The total water used by plants (l/tray) will be computed according to the equation:

Total water use = Total water applied in Irrigation-Total drained water out of trays

Water use efficiency in kg per meter cube of water can be calculated by below formula.

$$WUE = \frac{Total\ green\ fodder\ produced\ (kg/tray)}{Total\ water\ used\ (m^3/tray)}$$

Water applied to each tray per day was 1 l. The extra water drained from each tray was collected and measured every day. After 9 days total amount of water applied and total amount of water drained was calculated. The weight of the fresh fodder grown was taken. Total water drained was deducted from total water applied to know the amount of water used by the maize fodder to grow. The total green fodder produced was divided by the total water used to get the water use efficiency.

3.3 OBSERVATIONS

3.3.1 Total Water Applied in Irrigation

Water which was applied in the irrigation through automation was already fixed by measuring the discharge of water through mists, foggers and micro sprinklers into the trays. Irrigation was done on time basis, according to the time fixed based on the requirement and entered in the timer.

3.3.2 Total Water Drained Out of Trays

Water which was drained out of trays was collected in another tray as shown in Plate3.11which was kept under each tray. The drained water was recorded daily using measuring jar and given in Appendix I.

Plate3.11 Collecting drained water

3.3.3 Total Water Use

Total water applied to the tray was deducted by the total water drained out in order to calculate total water usage.

3.3.4 Total Green Fodder Production (kg/tray)

After 9 days the green fodder grown in the tray under different treatment was measured and noted.

3.4 PHYSICAL AND CHEMICAL ANALYSIS

Chemical analysis was done to the hydroponic maize fodder to find out the Crude protein and Crude fibre according to Association of Official Agricultural Chemists (AOAC, 1980). This was done for the highest yield treatments recorded during the harvesting time. The analysis was done in Department of Processing and Food Engineering KCAET, Tavanur. After the analysis data were recorded and compared between the treatments to find the best treatment according to the chemical analysis. The procedure for the estimation of these parameters are as follows:

3.4.1 Moisture Content

The moisture of fresh fodder was determined by using the oven drying method using hot air oven.

$$MC = \frac{W_1 - W_2}{W_2} \times 100$$

Where,

MC = Moisture content (%)

W_1= Initial weight of sample (g)

W_2= Final weight of sample (g) and

3.4.2 Crude Protein

Kjeldahl's method was used to estimate crude protein. It has mainly four steps to complete the test such as digestion, distillation, titration and calculation. Catalyst (potassium sulphate + copper sulphate) and sulphuric acid were used in digestion. Sodium hydroxide solution and boric acid solution were used in distillation. Hydrochloric acid and methyl red indicator were used in titration.

Calculation:

$$N\% = \frac{V \times n \times F_1 \times MW_n}{W_s \times 10}$$

$$Crude\ protein = N\% \times Factor \times F_2$$

Where, V = Burette reading (0.1 N HCl)

n = Normality of HCl (0.1) F_1 = Acid factor for HCl (1)

MW_n= Molecular weight of Nitrogen (14.007)

W_s= Weight of the sample

N% = Nitrogen percentage

Factor = Conversion factor for forage and feed (6.25)

F_2 = Dilution factor (10)

3.4.3 Crude Fibre

Crude fibre estimation (AOAC 978.10) was conducted which involved four major steps. Boiling in acid, boiling in base, drying the fibre and incineration. For analysis, 2 gm of the HMF sample was used (W_s). For acid boilingand boiling in base 0.128 M Sulphuric acid and 0.313 M sodium hydroxide were used respectively. The fibre was collected after these steps, dried by keeping in crucible at 130 ˚C for 2 hours and weighed (W_1). Crucibles were kept in muffle furnace at 550 ˚C for 2 hours and weighed (W_2) again.

Calculation

$$Crude\ fibre\ \% = \frac{(W_1 - W_2)}{W_s} \times 100$$

Where,W_s = weight of sample

W_1 = weight of crucible with fibre

W_2 = weight of crucible with ash

3.5 STATISTICAL ANALYSIS

The statistical analysis of data taken during research period was done. The method used for statistical analysis was "Analysis of Variance (ANOVA)" which was suitable for the design used (CRD). Post-hoc Tukey HSD test was done to compare the means.

3.6 COST ECONOMICS OF HYDROPONIC GREEN FODDER PRODUCTION SYSTEM

Cost-effectiveness of hydroponic fodder production was calcu1ated in terms of net return, gross return and benefit cost ratio. For this purpose, the life period of the unit was considered as 10 years. Standard market rates were considered for the calculation.

Fixed and Variable costs were taken into consideration to estimate the gross cost of production. Variable costs included seed, electricity and human power. Fixed cost included depreciation and cost of equipment.

3.6.1 Fixed Cost

Fixed costs are indirect costs of business expenses that are not dependent on goods or services produced by the system. They tend to be time related, such as interest or rents being paid per month or per year, and are often referred to as overhead or fixed cost. The depreciation of the system was worked out by straight-line method as fallows;

$$D = \frac{I - S}{L}$$

Where,

D=Depreciation yearly I=Initial cost of system

S= salvage value @ 10%L= Useful life of system

3.6.2 Variable Cost

These are the expenses associated with the maintenance and administration of a hydroponic fodder production system on a day-to-day basis. The total variable cost for a hydroponic system includes the cost of goods and operating expenses.

Operating cost = Cost of goods + operating expenses

3.6.3 Gross Cost

Gross cost comprised of fixed cost and operating cost.

3.6.4 Gross Return

Gross return was predicted by multip1ying total volume of output with the price at the time of harvesting period

3.6.5 Net Return

Net return was calculated by subtracting all the fixed and variab1e costs from the gross return

3.6.6 Benefit Cost Ratio

It was calculated using the formula as follows;

BCR = GR/GC

Where, GR = Gross return GC = Gross cost

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

This chapter deals with the examination of results got through the analysis of the data collection using the methodologies described in the chapter materials and methods. In this study, four different light conditions, three different water application methods, its effect on the water use efficiency and total green fodder production are explained. It also deals with the automation that was done for the irrigation purpose for hydroponic system. The achieved results of the experiment supported with the suitable discussion are presented in this chapter.

4.1 AUTOMATION OF IRRIGATION FOR HYDROPONIC SYSTEM

Multispin UTR 1044 model is a 12V DC digital timer using which automation of irrigation was done. The operation time and irrigation interval were set according to fixed water application rate and discharge capacity of the emitters. Power was connected to timer and the timer was connected to pump. For the set timing the timer was switching on and off the pump which supplied water to emitters with pressure.

4.2 EFFECT OF DIFFERENT LIGHT CONDITIONS AND WATER APPLICATION METHODS ON YIELD

Weight of the fodder in each treatment was taken after 9 days. Variation in total fodder produced in different treatments was observed. The table 4shows the total hydroponic maize fodder production per tray in different replications and average was taken for the statistical analysis.

Table 4 Hydroponic maize fodder (HMF) production for various treatments

SI NO	Treatment	Yield (kg/tray)			
		R_1	R_2	R_3	Average
1	I_1L_1	1.75	1.73	1.70	1.73
2	I_1L_2	1.74	1.71	1.70	1.72
3	I_1L_3	1.89	1.90	1.91	1.90
4	I_1L_4	1.81	1.81	1.83	1.82
5	I_2L_1	1.72	1.69	1.69	1.70
6	I_2L_2	1.62	1.68	1.63	1.64
7	I_2L_3	1.89	1.90	1.91	1.90
8	I_2L_4	1.75	1.72	1.74	1.74
9	I_3L_1	1.93	1.98	1.96	1.95
10	I_3L_2	1.91	1.91	1.91	1.91
11	I_3L_3	2.10	2.09	2.14	2.11
12	I_3L_4	1.99	2.00	1.99	1.99

4.2.1 Hydroponic Fodder Production underMist Irrigation at Different Light Conditions

The Fig.4.1shows that the highest yield obtained for Mist irrigation was 1.9kg. This result was found for combination of LED red + blue (L_3). The least yield obtained was around 1.72kg resulted in LED blue (L_2).

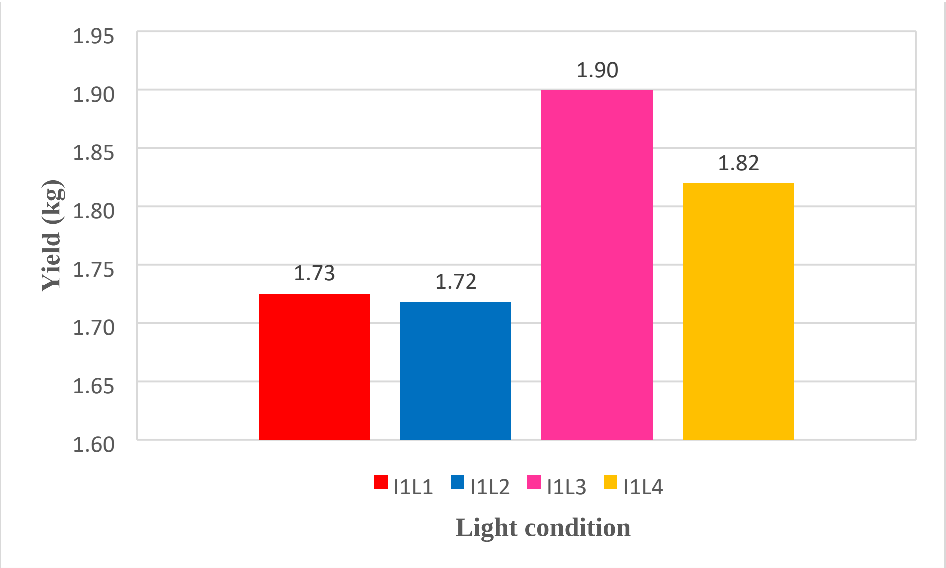


Fig. 4.1Green fodder production in kg/tray for mist irrigation

4.2.2 Hydroponic Fodder Production in Micro Sprinkler Irrigation under Different Light Conditions

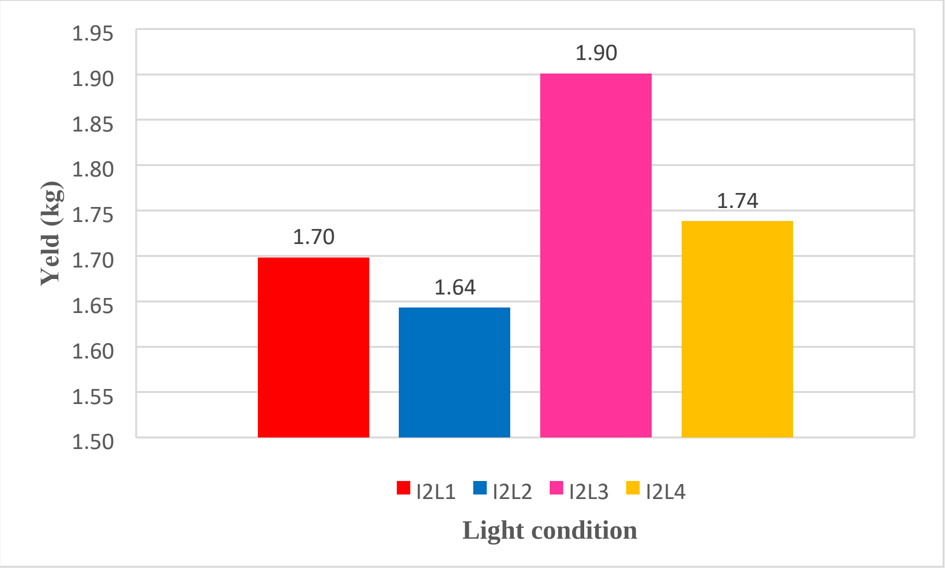


Fig. 4.2Green fodder production in kg/tray for micro sprinkler irrigation

From Fig. 4.2 it is clear that the highest yield obtained for micro sprinkler irrigation was 1.90 kg. This result was found for combination of LED red + blue (L_3). The least yield obtained was around 1.64kg and was resulted in LED blue (L_2).

4.2.3 Hydroponic Fodder Production in Fogger Irrigation under Different Light Conditions

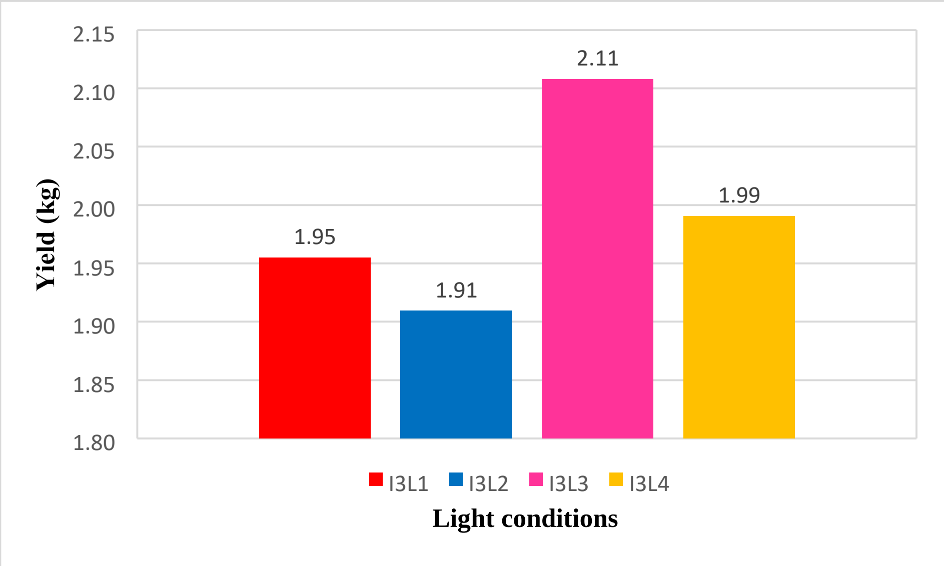


Fig. 4.3Green fodder production in kg/tray for fogger irrigation

The Fig.4.3shows that the highest yield obtained for fogger irrigation was 2.11kg. This result was found for combination of LED red + blue (L_3). The least yield obtained was around 1.91kg and was for LED Blue (L_2).

4.2.4 Comparison of Yield Under Different Irrigation Methods at Different Light Conditions

The Fig. 4.4graphicallyshows how the yield was affected by different treatments. It is clear from the graph that fogger irrigation along with LED red + blue light (L_3) as energy source produced highest green fodder yield (2.11 kg/tray). LED red(L_1) and LED blue(L_2) individually produced less fodder compared to combination of them (L_3). Even in case of mist and micro sprinkler irrigation the treatment with combination of red + blue light (L_3) gave higher yield compared to other light conditions (1.901 kg and 1.899 kg respectively). Least yield was 1.64 kg per tray obtained for micro sprinkler with LED blue light (I_2L_2). LED blue shows the least yield for every irrigation method. The yield found under the natural sunlight was comparatively higher than LED red (L_1) and LED blue (L_2). The effect of different light conditions on the HMF growth is clearly shown by the experimental results. Statistically significant increase in the fodder yield is found under (L_3) LED red + Blue. This result is in accordance to the results found by Bian *et al.,* (2018) and Kobayashi *et al.*, (2013), who also found the highest yield under the combination of red + blue LED.

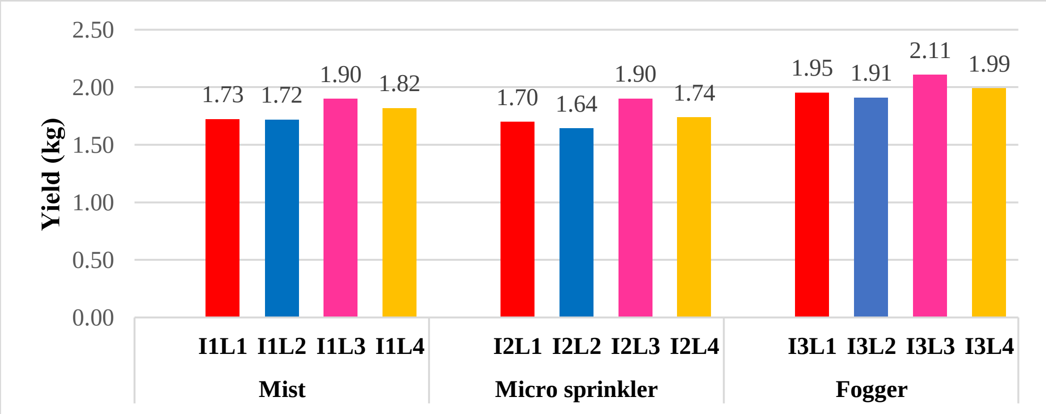


Fig. 4.4 Comparison of yield under different irrigation methods at different light conditions

In case of irrigation methods, yield under the fogger system with different light is the highest as compared to the mist and micro sprinkler. Coverage of fodder growing trays and uniformity of application was found excellent in fogger irrigation whereas unequal distribution was found in mist and micro sprinkler which might have led to poor growth of HMF. Due to unequal distribution of water under micro sprinkler irrigation some parts of the tray were irrigated more and as a result mold growth was observed in those trays.

4.2.5 ANOVA of Total Fodder Production

Table 5 shows the results of ANOVA test done for Yield data and Table 6 shows the comparison of yield under different treatments.

Table 5 ANOVA of fodder yield

Source of Variation	Sum of square	Degree of freedom	Mean square	F	P-value	F-critical
Irrigation method (I)	0.41	2	0.2	542.55	1.05E-20	3.403
Light condition (L)	0.23	3	0.077	205.52	3.09E-15	3.009
I × L	0.014	6	0.0014	3.86	0.0077	2.508
Total	0.66	35				

Table 6 Comparison of Yield under different treatments

Irrigation	Yield (kg/tray)			
	LED Red	LED Blue	LED Red + Blue	Sun Light
Mist	1.73 ^{c}	1.72 ^{b}	1.90 ^{b}	1.82 ^{b}
Micro Sprinkler	1.70 ^{bc}	1.64 ^{c}	1.90 ^{b}	1.74 ^{c}
Fogger	1.96 ^{a}	1.91 ^{a}	2.11 ^{a}	2.00 ^{a}

Means followed by the same letter in a column are not significantly different at $P < 0.05$.

4.3 EFFECT OF DIFFERENT LIGHT CONDITIONS AND WATER APPLICATION METHODS ON WATER USE EFFICIENCY

Water use efficiency was expressed in kg of fodder produced per tray per cubic meter of water and tabulated in Table 7. Due to scarcity of water and land, it is very important to have a system which can produce higher yield using minimum amount of water leading to a very high-water use efficiency. The results of this experiment show that the hydroponic method of growing fodder has very high-water use efficiency.

Table 7 Water use efficiency of different treatments

SI NO	Treatments	WUE (kg/m^3)			
		R_1	**R_2**	**R_3**	**Average**
1	I_1L_1	473.49	479.78	471.65	474.97
2	I_1L_2	478.63	472.62	469.59	473.61
3	I_1L_3	494.68	497.25	504.98	498.97
4	I_1L_4	502.59	480.96	501.96	495.17
5	I_2L_1	445.07	447.90	433.07	442.01
6	I_2L_2	418.18	436.59	422.46	425.74
7	I_2L_3	477.39	482.22	479.50	479.70
8	I_2L_4	444.09	420.55	434.57	433.07
9	I_3L_1	476.95	499.62	483.79	486.79
10	I_3L_2	464.22	466.92	487.07	472.74
11	**I_3L_3**	**506.40**	**509.91**	**530.00**	**515.43**
12	I_3L_4	484.69	496.00	484.55	488.41

4.3.1 Effect of different light conditions on WUEundermist irrigation

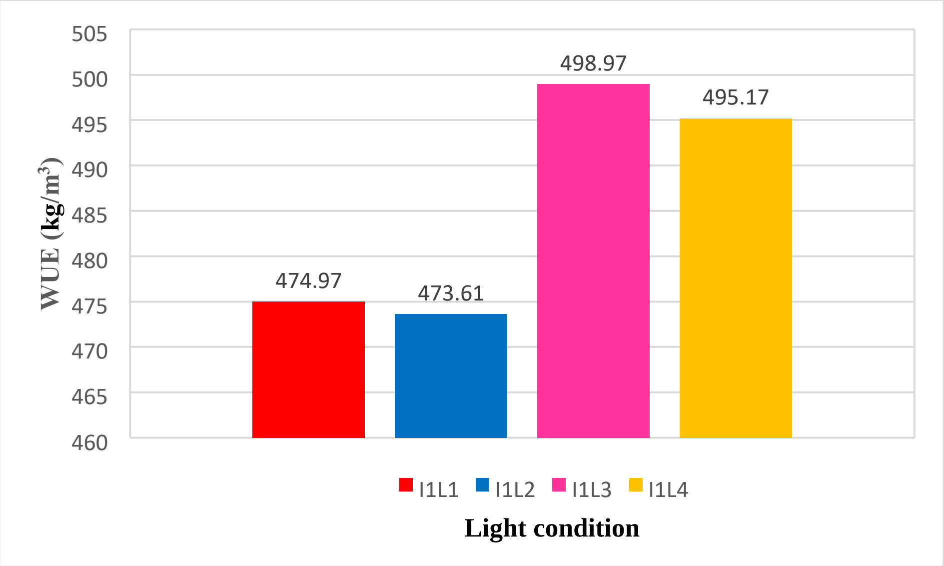


Fig. 4.5Effect of different light conditions on WUE in mist irrigation

The above Fig. 4.5 shows how WUE is affected by change in the light condition.

The highest WUE recorded was 498.97kg/m^3 in the case of mist irrigation. The graph clearly indicates that it was obtained in combined red + blue LED. The lowest WUE observed in LED blue and that was around 473.61kg/m^3.WUE not only depends on yield but it mainly depends on water used by crop.

4.3.2 Effect of Different Light Conditionson WUEunder Micro Sprinkler Irrigation

The highest WUE recorded was 479.70kg/m^3 in the case of micro sprinkler irrigation. The Fig.4.6clearly indicates that it was obtained in combined red + blue LED. The lowest WUE observed in LED blue and was around 425.74kg/m^3.

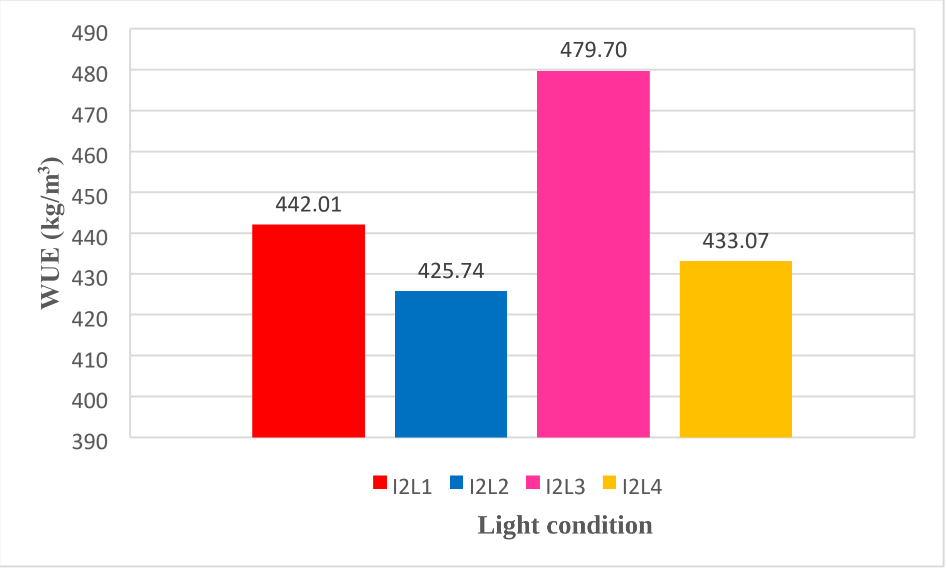


Fig. 4.6 Effect of different light conditions on WUE under micro sprinkler irrigation

4.3.3 Effect of Different Light Conditionson WUEunder Fogger Irrigation

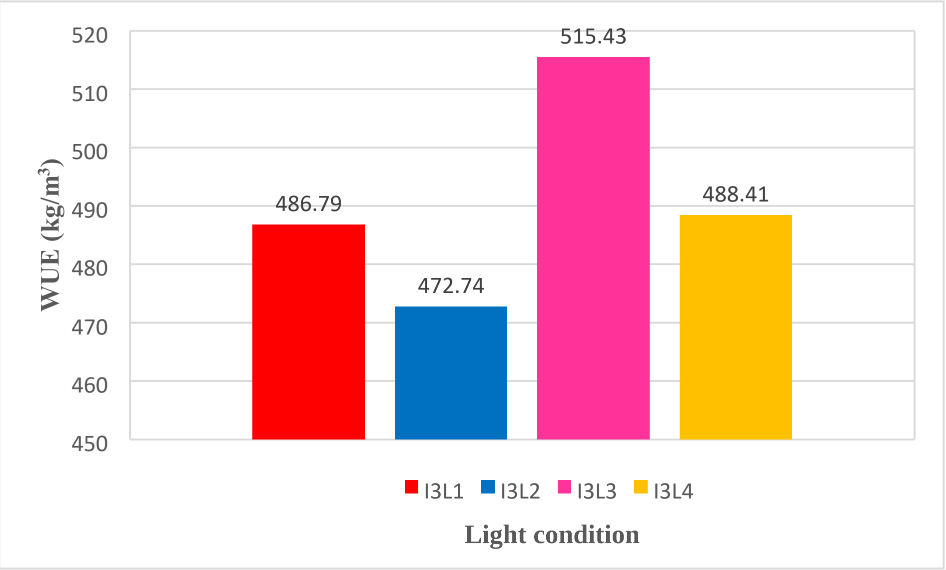


Fig. 4.7 Effect of different light condition on WUE in fogger irrigation

The highest WUE recorded was 515.434kg/m^3 in the case of micro fogger irrigation and it was obtained in combined red + blue LED shown in Fig. 4.7. The lowest WUE observed in LED blue and was around 472.738kg/m^3. The LED red + blue combination gave higher value in each irrigation method used in the experiment.

4.3.4 Comparison of WUE of Different Irrigation Methods under Different Light Conditions

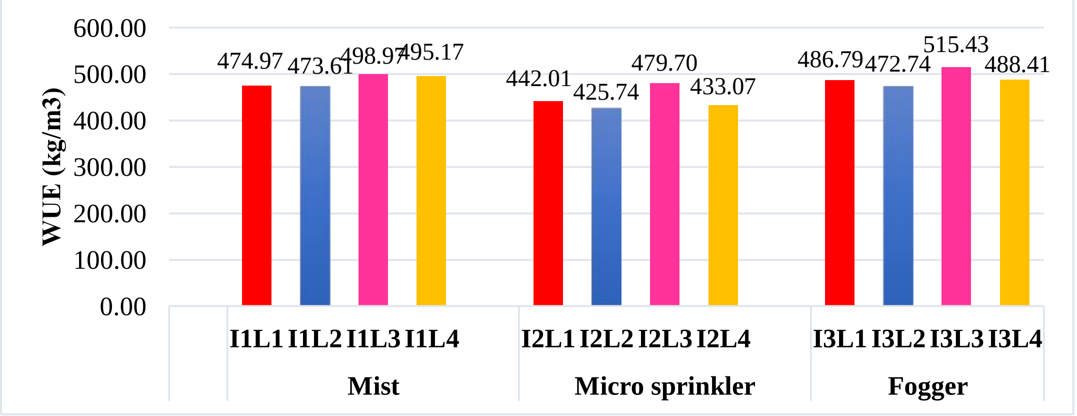


Fig. 4.8Comparison of WUE of different irrigation methods under different light conditions

The comparison graph (Fig. 4.8) clearly shows the dominance of fogger irrigation with LED red+ blue combination. The highest WUE obtained was 515.43kg/m^3. The least WUE observed was around 425.74kg/m^3, found in micro sprinkler irrigation under LED blue light. The higher WUE obtained might be the result of fogger irrigation which gives very fine droplets and equally applies it over the tray. Also, it increases humidity around the growing fodder which is one of the main factors involved in better growth of fodder grass.

On the other hand, micro sprinkler and mist treatment resulted in comparatively less WUE. This might be the result of unequal distribution of irrigation water over the hydroponic trays. Mold growth was observed in some trays which blocked the drainage holes of the trays and resulted in stagnant water and significantly more water used per tray. Even though the yield was more the WUE decreased due to increased water consumption.

The seed rate used (350 g per tray) and water level (1 l per tray per day) which was selected based on review of literature found suitable. These considerations found satisfactory in the experiment, which helped to design and develop small scale indoor hydroponic system with artificial lighting for fodder production. The indoor system (I_3L_3) is superior to fodder grown in poly house (L_4) which is justified by the higher yield and WUE observed in treatment I_3L_3.

Table 8ANOVA of WUE

Source of Variation	Sum of square	Degree of freedom	Mean square	F	P-value	F-critical
Irrigation method (I)	7886.63	2	3943.317	47.27	4.75E-09	3.403
Light condition (L)	9470.90	3	3156.968	37.84	2.94E-09	3.009
I × L	1765.48	6	294.2463	3.52	0.012	2.508
Total	21125.2	35				

Table 9 Comparison of WUE under different treatments

Irrigation	WUE (kg/m^3)			
	LED Red	LED Blue	LED Red + Blue	Sun Light
Mist	474.97^{ab}	473.62^{ab}	498.97^{ba}	495.17^{b}
Micro Sprinkler	442.01^{b}	425.74^{b}	479.71^{b}	433.07^{b}
Fogger	486.79^{a}	472.74^{a}	515.43^{a}	488.41^{a}

Means followed by the same letter in a column are not significantly different at $P < 0.05$.

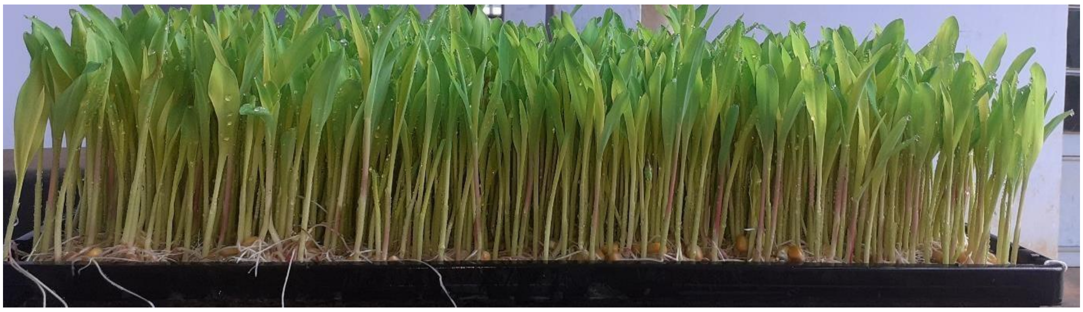
Like yield the WUE results were subjected to statistical analysis. The calculated F value was higher compared to critical value, also the P-value was less than 0.05 (Table 8) allowing us to conclude that there is a significant variation in WUE because of different factors used in the treatment. The fogger irrigation is suitable for hydroponic fodder growth. This was proved by the experiment. This might be because of very fine droplet size produced by the fogger which equally reached every corner of the tray. It helped to maintain high relative humidity around growing fodder. Fogger gave irrigation for fodder to grow and also maintainedfavourable micro climatic condition in the system. LED lights proved to be an alternative source of energy for fodder growth.Comparison of WUE under different treatments are given in Table 9.

When fodder was grown in closed room, evaporation losses tend to be very less compared to outdoor condition. This might be the reason for efficient water use by the crop in treatment where it was grown inside the room with LEDs. Solar energy is not consistent throughout the day. But in case of LEDs it is highly consistent. They emit energy constantly throughout the operating time and this can also be one of the reasons for significantly higher growth and WUE found in fodder grown with the help of LEDs (LED red + blue).

HMF grown under different light conditions are shown in Plate 4.1.

(a)

(b)



(c)

(d)

Plate 4.1 HMF grown under (a) LED red (b) LED blue (c) Led red + blue (d) poly house respectively

4.4 PHYSICAL AND CHEMICAL ANALYSIS

Moisture content, crude fibre and crude protein were analysed for the four samples and shown in table 10. These samples selected were from the highest yield given in four different light conditions (I_3L_1, I_3L_2, I_3L_3, and I_3L_4). Table 10 Results of physical and chemical analysis

Sample	kg/Tray	Shoot length(cm)	Root length(cm)	Moisture content %	Crude protein %	Crude Fiber %
I_3L_1	1.61	26.6	11.2	77.53	11.81	9.25
I_3L_2	1.65	25.9	10.5	76.77	10.50	8.59
I_3L_3	1.76	31.5	14.2	76.585	13.56	12.59
I_3L_4	1.54	25.2	11.3	79.953	12.25	10.59

The fodder grown in fogger irrigation with LED red + blue combination showed best results. Not only it gave highest yield but also it contained higher amount of crude protein (13.56) as well as crude fibre (12.59).

4.5 ECONOMIC ANALYSIS OF HYDROPONIC FODDER PRODUCTION SYSTEM

A prototype fodder production system which produces 7 to 8 kg fodder per day was built using the best light and irrigation conditions found in the experiment(I_3L_3) shown in Plate 4.2.

Straight line method was used to calculate the cost of hydroponic fodder production system shown in Table 11. Calculation is mentioned in Appendix II. The cost of material was calculated by ascertaining the raw material price in the market and the estimated unit cost of hydroponic fodder production system was found to be Rs 17030. The experimental results showed that the weight of the fodder produced in hydroponic unit was about 6 times that of seeds. This unit having 4 trays per day capacity can yield approximately 7.5 kg maize fodder per day.

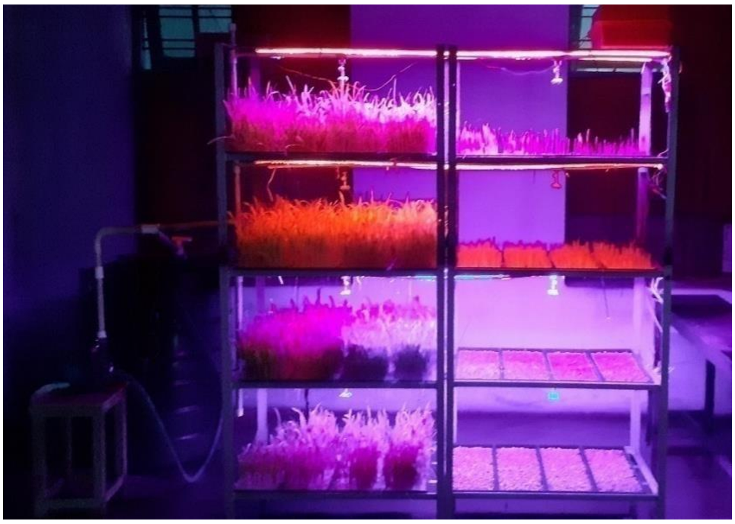


Plate 4.2 Indoor prototype HMF production system

Table 11Cost Economics of hydroponic fodder production system

Particulars	**Amount in Rs**
Structural cost	17030
Fixed cost (per day)	
Deprecation	4.199
Interest	3.079
Total fixed cost	7.278
Variable cost (per day)	
Seed cost (1.4 kg)	25.2
Labour (1hr)	25
Electricity cost	11.5
Total variable cost	61.7
Total production cost per day	69
Total return (Rs. 15 per kg)	112.5
Net return	43.5
Benefit cost ratio – **1.63**	

4.6 COMPARISON BETWEEN HYDROPONIC GREEN FODDER AND CONVENTIONAL PRODUCTION SYSTEM

Table 12 shows the comparison between hydroponic and conventional green fodder production system practiced on the parameters like area, time of production, water requirement soil fertility, fodder yield, fertilizer application, fencing, farm protection, labour requirement and green fodder utilization. Clearly the hydroponic fodder production was better over conventional system. The water use from the crop was very less compared to conventional farm.

Table 12 Comparison between hydroponic and conventional fodder production system

S.No	**Parameters**	**Conventional method (Naik et al., 2019)**	**Hydroponic method**
1	Area requirement to produce 600 kg per day	1 hectare	150 square meters
2	Number of days for production	65-70 days	Less than 10 days
3	Water requirement	Around 30 l/kg fodder	2.5 to 3 l/kg of maize fodder
4	Soil fertility	Essential	Not necessary
5	Fertilizer application	Much required	Not required for fodder
6	Fodder yield	Depends on environmental parameters and cultivation practices	Under controlled conditions
7	Labour power	High labour requirement	Less required
8	Availability of fodder	Season wise	Every day in the year

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSIONS

Due to water scarcity, changing climatic conditions and urbanization, the availability of land is becoming less for green crop production. To increase the milk production of dairy animals, feeding green fodder is very essential.Hydroponics is one of the best and advanced method for the efficient uti1ization of water. Advantages of hydroponic fodder production are high WUE, high fodder production from unit area, less labour cost, relatively low operating cost, absence of weed growth, 1ess attack of insects and pests, shorter growing period and highly nutritive feeding material to increase milk production of lactating animal.

The current study entitled "Development and evaluation of small scale hydroponic green fodder production system" has been undertaken at Kelappaji College of Engineering and Technology Tavanur, with the objective of hydroponic fodder production inside a room with the help of artificial lighting. Hydroponic structure was constructed using PVC pipes to grow fodder under different irrigation and light conditions. Mainly three different irrigation application methods such as mist (I_1), micro sprinkler (I_2) and fogger (I_3) were used and light arrangements were made with LEDs of red (L_1), blue (L_2) and red + blue (L_3)colours as well as natural sunlight (L_4) for comparison. Total 3 replications and 36 treatments were made. Total fodder production per tray and WUE (kg fodder/m^3 water) was calculated foreachtreatment.

Based on the results fogger irrigation (I_3) and LED red + blue light (L_3) was found to be the best combination for fodder growth. A small-scale hydroponic fodder production system was built using these conditions (I_3L_3) and economic analysis was done for the system developed. From the results of the experiment the following conclusions are made.

1. Fogger irrigation along with LED red + blue light as energy source produced highest green fodder yield (2.11 kg/tray)
2. Least green fodder yield was 1.64 kg per tray obtained under microsprinkler with LED blue light (I_2L_2)
3. The highestWUE was recorded in fogger irrigation with Red + Blue light (515.43 kg/m^3)
4. The lowest WUE observed was around 425.74kg/m^3, found in micro sprinkler with LED blue light (I_2L_4)
5. The automation by using Multipoint UTR 1044 digital timer worked very well
6. ANOVA of both independent parameters were statistically significant at 5% level
7. Hydroponic fodder produced using LED red + blue and fogger irrigation is having the highest protein (13.56 %) and crude fiber (12.59 %)
8. Gross return and Benefit Cost ratio of hydroponic maize fodder was Rs. 112.5 per day and 1.63 respectively

The hydroponic system developed to produce maize fodder is economical, efficient and easy to adopt by the farmers.WUE of the system is high as compared to conventional method. This is simple and fast way to produce the fodder that can be used in cattle farming. This system helps to reduce drudgery and save the land for other uses. System can be modified as solar assisted to conserve the energy. Further study can be conducted by growing fodder under different light intensities to optimize yield.

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CHAPTER IV
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APPENDICES

APPENDIX I

Details of water collected (ml) from each tray under different treatments.

Mist Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
LED Red	1	793	806	814	802	830	826	819	801	803
	2	740	810	783	753	822	862	883	876	833
	3	727	740	742	770	757	725	741	780	793
	4	641	646	672	635	679	683	662	658	653
	5	617	614	622	631	637	540	586	589	598
	6	560	535	550	579	526	576	580	600	609
	7	470	462	463	488	492	495	450	430	417
	8	375	383	388	400	360	343	348	355	379

Mist Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
LED Blue	1	818	877	833	807	798	766	779	770	785
	2	763	772	755	790	832	789	852	872	880
	3	720	737	746	759	770	795	802	750	725
	4	680	695	673	687	693	692	679	675	677
	5	630	622	606	648	602	626	625	619	622
	6	588	550	553	562	530	530	520	535	564
	7	442	450	453	457	465	468	440	443	480
	8	378	387	365	366	352	358	356	364	372

Mist Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
LED Red + Blue	1	856	789	772	822	842	839	886	890	875
	2	782	806	822	789	795	825	829	842	807
	3	775	774	756	720	739	752	691	701	722
	4	688	642	637	688	675	666	673	640	639
	5	570	565	574	550	525	570	579	595	601
	6	500	507	525	514	550	553	508	509	530
	7	400	402	410	417	396	392	388	407	415
	8	350	359	379	371	330	327	326	342	350

Mist Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
Sunlight	1	823	804	798	782	786	762	814	798	835
	2	748	782	783	775	771	756	785	768	783
	3	705	722	733	698	648	702	705	722	721
	4	661	663	622	704	668	635	692	669	673
	5	606	598	663	512	588	558	519	563	578
	6	604	583	578	518	565	553	578	585	595
	7	502	505	518	447	485	496	504	518	496
	8	418	392	443	423	422	398	361	402	389

Micro sprinkler Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
LED Red	1	763	782	798	815	835	802	816	796	776
	2	733	728	716	751	747	714	718	738	741
	3	711	719	701	699	693	688	703	715	719
	4	670	658	666	672	656	675	682	683	670
	5	574	578	583	591	598	508	562	565	578
	6	528	526	516	545	538	532	509	504	506
	7	442	450	463	485	506	498	432	411	445
	8	378	382	355	402	410	398	372	378	356

Micro sprinkler Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
LED Blue	1	817	845	852	839	828	801	816	855	812
	2	749	719	726	723	698	717	726	735	709
	3	701	699	673	725	730	703	689	675	698
	4	650	658	649	644	653	660	672	670	639
	5	584	586	570	569	545	555	538	592	564
	6	518	495	482	516	535	539	518	520	524
	7	432	428	420	467	450	462	485	430	470
	8	383	387	371	369	385	402	401	390	350

Micro sprinkler Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
LED Red + Blue	1	841	848	855	870	850	813	809	820	802
	2	712	725	713	706	707	713	693	697	702
	3	677	699	715	725	685	693	679	707	700
	4	609	613	627	616	642	639	630	625	619
	5	576	552	561	564	573	577	562	564	570
	6	516	490	508	499	526	522	524	540	499
	7	415	416	423	399	422	436	434	425	416
	8	379	363	355	380	357	378	371	360	362

Micro sprinkler Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
Sunlight	1	759	723	850	822	773	801	795	808	765
	2	709	725	753	672	702	695	758	719	728
	3	652	620	645	660	679	687	682	636	652
	4	645	652	639	602	629	582	673	665	655
	5	581	583	602	589	545	552	560	545	569
	6	576	569	552	520	487	545	552	530	547
	7	445	410	469	482	489	455	445	448	462
	8	371	402	359	327	319	302	320	328	362

Fogger Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
LED Red	1	775	749	754	790	775	785	732	745	775
	2	720	713	730	745	735	740	712	723	730
	3	670	677	690	703	795	665	670	672	682
	4	603	612	617	599	589	605	617	620	603
	5	570	582	549	519	520	532	545	549	559
	6	492	499	502	509	515	525	498	445	485
	7	412	459	442	415	432	458	458	455	452
	8	385	392	359	375	389	401	372	389	392

Fogger Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
LED Blue	1	790	801	821	793	750	762	734	749	796
	2	745	703	708	699	685	709	711	720	730
	3	701	689	679	683	670	675	682	688	690
	4	559	575	580	600	599	592	687	689	679
	5	530	525	510	509	518	532	560	575	519
	6	489	449	478	492	500	519	502	499	487
	7	413	419	444	457	439	448	459	469	466
	8	359	362	366	375	349	385	359	342	349

Fogger Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
LED Red + Blue	1	818	804	774	804	779	730	762	798	802
	2	699	726	714	802	711	721	729	724	708
	3	659	668	669	679	684	686	689	684	678
	4	589	592	602	584	586	591	602	611	591
	5	518	528	499	491	518	528	534	538	539
	6	467	468	484	497	441	484	508	517	504
	7	428	409	424	439	434	430	454	459	449
	8	348	344	354	361	369	381	351	364	311

Fogger Irrigation										
Light	Day	R_1			R_2			R_3		
		Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3	Tray 1	Tray 2	Tray 3
Sunlight	1	760	747	778	780	845	815	758	723	768
	2	714	715	761	703	742	747	755	740	714
	3	623	655	640	687	680	657	640	667	676
	4	654	597	634	621	578	597	614	604	625
	5	576	577	560	578	631	597	557	550	515
	6	504	493	480	510	543	547	540	542	547
	7	457	447	440	405	407	423	460	425	422
	8	380	364	340	376	382	304	276	380	355

APPENDIX II

Details of cost economics calculations.

Capital cost:

S .No.	Materials	Value (Rs.)
1	Iron frame	1500.00
a	Pump	3600.00
3	Led light	1680.00
4	Timer	1500.00
5	Water tank	2500.00
6	Pipe	500.00
7	Foggers	1400.00
8	Fittings	500.00
9	Trays	3200.00
10	Labour cost (25% of total material cost)	650.00
	Total	**17030.00**

$$Depreciation = \frac{Capital\ cost - Salvage\ value}{Useful\ life}$$

Salvage value = 10% of capital cost

Useful life of system = 10 years

$$Depreciation = \frac{17030 - 1703}{10 \times 365} = 4.199\ Rs\ per\ day$$

$$Interest = \frac{Capital\ cost + Salvage\ value}{2} \times \frac{annual\ interest}{365}$$

Annual interest = 12%

$$Interest = \frac{17030 + 1703}{2} \times \frac{0.12}{365} = 3.079\ Rs\ per\ day$$

$$Fixed\ cost = 4.199 + 3.079 = 7.278\ Rs\ per\ day$$

Variable cost:

S .No.	Particulars	Value (Rs.)
1	Seed cost	25.2
2	Labour cost	25
3	Electricity	11.5
Total		**61.7**

Total cost of production = Fixed cost + variable cost

Total cost of production = 7.278 + 61.7 = 68.978 ≈ 69 Rs per day

Fodder production per day = 7.5 Kg

Gross return = 7.5 × Rs. 15 = Rs. 112.5

Net return = 112.5 – 69 = 43.5 Rs. per day

$$Benifit\ cost\ ratio = \frac{Gross\ return}{Cost\ of\ production}$$

$$Benifit\ cost\ ratio = \frac{112.5}{69} = \mathbf{1.63}$$

DEVELOPMENT AND EVALUATION OF SMALL SCALE HYDROPONIC GREEN FODDER PRODUCTION SYSTEM

By

ADARSHA GOPALAKRISHNA BHAT

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ABSTRACT OF THESIS

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ABSTRACT

A research on development and evaluation of small scale hydroponic green fodder production system was conducted in PFDC building of Kelappaji College of Agricultural Engineering and Technology Tavanur. The objective of research work was to develop a small scale hydroponic green fodder production system, testing of developed system under different micro climatic condition and estimation of water use efficiency for different water application method.

Three different water application methods mist (I_1), micro sprinkler (I_2), fogger (I_3) were selected. Artificial light source of LED red (L_1), LED blue (L_2), LED red + blue (L_3) and sunlight were taken for the study. Statistical analysis was conducted to understand the significance of different treatments used in the experiment. A working prototype with best treatments observed during the study was built and cost economics were studied.

The highest yield was observed in treatment involving fogger irrigation and LED red + blue (2.11 kg/tray) with the highest water use efficiency (515.43 kg/m^3) compared to other treatments. The results are in accordance to the results found by Bian *et al*., (2018) and Kobayashi *et al*., (2013), who also found the highest yield under the combination of red + blue LED. Seed to fodder ratio obtained was 1: 6. Chemical analysis showed higher percentage of crude protein (13.56%) and crude fibre (12.59%) in this treatment.

Higher growth of green fodder under artificial light source can be attributed to the continuous supply of energy compared to highly varying sunlight and also the uniform distribution of water by fogger irrigation which maintained favourable condition for fodder growth. Results clearly shows that growing green fodder with artificial light source (LED red + blue) and water supply with fogger can be commended to farmers for achieving better growth of green fodder for domestic animals.