EFFECT OF WATER SOURCES ON THE PRODUCTION AND NUTRIENT CONTENT OF MAIZE FODDER UNDER HYDROPONIC SYSTEM

Khulna University Library
Thesis Acc. No: 5408
Authorised Sign:
Date: 28.5.25

A THESIS

BY

STUDENT ID: MS-210818

A Thesis (Course No. AN-6104) Submitted to Agrotechnology Discipline in Partial Fulfilment of the Requirement for the Degree of Master of Science in Animal Nutrition

AGROTECHNOLOGY DISCIPLINE

KHULNA UNIVERSITY

KHULNA-9208

EFFECT OF WATER SOURCES ON THE PRODUCTION AND NUTRIENT CONTENT OF MAIZE FODDER UNDER HYDROPONIC SYSTEM

A Thesis

By

Student ID: MS- 210818

Approved as to style and contents

Prof. Dr. Md. Shafiqul Islam
(Supervisor)

Prof. Dr. Sarder Safiqul Islam
(Co-Supervisor)

Prof. Md. Rejaul Islam

Chairman, Examination Committee and Head of Agrotechnology Discipline

Khulna University, Khulna-9208

December, 2024

DEDICATED

TO

MY

BELOVED PARENTS

KHULNA UNIVERSITY
Central Library
KHULNA

ACKNOWLEDGEMENT

First and foremost, praises and thanks to God, the Almighty, for showering His blessings throughout my research work to complete the research work perfectly.

I want to express my heartfelt gratitude to my supervisor, **Dr. Md. Shafiqul Islam, Professor**, Agrotechnology Discipline, Khulna University, Khulna-9208 for allowing me to complete the research and providing me with vital guidance. I've been extremely inspired by his genuineness, vision, dynamism, and consistent encouragement. Working and studying under his direction was a wonderful honor and privilege.

Dr. Sarder Safiqul Islam, Professor, Agrotechnology Discipline, Khulna University, is my respected instructor and co-supervisor, and I am grateful for his support, timely suggestions with compassion, supervision, and constructive criticism, which enabled me to successfully complete this research.

I am extremely thankful to our Discipline Head and all the teachers of Agrotechnology Discipline, Khulna University, Khulna-9208 for their kind help and co-operation throughout my research work.

I also express my thanks to **Arghya Kumar Gain** MS Student, Animal Nutrition, Agrotechnology Discipline, Khulna University to completing the research work.

Finally, I am grateful to my parents, friends, and family for their unwavering love, prayers,and support in helping me to complete this research on time. It would have been extremelydifficult for me to finish my studies without their understanding and encouragement throughout the previous few years.

December, 2024 Author

ABSTRACT

In addition to providing high-quality fodder, fodder production technology is becoming a part of the growing number of centralized livestock farms. The purpose of this study was to examine how various water sources affect the hydroponic production of maize fodder. The investigation was carried out in a small portion of the Acharya Jagadish Chandra Bose Academic Building's underground basement at Khulna University. Five treatments and three replications were used in the CRD experiment. In order to test yield, feed quality, and water use efficiency under hydroponic settings, irrigation was applied to maize fodder using tap water, pond water, borehole water, river water, and sewage water. On the eleventh day, the fodder was harvested. On the 5th, 7th, 9th, and 11th days, the sample was gathered for analysis. The height of the plants and the length of the roots and shoots of hydroponic maize fodder have been successfully improved by using sewage water for irrigation. The longer roots compared to the other treatment resulted in higher fodder production from tap water. Approximately 2.5 liter of water are needed to produce one kilogram of fresh hydroponics maize fodder (11-d). On the 11th day of harvest, plant height was significantly significant ($p<0.001$). On the 9th day of harvesting, the length of the plant roots and shoots was significantly significant ($p<0.001$). On the 11th day of harvesting, the total amount of water used (liter kg-1 fresh matter) was significantly significant ($p<0.001$). On the 11th day of harvesting, the fresh yield was a highly significant yield parameter ($p<0.001$). Plants that were irrigated with sewage water had substantially greater proximate concentrations of dry feed than the other treatments. According to the study's findings, high yields and little water use could be achieved by safely irrigating hydroponic green Maize fodder with tap, pond, borehole, river, and sewage water. Additionally, using sewage water to irrigate green forages in hydroponic systems is thought to be a practical substitute for traditional wastewater disposal methods.

Keywords: Sewage water, Harvest, Borehole water, Irrigation, Fodder Production, Hydroponics.

CONTENTS

KHULNA UNIVERSITY Central Library KHULNA

List of Table

ELABORATION

ADF = Acid Detergent Fiber
NDF = Neutral Detergent Fiber
NFC = Non-Fibrous Carbohydrates
GHG = Green House Gas
HBF = Hydroponic Barley Fodder
ADG = Average Daily Gain
FCR = Food Conversion Ratio
TMR = Total Mixed Ration
ME = Metabolizable Energy
TDN = Total Digestible Nutrient
PCA = Principal Component Analysis
GDP = Gross Domestic Product
CF = Crude Fiber
CP = Crude Protein
EE = Ether Extract
FCR = Free Chlorine Residual
WWTP = Waste Water Treatment Plant
TWU = Total Water Use
WUE = Water Use Efficiency
SPAD = Soil Plant Analysis Development
AOAC = Association of Analytical Chemists
GLM = General Linear Model
BARI = Bangladesh Agricultural Research Institute
GW = Ground Water
EPA = Environment Protection Agency
WP =Water Productivity
DMRT= Duncan's Multiple Range Test
DM = Dry Matter
NFE = Nitrogen Free Extract

CHAPTER I

INTRODUCTION

An essential component and natural source of dietary sustenance for ruminant's is green fodder. During the dry season, it is lacking in both quantity and quality, which makes the animals perform poorly overall. Therefore, it is advised to feed high-quality green fodder more regularly in order to improve the quality of livestock products (Dung et al., 2010). Green grass provides animals with nutrients that increase their productivity and ability to reproduce. For proper digestion and digestive system motility, they require a lot of green fodder.

Technology for producing fodder is becoming a viable substitute for both high-quality fodder and the growing number of centralized livestock farms. It is challenging to produce enough conventional green fodder and grain in many nations to feed the world's cattle population. This is due to a lack of irrigation facilities, a shortage of labor, fertilizer, and other resources, as well as a lack of land. Producing enough feed is made more difficult by additional considerations such regular droughts, natural disasters, and water constraint. A persistent issue in sustainable livestock production is the lack of fodder, which affects the cattle's ability to reproduce and production of milk (Bekuma, 2019).

The majority of ruminant feed resources come from natural pasture. Green fodder is not commonly produced the old-fashioned way, because growing, fertilizing, and watering require a lot of money, land and time. According to Mohapatra et al., (2019), it takes a long time to grow (45–60 days) and cannot produce the same grade of green feed year-round. Hydroponics may be an alternate complementary fodder production technology that would improve fodder and livestock production due to the imbalance between the availability and demand of green fodder for growing ruminant animals (Bamikole et al., 2020).

One of the largest issues facing the globe today is water scarcity, particularly for agriculture's primary freshwater consumers. Hydroponic systems will assist ease the growing water constraint and demand for crop production water.

Irrigation uses around 70% of the world's water supply, and this percentage is predicted to rise significantly over the coming years. An estimated 2.663 km^3 of water are utilized for irrigation in each year, which is insufficient to meet global population demands. It is also anticipated that water demand for factories, residences, and animals will increase significantly, reaching at least 50% by 2025. It appears that the agricultural industry will face challenges in many regions of the world in the future due to the rise in non-agricultural demand and the uncertainties surrounding water management brought on by climate change (Akhtar et al., 2013).

Green fodder for a broad range of forage crops can be produced using hydroponic systems without the use of chemicals such artificial growth promoters, fungicides, insecticides, or pesticides. This technique guarantees reduced water requirements, steady output throughout the year, and increased fodder yields (Tudor et al., 2003). In order to produce fodder hydroponically, seeds must be germinated in a sanitary manner. One of the eco-friendly methods of producing fodder is hydroponics. In addition to managing climate and growing conditions, it is extremely water efficient and minimizing water waste. Utilizing a recirculating system, which minimizes water waste during the production process, is the primary distinction between hydroponic and conventional fodder production.

Compared to field circumstances, hydroponic forage cultivation uses only 2–3% more water to produce the same amount of feed. On a small piece of land, this technique can yield fodder in 7–10 days (Tudor et al., 2003). The manufactured fodder has a high protein, fiber, vitamin, and mineral content. In many nations worldwide, especially in arid or semi-arid regions, hydroponic farming is one of the greatest methods for producing green fodder due to these remarkable qualities.

Making green feed to livestock could be an imaginary approach to maintain dairy farming's affordability and sustainability. However, there are other obstacles dairy farmers must overcome in order to produce green fodder, including a lack of land, water, and high-quality seeds, as well as the requirement for extra labor, fertilizer, longer growing seasons, and fences to keep out wild animals and natural disasters. For this reason, hydroponics is starting to replace traditional techniques for producing feed for farm animals (Naik et al., 2015).

The growing conditions for hydroponics must be appropriate for the forage seeds to germinate properly in a short amount of time in dedicated green plant growing rooms. Barley, oats, Maize, and other grains are used to make fresh fodder.

It is advised to use water efficiently in semi-retreat circumstances for hydroponic cultivation (Girma et al., 2018). Even in regions with less rich soil and less water, hydroponics may sustain a huge population and allow third-world countries to feed themselves. In places with limited space, it can also be a useful resource for growing food.

The roots in hydroponics receive mechanical support, which bears the weight of the plant and keeps it upright. Sand, gravel, river rock, Oasis cubes, floral foam, and sew-dust are common media used in hydroponic systems (Gaikwad et al., 2020). In order to better understand how hydroponics fodder is created for sustainable livestock for climate change production.

Apart from its distinct features, hydroponic systems are among the most important agricultural practices currently employed for the production of green fodder in many nations worldwide, especially in arid and semi-arid regions. Achieving the highest possible fodder yield and quality, however, requires careful consideration of the economics of the hydroponic method of producing green fodder by lowering seed prices, as well as the choice of forage crop.

Recent research has shown that nutrients from treated wastewater can be cleaned up by using certain types of plants inside a hydroponic system. Very few research on fodder production using hydroponic system of irrigation has been conducted in Bangladesh. Hydroponic (soil-free) culture could help tackle global problems like water shortages, pollution, and environmental instability in different ways.

OBJECTIVES OF THIS RESEARCH

i. To investigate the production performance of maize fodder on different sources of water in hydroponic conditions.

ii. To find out the nutritional value of maize fodder produced in hydroponic system.

iii. To estimate the cost-benefit ratio in maize fodder cultivation.

KHULNA UNIVERSITY
Central Library
KHULNA

CHAPTER II

LITERATURE REVIEW

2.1 Background of Hydroponic Fodder

Ponics, which means "working," and hydro, which means "water," are the Greek words from which the term hydroponics is derived. Accordingly, hydroponic feed, sometimes referred to as sprouted grains or sprouted fodder, is feed produced by cultivating plants without the use of soil in water or a nutrient-rich solution (Dung et al., 2010). In 1969, Woodward, an English scientist, attempted to grow plants in a range of water sources. Gericke (1920–1930) developed techniques for growing plants on a wide scale in nutrient solutions. Leitch (1939) reviewed a number of experiments with sprouted fodder for different kinds of poultry and animals.

Hydroponics technology was introduced to the state in 2011 when Goa Dairy set up multiple hydroponic fodder production units at various dairy cooperative societies under the Indian government's Rastriya Krishi Vikas Yojana (RKVY) (Naik et al., 2011; Naik et al., 2012a; Naik et al., 2012b).

Hydroponically grown grains, which grow up to 50% faster and generate larger quantities of higher-quality fodder, are an environmentally beneficial technique of fodder production (Kide et al., 2015). Hydroponic fodder production comprises sprouting animal feed seeds in a clean environment to produce a high-quality, nutrient-dense, disease-free product (Al-Hashmi, 2008). The process of producing hydroponically grown fodder in an intensive hydroponic growing system entail employing only water and nutrients to produce nutrient-rich grass and root combinations.

Growing green fodder hydroponically requires less water and wastes fewer of the critical natural and artificial resources required to produce fodder while mitigating the effects of climate and the growing environment (Elmulthum et al., 2023). Hydroponic sprouted fodder has a major nutritional benefit that can improve young animals' health and performance while cutting feed costs. Hydroponics technology can be used to grow a wide range of fodder crops, such as barley, oats, maize (Snow et al., 2008), sorghum, alfalfa, cowpea (AI-Karaki and AI-Hashimi, 2012), and maize.

However, the type of hydroponic fodder produced is determined by the region's agroclimatic conditions and the ease of access to seeds. Maize is a great choice for hydroponic fodder production in India because it grows quickly and is widely available, producing high biomass at a low cost (Naik et al., 2015). According to Kerr, the concept of hydroponic fodder dates back to the 1800s, or possibly earlier, to the "Hanging Gardens of Babylon," when European dairy farmers fed sprouted grains to their cows in the winter to maintain milk output and boost fertility (Kerr et al., 2014). For farmers without land, it provides a realistic and sustainable alternative technology for growing fodder without soil.

Hydroponic technology can be used to grow a wide range of fodder crops, including rye, alfalfa, horse gram, ragi, bajra, jowar, and triticale. This fodder resembles a mat that is 20 to 30 cm tall and is composed of plants, seeds, and roots that are exceptionally pleasant, easily digestible, and nutrient-dense for animals. The height of the forage mat varies depending on the grain type, and it produces roughly 7 to 9 kg of fresh forage or 0.9 to 1.1 kg of dry matter.

2.2Fundamentals of Hydroponic Fodder Production

Cereal grains are produced hydroponically, which means without the use of a solid growing medium, and with the necessary moisture and nutrients. Germination happens in response to the moisture and nutrients supplied, resulting in a 20-30 cm long bright green stem with entwined roots in 7-10 days. Fodder can be made from a variety of cereal grains, including horse gram, bajra, millet, and maize, and they will change structurally and chemically as they develop. The breakdown of nutrients into their more basic forms has been discovered to need enzyme activity. The amount of sprouted and high-quality fodder is determined by several factors, including grain variety, quality, and treatments such as fertilizer availability, pH, water quality, and soaking duration (Sneath and McIntosh, 2003).

2.3 Reasons for Hydroponic Fodder Production

2.3.1 Conservation of Water

Hydroponic systems reduce water wastage by delivering water directly to the roots and recycling it numerous times. According to study findings, a hydroponic system utilizes about 2% to 5% of the water in a normal system to produce feed. According to reports, generating one kilogram of hydroponically produced fodder requires only 1.5 to 2 liters of water, whereas producing one kilogram of barley, alfalfa, and Rhode's grass in average field conditions requires 73, 85, and 160 liters of water, respectively (AI-Karaki and AI-Hashimi, 2012; Naik and Singh, 2014). This is especially important in areas where there is a chronic paucity of water or there is no irrigation infrastructure.

2.3.2 Appropriate Use of Space

Hydroponic systems reduce water wastage by delivering water directly to the roots and recycling it often. Hydroponic systems are ideal for urban people with small yards because they take up much less space. Hydroponics technology can generate up to 1000 kg of maize fodder per day in 45-50 m^2 of area, which is similar to conventional fodder produced on 25 acres of cultivable land (Naik and Singh, 2013; Rachel Jemimah et al., 2015). To conserve land, a hydroponic system can be simply started indoors using several racks with several stages. A square meter of land may literally feed two cows each day, increasing milk yield by 13% (Yvonne Kamanga, 2016).

2.3.3 Reduces the Growth Time

Whereas conventional fodder takes at least 45 days to grow, hydroponic technology grows fodder from seed to fodder in just 8 days.

2.3.4 Fodder Yield

Fodder output can be accelerated by up to 25% by feeding nutrients directly to the plants rather than forcing them to build vast root systems in search of food. In 7-8 days, one kilogram of unsprouted seed yields 8-10 kg of green feed (Sneath and McIntosh, 2003). According to Naik (Naik et al., 2014), fresh maize fodder produced hydroponically yields 5 to 6 times more and is more nutritious than standard farm production.

2.3.5 Provides Essential Nutrients

In hydroponic green fodder, the content (DM basis) of calcium, neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP) increased relative to unsprouted seed, while non-fibrous carbohydrates (NFC) and organic matter decreased (Kide et al., 2015; Mehta and Sharma, 2016). Hydroponic fodder is high in vitamins A, E, and C, as well as thiamine, riboflavin, niacin, biotin, free folic acid, and antioxidants such as -carotene (Naik et al., 2015) and minerals (Fazaeli et al., 2011). When compared to standard green fodder grown for 65-80 days, the biomass conversion ratio can be 6-7 times higher (Naik et al., 2015).

2.3.6 Persistent Flow of Green Fodder

Fodder can be produced year-round, regardless of monsoon success, land availability, natural calamities, or labor scarcity, promoting long-term agricultural and livestock output. Perhaps this regularity will result in a promising yield of milk, better-quality meat, and other animal products. Hydroponically grown fodder has the potential to dramatically improve the quality of animal products.

2.3.7 Reduced Carbon Footprints

Hydroponic agriculture uses fewer inorganic chemicals than regular agriculture. As a result, global warming and greenhouse gas emissions are significantly reduced (Xu et al., 2015). In response, hydroponic systems help to reduce carbon emissions and fuel use while delivering products from remote agricultural farms.

2.3.8 Limits of Pesticides, Insecticides and Herbicides

Traditional outdoor farming requires the application of herbicides, fungicides, and/or insecticides to achieve the greatest results. Hydroponic fodder is grown in a controlled environment that does not require soil, minimizing the need for pesticides, insecticides, and herbicide. With a specific chemical, the susceptibility of any virus in hydroponically grown fodder can be easily eliminated (Shit, 2019).

2.3.9 Impact on Animal Production

Hydroponic fodder is incredibly digestible and appetizing, and the animals love it. They are exceptionally succulent and can be taken by large ruminants, mature pigs, small ruminants, and rabbits at rates of 1-1.5% of body weight (Jeton, 2016), or 15-25, 0.25-2.0, 1.5-2.0, and 0.1-0.2 kg/animal/day, respectively (Naik et al., 2013; Rachel Jemimah et al., 2015). Saidi and Abo Omar (2015) found that hydroponic barley fodder (HBF) enhanced ewe health, mortality, conception rate, and abortion. When children and rabbit kittens were fed hydroponic horse gram or sun hemp fodder instead of 50% concentrate combination, there were no negative impacts on average daily gain or feed conversion ratio (FCR) (Naik et al., 2013; Rachel Jemimah et al., 2015; Reddy et al., 1988).

Animals fed a total mixed ration (TMR) that included hydroponic maize or barley fodder produced 8.0-14.0% more milk per day than those fed ordinary green fodder (Rachel Jemimah et al., 2015; Yvonne Kamanga, 2016). Hydroponic fodder promotes longer lactation periods, higher fat percentages, and better overall herd health. In addition to increased milk supply and conception rate, other benefits included longer herd life, improved health, and decreased veterinary aid expenses (Naik et al., 2015).

The fast-growing chicken business benefits from hydroponic fodder in various ways, including faster weight gain, higher quality carcass, lower feed costs per kg of weight gain, and increased health and production potential (Rachel Jemimah et al., 2015). The nutritional value of various hydroponic fodders, as well as their nutrient digestibility, make them ideal for cow consumption and production.

2.4 Health Hazzard of Infected Hydroponic Fodder

It is not suggested to feed dairy or beef animals hydroponically contaminated with Aspergillus clavatus. Colonic convulsions, stiff gait, tremors, progressive paresis, knuckling of the fetlocks, dragging of the hind legs, high stepping in the hind limbs, posterior ataxia, hypersensitivity, recumbency, decreased milk supply, and death are all possible symptoms (McKenzie et al., 2004).

2.5 Production of Hydroponic Fodder

Hydroponics may be produced swiftly in greenhouses with regulated settings. A greenhouse is a framed or inflatable structure coated in a transparent material that allows crops to grow in a somewhat controlled environment. Nonetheless, the framework must be large enough to allow individuals to engage in cultural processes. There are two types of greenhouses that can be used to produce hydroponically grown fodder: high-tech greenhouses and low-tech greenhouses, depending on the farmer's budget and building materials.

2.6 Nutrient Solution for Hydroponic Production

A nutrient solution in hydroponic systems is an aqueous solution mostly constituted of inorganic ions that are physiologically required for the whole life cycle of plants (Taiz and Zeiger, 1998). Currently, the majority of plants are assumed to require 17 elements: carbon, hydrogen, oxygen, nitrogen, phosphorus, copper, potassium, calcium, magnesium, sulfur, zinc, manganese, molybdenum, boron, chlorine, iron, and nickel (Salisbury and Ross, 1992). Other elements, such as sodium, silicon, vanadium, selenium, cobalt, aluminum, and iodine, are thought to be beneficial because they can either promote growth, counteract the negative effects of other elements, or replace vital nutrients in a less focused capacity (Trejo Tellez et al., 2007).

2.7 Land for Hydroponic Technology

Hydroponic technology is used in harsh conditions such as deserts, areas with insufficient soil, and urban areas where traditional agriculture has been driven out due to high land costs. It is most likely suited to semi-arid, arid, and drought-prone regions of the world with frequent water shortages or limited resources for fencing, irrigation, and land preparation. Farmers in coastal and mining regions, where the ground is stony and barren, profit considerably from the technology's ability to produce green fodder. The primary reasons for transitioning to hydroponic fodder production include fodder degradation by stray cattle and wild animals, rising labor expenses for growing methods, and insufficient participation of educated unemployed youths in fodder farming (Shit, 2019).

2.8 Environmental Factors for Hydroponic System

Environmental conditions are critical for optimizing the growth and production of hydroponically grown feed. The average concentration of environmental signals like as length (12-16 hours), temperature (19-22 ° C), 60% humidity, light intensity (2000 lux), and 3 minutes of aeration every two hours should be maintained (El-Deeba et al. 2009). Hydroponic fodder production consumes far less electricity than conventional fodder cultivation. The sixth day following sowing, when the barley seed sprouts retain their optimum biomass and nutrient production, is the final phase in harvesting. Furthermore, sprouted barley has the highest feed quality among all hydroponic fodders, including rye, maize, oats, and triticale (Heins et al., 2015).

2.9 Nutritive Value of Hydroponic Fodders

The nutritional value of hydroponically cultivated fodder derived from cereal grains varies. As starch content decreases, so does dry matter and organic matter content. Sprouting is the process by which plants convert starch into soluble sugar as part of their metabolic transformation. Nonetheless, when the plant grows, its structural lipids and chlorophyll levels increase, causing the ether extract of hydroponic feed to rise. Along with sprouting, focus increases. While nitrogen-free extract (NFE) decreases, linoleic acid, neutral detergent fiber (NDF), crude fiber (CF), and acid detergent fiber (ADF) increase as structural carbohydrates form. Sprouting reduces organic matter and increases overall ash content.

From day four onwards, the mineral content of the sprout rises due to root growth, which improves mineral uptake and makes it a more helpful nutrient. Dung et al. (2010) use a solution instead of water.

Hydroponic fodder provides superior nutrient quality than traditional non-leguminous fodders in terms of NFE, ether extract (EE), organic matter, and crude protein. According to Al-Ajmi (2009), there is a decrease in energy intake during plant respiration, as well as in gross energy (GE), metabolizable energy (ME), and total digestible nutrient (TDN) levels.

Respiration during the sprouting phase is the principal cause of the 7-47% dry matter (DM) loss from the initial seed that happens during 6-7 days (Sneath and McIntosh 2003, Dung et al., 2005, Fazaeli et al., 2012, Putnam et al., 2013). Soaking seeds activates enzymes, releasing water and carbon dioxide, which releases energy and breaks down the endosperm's starch into simple sugar. This causes a loss of dry matter (DM), as the starch in the seed converts into fiber and pectin in the roots and early shoots.

Sprouts maintain their highest level of enzymes from germination to seven days of maturity, making them the most enzyme-rich plants. They are high in antioxidants, specifically alpha-carotene (Sneath and McIntosh, 2003). There is no nutritional waste because the roots and shoots are consumed simultaneously. Depending on their physiological status, dairy animals can receive up to 25 kg of low-concentrate roughage each day.

2.10 Hydroponic Feed on Livestock Productivity

2.10.1 Milk Production

Research has shown that feeding hydroponically produced fodder increases milk output more than feeding cows grain, hay, or silage. Aquaponic providing hydroponic fodder to nursing cows increases milk yield by 13.73% (Naik et al., 2013), 10.07% (Reddy et al., 1988), and 12.5%. According to Canadian dairy farmers, providing their cows with hydroponic fodder boosts their intake of feed and improves milk production by 3.6 kg per day throughout the lactation phase. Additionally, South African farmers recorded a reduction of 3.6 liters of milk following a daily feed break of 6.8 kg (Mooney, 2005). Farmers in Maharashtra's Satara area reported that their milk yields had increased by 0.5 to 2.5 liters per animal. Daily and net profit of INR 25–50/-per animal daily as a result of feeding their dairy animals hydroponically produced fodder (Bakshi et al., 2017). According to Agius, the principal component analysis (PCA) showed that dietary hydroponic supplementation raises the pH and milk fat percentage while maintaining higher milk quality (Agius et al., 2019). According to Mincera, Comisana sheep fed hydroponically germinated oats showed improvements in welfare and milk yield (Mincera et al., 2009).

2.10.2 Meat Production

Hydroponic fodder increases lamb body weight gain, possibly due to the availability of high bioactive enzymes and components that improve cattle performance (Naik and Singh, 2013). Furthermore, enhanced food digestibility and microbial activity in the rumen are reflected in an increase in body 8. When beef cattle are fed hydroponic fodder instead of corn, they gain an average of 200 grams. Similarly, birds and other animals have an 8% increase in body weight gain (Muhammad et al., 2013). Cross-breed calves (Rajkumar et al., 2017), Awassi lambs (Atta, 2016), and goats (Kide et al., 2015a) fed hydroponic maize and barley feed exhibited greater body weight gain.

2.10.3 Overall Performance

Hydroponic fodder may also provide additional health benefits. Sprouts contain the largest concentration of enzymes found in food, with peak enzyme activity occurring between germination and 7-8 days of age. They are high in naturally occurring antioxidants such as beta-carotene, vitamins C and E, and trace minerals like zinc and selenium. Feeding sprouted grains to animals strengthens their immune system and neutralizes the acidic environment by providing alkaline digestive enzymes. Sprouted grains are high in pigments including xanthophylls, chlorophylls, protein-sparing factors, and grass juice, all of which help cattle reproduce and produce more (Shit, 2019).

2.11 Yield of Hydroponics Fodder

The fresh yield and DM content of the crops are critical for the effective production of fodder under hydroponics. The imbibition of water (leaching) and enzymatic activities (oxidation) that deplete the food reserves of the seed endosperm without any adequate replenishment from photosynthesis by the young plant during the short growing cycle are primarily responsible for the increase in fresh weight and subsequent decrease in DM content observed during seed sprouting (Sneath and McIntosh, 2003). When the chloroplasts are triggered on day five of a seven-day sprout, photosynthesis begins, but there isn't enough time for any appreciable DM accumulation (Dung et al., 2010b). According to reports (Hillier and Perry 1969; Peer and Leeson 1985a), fresh yields of 2.8–8 folds in 6–8 days with a DM content of 8–19.7% in hydroponic barley and 3.5–6.0 folds in 7-8 days with a DM level of 10.3–18.5% in Maize fodder have been recorded. In 7–10 days, farmers growing hydroponically grown maize fodder in inexpensive greenhouses or devices reported a fresh yield of 8–10 kg from one kilogram of locally grown Maize seeds (Naik et al., 2013b). The type of crops, harvesting days, amount of free water drained before weighing, type and quality of seed, seed rate, seed treatment, water quality, pH, irrigation frequency, nutrient solution used, light, growing period, temperature, humidity, clean and hygienic condition of the greenhouse, etc. are the main factors influencing the fresh yield and DM content of the hydroponics fodder (Trubey and Otros,1969).

2.12 Livestock Feeds and Forage Status

Livestock production is a crucial component of agriculture that can support the livelihoods and food security of large numbers of people in the developing world. Including ruminant and nonruminant output, the livestock industry as a whole contributes between 15 and 17% of the GDP and 37 and 87% of household income (Mengistu et al., 2021). Zaharaby reported that feeds and fodder are considered as the biggest problem for obtaining optimum return from livestock and their development in the country (Zaharaby, 2002). According to a previous study, only about 44% of the dry matter, 26% of the crude protein and 17% of the energy requirements are met by the available feed resources in the country (Saadullah, 2000). With 19.95% of the nation's GDP coming from agriculture (BBS, 2011), Bangladesh's agriculture has been changing since independence, going from a traditional to an input-supported system and tackling shifting agroecological, socio-economic, and climatic conditions. According to Sere (Sere et al., 2008), inadequate livestock nutrition is a common problem in the developing world, and a major factor affecting the development of viable livestock industries in poor countries. In livestock farming, optimum production may not be achieved without ensuring an abundant supply of feeds and fodder to the animals. One of the main barriers to Bangladesh's livestock development is the severe lack of feed and fodder. Roughage and concentrate are the main foods that ruminant animals consume. The main sources of roughage for Bangladeshi ruminants are crop residues (rice and Maize straw, maize stover, sugar cane by-products, pulse crop shreds, banana pseudo stem), green grasses (winter and monsoon fodder, natural green biomass, water, and crop weeds), and tree foliage and leaves (jackfruit, Leucaena, mulberry, and other edible tree leaves and bushes). Losses from natural disasters, roughage transportation challenges, lack of preservation and processing facilities, user ignorance, and other applications impact the availability of roughages for animals (Sarker et al., 2016). Conversely, concentrate feeds are mostly made of grain by-products, which are thought to have the necessary nutritional quality but whose quantitative supply is insufficient to meet demand. Due to this, the feed crisis for rearing cattle has gotten worse, and the free-market trade policy has made dairy and fattening farms extremely competitive and difficult to maintain. According to Tareque, there are 29.1 million tons of roughage accessible for ruminants (Tareque, 1985). However, according to other reports (Tareque and Saadullah, 1988), the average amount of fresh green grass available per animal per day is roughly 1 kg from roadside, fallow areas, homesteads, and embankments.

Huque and Sarker (2013) calculated the nation's feed needs. The expected yearly production of concentrates is 2.76 million tons, while the overall production of fibrous feed, excluding roadside grazing and cut-and-carry grasses, is 32.8 million tons. However, it is reported that animals only have access to 50% of the fibrous feed available and that a percentage of the concentrate is lost to other purposes. It was determined that the current stock of farm animals requires an estimated 27.0 million tons of dry matter in fibrous feed and that the concentrate, which includes fish and poultry, requires 12.6 million tons. The estimated annual deficiency of roughage dry matter would be calculated as 39.3%, and that of concentrate dry matter as 78.1% of the total quantitative requirement, taking into account the availability of fibrous dry matter to animals (50.0% of the total production makes 16.4 million tons). The quantitative requirement for roughage dry matter is nevertheless somewhat reduced by roadside grazing and cut-and-carry grasses; however, the animals' production performances are still impacted by their qualitative deficiencies (av. M/D-5.5 MJ/Kg DM and CP-6.5% DM) and the time interval between production and demand. If the byproducts are used improperly, the concentrated dry matter deficit could increase even further. According to a published report, the average availability of green grass is only 2.5 kg/h/day (Sarker et al., 2016). The demand and supply gaps of feeds and fodders (Huque and Sarker, 2014) and seasonal and regional variations in biomass availability often limit ruminant production and productivity in many developing countries including Bangladesh. In Bangladesh, plenty of information on seasonal feeds and fodder dynamics is very scanty.

2.13 Water uses in Crops

Irrigation is becoming increasingly important in the world's agriculture. Supplemental irrigation is becoming more common in semi-humid areas as well while being mostly used in arid and semi-arid zones. The track record of enhanced crop yield owing to irrigation is unmistakable (Shalhevet, 1994).

The amount of water extracted worldwide has nearly doubled in the last 40 years. The irrigated land increased from 138 million ha in 1961 to 277 million ha in 2003 in order to increase food production. Due to population and economic expansion, water use will continue to rise in the ensuing decades (Liu et al., 2009). All living things depend on water, which makes up between 50 and 97 per cent of plant and animal matter as well as roughly 70 per cent of the typical human body weight (Buchholz, 1998). Unfortunately, water is also the most mismanaged resource in the world (Fakayode, 2005). The majority of the world's groundwater (GW) resources are depleting at an alarming rate, and in the future, they might not be able to keep up with the needs of industry and agriculture. According to estimates, the agricultural industry uses the most greenhouse gas emissions (GW) and uses around 80% of the real water resources for irrigation. Due to a lack of better options, many farmers in locations adjacent to urban and peri-urban areas are even forced to irrigate their crops with wastewater (Ghimire, 1994). Eighty to ninety per cent of the freshwater consumed by people comes from agriculture as, in stark contrast to household and industrial withdrawals, the majority of the water used by agriculture is lost through transpiration and evaporation. It is evident that in many areas, significantly reducing water use is necessary to achieve sustainable agriculture (Morison et al., 2008).

2.13.1 Surface Water

Irrigation is becoming increasingly important in the world's agriculture. Supplemental irrigation is becoming more common in semi-humid areas as well while being mostly used in arid and semi-arid zones. The track record of enhanced crop yield owing to irrigation is unmistakable.

Water and land resources are vital in cities and are increasingly important in the development of many rural communities. Farming, grazing, wildlife, natural vegetation, cattle, residential development, water retention, and transportation infrastructure are some of the significant land uses. Global conflicts over land usage are becoming more common, and one of the main causes of these conflicts is population expansion. Large tracts of land are used for agriculture in various parts of the world, including livestock farms, paddy fields, row crops, and specific income crops (Seeboonruang, 2012).

2.13.2 Groundwater

Nearly 2 billion people receive their water from groundwater worldwide, which also provides more than 40% of the water used for irrigation and, by overcoming local rainfall limitations, allows for 13% of total food production. Both large- and small-scale growers can boost agricultural output by using groundwater. With careful planning, it increases food security globally and may result in healthier diets. Many significant agricultural areas regularly and progressively overuse groundwater supplies (Yang X. et al., 2021).

The procedures used in agricultural production are often blamed for the degradation of groundwater in rural regions. It may take years for nonpoint sources of contamination to cause noticeable changes in groundwater quality; as a result, these changes reflect the cumulative effect of previous N and water management techniques. Due to challenges in collecting representative soil samples, it is sometimes difficult to assess the combined effects of N and water management in the soil vadose zone. As a result, it is commonly believed that monitoring groundwater quality represents a reasonable integration of all management techniques across time (Schepers et al., 1991).

One adaptable and dependable source of water is groundwater. On the other hand, shallow fresh groundwater is not used, and excessive pumping by deep public and private tube-wells frequently pulls up water with significant salinity and causes secondary soil salinization. As a result, it is necessary to use this valuable water more wisely. By using appropriate irrigation scheduling, shallow groundwater can also be utilized for sub-irrigation to assist close the gap between water supply and demand.

2.14 Water Scarcity

Water scarcity affects various ecosystems and over 40% of the world's population. Population expansion and rising per-capita protein and food-energy demands are putting more strain on the world's water and land resources. Most of the world's consumptive freshwater use is currently attributed to agriculture, and by 2050, that share is expected to increase. The increasing production of biologically produced energy and materials worldwide is expected to result in a significant rise in agricultural output in the future. Due to these pressures, in many parts of the world, land degradation and water scarcity are more pressing environmental issues than climate change (Pfister et al., 2011). The effective use of water in crop production has been a source of concern for man for generations. It's true that managing the water requirements of crops and cultivating them was likely a prerequisite for civilization (Tanner et al., 1983).

Any type of water that has been contaminated is considered wastewater. In many nations around the world, rapid industrialization and urbanization have led to problems with water quantity and quality. Wastewater production has increased as a result of this. Worldwide, improper water handling and use in a variety of sectors, including municipalities, agriculture, and industry, results in 380 trillion L/y of wastewater (McAteer et al., 2020). According to Environment Protection Agency (EPA), the wastewater is categorized as grey water (household wastewater from washing), black water (toilet wastewater), sewage (greywater, blackwater, and trade waste), and industrial wastewater. Given the potential for future water scarcity, this enormous volume of wastewater output is cause for concern (Hao et al., 2019).

2.15 Reutilization of Different Wastewater

The current global population of 6000 million will increase by 35% to approximately 8100 million by 2030. There will be a significant increase in the demand for food due to the expanding population. Water consumption from non-agricultural sectors will continue to rise concurrently in both developed and emerging nations. The world's geographical area is approximately 40% covered by dry and semi-arid climates. Under these circumstances, it's critical to maximize crop water productivity (WP) and make efficient use of wastewater (Ali et al., 2008). Utilizing wastewater for crop irrigation can have a positive economic impact by utilizing its N and P levels, supplying plants with nutrients while reducing the need for fertilizers, and promoting regional food production. Since the beginning of the industrial revolution, wastewater treatment has been seen as a social and environmental issue. Numerous studies conducted in the 19th and 20th centuries attempted to identify the components of wastewater to develop more effective methods for eliminating and disposing of pollutants from wastewater (Tang, 2004).

The most popular technique for disinfecting wastewater is chlorination, yet this process can produce hazardous and mutagenic byproducts that could be dangerous to aquatic and human life (Monarca et al., 2000). Since chlorine inactivates the majority of bacterial and viral pathogens quickly and affordably while leaving a free chlorine residual (FCR) in the water for protective benefits, chlorine is a disinfection technique that is frequently employed in humanitarian emergencies to treat water supplies (Wu et al., 2022). Chlorination has been the most widely used wastewater disinfection technique since the late 1940s and is a key component in the global prevention of waterborne infectious illnesses. It is possible to use a variety of chlorine derivatives, including gaseous chlorine, hypochlorite, and chloramine compounds. In recent years, a number of WWTPs in the United States have switched from gaseous chlorine to hypochlorite in an effort to reduce operating and maintenance (O&M) costs and enhance operator safety (Lazarova et al., 1999).

2.16 Reuse of Wastewater for Agriculture Irrigation

There is a limited amount of fresh water, therefore it is essential to preserve it and use lower-quality irrigation water. As freshwater scarcity increases in areas like dry and semi-arid countries, agriculture—which depends greatly on it and uses most of it worldwide—may face life-threatening consequences (Rusan et al., 2007). Approximately 70% of the water collected is used for agricultural irrigation in arid and semi-arid regions of the world. To complement the current freshwater sources, it is imperative to identify additional alternative water sources, such as desalinated river water and treated wastewater (surface water, groundwater). gradually replacing freshwater used for irrigation with purified wastewater (Ofori et al., 2021). In Pakistan, 30% of wastewater is used directly for irrigation, whereas 64% of it is disposed of untreated in rivers (Choudhary & Mushtaq, 2023).

CHAPTER III

METHODOLOGY

3.1 Experimental Site

The experiment was conducted at the small part basement of Acharya Jagadish Chandra Bose Academic Building (academic building-2) Khulna University, Khulna. The minimum and maximum temperature of the house were 18°C - 23°C respectively.

3.2 Preparation of Shelf and Tray

Trays were made from tin sheets. Fifteen (15) steel trays have the same dimensions of 46cm long and 41cm wide for each plot. Every day location of each tray was changed to get better results from the experiment. The tray was poured on one side so that water could be removed rapidly. The shelf was made on such a slope that water could be poured into another tray that stayed on the bottom side. The shelf was made around the inside of the shed. It was made of local instruments at least cost. Wood was used to make the shelf. Three shelves were made on each side of the shed. The well drainage system was available there. There was enough ventilation system for proper light and air.

3.3 Experimental Seed Collection and Preparation

Maize seed (KMHB-410) was purchased from the Khulna local market. These seeds were quickly sun-dried to reduce their moisture content to 12–14%. The seeds were twice washed in a pail with freshwater after they had been weighed. The cleaned seeds sterilized by soaking 30 minutes in a 20% sodium hypochlorite solution (household bleach) to control the formation of mold. The seeds were washed twice more with fresh water. After that, soak the seeds for at least 12 hours in treatments water. The optimum temperature at soaking is 23°C. Water was removed after 12 hours and the seeds was left without water for at least one hour. Seeds were placed in a gunny bag after being given time to breathe. The germination stage being very sensitive to the salinity level or others, due to this reason the salinity level of all treatments was checked before germination to reach maximum result.

3.4 Steps of Operation

Operation related to hydroponic fodder production was followed below: -

i. At first seeds were weighed after buying from the market.
ii. The seeds were washed with fresh water two times.
iii. The cleaned seeds sterilized by soaking 30 minutes in a 20% sodium hypochlorite solution (household bleach) to control the formation of mold.
iv. Then soak the seeds for at least 12 hours in each treatments water.
v. After 12 hours of soaking passing away seeds were given breathing time about one hour.
vi. After breathing time, the seeds were placed into a gunny bag (12 hours for Maize seed).
vii. After germination occurred properly, seeds were placed in the trays through spreading.
viii. Water was given timely. The samples were collected at 5th, 7th, 9th and 11th days for analysis. Lastly harvested on the 11th day and recorded the performance data.

3.5 Experimental Water Collection

In this experiment, five (5) types of different water were collected.

i. Tap water: Tap water was collected from the Gollamari area, Khulna.
ii. Pond water: Pond water was collected from Khulna University campus (Near the central field).
iii. River water: River water was collected from the Rupsha river, Khulna.
iv. Borehole water: Borehole water was collected from the Nirala residential area, Khulna.
v. Sewage water: Sewage water was collected from the drain of residential halls of Khulna University.

3.6 Experimental Water Preparation

Sewage water was treated to remove the microbes. Chlorine tablet is very popular to remove the microbes from the wastewater. The simplest way to get rid of the chlorine is to let it sit out in an open container for 24 hours until the chlorine evaporates (USEPA, 1999).

Every water was mixed with nutrient solution at 3ml solution for 1-litre water.

3.7 Analysis of Water Composition

Table 3.7 Analysis of Different Water Quality

Types of water / Parameter	Tap water	Pond water	Sewage water	River water	Borehole water
pH	7.8	7.9	8.0	7.3	7.0
Electric Conductivity (μS/cm)	840	750	2090	740	780
Total Suspended Solid(mg/L)	0.0102	0.0146	0.0166	0.0178	0.0048
Total DissolvedSolid (mg/L)	470	400	1080	390	390

The water quality was analyzed in Chemistry Laboratory of Soil, Water and Environment Discipline at Khulna University.

3.8 Chemical Composition of Nutrient Solution (Source: Manufacturer- Haovegfloer, Made in China)

3.8.1 Nutrient Solution A

i. Total N → 9.00%

ii. Soluble P_2O_5→ 8.0%

iii. K_2O → 30.0%

iv. Mg → 3.0%

v. EDTA-Fe → 0.30%

vi. EDTA-Mn → 0.06%

vii. EDTA-Cu → 0.005%

viii. EDTA-Zn → 0.01%

ix. B → 0.1%

3.8.2 Nutrient Solution B

i. Total N → 11.5%

ii. CaO → 8.0%

3.9 Irrigation

Irrigation was applied at 6-hour intervals in a day using a sprayer machine. For the first two days, 4-time spray was performed. Then water was applied at 6 times a day.

Table 3.9 Amount of water applied per day

Day	Water Use	Day	Water Use
1^{st}	100 ml	7^{th}	300 ml
2^{nd}	100 ml	8^{th}	300 ml
3^{rd}	200 ml	9^{th}	300 ml
4^{th}	200 ml	10^{th}	200 ml
5^{th}	250 ml	11th	200 ml
6^{th}	250 ml		

3.10 Percentage of Germination

The percentage of germination indicates the proportion by number of seeds which have produced normal seedlings within specified period under favorable conditions. It is calculated by using the following formula-

$$\text{Percentage of germination} = \frac{\text{No.of normal seedlings}}{\text{No.of seeds set for the test}} \times 100$$

3.11 Total Water Use and Water Use Efficiency

The total added and drained water out of trays throughout the course of the experiment was recorded per tray every day to compute total water use and water use efficiency (AI-Karaki and AI-Hashimi, 2012). The total water used by plants (liters/tray) was computed according to the equation:

1. Total water use (liter/tray) = Total applied water by irrigation − Total drained out water.
2. Water use efficiency (WUE) in kg fresh weight/m^3 water was computed according to the equation:

$$\text{WUE} = \frac{\text{Total green fodder produced (kg/tray)}}{\text{Total water supplied (liter/tray)}}$$

3.12 Lighting

The light was provided at 18 hours daily. In the daytime the lighting system was stopped for 6 hours. The lux meter reading in the room was 280-320 lux during the day and 180-220 lux at night.

3.13 Treatment and Design of Experiment

The experiment was conducted using CRD (Completely Randomized Design) with five treatments having three replications. The five sources of irrigation water were the treatments; i.e., T_1= Tap water, T_2= Borehole water, T_3= Pond water, T_4= River water and T_5= sewage water.

Table 3.13 Layout of the Experiment

	Replication(R)		
Treatment(T)	R_1	R_2	R_3
T_1	T_1R_1	T_1R_2	T_1R_3
T_2	T_2R_1	T_2R_2	T_2R_3
T_3	T_3R_1	T_3R_2	T_3R_3
T_4	T_4R_1	T_4R_2	T_4R_3
T_5	$T_5 R_1$	$T_5 R_2$	$T_5 R_3$

T_1 = Tap water; T_2 = Borehole water; T_3 = Pond water; T_4 = River water; T_5 = Sewage water

In each treatment 3ml nutrient solution liter^{-1} of treatment water was added. A nutrient solution for hydroponic systems is an aqueous solution containing mainly inorganic ions which play vital physiological role to complete plant life cycle.

3.14 Harvesting

After 5th, 7th, 9th and 11th days of seed placing, the samples of the fodders were collected for data collection. Leaf chlorophyll content index was measured at 7th, 9th and 11th day.

3.15 Collection of Data

3.15.1 Agronomic Data

The physical data collected from the experiment are

- ✓ Leaf chlorophyll content index
- ✓ Plant height(cm)
- ✓ Root length(cm)
- ✓ Root and shoot length(cm)
- ✓ Biomass index

i. Plant height: Plant height was recorded at 5th, 7th, 9th and 11th days by the help of meter scale.

ii. Root length: Root length was recorded at 5th, 7th, 9th and 11th days by the help of meter scale.

iii. Root and shoot length: Root and shoot length was recorded at 5^{th}, 7^{th}, 9^{th} and 11^{th} days by the help of meter scale.

iv. Biomass index: Each tray's total plant quantity was measured and compared with the seed mass.

The leaf chlorophyll content index (SPAD meter readings) was recorded at 7^{th} day, 9^{th} day, 11^{th} day of crop growth. The numerical SPAD value is proportional to the concentration of chlorophyll present in the leaf and is calculated from the measured absorbance of a leaf in the red and near-infrared regions. Since chlorophyll index increases with the amount of nitrogen, a higher SPAD value indicates better nitrogen nutrition of the plant. Based on the plant development, readings were taken on young leaves from 5 plants per substrate. This data was collected at the time of 12 pm to 2 pm.

3.16 Preparation of Samples for Laboratory Analysis

The fodder samples were dried before grinding. After grinding, the samples were kept in polyethylene bags, labelled and stored for further analysis.

3.17 Proximate Analysis

The chemical composition was determined as per the standard method of the Association of Official Analytical Chemists (AOAC, 1990).

3.18 Gross Energy Calculation

Gross energy was calculated by the formula (Crisan & Sands, 1978)-

Gross Energy = (5.7* protein(gm)) + (9.4*fat(gm)) + (4.1*NFE (gm) + fiber(gm))

3.19 Statistical Method and Analysis

Data were analyzed using the General Linear Model (GLM) procedure of SAS version 9.1, 1994 (SAS Institute, Inc.). DMRT was used to compare the treatment means with significance consider at $p<0.001$.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Agronomic Growth Parameters of Hydroponic Maize Fodder

4.1.1 Plant height of hydroponic Maize fodder

It is shown in table 4.1.1 that the highest plant height at 5th day was found in T_5 (14.60 ± 0.26 cm) and the lowest one was in T_3 (11.87 ± 0.20 cm). Treatments had highly significant effect ($p<0.01$) on plant height at 5th day. Similarly, the highest plant height at 9th day was found in T_5 (24.51 ± 0.30 cm) but the lowest one was in T_3 (21.93 ± 0.23cm) which was significantly ($p<0.01$) affected. In a study (Bari et al., 2022) found that the plant height of Maize fodder at 8th day was 14.10 cm which is partially matched with present study and in the case of maize fodder plant height, 24.87 cm (Jolad et al., 2020) was found which supports the present result. The highest plant height at 11th day was found in T_5 (29.33 ± 0.64 cm) and the lowest one was in T_3 (26.03 ± 0.96cm) which was also significantly ($p<0.01$) affected.

Table 4.1.1 Plant height of hydroponic maize fodder

Treatment	Plant height at 5th day (cm)	Plant height at 7th day (cm)	Plant height at 9th day (cm)	Plant height at 11th day (cm)
T_1	$13.27^{ab} \pm 0.39$	19.80 ± 0.35	$22.93^{bc} \pm 0.32$	$27.31^{bc} \pm 0.2$
T_2	$14.67^{a} \pm 0.32$	19.97 ± 0.40	$22.19^{abc} \pm 0.55$	$27.23^{bc} \pm 0.3$
T_3	$11.87^{b} \pm 0.20$	19.47 ± 0.28	$21.93^{c} \pm 0.23$	$26.03^{c} \pm 0.96$
T_4	$13.60^{a} \pm 0.06$	17.81 ± 0.02	$23.97^{ab} \pm 0.02$	$27.99^{ab} \pm 0.8$
T_5	$14.60^{a} \pm 0.26$	18.87 ± 0.56	$24.51^{a} \pm 0.30$	$29.33^{a} \pm 0.64$
CV (%)	6.24	6.21	3.26	3.51
p value	**	NS	**	*

T_1 = Tap water; T_2 = Borehole water; T_3 = Pond water; T_4 = River water; T_5 = Sewage water

*NS=non-significant, Means with different superscripts in a column differ significantly; **=$p<0.01$, *=$p<0.05$*

4.1.2 Root length of hydroponic Maize fodder

It is shown in table 4.1.2 that the highest root length at 5th day was found in T_1 (15.30 ± 0.47cm) and the lowest one was in T_5 (13.73^a ± 0.14 cm) which has no significant effect. Similar trend was found in case of 7th day. In a study (Bari et al., 2022) found that the root length of maize fodder at 8th day was 9.72 cm which is partially matched with present study and in the case of maize fodder root length, 17.5 cm (Jemimah et al., 2015) was found which supports the present findings. Due to adding nutrient solution the present result might be better rather than those of other studies. The highest root length at 11th day was found in T_2 (26.61 ± 0.48cm) and the lowest one was in T_3 (25.25 ± 0.66cm). There was no significant effect on the root length at 11th day among all the treatments.

Table 4.1.2 Root length of hydroponic maize fodder

Treatment	Root length at 5th day (cm)	Root length at 7th day (cm)	Root length at 9th day (cm)	Root length at 11th day (cm)
T_1	15.30 ±0.47	20.03^a ± 0.52	23.03 ± 0.79	25.56 ± 0.97
T_2	14.87 ± 0.19	19.37^{ab} ± 0.38	21.75 ± 0.59	26.61 ± 0.48
T_3	15.13 ± 0.18	20.67^a ± 0.38	22.43± 0.71	25.25 ± 0.66
T_4	14.43 ± 0.14	18.74^{ab} ± 0.16	23.10 ± 0.16	26.05± 0.29
T_5	13.73 ± 0.14	17.84^b ± 0.58	22.89 ± 0.57	25.65 ± 0.23
CV (%)	7.98	6.08	8.00	6.93
P value	NS	*	NS	NS

T_1 = Tap water; T_2 = Borehole water; T_3 = Pond water; T_4 = River water; T_5 = Sewage water
*NS=non-significant, Means with different superscripts in a column differ significantly; ***=$p<0.001$, **=$p<0.01$, *=$p<0.05$*

4.1.3 Leaf chlorophyll content index of hydroponic maize fodder

It is shown in table 4.1.3 that the highest chlorophyll index at 7th day was found in T_4 (22.59 ± 0.66) and the lowest one was in T_2 (19.84 ± 0.53) which had no significant effect. In the 9th day of the experiment treatment has a significant effect ($p<0.01$) on the chlorophyll content index of hydroponic maize fodder. In a study it is found that the highest chlorophyll content of maize fodder at 10th day was 24.62 (Jolad et al., 2020) which is partially matched with present study and in the case of maize fodder, 24.87 (Jolad et al., 2020) was found which supports the present result. The highest chlorophyll index at 11th day was found in T_5 (24.76 ± 0.90) and the lowest one was in T_2 (21.00 ± 0.96) which had highly significant effect ($p<0.001$).

Table 4.1.3 Leaf chlorophyll content index of hydroponic maize fodder

Treatment	Chlorophyll at 7th day	Chlorophyll at 9th day	Chlorophyll at 11th day
T_1	21.08± 0.23	$21.93^{b} \pm 0.78$	$22.78^{ab} \pm 1.17$
T_2	19.84 ± 0.53	$21.26^{b} \pm 0.41$	$21.00^{b} \pm 0.96$
T_3	20.73 ± 0.46	$22.09^{b} \pm 0.22$	$24.51^{a} \pm 0.57$
T_4	22.59 ± 0.66	$24.64^{a} \pm 0.54$	$23.47^{a} \pm 0.46$
T_5	20.73 ± 0.30	$25.07^{a} \pm 0.67$	$24.76^{a} \pm 0.90$
CV (%)	6.36	5.14	4.83
P value	NS	**	*

T_1 = Tap water; T_2 = Borehole water; T_3 = Pond water; T_4 = River water; T_5 = Sewage water
NS=non-significant, Means with different superscripts in a column differ significantly; ***=p<0.001, **=p<0.01, *=p<0.05

4.1.4 Association of growth parameters of hydroponic Maize fodder

The results of Pearson's correlation co-efficient analysis among the plant height and chlorophyll index of maize fodder are presented in Table 4.1.4 Highly significant ($p<0.001$) association was found in plant height at 5th day and chlorophyll index at 7th day ($r = 0.93$), plant height at 7th day and chlorophyll index at 7th day ($r = 0.91$), plant height at 9th day and chlorophyll index at 9th day ($r = 0.93$), plant height at 11th day and chlorophyll index at 7th day ($r = 0.82$).

Table 4.1.4 Correlation matrix of plant height and chlorophyll index of hydroponic Maize fodder

Parameters	Plant height at 5th day	Plant height at 7th day	Plant height at 9th day	Plant height at 11th day	Chlorophyll at 7th day	Chlorophyll at 9th day	Chlorophyll at 11th day
Plant height at 5th day	1						
Plant height at 7th day	0.91^{***}	1					
Plant height at 9th day	0.84^{***}	0.91^{***}	1				
Plant height at 11th day	0.94^{***}	0.82^{***}	0.85^{***}	1			
Chlorophyll at 7th day	0.93^{***}	0.91^{***}	0.91^{***}	0.92^{***}	1		
Chlorophyll at 9th day	0.46^{*}	0.41^{NS}	0.35^{NS}	0.31^{NS}	0.43^{NS}	1	
Chlorophyll at 11th day	0.42^{NS}	0.44^{*}	0.41^{NS}	0.45^{NS}	0.41^{NS}	0.11^{NS}	1

*NS=non-significant, ***=p<0.001, **=p<0.01, *=p<0.05*

4.1.5 Total water use and water use efficiency of hydroponic Maize fodder

It is shown in table 4.1.5 that the highest water use (liter/tray) was found in T_4 (2.20 ± 0.06 liter) and the lowest one was in T_3 (1.98 ± 0.05 liter). There was no significant effect on total water use among all the treatments. In a study it is found that the total water use of maize fodder was 4.1 liter (Al-Karaki et al., 2012) which is partially agreed with present findings. The highest water use (liter/kg fresh matter) was found in T_5 (3.26 ± 0.07 liter) and the lowest one was in T_1 (2.74 ± 0.11 liter). Treatments had highly significant effect ($p<0.001$) on total water use at liter/kg fresh matter. In a study it is found that the total water use of maize fodder was 1.80 liter/kg fresh matter (Al-Karaki et al., 2012) which is partially consistent with present study. The highest water use efficiency (kg fresh matter/m^3) was found in T_1 (392.79 ± 4.77 kg) and the lowest one was in T_5 (358.56 ± 4.77 kg). All the treatments had highly significant effect ($p<0.001$) on water use efficiency at kg fresh matter/m^3. The highest water use efficiency (kg dry matter/m^3) was found in T_5 (3.68 ± 0.18 kg) and the lowest one was in T_2 (2.85 ± 0.27 kg). All the treatment had significant effect ($p<0.05$) on water use efficiency at kg dry matter/m^3.

Table 4.1.5 Total water use and water use efficiency of hydroponic Maize fodder

Treatment	Total water use		Water use efficiency	
	Liter tray^{-1}	Liter kg^{-1} fresh matter	kg fresh biomass m^{-3}	kg dry biomass m^{-3}
T_1	1.99 ± 0.09	2.74^{c} ± 0.11	392.79^{a} ± 4.77	3.04^{bc} ± 0.22
T_2	2.05 ± 0.08	2.93^{bc} ± 0.08	378.38^{b} ± 3.12	2.85^{c} ± 0.27
T_3	1.98 ± 0.05	2.83^{c} ± 0.06	378.38^{b} ± 3.12	3.11^{abc} ± 0.17
T_4	2.20 ± 0.06	3.18^{ab} ± 0.09	374.77^{b} ± 1.80	3.48^{ab} ± 0.04
T_5	2.16 ± 0.05	3.26^{a} ± 0.07	358.56^{c} ± 4.77	3.68^{a} ± 0.18
CV (%)	5.46	4.97	1.70	10.26
P value	NS	***	***	*

T_1 = Tap water; T_2 = Borehole water; T_3 = Pond water; T_4 = River water; T_5 = Sewage water
*NS=non-significant, Means with different superscripts in a column differ significantly; ***=$p<0.001$, *=$p<0.05$*

4.1.6 Yield, cost and biomass of hydroponic Maize fodder

It is shown in table 4.1.6 that the highest yield/tray was found in T_3 (735.33 ± 5.77gm) and the lowest one was in T_1 (713.33 ± 8.82 gm) which had highly significant effect ($p<0.001$). In a study it is found that the yield of maize fodder within 10 days was 543 gm and 551 gm (Lamnganbi et al., 2017), within 11 days was 688 gm (Mohapatra et al., 2019) which is consistent with present findings and in the case of maize fodder yield, 672 gm (Lamnganbi et al., 2017) was found which also supports the present result. The highest biomass was found in T_3 (43.24 ± 0.31 t ha^{-1}) and the lowest one was in T_1 (40.46 ± 0.48 t ha^{-1}). Treatment had highly significant effect ($p<0.001$) on biomass production. The biomass production of maize fodder was 37.9 t ha^{-1} (Al-Karaki, 2011) which is consistent with present findings and in the case of barley fodder biomass, 34 t ha^{-1} (Al-Karaki et al., 2012) was found which supports the present result. The highest cost of production/ton was found in T_3 (27832 ± 217.96 BDT.) and the lowest one was in T_4 (26626 ± 134.33 BDT.). All the treatment had highly significant effect ($p<0.001$) on cost of production/ton.

Table 4.1.6 Yield, cost and biomass of hydroponic Maize fodder

Treatment	Yield tray^{-1} (g)	Fresh Biomass (t ha^{-1})	Cost of production ton^{-1} (BDT.)
T_1	$713.33^a \pm 8.82$	$40.46^a \pm 0.48$	$26654^c \pm 319.58$
T_2	$715.33^b \pm 5.77$	$41.02^b \pm 0.31$	$26932^c \pm 217.96$
T_3	$735.33^b \pm 5.77$	$43.24^b \pm 0.31$	$27832^c \pm 217.96$
T_4	$726.67^b \pm 3.33$	$42.56^b \pm 0.18$	$26626^b \pm 134.33$
T_5	$715^c \pm 8.82$	$40.88^c \pm 0.48$	$26740^a \pm 398.40$
CV (%)	1.70	1.70	1.72
P value	***	***	***

T_1 = Tap water; T_2 = Borehole water; T_3 = Pond water; T_4 = River water; T_5 = Sewage water
*NS=non-significant, Means with different superscripts in a column differ significantly; ***=p<0.001, **=p<0.01, *=p<0.05*

4.1.7 Association of biomass and water uses efficiency of hydroponic Maize fodder

The results of Pearson's correlation co-efficient analysis among the biomass, total water use, yield, cost of BARI ghom-30 are presented in Table 4.1.7 Highly significant ($p<0.001$) association was found between biomass and water use efficiency ($r=-0.66$), biomass and cost ($r= -0.89$), water use efficiency and cost ($r= 0.76$), yield and cost ($r=0.76$).

Table 4.1.7 Correlation matrix of biomass, water use efficiency, yield and cost of hydroponic Maize fodder

Parameters	Biomass	Total water use (Liter tray^{-1})	Water use efficiency (kg fresh matter m^{-3})	Water use efficiency (kg DM m^{-3})	Yield (g)	Cost (BDT t^{-1})
Biomass	1					
Total water use (Liter tray^{-1})	-0.31	1				
Water use efficiency (Kg fresh matter m^{-3})	1***	-0.31	1			
water use efficiency (kg DM m^{-3})	-0.66***	0.09^{NS}	-0.66**	1		
Yield (g)	1***	-0.31	1***	-0.66**	1	
Cost (BDT t^{-1})	-0.89***	0.48*	-0.89***	0.76***	-0.89**	1

NS=non-significant, ***=$p<0.001$, **=$p<0.01$, *=$p<0.05$

4.2 Nutritional Parameter of Hydroponic Maize Fodder

4.2.1 Nutritional composition of hydroponic Maize fodder

It is shown in table 4.2.1 that the highest dry matter per cent was found in T_2 (13.22 ± 0.43) and the lowest one was in T_3 (11.94 ± 0.20) which had highly significant effect ($p<0.001$). In a study it is found that the dry matter per cent of maize fodder was 10.64 (Yurina et al., 2019) which is partially supports the present findings and in the case of maize fodder the dry matter per cent, 14.79 (Natsheh, 2020) was also found. The highest crude protein per cent was found in T_2 (12.24 ± 0.91) and the lowest one was in T_3 (11.26 ± 0.49) which had highly significant effect ($p<0.05$). The crude protein per cent of maize fodder was 12.10 (Yurina et al., 2019) which is partially agreed with present results. The highest crude fiber per cent was found in T_5 (13.68±0.51) and the lowest one was in T_3 (7.83 ± 0.51). There was no significant effect on crude fiber among all the treatments. The crude fiber per cent of maize fodder was 3.40 (Yurina et al., 2019) and in maize fodder the crude fiber per cent, 5.30 (Natsheh, 2020) was found. The highest ether extract per cent was found in T_5 (5.27 ± 0.37) and the lowest one was in T_1 (4.14 ± 0.16). There was no significant effect on ether extract among all the treatments. The highest ash per cent was found in T_5 (4.32 ± 0.22) and the lowest one was in T_1 (3.50 ± 0.30). There was no significant effect on ash among all the treatments. In a study it is found that the ash per cent of maize fodder was 4.09 (Yurina et al., 2019) which is consistent with present study and in the case of maize fodder the ash per cent, 2.50 (Natsheh, 2020) was found which supports the present result. The highest nitrogen free extract per cent was found in T_1 (67.06 ± 0.96) and the lowest one was in T_5 (61.98 ± 1.01). All the treatment had significant effect ($p<0.05$) on nitrogen free extract. In a study it is found that the nitrogen free extract per cent of Maize fodder was 71.12 (Yurina et al., 2019) which is partially agreed with present study and in the case of maize fodder the nitrogen free extract per cent, 78.34 (Natsheh, 2020) was found which also supports the present result. The highest gross energy was found in T_5 (232.76 ± 2.62 kcal) and the lowest one was in T_1 (210.72 ± 3.98 kcal). All the treatment had highly significant effect ($p<0.01$) on gross energy.

Table 4.2.1 Nutritional composition of hydroponic Maize fodder

Treatment	DM (%)	CP (%)	CF (%)	EE (%)	ASH (%)	NFE (%)	GE (kcal/kg)
T_1	$12.06^{b}\pm0.17$	$11.84^{b}\pm0.69$	13.04 ± 0.33	4.14 ± 0.16	3.50 ± 0.30	$67.06^{a}\pm0.96$	$210.72^{c}\pm3.98$
T_2	$13.22^{b}\pm0.43$	$12.24^{b}\pm0.91$	12.30 ± 0.29	4.57 ± 0.39	3.56 ± 0.04	$66.42^{ab}\pm0.82$	$215.53^{bc}\pm3.72$
T_3	$11.94^{b}\pm0.20$	$11.26^{ab}\pm0.49$	13.26 ± 0.51	4.34 ± 0.44	4.28 ± 0.42	$66.14^{ab}\pm1.45$	$214^{bc}\pm 4.34$
T_4	$12.84^{a}\pm0.12$	$12.18^{ab}\pm0.91$	13.03 ± 0.51	4.39 ± 0.27	4.23 ± 0.24	$63.18^{bc}\pm1.41$	$222.83^{ab}\pm3.64$
T_5	$12.24^{a}\pm0.21$	$12.04^{a}\pm 0.73$	13.68 ± 0.51	5.27 ± 0.37	4.32 ± 0.22	$61.98^{c}\pm 1.01$	$232.76^{a}\pm 2.62$
CV (%)	6.46	7.31	8.38	12.98	11.93	3.09	2.93
P value	***	*	NS	NS	NS	*	**

T_1 = Tap water; T_2 = Borehole water; T_3 = Pond water; T_4 = River water; T_5 = Sewage water

*NS=non-significant, Means with different superscripts in a column differ significantly; ***=$p<0.001$, **=$p<0.01$, *=$p<0.05$*

DM= Dry Matter; CP= Crude Protein; CF= Crude Fiber; EE=Ether Extract; GE= Gross Energy where accessible, ensuring proper treatment and safety protocols for sewage water to minimize health risks.

- Additional studies should explore the long-term effects of using sewage water, the impact of hydroponic fodder on livestock health and productivity, and the scalability of this technology in diverse agro-climatic regions.

CHAPTER VI

REFERENCE

Agius, A., Pastorelli, G., and Attard, E. (2019). Cows fed hydroponic fodder and conventional diet: effects on milk quality. Arch Anim Breed 62: 517–525.

Al-Karaki, G. N., and Ai-Hashimi, M. (2012). Green fodder production and water use efficiency ofsome forage crops under hydroponic conditions. Internl. Schol. Res. Network. DOI, 10 (2012), 924672.

Akhtar, F., Tischbein, B., and Awan, U. K. (2013). Optimizing deficit irrigation scheduling under shallow groundwater conditions in lower reaches of Amu Darya River Basin. Water resources management, 27, 3165-3178.

Al-Ajmi, A., Salih, A., Kadhim, I., and Othman, Y. (2009). Yield and water use efficiency of barley fodder produced under a hydroponic system in GCC countries using tertiary treated sewage effluents. J Phytol 1: 342-348.

Al-Hashmi, M. M. (2008). Hydroponic green fodder production in the Arabian Gulf Region (Doctoral dissertation, Arabian Gulf University).

Ali, M. H., & Talukder, M. S. U. (2008). Increasing water productivity in crop production—A synthesis. Agricultural water management, 95(11), 1201-1213.

Al-Karaki, G. N. (2011). Utilization of treated sewage wastewater for green forage production in hydroponic systems. Emirates Journal of Food and Agriculture, 80-94.

Atta, M. (2016). Effect of hydroponic barley fodder on Awassi lambs' performance. J Biol, Agril Healthcare 6(8): 60-64.

Bakshi, M. P. S., Wadhwa, M., & Harinder, P. S. M. (2017). Hydroponic fodder production: a critical assessment. Broadening Horizons 48: 1-10.

Bamikole, A. A., Sunday, O. O., Tunde, A. G., Yemisi, A. R., & Alaba, J. O. (2020). Water use efficiency and fodder yield of maize (Zea mays) and Maize (Triticum aestivum) under hydroponic conditions as affected by sources of water and days to harvest. African Journal of Agricultural Research, 16(6), 909-915.

Bari, M. S., Islam, M. N., Islam, M. M., Habib, M. R., Sarker, M. A. H., Sharmin, M. M., & Islam, M. A. (2022). Changes in morphology, nutrient content and production costs of hydroponic Maize as fodder.

BBS, (Bangladesh Bureau of Statistics) (2011). Statistical Year Book of Bangladesh, Statistics Division, Ministry of Planning, The Government of Peoples Republic of Bangladesh.

Bekuma, A. (2019). Nutritional Benefit and Economic Value of Hydroponics Fodder Production Technology in Sustainable Livestock Production Against Climate Change-A Mini-Review. Advances in Applied Sciences, 4(1), 23.

Bhise, V. J., Chavan, J. K., & Kadam, S. S. (1988). Effects of malting on proximate composition and in vitro protein and starch digestibility of grain sorghum. Journal of food science and technology (Mysore), 25(6), 327-329.

Buchholz, R. A. (1998). Principles of environmental management: the greening of business (No. Ed. 2). Prentice-Hall Inc.

Chavan, J. K., Kadam, S. S., & Beuchat, L. R. (1989). Nutritional improvement of cereals by sprouting. Critical reviews in food science & nutrition, 28(5), 401-437.

Choudhary, A., & Mushtaq, A. (2023). From pollutant to valuable product: A novel reutilization strategy of wastewater. Int. J. Chem. Biochem. Sci, 23(1), 31-37.

Chung, C. T., Niemela, S. L., & Miller, R. H. (1989). One-step preparation of competent Escherichia coli: transformation and storage of bacterial cells in the same solution. Proceedings of the National Academy of Sciences, 86(7), 2172-2175.

Crisan, E. V., & Sands, A. (1978). Nutritional value. The biology and cultivation of edible mushrooms, 137-168.

Cuddeford, D. (1989). "Hydroponic grass." In Practice 11 (5): 211-214.

Dung, D. D., Godwin, I. R., & Nolan, J. V. (2005). Nutrient content and in Sacco digestibility of barley grain and sprouted barley. J Anim Vety Adv 9: 2485-2492.

Dung, D. D., Godwin, I. R., & Nolan, J. V. (2010). Nutrient content and in Sacco degradation of hydroponic barley sprouts grown using nutrient solution or tap water. Journal of Animal and Veterinary Advances, 9(18), 2432-2435.

Dung, D. D., Godwin, I. R., & Nolan, J. V. (2010). Nutrient content and in Sacco digestibility of barley grain and sprouted barley. Journal of animal and veterinary Advances, 9 (19), 2485-2492.

Dung, D. D., Godwin, I. R., and Nolan, J. V. (2010b). Nutrient content and Sacco digestibility of barley grain and sprouted barley. J. Anim. Vet. Adv. 9 (19): 2485-2492.

Dung, D. D., Godwin, I.R., & Nolan, J. V. (2010). Nutrient content and in Sacco degradation of hydroponic barley sprouts using nutrient solution or tap water. J Anim Vety Adv 9: 2432-2436.

El-Deeba, M. M., El-Awady, M. N., Hegazi, M. M., Abdel Azeem, F.A., & El-Bourdiny, M.M. (2009). Engineering factors affecting hydroponics grass-fodder production. In agric. eng. and variables of the present epoch. The 16th annual conference of the Misr Society of Ag. Eng. 25: 1647-1666.

Elmulthum, N. A., Zeineldin, F. I., Al-Khateeb, S. A., Al-Barrak, K. M., Mohammed, T. A., Sattar, M. N., & Mohmand, A. S. (2023). Water use efficiency and economic evaluation of the hydroponic versus conventional cultivation systems for green fodder production in Saudi Arabia. Sustainability, 15(1), 822.

Emam, M. S. A. (2016). The sprout production and water use efficiency of some barley cultivars under intensive hydroponic systems. Middle East Journal of Agriculture Research, 5(2), 161-170.

Fazaeli, H., Golmohammadi, H.A., Shoayee, A. A., Montajebi, and S. Masharaf. (2011). Performance of feedlot calves fed hydroponics fodder barley. Journal of Agricultural Science and Technology, 13: 367-375.

Fazaeli, H., Golmoihammadi H. A., Tabatabayee S. N., & AsghariTabrizi, M. (2012). Productivity and nutritive value of barley green fodder yield in a hydroponic system. World Appl Sci J 16: 531-539.

Finney, P. L. (1983). Effect of germination on cereal and legume nutrient changes and food or feed value: A comprehensive review. Mobilization of reserves in germination, 229-305.

Gaikwad, D. J., & Maitra, S. (2020). Hydroponics cultivation of crops. Protected Cultivation and Smart Agriculture, 279-287.

Ghimire, S. K. (1994). Evaluation of industrial effluents toxicity in seed germination and seedling growth of some vegetables (Doctoral dissertation, M. Sc. Dissertation, Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, Nepal).

Girma, F. & Gebremariam, B. (2018). Review on hydroponic feed value to livestock production. Journal of Scientific and Innovative Research, 7(4), 106-109.

Hao, X., Li, J., van Loosdrecht, M. C., Jiang, H., & Liu, R. (2019). Energy recovery from wastewater: Heat over organics. Water Research, 161, 74-77.

Heins, B. J., Paulson, J. C., & Chester-Jones, H. (2015). Evaluation of forage quality of five grains for use in sprouted fodder production systems for organic dairy cattle. J Dairy Sci 98 (Suppl. 2): Abstr. 64.

Hillier, R. J., and Perry, T.W. (1969). Effect of hydroponically produced oat grass on ration digestibility of cattle. J. Anim. Sci. 29: 783-785.

Huque, K. S., & Sarker, N. R. (2014). Feeds and feeding of livestock in Bangladesh: performance, constraints and options forward.

Huque, K. S., and Sarker, N.R. (2013). Current status of farm animal nutrition & feeding perspectives & challenges of Bangladesh. Paper presented in a seminar on Livestock feeding & nutrition- global perspective & options for Bangladesh, jointly organized by FAO and BLRI on 23 Sept. 2013.

Jemimah, E. R., Gnanaraj, P. T., Muthuramalingam, T., Devi, T., Babu, M., & Sundharesan, A. (2015). Hydroponic green fodder production-TANUVAS experience. Tamil Nadu Veterinary and Animal Sciences University, Chenani, India.

Jensen, H. and Malter, A. (1995). Protected agriculture a global review. World Bank Technical Report, Pp 253.156.

Jeton, S. (2016). Hydroponic fodder production. 'Feed the future programme' of US Government global hunger and food security initiative in Ethiopia sponsored by USAID.

Jolad, R., Sivakumar, S. D., & Babu, C. (2020). Quality of different crops under hydroponics fodder production system. Journal of Pharmacognosy and Phytochemistry, 9(1), 1434-1439.

Kerr, S., Conway, L., & Conway, A. (2014). Fodder for forage: fact, folly, fable or fabulous?

Kide, W., Desai, B., & Dhekale, J. (2015a). Feeding effects of maize and barley hydroponic fodder on dry matter intake, nutrient digestibility and body weight gain of Konkan Kanyal goats. Life Sci Int Res J 2(2): 96-101.

Kide, W., Desai, B., & Kumar, S. (2015). Nutritional improvement and economic value of hydroponically sprouted maize fodder. Life Sci. Int. Res. J, 2(2), 76-79.

Kulkarni, M. G., Street, R. A., & Van Staden, J. (2007). Germination and seedling growth requirements for propagation of Dioscorea dregeana (Kunth) Dur. and Schinz—A tuberous medicinal plant. South African Journal of Botany, 73(1), 131-137.

Kumar, R., Mathur, M., Karnani, M., Choudhary, S. D., & Jain, D. (2018). Hydroponics: An alternative to cultivated green fodder: A review. Journal of Entomology and Zoology Studies, 6(6), 791-795.0

Lamnganbi, M., & Surve, U. S. (2017). Biomass yield and water productivity of different hydroponic fodder crops. Journal of Pharmacognosy and Phytochemistry, 6(5), 1297-1300.

Lazarova, V., Savoye, P., Janex, M. L., Blatchley Iii, E. R., & Pommepuy, M. (1999). Advanced wastewater disinfection technologies: state of the art and perspectives. Water science and technology, 40(4-5), 203-213.

Liu, J., Zehnder, A. J., & Yang, H. (2009). Global consumptive water uses for crop production: The importance of green water and virtual water. Water Resources Research, 45(5).

McAteer, P. G., Trego, A. C., Thorn, C., Mahony, T., Abram, F., & O'Flaherty, V. (2020). Reactor configuration influences microbial community structure during high-rate, low-temperature anaerobic treatment of dairy wastewater. Bioresource Technology, 307, 123221.

McKenzie, R. H., Middleton, A. B., Hall, L., DeMulder, J., & Bremer, E. (2004). Fertilizer response of barley grain in south and central Alberta. Canadian journal of soil science, 84(4), 513-523.

Mehta & Sharma (2016). Customers' persistence for green banking in Nepal. Asian Journal of Research in Banking and Finance, 6(10), 30-44.

Mengistu, S., Nurfeta, A., Tolera, A., Bezabih, M., Adie, A., Wolde-Meskel, E., & Zenebe, M. (2021). Livestock production challenges and improved forage production efforts in the Damot Gale District of Wolaita Zone, Ethiopia. Advances in Agriculture, 2021, 1-10.

Mincera, E., Ragni, M., Minuti, F., Rubino, G., & Marisco, G. (2009). Improvement of sheep welfare and milk production fed on a diet containing hydroponically germinating seeds. Italian J Anim Sci 8(2): 634-636.

Mohapatra, K. K., Mohapatra, S., Ekka, R., Behera, R. C., & Mohanta, R. K. (2019). Variations in round-the-year fodder production in a low-cost hydroponic shed. National Academy Science Letters, 42, 383-385.

Monarca, S., Feretti, D., Collivignarelli, C., Guzzella, L., Zerbini, I., Bertanza, G., & Pedrazzani, R. (2000). The influence of different disinfectants on mutagenicity and toxicity of urban wastewater. Water Research, 34(17), 4261-4269.

Mooney, J. (2005). Growing cattle feed hydroponically. Meat Livestock Australia. 30.

Morison, J. I. L., Baker, N. R., Mullineaux, P. M., & Davies, W. J. (2008). Improving water use in crop production. Philosophical Transactions of the Royal Society B: Biological Sciences, 363(1491), 639-658.

Muhammad, S., Afzal, H., & Mudassar, S. (2013). Use of sprouted grains in the diets of poultry and ruminants. Paripex - Indian J Res 2(10): 20-27.

Naik, P. K. & Singh, N. P. (2013). Hydroponics fodder production: an alternative technology for sustainable livestock production against impending climate change. In: compendium of model training course 'Management strategies for sustainable livestock production against impending climate change'. Southern regional station, NDRI, Adugodi, Bengaluru, India. 70-75.

Naik, P. K. and Singh, N. P. (2014). Production and feeding of hydroponics green fodder. Indian Farming. 64 (6): 42- 44.

Naik, P. K., Dhuri, R. B., & Singh, N. P. (2011). Technology for production and feeding of hydroponics green fodder. Extension folder, 45.

Naik, P. K., Dhuri, R. B., Swain, B. K., and Singh, N. P. (2012a). Cost of production of hydroponics fodder maize In Proc of 8th Biennial Animal Nutrition Association Conference on AnimalNutrition Research Strategies for Food Security November 28-30 2012 Bikaner RajasthanIndia p12

Naik, P. K., Dhuri, R. B., Swain, B. K., and Singh, N. P. (2012b). Nutrient changes with the growth of hydroponics fodder maize. Indian Journal Animal Nutrition (29): 161-163.

Naik, P. K., Gaikwad, S. P., Gupta, M. J., Dhuri, R. B., & Dhumal, G. M. (2013). Low-cost devices for hydroponics fodder production. Indian Dairyman 65: 68-72.

Naik, P. K., Gaikwad, S. P., Gupta, M. J., Dhuri, R. B., Dhumal, G. M. and Singh, N. P. (2013b). Low-cost devices for hydroponics fodder production. Indian Dairyman. 65: 68-72.

Naik, P. K., Swain, B. K., and Singh, N. P. (2015). Production and Utilization of Hydroponics Fodder Indian Journal Animal Nutrition 32 (1): 1-9.

Natsheh, B. (2020). Barley green fodder production and effect of different saline water levels under hydroponic condition. In Proceedings of the 6th International Conference on Agriculture (Vol. 2, pp. 12-19).

Ofori, S., Puškáčová, A., Růžičková, I., & Wanner, J. (2021). Treated wastewater reuse for irrigation: Pros and cons. Science of The Total Environment, 760, 144026.

Peer, D. J. and Leeson, S. (1985b). Nutrient content of hydroponically sprouted barley. Anim. Feed Sci. Technol. 13: 191-202.

Pfister, S., Bayer, P., Koehler, A., & Hellweg, S. (2011). Environmental impacts of water use in global crop production: hotspots and trade-offs with land use. Environmental science & technology, 45(13), 5761-5768.

Putnam, D. H., Robinson, P. H., & Lin, E. (2013). Does hydroponic forage production make sense? Alfalfa and forage news. News and information from UC Cooperative Extension about alfalfa and forage production. Retrieved 16.09.17 from http:// ucanr.edu/blogs/blogcore/ postdetail. cfm?postnum=11721.

Rachel Jemimah, E., Gnanaraj, P. T., Muthuramalingam, T., Devi, T., Babu, M., & Sundharesan, A. (2015). Hydroponic green fodder production-TANUVAS experience.

Rajkumar, G., Dipu, M. T., Lalu, K., Shyama, K., & Banakar, P. S. (2017). Evaluation of hydroponics fodder as a partial feed substitute in the ration of crossbred calves. Indian J Anim Res 52(12): 1809-1813.

Reddy, G. V. N., Reddy, M. R., & Reddy, K. K. (1988). Nutrient utilization by milch cattle fed on rations containing artificially grown fodder. Indian J Anim Nutri 5(1): 19-22.

Rusan, M. J. M., Hinnawi, S., & Rousan, L. (2007). Long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. Desalination, 215(1-3), 143-152.

Saadullah, M., and Hossain, M. M. (2000). Quantification of locally available feed resources and feeding systems of animals in different regions of Bangladesh. Research Report, October, 2000. Pp. 1-94.

Saddique, Q., Cai, H., Ishaque, W., Chen, H., Chau, H. W., Chattha, M. U., & He, J. (2019). Optimizing the sowing date and irrigation strategy to improve maize yield by using CERES (crop estimation through resource and environment synthesis)-maize model. Agronomy, 9(2), 109.

Salisbury, F. B. & Ross, C. W. (1992). Plant physiology. Wadsworth Publishing Company, California, USA.

Sarker, N. R., Rahman, S. M. R., Habib, M. A., Huque, K. S., Mohiuudin, M., & Amin, R. (2016). Characterization of existing dairy production systems and quantification of feeds and fodder availability and their requirements in Bangladesh. Research Report, 2016, BLRI, Savar, Dhaka-1341.

Schepers, J. S., Moravek, M. G., Alberts, E. E., & Frank, K. D. (1991). Maize production impacts on groundwater quality. Journal of Environmental Quality, 20(1), 12-16.

Seeboonruang, U. (2012). A statistical assessment of the impact of land uses on surface water quality indexes. Journal of Environmental Management, 101, 134-142.

Seré Rabé, C., Ayantunde, A. A., Duncan, A. J., Freeman, H. A., Herrero, M. T., Tarawali, S. A.,

& Wright, I. A. (2008). Livestock production and poverty alleviation—challenges and opportunities in arid and semi-arid tropical rangeland-based systems.

Shalhevet, J. (1994). Using water of marginal quality for crop production: major issues. Agricultural water management, 25(3), 233-269.

Sharma, N., Acharya, S., Kumar, K., Singh, N., & Chaurasia, O. P. (2018). Hydroponics as an advanced technique for vegetable production: An overview. Journal of Soil and Water Conservation, 17(4), 364-371.

Shit, N. (2019). Hydroponic fodder production: an alternative technology for sustainable livestock production in India. Exploratory Animal & Medical Research, 9(2).

Sneath, R., & McIntosh, F. (2003). Review of hydroponic fodder production for beef cattle. Department of Primary Industries: Queensland Australia, 84, 54.

Snow, A. M., Ghaly, A. E., & Snow, A. (2008). A comparative assessment of hydroponically grown cereal crops for the purification of aquaculture wastewater and the production of fish feed. American Journal of Agricultural and Biological Sciences, 3(1), 364-378.

Taiz, L., & Zeiger, E. (1998). Plant Physiology, pp735-736.

Tang, C., Chen, J., Shindo, S., Sakura, Y., Zhang, W., & Shen, Y. (2004). Assessment of groundwater contamination by nitrates associated with wastewater irrigation: a case study in Shijiazhuang region, China. Hydrological Processes, 18(12), 2303-2312.

Tanner, C. B., & Sinclair, T. R. (1983). Efficient water uses in crop production: Research or research? Limitations to efficient water use in crop production, 1-27.

Tareque, A. M. M. (1985). Bangladesh Pasupathi Bartaman Porishthiti Samashyaboli. BARC, Dhaka, Bangladesh.

Tareque, A. M. M. and Saadullah, M. (1988). Feed Availability, Requirements for Animals and Current Pattern of Utilization in Bangladesh. International Development Research Centre (IDRC), Canada.

Trejo-Téllez, L. I., Gómez-Merino, F. C., & Alcántar, G. G. (2007). Elementos Benéficos, In: Nutrición de Cultivos, G. Alcántar G and L. I. Trejo-Téllez, L. I. (Eds.), 50-91, Mundi Prensa, México DF, México.

Trubey, C. R. and Otros, Y. (1969). Effect of light, culture solution, and growth period on growth and chemical composition of hydroponically produced oat seedlings. Agron. J. 61: 663-665.

Tudor, G., Darcy, T., Smith, P., & Shallcross, F. (2003). The intake and live weight change of drought master steers fed hydroponically grown, young-sprouted barley fodder (Auto Grass). Department of Agriculture Western Australia, 8.

US Environmental Protection Agency (USEPA). (1999). Wastewater Technology Fact Sheet: Chlorine Disinfection.

Wu, H., & Dorea, C. C. (2022). Evaluation and application of chlorine decay models for humanitarian emergency water supply contexts. Environmental Technology, 43(21), 3221-3230.

Xu, Z., Sun, D. W., Zeng, X. A., Liu, D., & Pu, H. (2015). Research developments in methods to reduce the carbon footprint of the food system: a review. Critical reviews in food science and nutrition, 55(9), 1270-1286.

Yang, X., Steenhuis, T. S., Davis, K. F., van der Werf, W., Ritsema, C. J., Pacenka, S., & Du, T. (2021). Diversified crop rotations enhance groundwater and economic sustainability of food production. Food and Energy Security, 10(4), e311.

Yurina, N. A., Koshchaev, A. G., Osepchuk, D. V., Maksim, E. A., Danilova, A. A., & Shumeiko, D. V. (2019). Artificial ecological system–hydroponics: the Maize grains germination rate. International journal of engineering and advanced technology, 9(1), 4957-60.

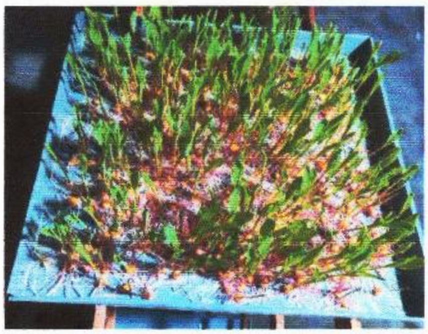
Yvonne KM (2016). YAP proposal #255: Hydroponic fodder: increasing milk production and income! YAP- Youth Agripreneur Project. https://blog.gfar.net /2016/ 03/09/yapproposal-242-hydroponic-fodder-increasing-milk-productionandincome-yvonn- kamanga- malawi.

Zaharaby, A. K. M., Mia, M. M., Reza, A., Khan, M. J., & Ali, M. L. (2001). Agricultural weeds as an alternative feed resource for ruminants in Bangladesh. The Indian Journal of Animal Sciences, 71(4).

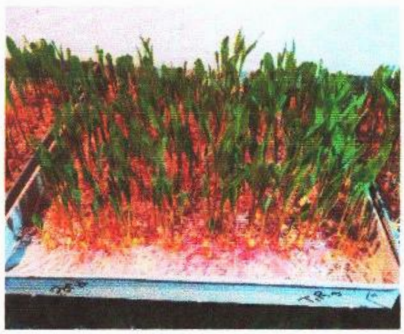
Day-1

Day-2

Day-3

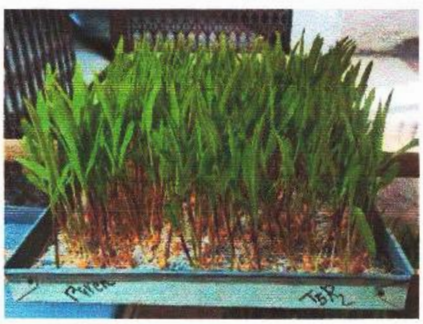


Day-4



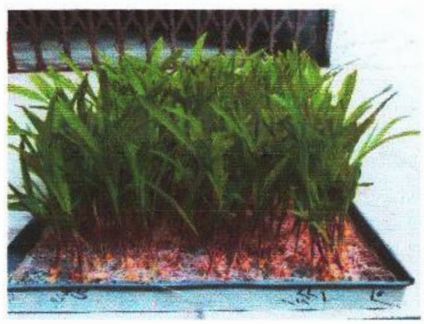
Day-5

Day-6



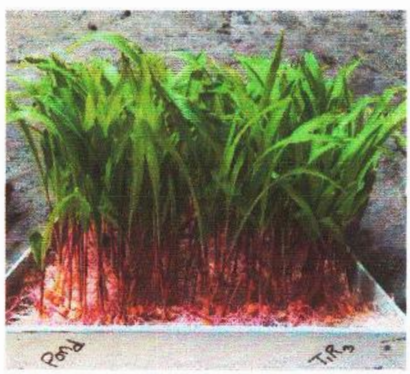
Day-7

Day-8

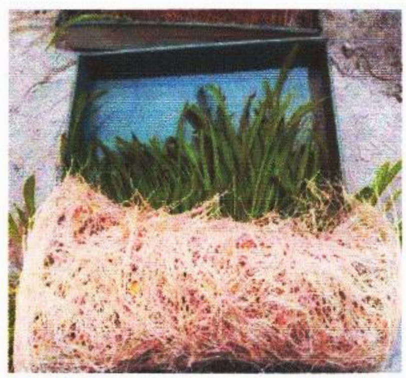


Day-9

Day-10

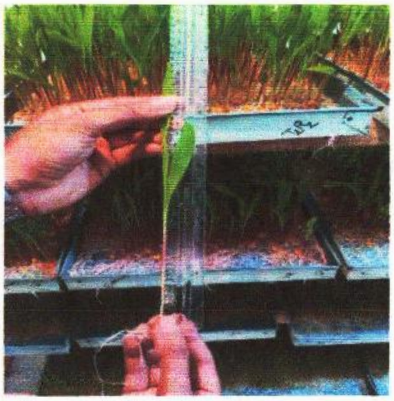


Day-11

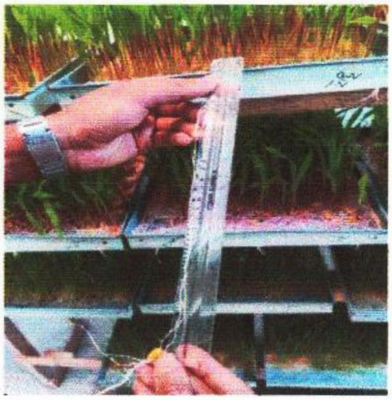


Final Product

Irrigation



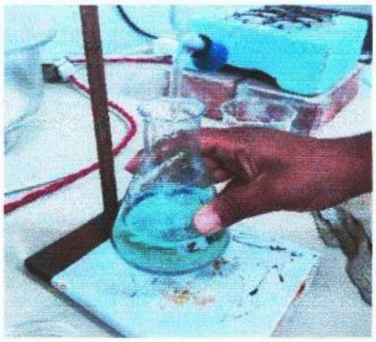
Plant Height

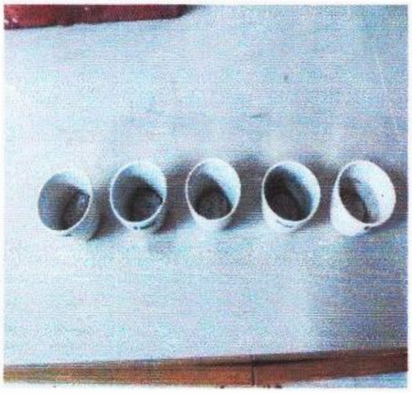


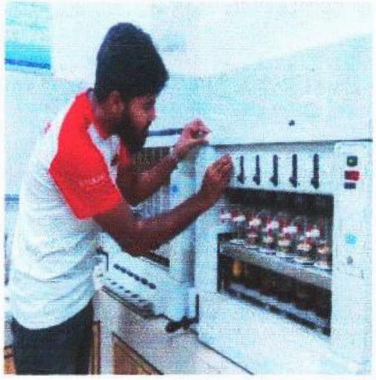
Root Length

Chlorophyll reading

Supervision of Professor Dr. Md. Shafiqul Islam Sir







Proximate Analysis