PERFORMANCE EVALUATION OF HYDROPONIC FODDER PRODUCTION SYSTEM FOR JOWAR CROP AT DIFFERENT LIGHT CONDITIONS

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PROJECT REPORT

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DECLARATION

We hereby declare that this project report entitled "**PERFORMANCE EVALUATION OF HYDROPONIC FODDER PRODUCTION SYSTEM FOR JOWAR CROP AT DIFFERENT LIGHT CONDITIONS"** is a bonafide record of research work done by us during the course and the project report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this project report entitled **"PERFORMANCE EVALUATION OF HYDROPONIC FODDER PRODUCTION SYSTEM FOR JOWAR CROP AT DIFFERENT LIGHT CONDITIONS"** is a record of project work done jointly by **Ms. Ardra Santhosh, Ms. Gopika Subhash, Ms. Karthika M P and Ms. Manjusha K P** under my guidance and supervision and that it has not previously formed the basis for any degree, diploma, fellowship or associateship or other similar title of another University or Society.

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SYMBOLS AND ABBREVIATION

^{o}	Degree
'	Minute
/	Per
%	Percentage
ANOVA	Analysis of Variance
BAHS	Basic animal husbandry statistics
BCR	Benefit Cost Ratio
C	Celsius
cm	Centimetre
CRD	Completely Randomized Design
DC	Direct Current
DM	Dry Matter
et al.	And Others
Fig.	Figure
g	Grams
HJF	Hydroponic Jowar Fodder
hp	Horse Power
h	Hours
KCAET	Kelappaji College of Agricultural Engineering and Technology
KVK	Krishi Vigyan Kendra
l	Litre
LED	Light Emitting Diode
lph	Litres Per Hour
m^3	Cubic Meter
PFDC	Precision Farming Development Centre
V	Volts
WUE	Water Use Efficiency

CHAPTER I

INTRODUCTION

Indian livestock sector is one of the largest in the world with holdings of 11.6 percent of the world (BAHS, 2014). In recent years, the livestock sector has emerged as an important segment of an expanding and diversifying agricultural sector in the Indian economy (Tisdell and Gali, 2000). The livestock farming is a very important socio-economic activity in Indian agriculture, as milk is the second largest agricultural commodity contributing to GNP (Gross National Products), next only to rice (Sarkar and Ghosh, 2010). Goat and sheep are known as the poor man's cow or bank on hooves which can survive with least resources. The livestock provides main food items such as milk, meat and eggs for human consumption. Rural Poverty is largely concentrated among the landless and the marginal households comprising about 70 percent of rural population (Kozel and Parker, 2003). Several empirical studies indicate that livestock rearing has significant positive impact on equity in terms of income and employment and poverty reduction in rural areas (Singh and Hazell, 1993). Livestock generates a continuous stream of income and reduces seasonality in livelihood patterns particularly of the rural poor.

India with only 2.29% of land area of the world, is maintaining nearly 17.4% of world human population and 10.7% of livestock (more than 510 million heads) creating a huge pressure on land, water and other resources (Roy *et al*., 2019). India is characterized by genetic richness in flora and fauna and fragile biomes. Livestock are an integral component for green eco-sustainability. India has rich livestock genetic diversity with possessing premier dairy buffaloes, draft cattle, carpet wool sheep, and prolific goat breeds. India with largest livestock and second largest human population needs judiciously conceived strategy to meet the ever-increasing food, feed and fodder demand with adequate quality and quantity. The demand for animal-based food products is on increase. In last few decades, per capita consumption of meat in India has increased by many times higher as compared to increase in the consumption of food grains. This will continue to rise in the future due to increasing urbanisation, change in food habit and enhanced purchasing power. Feed cost accounts for about 70-75% of the total cost of livestock production, particularly in milch animals. So, to increase the margin of profit from livestock/dairy farming, proper feeding strategies need to be followed with proper inclusion 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. Indian subcontinent is one of the world's mega centers of crop origin and crop plant diversity due to a wide spectrum of eco-climate ranging from humid tropical to semiarid, temperate to alpine. India possesses a rich genetic diversity with reports of 245 genera and 1256 species of Poaceae of which one third are considered to have fodder value and are utilized in the form of grazing and cultivation. Similarly, about 60 genera and 400 species of Leguminosae are reported out of which 21 genera are useful as forage (Ramteke *et al*.,2021).

With the advent of civilization, open field/soil-based agriculture is facing some major challenges; most importantly decrease in per capita land availability. In 1960 with 3 billion population over the World, per capita land was 0.5 ha but presently, with 6 billion people it is only 0.25 ha and by 2050, it will reach at 0.16 ha (Sengupta and Banerjee,2012). Due to rapid urbanization and industrialization as well as melting of icebergs (as an obvious impact of global warming), arable land under cultivation is further going to decrease. Again, soil fertility status has attained a saturation level, and productivity is not increasing further with increased level of fertilizer application. Besides, poor soil fertility in some of the cultivable areas, less chance of natural soil fertility build-up by microbes due to continuous cultivation, frequent drought conditions and unpredictability of climate and weather patterns, rise in temperature, river pollution, poor water management and wastage of huge amount of water, decline in ground water level, etc. are threatening food production under conventional soil-based agriculture. Under such circumstances, in near future it will become impossible to feed the entire population using open field system of agricultural production only. Naturally, soil-less culture is becoming more relevant in the present scenario, to cope-up with these challenges. In soil-less culture, plants are raised without soil. Improved space and water conserving methods of food production under soil-less culture have shown some promising results all over the World.

Hydroponics, also called aquaculture, nutriculture, soilless culture, or tank farming, the cultivation of plants in nutrient-enriched water, with or without the mechanical support of an inert medium such as sand, gravel, vermiculite, rockwool, perlite, peatmoss, coir or saw dust. *Liquid* hydroponic systems have no other supporting medium for the plant roots; *aggregate* systems have a solid medium of support. Hydroponic systems are further categorized as open (i.e., once the nutrient solution is delivered to the plant roots, it is not reused) or closed (i.e., surplus solution is recovered, replenished, and recycled).

In combination with greenhouses, it is high-technology and capital-intensive. It is also highly productive, conservative of water and land, and protective of the environment. Yet for most of its employees, hydroponic culture requires only basic agriculture skills. Since regulating the aerial and root environment is a major concern in such agricultural systems, production takes place inside enclosures designed to control air and root temperatures, light, water, plant nutrition, and adverse climate.

There are many types of controlled environment/hydroponic systems. Each component of controlled-environment agriculture (CEA) is of equal importance, whether it be the structural design, the environmental control, or the growing system. Not every system is cost effective in every location. All too often, importance is given to only one or two of the key components, but the system fails due to lack of attention to any one of the components. If improper attention is given to the greenhouse structure and its environment, no hydroponic system will prove economically viable. While hydroponic and CEA are not synonymous, CEA usually accompanies hydroponics. Their potentials and problems are inextricable (Jensen, 1997).

There are many advantages of growing plants under soil-less culture over soil-based culture. These gardens produce the healthiest crops with high yields and are consistently reliable; gardening is clean and extremely easy, requiring very little effort. Here nutrients are fed directly to the roots, as a result plants grow faster with smaller roots, plants may be grown closer, and only 1/5th of overall space and 1/20th of total water is needed to grow plants under soil-less culture in comparison to soil-based culture. There is no chance of soil-borne insect pest, disease attack or weed infestation too. Overall soil-less culture provides efficient nutrient regulation, higher density planting, and leading to increased yield per acre along with better quality of the produce. It is also effective for the regions of the World having scarcity of arable or fertile land for agriculture (Sardare *et al*.,2013).

Jowar is one of the important food and fodder cereal crops cultivated across India, Sorghum popularly known as "Jowar" in India. The advantage of this cereal crop is that it can be cultivated in both Kharif and Rabi season. Jowar is the 5th most important cereal crop in the world after rice, wheat, maize & barley (Jawarkar, 2018). The nutritional value of sorghum is same as of that of corn and that is why it is gaining importance as livestock feed. Sorghum (or) Jowar is also used for ethanol production, producing grain alcohol, starch production, production of adhesives and paper other than being used as food and feed for livestock. Jowar (or) Sorghum cultivation is gaining popularity due to its nature of extreme drought tolerance. Sorghum is very nutritious just like corn and can be used as green fodder, dry fodder, hay or silage.

Major sorghum or jowar producing states in India are Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Telangana, Tamil Nadu, Gujarat, UP, Rajasthan and Haryana. It thrives well at a temperature between 25°C and 32°C but below 16°C is not good for the crop. Jowar crop requires rainfall about 40 cm annually. Jowar is extreme drought tolerant crop and recommended for dry regions. Too much of moist and prolonged dry conditions are not suitable for jowar cultivation. If the crop is sown in monsoon time (July) it may require 1 to 3 irrigations depending upon rains. For summer crops, 6 to 7 irrigations may be carried out due to high temperature. In South India, Rabi season crops need about 4 to 5 irrigations.

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.

By considering all these points, the present study entitled “Performance evaluation of hydroponic fodder production system for jowar crop at different light conditions” focuses on the fulfilment of hydroponic green fodder production with less time and better water use efficiency in the dark room with artificial lighting. The study was undertaken with the objective:

- Evaluation of the hydroponic fodder production system for jowar under different light conditions

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

Muela *et al*. (2005) studied the use of green fodder produced in hydroponic system as supplement for lactating cows during the dry season. After the intensive study they concluded that the hydroponic green fodder is a viable supplement for sustaining the weight of cows.

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 6 (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).

Kammar *et al*. (2019) tried to explain the pros and cons of the hydroponics technology. Data was collected using self-structured interview schedule on their visit to KVK and analysed using simple frequencies and percentage. Majority of the farmers adopted a 72 trays model which produced on an average 4.5 fresh fodder from 500 g maize grains per tray. The daily fresh fodder production was 45 kg per day/ unit. The qualitative data was obtained from the observation of the hydroponic unit maintained at KVK Bagalkot. The results implied that, maize is the best source for producing fodder under hydroponics, the system of hydroponics can be prepared using low-cost material, no soil media is used and no nutrients are added to the water used for hydroponics production. But, in rural areas, where the timer facility is not used, it was difficult to get the uniform growth of fodder. There was an incidence of not getting proper germination where the grains were infested.

Ramteke *et al*. (2019) conducted a study on growing plants without soil but in water or nutrient solution in a greenhouse (hi-tech or low-cost devices) for a short duration (approx. 7-8 days) is hydroponics fodder Production. In India, maize grain is preferred over other cereal grains for hydroponics fodder production. The hydroponics green fodder looks like a mat of 20-25 cm length consisting of roots, seeds and stems. To produce one kg of fresh hydroponics maize fodder (7-d), about 1.50-3.0 litres of water is required. Yields of 5-6 folds on fresh basis and DM content of 11-14% are common for hydroponics maize fodder, however, DM content up to 18% has also been observed. The hydroponics fodder has more health benefits due to its palatability, easily digestibility and nutritious. Seed for hydroponic cultivation is major input contributes about 90% of the total cost of production of hydroponics. In situations, where conventional green fodder cannot be grown successfully, hydroponics fodder can be produced by the farmers for feeding their dairy animals using low-cost devices. Supplementation about 5-10 kg fresh hydroponics fodder per cow per day increases milk production (8-13%) by increases in the digestibility of the nutrients.

2.2 HYDROPONICALLY GROWN JOWAR AS A FODDER

Under the scenario of water scarcity, the best alternative to the field Jowar is hydroponic Jowar. Study was planned to compare the partial and complete replacement of green Jowar with hydroponic Jowar and their effect on their hematological parameter in Osmanabadi does. Jowar was grown from the same seeds in field and in hydroponic machine. The T_0 group was fed with control diet. The T_1 group was fed with the 50% replacement of field Jowar with hydroponic Jowar and T_2 group was fed with 100% replacement of field Jowar with hydroponic Jowar. The study indicated positive effect of feeding of hydroponic Jowar fodder in goat health. (Jawarkar *et al*.,2018).

Wahyono *et al*. (2018) conducted a study to evaluate the influence of low gamma irradiation dose on growth performance, in vitro gas production and rumen fermentation product of sorghum hydroponic fodder (SHF) to utilize them in ruminant diets. All seeds were planted in nutrient film technique hydroponic system. This study used Completely Randomized Design with four replications. The observed parameters were total fresh yield, plant height and conversion ratio from seeds to SHF. Results showed that lower irradiation dose for seeds sterilization decreased plant height and total fresh yield on SHF production. It was concluded that lower irradiation dose for seeds sterilization decreased growth performance of SHF. However, 100 Gy gamma irradiation increased in vitro total gas production.

Badamasi and Dagari, (2019) conducted greenhouse hydroponic experiments to study the morphological and biochemical responses of *Sorghum bicolor L.M* to different Zinc (Zn) levels. Two-week-old seedlings transplanted in hydroponic solutions were treated with different doses of Zn in the concentration ranges of 5,25,50,100 and 200 mg/l supplied as $ZnSO_4.5H_2O$ after 21 day of culture, the plants were harvested, blotted to dryness and separated into roots and shoots. The root and shoot lengths, dry weights and non-enzymatic biochemical parameters such as proline, Chlorophyll a, b, Carotenoids(pigments) were determined. The results indicate that Zn applications significantly ($p<0.05$) depressed the lengths of root and shoot, dry weights and pigment contents compared to untreated plants(control).

2.3 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. 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 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. 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.

Bian *et al*. (2018) said that adding light can increase crop yields in nursery by enhancing photosynthesis and 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 77 % red and 23% 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.

Pennisi *et al*. (2019) claimed that indoor plant cultivation can result in significantly improved resource use efficiency (surface, water, and nutrients) as compared to traditional growing systems, but illumination costs are still high. LEDs (light emitting diodes) are gaining attention for indoor cultivation because of their ability to provide light of different spectra. In the light spectrum, red and blue regions are often considered the major plants' energy sources for photosynthetic CO_2 assimilation. This study aims at identifying the role played by red: blue (R: B) ratio on the resource use efficiency of indoor basil cultivation, linking the physiological response to light to changes in yield and nutritional properties. The greatest biomass production was associated with LED lighting as compared with fluorescent lamp. From this study it can be concluded that an RB ratio of 3 provides optimal growing conditions for indoor cultivation of basil, fostering improved performances in terms of growth, physiological and metabolic functions, and resources use efficiency.

Patil *et al*. (2020) conducted a study on the Effect of LED Lights on Fodder Production in Pipe Framed Hydroponic Structure. The field experiments were laid out in factorial randomized block design with 19 treatments and 3 replications for maize crop. The treatments consisted of two LED's reddish purple and white, three durations viz., 4 h, 8 h and 12 h and three LED light intensity levels viz., 480 lux, 740 lux and 930 lux along with control treatment. It was found that reddish purple LED, 12 h duration of LED and LED light intensity of 930 lux showed better desirable results compared to white LED and control, 4 h and 8 h duration of LED and light intensity of 740 lux and 480 lux.

2.4 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.

Hydroponic system requires periodic labour, a systematic approach, repetitive motion and a structured environment. Automation, robotics and IoT have allowed farmers to monitoring all the variables in plant, root zone and environment under hydroponics. Maldonado *et al*. (2019) introduced findings in design with real time operating systems based on microcontrollers; pH fuzzy logic control system for nutrient solution in embed and flow hydroponic culture; hydroponic system in combination with automated drip irrigation; expert system-based automation system; automated hydroponics nutrition plants systems; hydroponic management and monitoring system for an intelligent hydroponic system using internet of things and web technology; neural network-based fault detection in hydroponics; additional technologies implemented in hydroponic systems and robotics in hydroponic systems. The above advances will improve the efficiency of hydroponics to increase the quality and quantity of the produce and pose an opportunity for the growth of the hydroponics market in near future.

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.

2.5 HYDROPONIC FODDER SYSTEM UNDER ARTIFICIAL LIGHTING

Chua *et al*. (2020) conducted a study on the response of loose head lettuce toward the irradiance of the supplemental red-blue LED light with different power (Watt [W]). The investigation was done by comparing the treated lettuce with the lettuce cultured under only natural light. The lettuce plants were treated with red LED (640-660 nm) + blue LED (440-450 nm). The power output of the LEDs was specified to 3, 6, 9, 15, and 20 W. The results showed that the fresh weight of the lettuce that was irradiated with 3 W LED light was significantly higher compared to the lettuce that was exposed to LEDs with other power outputs. Hence, it can be concluded that supplementary LEDs lighting technology can be used as an alternative lighting source to improve the growth of lettuce in hydroponic systems.

Moreover, the use of 3 W LEDs in hydroponic systems could yield a higher shoot weight and fresh weight.

Bhat *et al*. (2021) conducted a field experiment to develop a small scale indoor hydroponic fodder production system. The study shows that green fodder can be efficiently grown at indoor condition. Hydroponic technique helped to achieve yield of 7.535 kg per day with a water requirement of only 4.78 litres per kg. The combination of red and blue LED lights supplied continuous energy for 12 hours a day for the better growth of crop. Results clearly show that the indoor hydroponic fodder production system with artificial supply of light can be recommended for the farmers to meet their fodder requirement.

CHAPTER III

MATERIALS AND METHODS

This chapter elaborates about location, materials used for the research work and methodologies adopted for the evaluation of 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 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 original setup is shown in Plate 3.2.

Plate 3.1 Experimental setup

Plate 3.2 Experimental setup in dark room

3.1.3 Materials required

3.1.3.1 *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 jowar seeds. Tray used is shown in Plate 3.3.

Plate 3.3 Hydroponic tray

3.1.3.2 *Water tank*

A plastic vertical water tank having capacity of 500 l was used to store the water for the irrigation of hydroponic fodder (Plate 3.4).

Plate 3.4 Water tank

3.1.3.3 *Irrigation pump*

An irrigation pump of 0.5 Hp, 240 V was used (Plate 3.5). Total head of the pump was 20 meters with discharge of 1 lps. Excess water in the system was sent back to the tank to utilize the water more efficiently.

Plate 3.5 Irrigation pump

3.1.3.4 *Timer*

Timer was used for the automation of the system which is shown in Plate 3.6. 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 3.6 Timer

3.1.3.5 *Artificial light arrangements*

LED was used for artificial light arrangement (Plate 3.7). Medium density (60 LED/ meter) requires power of 6 Watt/meter and voltage of 12 Volt (DC). Red and Blue colour LEDs were used.

Plate 3.7 LED light strip

3.1.3.6 *Irrigation method*

The irrigation method used was fogger of 16 lph capacity (Plate 3.8).

Plate 3.8 Fogger

3.1.4 Experimental design

The dependent and independent variables used in the experiment are listed in Table 3.1

Table 3.1 Dependant and independent parameters of the experimental design

Sl. No	**Experimental parameters**	**Particulars**
Independent variable		
1	Light condition	LED Red LED Blue LED Red + LED Blue
Dependent variables		
1	Total green fodder production	kg/tray
2	Water use efficiency	kg fresh fodder /cubic meters of water

Set of trays were placed such that each unit gets different light condition (LED red, LED blue, LED red + LED blue) with Fogger irrigation system. Three trials were done for all treatments and average was considered for the calculation.

Table 3.2 Treatment details

Statistical design	CRD
No of replications	8
Treatments	3
Total treatments	24

Table 3.3 Experimental design of the treatments

Treatments	Details of treatments
L_1	LED Red
L_2	LED Blue
L_3	LED Red & Blue

L_1= LED red

L_2 = LED blue

L_3= LED red + LED blue (77% Red +23% Blue)

3.2 EXPERIMENTAL METHODOLOGIES

3.2.1 Cleaning and washing of Jowar Seeds

Locally available Jowar (Sorghum) seeds of variety Nutri-Sugar (CSV-32) was selected for the experiment. Germination percentage of Jowar 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. The seeds were soaked for 3-5 minutes to remove unwanted dust and lightweight materials which floats on the water.

Plate 3.9 Jowar seeds

Plate 3.10 Washing of jowar seeds

3.2.2 Soaking and germination of seeds

After cleaning the Jowar seeds, it was kept for soaking in clean water for 24 hours. Then the water was removed and seeds were kept without water for one hour. 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.

Plate 3.11 Sprouted jowar seeds

3.2.3 Automation 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 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.

3.2.4 Irrigation of Hydroponic Jowar

Water level of 1 l per tray on a daily basis and seed rate of 208 g per tray was used in the experiment. The capacity and timings used for irrigation is given in the table below.

Table 3.4 Description of irrigation method

Irrigation method	**Capacity (lph)**	**Spray interval (minutes)**	**Spraying time (seconds)**
Fogger	16	20	35

3.2.5 Evaluation of Water Use Efficiency (WUE)

The total water added and drained out of trays have to be recorded for each tray to compute total water use and water use efficiency.

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

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

Water use efficiency in kg/m^3 of water can be calculated by below formula.

$$\text{WUE} = \frac{\text{Total green fodder produced (kg/tray)}}{\text{Total water used } (\text{m}^3/\text{tray})} \quad \ldots\ldots\ldots (1)$$

Water applied to each tray per day was 1l. The extra water drained from each tray was collected. 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 jowar 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 foggers and 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 Plate 3.12 which was kept under each tray.

Plate 3.12 Collecting drained water

3.3.3 Total Water Use

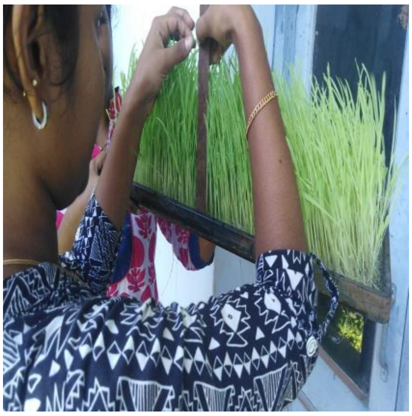
Total water applied to the tray was deducted by the total water drained out in order to calculate total water usage.

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.

3.3.5 Growth Parameters

Growth parameters like shoot length and root length of the Jowar fodder in the tray under different treatment were measured and noted. Shoot length was measured at the end of each day and root length after 9 days.



(a) (b)

Plate 3.13 Measuring Shoot length(a) and Root length (b)

3.4 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.

3.4.1 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 follows;

$$D = \frac{I-S}{L} \quad \text{……….} \ (2)$$

where,

D=Depreciation yearly

I=Initial cost of system

S= salvage value at 10%

L= Useful life of system

3.4.2 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

3.4.3 Gross Cost

Gross cost comprised of fixed cost and operating cost.

3.4.4 Gross Return

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

3.4.5 Net Return

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

3.4.6 Benefit Cost Ratio

It was calculated using the formula as follows;

$$BCR = GR/GC \qquad \text{………..} \ (3)$$

where,

GR = Gross return

GC = Gross cost

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, the effect of three light conditions on hydroponic fodder production and water use efficiency 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 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 4.1 shows the total hydroponic jowar fodder production per tray in different trials and average was taken for the statistical analysis.

Table 4.1 Hydroponic jowar fodder (HJF) production for various treatments

Sl. No	**Treatments**	**Yield(kg/tray)**			
		R_1	**R_2**	**R_3**	**Average**
1	L_1	0.472	0.504	0.488	0.488
2	L_2	0.625	0.572	0.658	0.618
3	**L_3**	**0.745**	**0.678**	**0.713**	**0.712**

4.2.1 Hydroponic fodder production under different light conditions

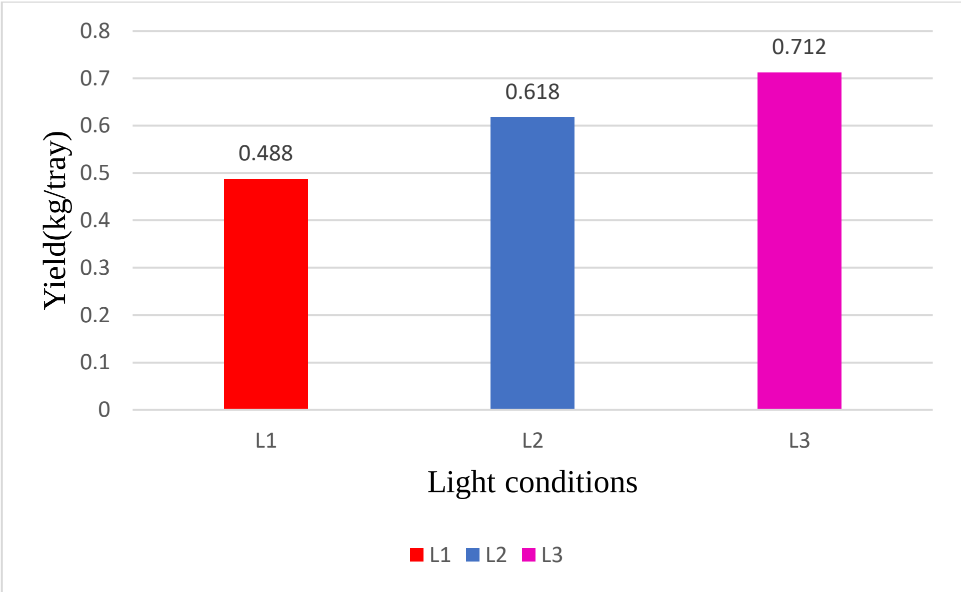


Fig. 4.1 Green fodder production kg/tray

The Fig. 4.1 shows that the highest yield obtained for fogger irrigation was 0.712 kg. This result was found for combination of LED red + blue (L_3). The least yield obtained was around 0.488 kg and was for LED Red (L_1).

Combination of blue (23%) and red (77%) colours have been found to be the best blend for plants and vegetables. This promotes good plant growth. Light quality significantly affects photosynthetic efficiency.

Table 4.2 ANOVA of fodder yield

Source of variation	**Degree of freedom**	**Sum of squares**	**Mean square**	**Variance(F)**	**F critical**
Treatments	7	0.299	0.0427	3.812	2.66
Error	16	0.179	0.0112		
Total	23	0.4787			

The calculated F value(variance) was higher compared to critical value, allowing us to conclude that there is a significant variation in yield because of different factors used in the treatment.

4.3 EFFECT OF DIFFERENT LIGHT CONDITIONS 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 4.3. 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 showed that the hydroponic method of growing fodder had very high-water use efficiency.

Table 4.3 Water use efficiency of different treatments

SL No	**Treatments**	**WUE (kg/m³)**			
		R_1	R_2	R_3	Average
1	L_1	481.63	514.25	497.47	497.78
2	L_2	637.75	583.22	670.83	630.6
3	$\mathbf{L_3}$	**761.77**	**693.71**	**729.52**	**728.33**

4.3.1 Effect of Different Light Conditions on WUE

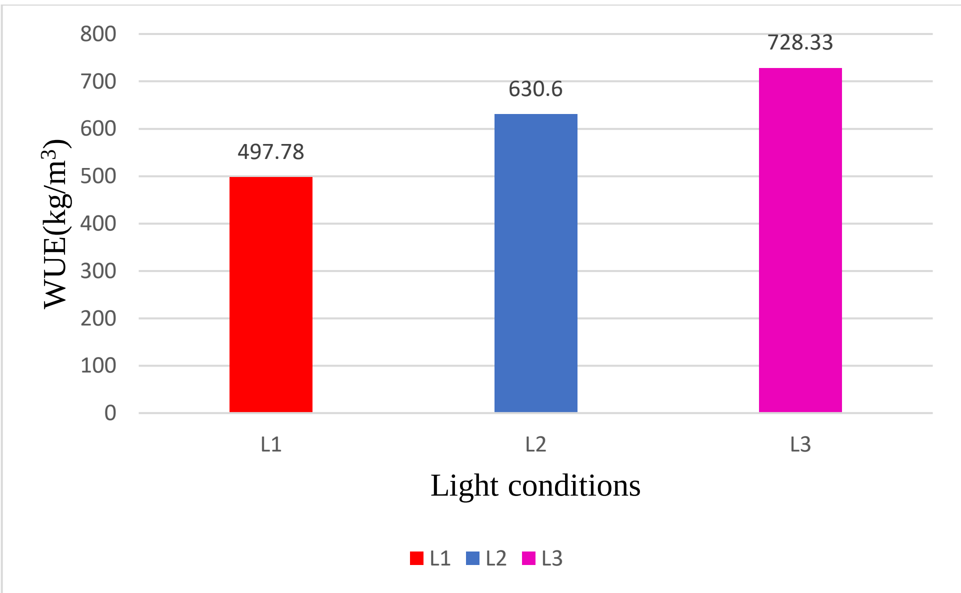


Fig. 4.2 Effect of different light condition on WUE

The highest WUE recorded was 728.33 kg/m^3 and it was obtained in L_3 shown in Fig. 4.2. The lowest WUE observed in L_1 was around 497.78 kg/m^3.

The seed rate used (208 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 evaluate hydroponic fodder production system with artificial lighting.

Table 4.4 ANOVA of water use efficiency

Source of variation	**Degree of freedom**	**Sum of squares**	**Mean square**	**Variance(F)**	**F critical**
Treatments	7	0.317	0.045	3.75	2.66
Error	16	0.189	0.012		
Total	23	0.506			

Like yield statistical analysis were done for results of WUE. The calculated F value(variance) was higher compared to critical value, allowing us to conclude that there is a significant variation in WUE because of different factors used in the treatment.

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).

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

(a)

(b)

(c)

Plate 4.1 HJF grown under (a) LED red (b) LED blue (c) Led red + blue respectively

4.4 PHYSICAL ANALYSIS

Root length and shoot length were analysed for the three samples and shown in table 4.5. Details of shoot and root length were mentioned in Appendix I. These samples were selected from the highest yield given in three different light conditions (L_1, L_2 and L_3).

Table 4.5 Results of physical analysis

Sample	Yield (kg/Tray)	Shoot length(cm)	Root length(cm)
L_1	0.488	21.20	19.80
L_2	0.618	21.90	19.60
L_3	**0.712**	**22.15**	**20.32**

The fodder grown under LED red + blue combination (L_3) showed best results.

4.4.1 Effect of different light conditions on shoot length for 8 days

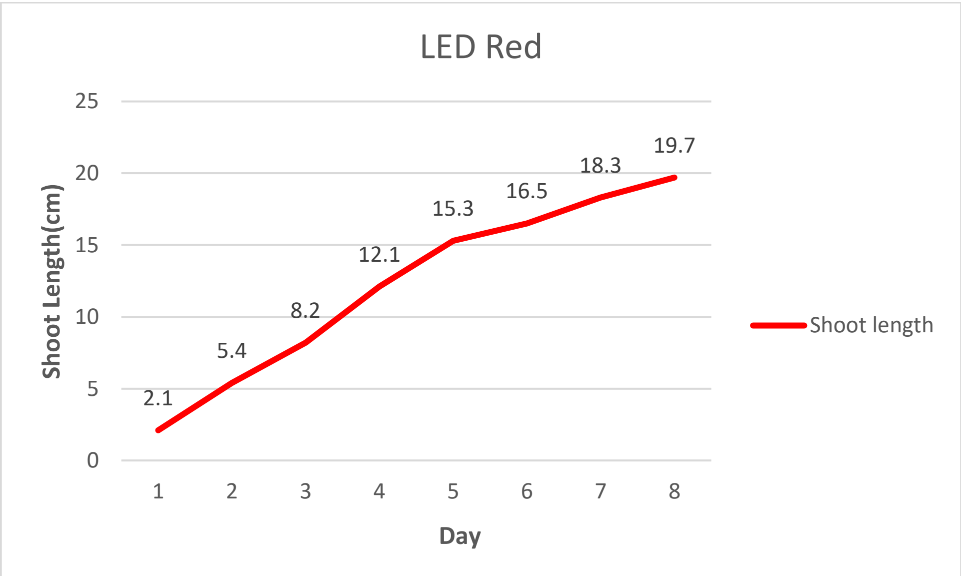


Fig.4.3 Effect of L_1 on shoot length

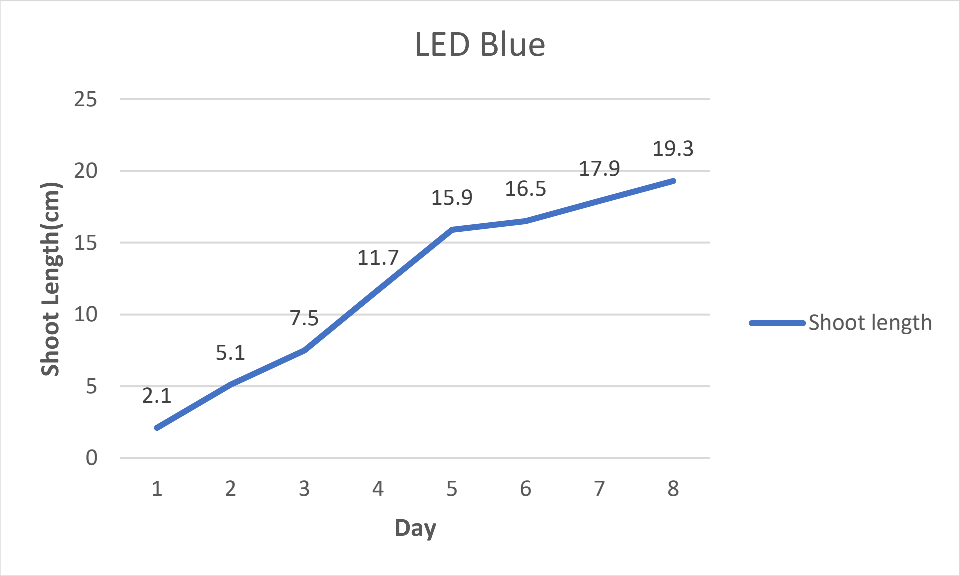


Fig.4.4 Effect of L_2 on shoot length

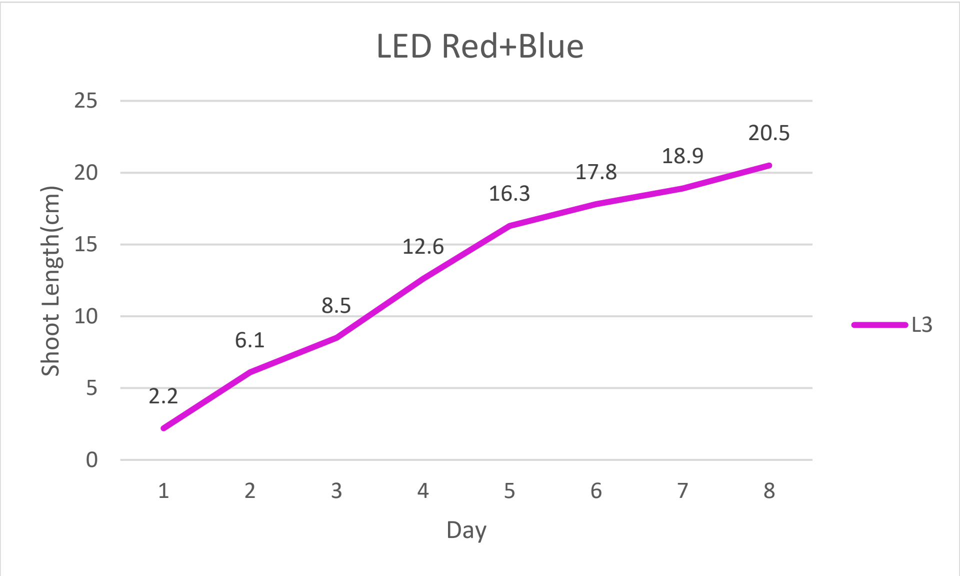


Fig.4.5 Effect of L_3 on shoot length

4.4.2 Comparison of different light conditions on shoot length

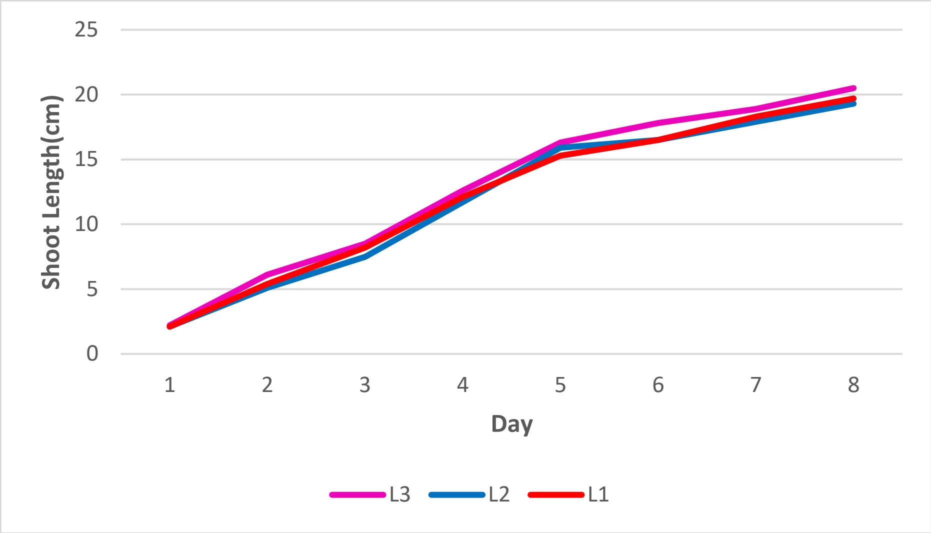


Fig.4.6 Comparison of different light conditions on shoot length

The shoot length of the plant under different light conditions was measured after the leaf growth on each day up to the day of harvest for each trial. The average of shoot length of the same day of different trial was calculated and a graph was plotted.

The highest shoot length was obtained as 20.5 cm for LED red+ blue (L_3) and the least result was obtained as 19.3 cm for LED blue (L_2). Hence only a slight difference is observed.

4.4.2 Effect of different light conditions on Root length

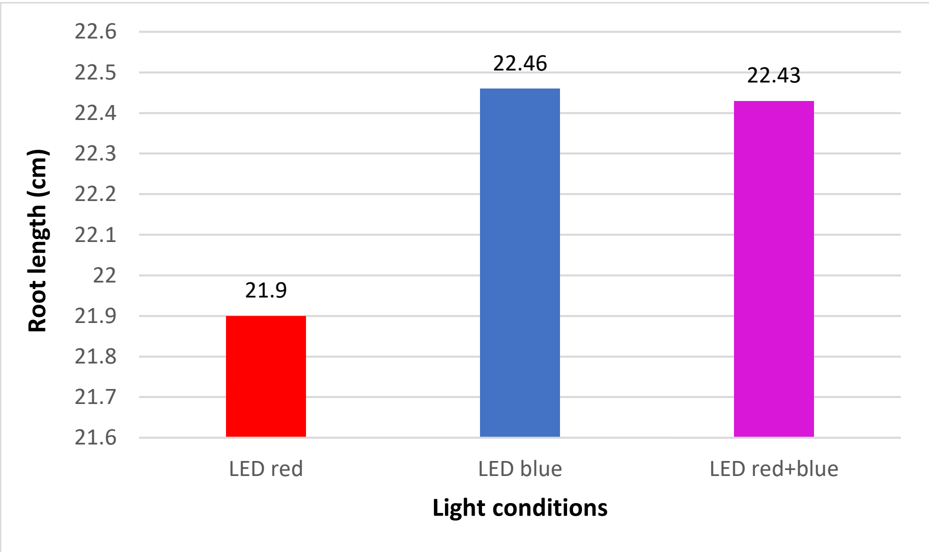


Fig 4.7 Effect of different light conditions on Root length

The Root length of the plant was measured for different light conditions for each trial for each tray, on the day of harvest (9^{th} day) and average of the root length was calculated for each light conditions.

The highest root length was observed as 22.46 cm under L_2 and the least root length was 21.90 cm under L_1. There is no much difference in root lengths.

Root length and shoot length are almost at par.

4.5 ECONOMIC ANALYSIS OF HYDROPONIC FODDER PRODUCTION SYSTEM

Straight line method was used to calculate the cost of hydroponic fodder production system shown in Table 4.6. 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 18800. The experimental results showed that the weight of the fodder produced in hydroponic unit was about 4 times that of seeds.

Table 4.6 Cost Economics of hydroponic fodder production system

Particulars	**Amount in Rs**
Structural cost	18800
Fixed cost (per day)	
Deprecation	4.636
Interest	3.4
Total fixed cost	8.036
Variable cost (per day)	
Seed cost (4.99 kg)	138.7
Labour (1hr)	25
Electricity cost	11.5
Total variable cost	175.2
Total production cost per day	183.236
Total return (Rs. 15 per kg)	220.95
Net return	37.714
Benefit cost ratio-**1.21**	

CHAPTER V

SUMMARY AND CONCLUSIONS

Green fodder is the natural diet for livestock. Its production to meet the current demand has become a greatest challenge among livestock farmers. Due to many reasons, green fodder production has been facing a serious crisis and so the livestock productivity. Many of the livestock farmers are switching to hydroponic fodder production from conventional production methods, as the fodder produced by this method are highly nutritious, provide sustainable fodder production round the year and conserve 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, less attack of insects and pests, shorter growing period and highly nutritive feeding material to increase milk production of lactating animal.

The current study entitled "Performance evaluation of hydroponic fodder production system for jowar crop at different light conditions" has been undertaken at Kelappaji College of Agricultural Engineering and Technology, Tavanur with the objective of hydroponic fodder production inside a room with the help of artificial lighting. Hydroponic structure with frame was constructed to grow fodder under different light conditions. Irrigation application method used was fogger and light arrangements were made with LEDs of red (L_1), blue(L_2) and red + blue (L_3). Total 8 replications and 24 treatments were made. Total fodder production per tray and WUE (kg fodder/m^3 water) was calculated for each treatment.

Based on the result fogger irrigation and LED red + blue light was found to be the best combination for fodder production. From the results of experiment the following conclusions were obtained:

1. Highest green fodder yield (0.712 kg/tray) was obtained under LED red + blue light(L_3) as energy source
2. Least green fodder yield was 0.488 kg per tray obtained under LED red light (L_1)
3. The highest WUE was recorded with Red + Blue light (728.33 kg/m^3)
4. The lowest WUE observed was around 497.78 kg/m^3 in LED red light (L_1)
5. The highest shoot length was obtained as 20.5 cm for LED red+ blue (L_3)
6. The least shoot length was obtained as 19.3 cm for LED blue (L_2)
7. The highest root length found was 22.46 cm for LED blue(L_2)
8. The least root length was 21.90 cm for LED red(L_1)
9. The automation by using Multipoint UTR 1044 digital timer worked very well

10. ANOVA of both dependent parameters were statistically significant at 5% level
11. Gross return and Benefit Cost ratio of hydroponic jowar fodder was Rs. 220.95 per day and 1.21 respectively

The hydroponic system developed to produce Jowar fodder is economical, efficient and easy to adopt by farmers. This is simple and fast way produce the fodder that can be used in cattle farming. This system helps to reduce drudgery and save the land for other use. System can be modified as solar assisted to conserve the energy. Blue (23%) and red (77%) colours have been found to be the best blend for plants and vegetables. This promotes good plant growth. Further study can be conducted by growing fodder under different light intensities to optimise yield.

CHAPTER V
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APPENDIX I

Details of shoot length:

Shoot Length(cm)					
Light	**Day**	**R_1**	**R_2**	**R_3**	**Average**
LED Red	1	1.6	2.5	2.3	2.1
	2	4.2	5.8	6.1	5.4
	3	7.5	8.4	8.7	8.2
	4	12.7	12.8	10.7	12.1
	5	16.6	16.3	13.1	15.3
	6	17.2	17.9	14.4	16.5
	7	17.8	21.3	15.8	18.3
	8	19.8	22.4	16.9	19.7

Shoot Length(cm)					
Light	**Day**	**R_1**	**R_2**	**R_3**	**Average**
LED Blue	1	1.7	2.6	1.9	2.1
	2	3.9	5.6	5.9	5.1
	3	6.2	7.6	8.6	7.5
	4	12.5	12.7	9.9	11.7
	5	16.9	16.5	14.2	15.9
	6	17.5	17.3	14.8	16.5
	7	17.9	20.1	15.9	17.9
	8	19.7	21.8	16.5	19.3

Shoot Length(cm)					
Light	**Day**	**R_1**	**R_2**	**R_3**	**Average**
LED Red+Blue	1	2.0	2.4	2.2	2.2
	2	4.5	7.2	6.5	6.1
	3	7.0	9.5	9.0	8.5
	4	13.0	13.3	11.5	12.6
	5	16.2	16.9	15.9	16.3
	6	17.4	19.2	16.9	17.8
	7	17.6	22.0	17.2	18.9
	8	20.0	24.0	17.6	20.5

Details of Root Length:

Root Length(cm)									
Light	**Trial**	**Tray 1**	**Tray 2**	**Tray 3**	**Tray 4**	**Tray 5**	**Tray 6**	**Tray 7**	**Tray 8**
LED Red	R_1	22.4	15.6	20.1	23.5	24.2	27.6	17.5	24.4
	R_2	17.8	14.1	13.2	15.4	12.3	16.8	15.5	19.8
	R_3	15.9	15.2	14.7	19.2	18.0	16.9	13.1	16.1
LED Blue	R_1	23.7	19.1	24.4	19.1	21.7	27.6	22.1	22.0
	R_2	18.4	14.3	15.6	13.2	17.5	19.5	16.5	17.5
	R_3	16.2	15.8	16.4	16.7	15.5	15.3	12.9	16.3
LED Red +Blue	R_1	21.7	24.0	23.2	23.9	21.6	17.4	20.4	27.2
	R_2	16.0	14.3	11.0	14.9	16.7	15.9	14.1	17.3
	R_3	16.9	15.9	13.5	19.1	18.4	17.8	13.2	16.8

APPENDIX II

Details of cost economics calculations.

Capital cost:

Sl.No.	Materials	Value (Rs.)
1	Iron frame	1500
2	Pump	3600
3	Led light	950
4	Timer	1500
5	Water tank	2500
6	Fogger	1400
7	Fittings	700
8	Trays	6000
9	Labour cost (25% of total material cost)	650
	Total	**18800**

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

Salvage value =10% of capital cost

Useful life system =10 years

$$\text{Depreciation} = \frac{18800 - 1880}{10 \times 365} \quad = 4.636 \text{ Rs per day}$$

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

Annual interest = 12%

$$\text{Interest} = \frac{18800 + 1880}{2} \times \frac{0.12}{365} = 3.4 \text{ Rs per day}$$

Fixed cost = 4.636 + 3.4 =8.036 Rs per day

Variable cost:

Sl.No.	Particulars	Value (Rs.)
1	Seed cost	138.7
2	Labour cost	25
3	Electricity	11.5
	Total	**175.2**

Total cost of production = Fixed cost + variable cost

Total cost of production = 8.036 + 175.2 = Rs. 183.236 per day

Fodder production per day = 14.73 kg

Gross return = 14.73 × Rs. 15 = Rs. 220.95

Net return = 220.95 – 183.236 = Rs. 37.714 per day

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

$$Benifit\ cost\ ratio = \frac{220.95}{183.236} = 1.21$$

PERFORMANCE EVALUATION OF HYDROPONIC FODDER PRODUCTION SYSTEM FOR JOWAR CROP AT DIFFERENT LIGHT CONDITIONS

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ABSTRACT OF THE PROJECT REPORT

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ABSTRACT

A Research on Performance evaluation of hydroponic fodder production system for jowar crop at different light conditions was conducted in PFDC building of Kelappaji College of Agricultural Engineering and Technology Tavanur. The objective of research work was to evaluation of hydroponic fodder production system for Jowar crop under different light conditions.

The fogger irrigation was selected as the water application method. Artificial light source of LED red (L_1), LED blue (L_2) and LED red + blue (L_3) were taken for the study. Statistical analysis was conducted to understand the significance of different treatments used in the experiment.

The highest yield was observed in treatment under LED red + blue (0.712 kg/tray) with the highest water use efficiency (728.33 kg/m^3) compared to other treatments. Seed to fodder ratio obtained was 1: 4.

Higher growth of green fodder under artificial light source can be attributed to the continuous supply of energy 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) can be recommended to farmers for achieving better growth of green fodder for domestic animals.