INFLUENCE OF FOLIAR SPRAYS OF WATER SOLUBLE FERTILIZERS ON GROWTH, YIELD AND QUALITY OF HYDROPONIC FODDER CROPS

By

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Reg. No. 015/016

A thesis submitted to the

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RAHURI - 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA**

In partial fulfilment of the requirements
for the degree

of

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DEPARTMENT OF AGRONOMY

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2017

CANDIDATE'S DECLARATION

I hereby declare that this thesis or a part

there of has not been submitted

by me or any other person

to any other University

or Institute for

a Degree or

Diploma.

Place: MPKV, Rahuri

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CERTIFICATE

This is to certify that the thesis entitled, "**INFLUENCE OF FOLIAR SPRAYS OF WATER SOLUBLE FERTILIZERS ON GROWTH, YIELD AND QUALITY OF HYDROPONIC FODDER CROPS**", submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRONOMY**, embodies the result of a *bonafide* research work carried out by **Miss. MUTUM LAMNGANBI,** under the guidance and supervision and that no part of this thesis has been submitted to any other University for any other Degree or Diploma.

The assistance and help received during the course of this investigation and sources of references have been duly acknowledged.

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Dated: / /2017 Research Guide

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Place : MPKV, Rahuri.
Date : /05/2017 (Mutum Lamnganbi)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATION

`	:	rupees
ADF	:	Acid Detergent Fibre
CP	:	Crude Protein
DM	:	Dry Matter
et al.	:	Et alli
Fig.	:	Figure
g	:	Gram
ha	:	Hectare (s)
hr	:	hour
i.e	:	that is
kg	:	Kilogram
L	:	Litre
Min	:	minute
ml	:	millilitre
MT	:	million tonnes
NDF	:	Neutral Detergent Fibre
t	:	tonnes
viz.	:	videlicet
Vs	:	versus
Wt.	:	Weight
WSF	:	Water Soluble Fertilizer

ABSTRACT

INFLUENCE OF FOLIAR SPRAY OF WATER SOLUBLE FERTILIZER ON GROWTH, YIELD AND QUALITY OF HYDROPONIC FODDER CROPS

By

Miss. MUTUM LAMNGANBI

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Hydroponic fodder production has been gaining popularity because of its flexibility in production system even in a changing environmental condition. Hydroponically grown fodder crops required less quantity of water as compared to conventional method of field grown fodder crops. Inadequate availability of nutritious fodder feed has become a limiting factor in India especially in water scarce region of Maharashtra state. Under these circumstances soil less cultivated fodder grasses can have more importance to bridge the gap between demand and supply of feed and fodder. The present investigation entitled “Influence of foliar spray of water soluble fertilizer on growth, yield and quality of hydroponic fodder crops” was conducted at

Department of Agronomy, Post Graduate Institute, MPKV, Rahuri, Maharashtra during summer, 2016. The main objective

was to find out the suitable hydroponic fodder crops with foliar application of water soluble fertilizers in respect of green biomass and nutritional quality. The experiment was laid out in factorial completely randomized design (FCRD) with eighteen treatment combinations in three replications. The main plot consist of F_1- No Foliar spray, F_2- Foliar spray of urea @ 0.5% and F_3 – Foliar spray of 19-19-19 WSF @ 0.5% while subplot consist of six cereal hydroponic crop viz., C_1- Pearl millet, C_2- Yellow Maize, C_3- Oat, C_4- Barley, C_5- Wheat, C_6- White Maize. The locally harvested grains of the above crops were used. The hydroponic structure consist of UV PVC pipe of size 1 inch and the dimension of rack was 2.55 m x 1.7 m with height of 1.5 m. in the above size rack three shelves was held. In each compartment there was 18 trays used for growing crops and the rack had capacity of 54 trays used for the experiment purpose. The tray size for growing hydroponic fodder crop was 50 cm x 30 cm x 5cm. The foliar application of nutrients on hydroponic fodder was done on 5th day. The water application was done for one minute after every three hours during day time by operating electric pump and through timer automatically. The fogger/ jet sprinkler were used for sprinkling water on the hydroponic crops. Superior result of biomass yield was recorded in yellow maize, white maize and wheat with foliar application of 19-19-19 WSF. The green biomass was maximum up to 8days later on

reduction in green biomass at 9th and 10th day. The biomass was increased 3-6 folds according to crop in a growing period of 10 days. The quality parameters analyzed like crude protein, ADF and NDF were analyzed in different treatment. The dry matter was optimum up to seven days and it was decreased as the number of growing days increases while fiber content and protein content increases with increase in number of days. The 19-19-19 WSF application had most beneficial effect on all the crops. Among all treatment combination, 19-19-19 WSF treated yellow maize had highest B:C ratio, maximum water productivity both physical and economic, excellent yield and average quality range and so these could be considered as the most superior treatment of all.

Key words : Hydroponic fodder, Foliar Spray, Water Soluble Fertilizers, Crude protein, Acid detergent fibre, Neutral Detergent Fibre, Green biomass

Pages 1 to 90

1. INTRODUCTION

Agriculture has three main spheres *Viz.*, Geoponic means cultivation in earth soil, Aeroponic means cultivation in air and hydroponic means cultivation in water.

The word hydroponic has been derived from two Greek words hydro means 'water' and ponic means 'working'. Thus fodder produced by growing plants in water or nutrient rich solution but without using any soil is known as hydroponic fodder or sprouted grains or sprouted fodder (Dung *et al.* 2010). So, hydroponic is the science of growing in water or working with water. Hydroponic methods have been used for a long time to grow plants, primarily vegetables, but hydroponics is now being used across many countries to take pressure off the land and grow green feed for livestock, birds and carp raised for agriculture.

Livestock sector has been playing important role in Indian economy and is an important sub-sector of Indian agriculture. The India's cow population has been estimated of about 218.8million, while there are 160 million goats, 115.9 million buffaloes and 75.5 million sheep (FAO, 2012).

The availability of fodder is decreasing due to climate change impacts on crop productivity and higher competition for land and water resources between fodder and cereal crops (ESNC, 2010). Cereal grains are used as foodstuff for human and animals since many years. To get maximum nutrients cost effectively from these grains, different treatments have been applied e.g. sprouting, fermentation, heat treatment etc. (Finney, 1982). Sprouting is a simple technique to germinate the seeds for the improvement of their nutritive value (Amal *et al.*, 2007). Development of this planting system has enabled the production of fresh fodder from Oats, Barley, Wheat and other grains (Rodriguez *et al.*, 2004). Sprouting of grains can be used efficiently as it has resulted not only in increased protein quantity but quality also. This is further complemented by increased sugars, certain minerals and vitamin contents. However, sprouting reduces total starch and dry matter content of grains (Lorenz, 1980). Germination eliminates the effect of phytic acid by the production of phytase enzymes and increased the plant enzyme contents (Shipard, 2005). Supplementation of hydroponics sprouts in the rations of dairy animals is coming up as a viable alternate technology for the livestock farmers due to lesser availability of green fodders (Naik and Singh, 2014; Naik *et al.,* 2015; Naik *et al.*, 2016). During sprouting, the activities of the inactive enzymes of the grains increased which ultimately break down the reserve chemical constituents that could be used for synthesis of new 23 compounds while breaking down undesirable constituents (Chavan and Kadam, 1989) thus leading to increase in the quality of the amino acids and concentrations of the vitamins (Koehler *et al.*, 2007).

Green fodder is the natural diet of cattle. Green fodder is the most viable method to not only enhance milk production, but to also bring about a qualitative change in the milk produced by enhancing the content of unsaturated fat, Omega 3 fatty acids, vitamins, minerals, proteins and carotenoids. Sprouts or green fodder has improve contents of total proteins, fats, certain essential amino acids, total sugars, vitamins and a decrease in dry matter content, starch and anti-nutrients (Chavan and Kadam, 1989).

Hydroponics fodder growing is the state-of-the-art technological intervention to supplement the available normal green fodder resources required by the dairy cattle. With increased pressure on farm lands to produce increasing needs of food grains, providing green fodder by hydroponics fodder growing is a necessity for the Indian dairy industry. Considerable commercial experience with soil less culture of crops has been gained since 1938.

Hydroponic technique can be used for green fodder production of many forage crops in a hygienic environment free of chemicals like insecticides, herbicides, fungicides and artificial growth promoters. It is a well-known technique for high fodder yield, year round production and least water consumption. It involves supplying cereal grain with necessary moisture and nutrients, to enable germination and plant growth in the absence of a solid growing medium. The resulting green shoots and root-mat are harvested and fed to livestock. The grain responds to the supply of moisture and nutrients by germinating, sprouting and then producing a 20-25 cm long vegetative green shoot with interwoven roots within 5 to 8 days. Unlike field production system that use run-to-waste irrigation practices, the hydroponic fodder system uses limited amount of water, thus reducing the waste water. It has been reported that hydroponic fodder production requires only about 2-3% of that water used under field conditions to produce the same amount of fodder. Fodder produced hydroponically is of a short growth period 7-10 days and does not require high-quality arable land, but only a small piece of land for production to take place. It is of a high feed quality, rich with proteins, fiber, vitamins, and minerals. All these special features of hydroponic system, in addition to others make it one of the most important agricultural techniques currently in use for green forage production in many countries especially in arid and semiarid regions of the world. However, determining the best fodder crop is an important matter in producing highest fodder yield and quality and at the same time considering the economic dimensions in the process of hydroponic green fodder production by saving of seeds cost.

Today, hydroponics is an established branch of agronomy. Progress has been rapid and results obtained in various countries have proved it to be thoroughly practical and to have very definite advantages over conventional methods. There are two chief merits of the soil-less cultivation of plants. First, hydroponics may potentially produce much higher crop yields. Secondly, it could reduce agricultural water use (Sinsinwar and Teja, 2012).

Maintaining or improving economic productivity of the agricultural sector while reducing agriculture water use is a major challenge in arid and semiarid regions. The demand on scarce water resources in these countries is increasing with time for both agricultural and non-agricultural purposes. Over recent years, severe shortages in food supplies for livestock have been experienced in India due to repeated droughts as well as shortages of water for irrigation. Many projects to produce forages have been established during the last two decades to cover some green and dry forage needs in these countries. Therefore, methods and technologies that can contribute to improved water use efficiency and productivity merit closer consideration like hydroponic technique.

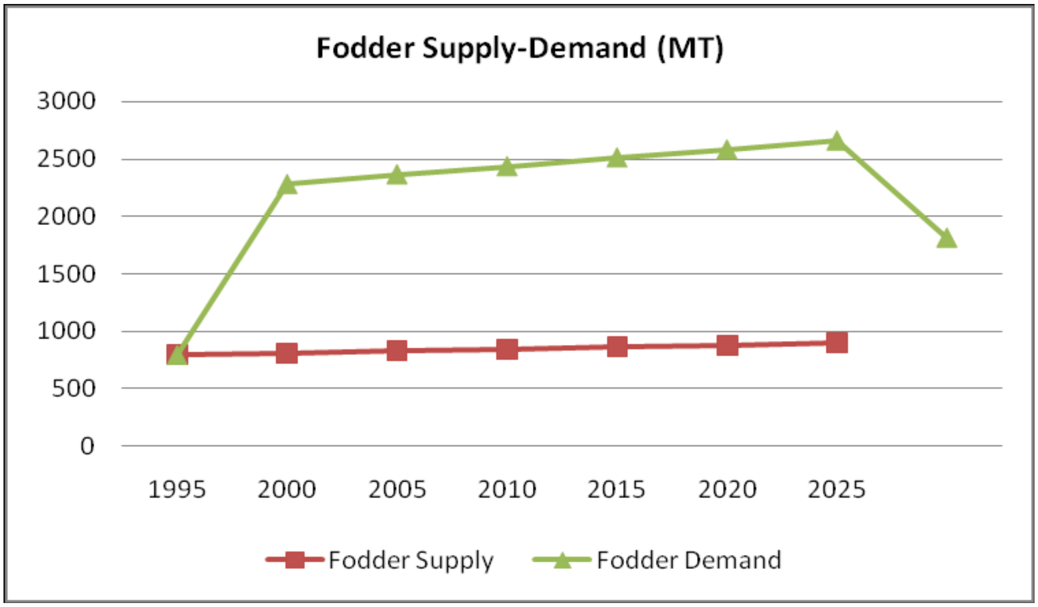
Hydroponic technology tested on various crops but as a nutritional quality and productivity of green fodder in hydroponic crops especially maize, pearl millet, barley and oat for dairy animals needs to be tested. The concept of vertical farming is important as population trend is at increasing while cultivable land will decline so fodder production needs to be increased in future, so hydroponic system required marginal land to erect system.

Thus, the science of growing plants in nutrient-rich solutions instead of soil has proven itself to be efficient both financially and environmentally.

The hydroponic green fodder production is an option that helps to solve this problem by producing food during drought and scarcity periods with acceptable yields and great value. Science also shows that there is great nutritional benefit provided by hydroponic sprouted grain and it is suitable for all livestock including, sheep, cattle, horses, goats, and provides animals with improved growth and overall health (Anon., 2013).

The advantages of this method include : Does not require soil, can use light weighted materials that may suit rooftop growing, higher yields because of more rapid maturation of plants and more plants per unit area, soil nutrients are not diminished so crop rotation is unnecessary, closed system means that pesticides and fertilizers are not washed into water table or streams, hydroponically grown fodder has high moisture content, hydroponically grown fodder is dust free, which reduces risk, and helps prevent and cure respiratory disease. In greenhouse only 2 to 3 liter of water are required to produce 1kg of green grass whereas conventional methods require an average of 80 liter water to produce the same quantity. The growing procedure is simple to operate: irrigation, cooling and lighting systems are controlled by one central electronic monitoring system and maintained at a very low cost, produces succulent green feed of constant quality and quantity every day of the year. The green feed produced is palatable, nutritious and free from contamination; Green feed is nutritious & rich in energy comparable to commercial feed. Thus, requirements for concentrated feed products are reduced.

As the population increases, large gap exists between requirement and availability of feed and fodder. As per planning commission, India is short in dry fodder by about 23.46 per cent, green fodder 62.76 per cent, concentrate 30 per cent. This deficit is result of numerous interdependent and exogenous factors. Therefore, livestock suffers from problems of underfeeding (Shah *et al.*, 2011).



Source: www.indiastat.com

Fig.1 Fodder supply and demand in India

Table 1 Fodder deficit in India (Figures in Million Tonnes)

Year	Supply			Demand			Deficit as % of demand	
	Green	Dry	Total supply	Green	Dry	Total demand	Green	Dry
1995	379.3	421	800.3	947	526	1473	59.95 (568)	19.95 (105)
2000	384.5	428	812.5	988	549	1537	61.10 (604)	21.93 (121)
2005	389.9	443	832.9	1025	569	1594	61.96 (635)	22.08 (126)
2010	395.2	451	846.2	1061	589	1650	62.76 (666)	23.46 (138)
2015	400.6	466	866.6	1097	609	1706	63.50 (696)	23.56 (143)
2020	405.9	473	878.9	1134	630	1764	64.21 (728)	24.81 (157)
2025	411.3	488	899.3	1170	650	1820	64.87 (759)	24.92 (162)

Source: www.indiastat.com

Till now there is no any systematic study has been conducted to evaluate the hydroponic fodder crops. Therefore, the present investigation entitled, "Influence of foliar sprays of water soluble fertilizers on growth, yield and quality of hydroponic fodder crops" was undertaken in the year 2016 with following objectives.

1. To find out the suitable hydroponic crop in respect green biomass and nutritious quality.
2. To find out the suitable grade of WSF for foliar sprays to hydroponic crops on the basis of green biomass and nutritional quality.
3. To find out the suitable combination of hydroponic crop with foliar spray grade of WSF on the basis of green biomass and nutritional quality.
4. To study the economics in different treatments.

2. REVIEW OF LITERATURE

The detailed review of literature related to chemical composition, fodder production system, growth performance, nutrient digestibility and economics of feeding hydroponics fodder crops is presented under the following heads in this chapter.

2.1 Growth and biomass yield under hydroponic method of production

2.2 Chemical composition of crops produced by hydroponic method

2.3 Effect of foliar application of WSF on growth, biomass yield and quality of fodder crops

2.4 Water requirement of different hydroponic fodder crops

2.5 Economics of different hydroponic fodder crops

2.1 Growth and biomass yield under hydroponic method of production

Trubey and Otros (1969); Ueno *et al.* (1966) found an increase in fresh weight of barley seedlings in a 6 day growing period.

Hillier and Perry (1969) reported that one hundred grams of oat seeds (89.7 % dry matter) yielded an average of 550 g grass (13.4 % dry matter). Each day the seedlings were irrigated for 30 min. and the temperature was maintained at 21^{0}C in a chamber utilizing fluorescent light.

Pearl millet grain is greater in CP and has a better amino acid profile than corn, with only lysine limiting for growth (Burton *et al.*, 1972).

Pearl millet grain out-yields other cereal grains under conditions of infertile soil, intense heat, limited rainfall, and short growing seasons (Freeman and Bocan, 1973).

Peer and Leeson (1985) estimated that there are a wide range of claims regarding to the productive yield of hydroponic fodder systems. These range from 6 to 10 times the weight of green fodder harvested relative to the weight of grain sown.

Petterson (1987) examined the ability of hydroponically grown barley to reduce the nutrient salt content of aquaculture waste water and reported yields ranging from 1 to 65 t ha^{-1} depending on light intensities and materials used for root support.

Kruglyakov (1989) put one kilogram of grain into a hydroponic system and produced 6 to 10 kilograms of fresh green sprouts, independent of weather and at any time of year.

Mac Kenzie (1990) evaluated the use of hydroponically grown barley to reduce the nutrient content of anaerobically digested dairy manure and reported a crop yield of 81 t ha^{-1} at a seed quantity of 250 g per tray.

Calder Bill (2002) has shown that the growing time of hydroponic plants takes as little as 7 days from seed germination to a fully grown plant as at a height of 25-30cm ready for harvest. All though Bill does suggest that for an even better result use an eight-day growing cycle. During recent droughts, which turned many farms into dust bowls, deer and cattle farmer, Peter Ryan, had no troubles keeping his livestock alive and healthy as he started producing hydroponic fodder in eight days from seed to harvest. Peter stated that 'for every 1kg of seed, 7-10kg of edible fodder is produced. However to grow the same amount of fodder in a paddock situation, if there was sufficient water for irrigation, would take up to 12 weeks from seed germination until ready to feed out to livestock'.

Scott (2002) reported that in 24 hours seeds sprout a root, green shoots day 2 and 3, by 5 days you can early harvest, 7 days is about maximum before they slow down and behave more like slow growing grasses. High levels of light are not necessary but cool temperatures and shade is recommended.

Sneath and Mclntosh (2003) reported that the starting of germination and visibility of roots varies with the type of seeds. In case of maize and cowpea seeds, germination starts after one or two days and the roots were clearly visible after 2 or 3 days, respectively. Photosynthesis is not important for the metabolism of the seedlings until the end of day-5 when the chloroplasts are activated. And various commercial hydroponic fodder producers claims yields of 6–10 times with DM per cent from 6.4–20, while trial yields range from 5–8 folds.

Snow *et al* (2008) reported that hydroponically grown wheat, barley and oats grew rapidly and fairly uniformly and showed no signs of mineral deficiency although fungal growth was evident. The average crop heights at harvest were 19.0, 25.5 and 25.2 cm for wheat, barley and oats respectively. The average yields of wheat, barley and oat at harvest was estimated to be 945, 883 and 636g per tray (64, 59 and 42 t ha^{-1}). The whole oat is first soaked in water for 4hr., then germinated for 48hr., transferred to culture baskets and placed in a dry culture vat for 6 days.

Dung *et al.* (2010) estimated that fresh sprouts weighed about 1.75 times their original pre-steeped weight after 1day, 2.0 times after 2 days, 2.3 times after 3 days, 2.7 times after 4 days, 3.3 times after 5 days, 3.6 times after 6 days and 3.7 times after 7 days.

Naik *et al.* (2011) reported that one tray containing 1.5 kg maize seeds produces 7-9 kg green fodder with fodder height of 20-25 cm. In comparison to conventional green fodders contain more protein, fat and soluble carbohydrates but less fibre, total ash and acid insoluble ash.

Fazaeli *et al.* (2012) conducted a study on cultivation and feed value of barley grain hydroponics and they reported the average green fodder yield ranged from 4.93 kg per kg of barley grain at day 6 to 7.21 kg at day 8 and they suggested, the production conversion ratio based on the amount of fresh fodder produced per unit of seed used could be approximately 4 to 8 times. Depending to the type of grain, the forage mat reaches between 15 to 30 cm high, where the production rate ranged about 7 to 9 kg of fresh forage corresponding to 0.9 to 1.1 Kg of dry matter (Al-Ajmi *et al.,* 2009 and Mukhopad, 1994).

Morsy *et al.* (2013) used hydroponic system for barely germination with in a period of 8 to 12 days. They used net house (40 % shading and natural solar light + fog cooling) and control cooling room as air condition (21^{o}C and florescent light) with capacity of 42 polyethylene trays sized 60 × 30 x 3 cm (0.18 m^2)

each. They reported increasing barley seed densities up to 1.5 cm produces total fresh sprouted weight 53.1kg/m^2.

The hydroponic maize fodder looked like a mat of 20–30cm height consisting of germinated seeds embedded in their white roots and green shoots (Naik *et al.,* 2013). The increase in weight of the hydroponic maize fodder than the seed weight on fresh basis was 5.5 folds. Yields of 5–6 folds on fresh basis (1 kg seed produces 5–6 kg HMF) and DM content of 11–14 per cent are common for HMF. However, sometimes the DM content up to 18.3 per cent was observed as in the present study.

For a seven day growing period of barley seeds, at the end period the grass of barley seedling growth reaches about 16-18 cm height. It has a carpet like appearance with dark green color and thick roots (Al-Saadi *et al.,* 2015).

2.2 Chemical composition of crops produced by hydroponic method

Lorenz (1980) investigated that sprouting of grains causes increased enzyme activity, a loss of total DM, an increase in total protein, a change in amino acid composition, a decrease in starch, increases in sugars, a slight increase in crude fat and crude fibre and slightly higher amounts of certain vitamins and minerals. Most of the increases in nutrients are not true increases; they simply reflect the loss of DM mainly in the form of carbohydrates due to respiration during sprouting. As total carbohydrates decreases, the per cent of other nutrients increases.

Peer and Leeson (1985) conducted feeding barley sprouts to pigs and they reported nutrient composition of hydroponic barley fodder as DM 16 per cent, NFE 61.3 per cent ,CP

15.5 per cent, CF 14.3, EE 5 per cent, Calcium 0.03 per cent and Phosphorus 0.47 per cent. A dry seed is metabolically dormant, its respiration rate is extremely low and its enzymes are present but inactive. As soon as the seed imbibes water, respiration rate increases, enzyme systems are activated and protein synthesis is started. Starch stored in the embryo and endosperm is used as a source of energy for respiration (Peer and Leeson, 1985).

Chavan and Kadam (1989) stated that the metabolic activity of resting seeds increases as soon as they are hydrated during soaking. Complex biochemical changes (carbohydrates to sugar, protein to amino acids and fats to fatty acids) occur during hydration and subsequent sprouting in various parts of the seed.

Cuddeford (1989) comments that dry barley grains contain up to 650 g starch/kg DM and that starch is the raw material that supports the growth of the plant. Sprouting activities in the seeds have many changes as in seed protein converted to essential amino acids, carbohydrates are converted to sugars and fats are converted to essential fatty acids. These activities increase as a result of increasing enzymes levels

As per Pandey and Pathak (1991), the artificially grown barley fodder had 14.69 per cent CP, 3.18 per cent EE and 78.55 per cent total carbohydrate

Azila (2001) conducted a study on nutritive value of barley fodder grown in a hydroponics system and reported the chemical composition as DM (18.6 %), CP (19.7 %), CF (13.2 %), Ca (0.104 %) and P (0.47 %).

Sneath and McIntosh (2003) reviewed the composition of sprouted barley and reported that the CP ranged from 11.38 to

24.9 per cent. Similarly, Reddy *et al.* (1988) observed 13.72 per cent CP, 16.33 per cent CF, 3.72 per cent EE, 62.12 per cent NFE and 0.17 per cent Ca and 0.48 per cent P in the artificially grown barley fodder and concluded that it was superior to certain common non-leguminous fodders, but comparable to leguminous fodders. Soaking grain increases its moisture content and enzyme activity. These enzymes breakdown storage compounds into more simple and digestible fractions for example, starch to sugars, proteins to amino acids and lipids to free fatty acids. There is an overall reduction in dry matter (DM) and total energy. Total weight of protein stays similar, however due to DM loss, the protein per cent increases giving an apparent increase in protein. There is an increase in fibre and some vitamins and a reduction in anti-nutritional compounds.

Intissar and Eshtayeh (2004) reported chemical composition of hydroponic barley as Protein 16.5 per cent, Ether extract 3.4 per cent, Moisture 84 per cent, Ash 3.6 per cent and Potassium mg/kg 180, Sodium mg/kg 36, Phosphorous mg/kg 150, Zinc mg/kg 4.634. CP content of hydroponic barley fodder was 16.3 per cent (Snow *et al.*, 2008)

Hydroponic is often defined as the cultivation of plants in water (Intissar and Eshtayeh, 2004). The word hydroponics derivate from the Greek radicals; hydro (water), ponos (work) despite being a relatively old technique, the technique hydroponics was investigated by Dr. W.F. Gerke in 1930 from University of California. Sprouting of grains for a limited period causes increased activities of hydrolytic enzymes, improvement in the contents of certain essential amino acids, total sugars, and B-group vitamins, and a decrease in dry matter, starch, and anti-nutrients.

Fazaeli *et al.* (2011) reported the chemical composition of barley grain and barley hydroponic fodder as below table.

Table 2. Chemical composition of barley grain and barley hydroponic fodder (% DM basis)

Parameters	Barley grain	Hydroponic fodder
Dry matter	90.40	19.26
Moisture	9.60	80.74
Ash	3.40	3.65
Organic matter	96.6	96.35
Ether extract	1.9	2.25
Crude protein	10.45	13.69
Calcium	0.26	0.32
Phosphorus	0.35	0.43

Fazaeli *et al.* (2012) conducted a study on productivity and nutritive value of barley green fodder yield in hydroponic system and reported that there was a significant difference ($P < 0.05$) between the original barley grain and hydroponics fodder barley for DM, where it was less than 20 per cent in case of green fodder (GF) but more than 90 per cent in initial grain. The DM content of GF was significantly ($P < 0.05$) reduced by increasing the growing periods from 6 to 7 days. The amount of fresh green fodder obtained per kg of planted barley grain was increased several times but this increase was due to the large uptake of water during germination of the seeds in a sharply reducing of DM per cent in green fodder.

Table 3 Chemical composition of barley grain before and after sprouting

Parameters	Barley grain (% DM)	Barley fodder (% DM)
Dry matter	91.4	13.3
Ash	2.81	4.11
Organic matter	97.19	95.89
Ether extract	1.9	3.86
Crude protein	11.73	14.67
Ca	0.26	0.36
P	0.42	0.43

Thadchanamoorthy *et al*. (2012) carried out a study to determine the nutritive value of hydroponically grown maize, and evaluate the feed intake, body weight gain and feed conversion efficiency of grower rabbits. As their report, Moisture, Ash, CP, EE, CF, NDF, ADF and in vitro digestibility per cent were higher in sprouted maize (73.93, 3.09, 16.54, 6.42, 8.21, 29.27, 10.16 and 79.87 %, respectively) than the levels found in seeds (10.26, 1.48, 8.21, 4.69, 2.11, 19.22, 5.50 and 68.75 % respectively). Maize fodder is the main energy source in livestock rations (ESNC, 2010).

Hassan and Mona (2013) studied on sprouted maize on date palm leaves and potatoes peel waste mixture. They evaluated sprouting techniques by planting white corn seeds (*Zea mays L.*) on four roughage mixtures of date palm leaves (*Phoenix dactylifera L.*) and potatoes peels waste (*Solanum tuberosum*). They reported, sprouting corn seeds on potatoes peel waste as a media had increased CP content from 13.89 to 15.17 per cent, EE from 1.21 to 2.39 per cent, CHO from 43.09 to 45.29, ash from 13.07 to 22.93 per cent, Calcium 0.06 per cent, Phosphorus 0.24 per cent and decreased OM content from 86.93 to 77.02 per cent, CF from 11.83 to 10.04 per cent, as compared with un-sprouted PPW. On the other hand, sprouting corn seeds on date palm leaves as a media had improved CP content from 3.75 to 7.52 per cent, EE from 2.20 to 2.22 per cent, CHO from 18.50 to 31.17, Ash from 13.50 to 17.75 per cent, Calcium 0.65 per cent and Phosphorus 0.1 per cent while decreased OM content from 89.88 to 82.25 per cent, CF from 33.15 to 31.99 per cent, as compared with none sprouted date palm leaves.

Maize hydroponics is more nutritious than conventional type (Naik *et al.,* 2013) fodder; as it contains more crude protein (13.30-13.6 vs 10.70-11.14 %), ether extract (3.27-3.50 vs 2.20-2.30 %), nitrogen free extract (66.70-75.32 vs 51.80-53.54 %) but less crude fiber (6.37-14.10 vs 22.25-25.90 %), total ash (1.75-3.80 vs 9.40-9.84 %) and acid insoluble ash (0.30-0.57 vs 1.03-1.40 %). Singh (2011) investigated on technology for production and feeding of hydroponics green fodder and reported the chemical composition of conventional maize fodder vs hydroponics maize fodder as Protein (10.67 vs 13.57 %), Ether extract (2.27 vs 3.49 %), Crude fiber (25.92 vs 14.07 %), Nitrogen free extract (51.78 vs 66.72 %), Total Ash (9.36 vs 8.34 %) and Acid Insoluble Ash (1.4 vs 0.33 %).

Naik *et al.* (2014) reported that the hydroponics maize fodder (HMF) had higher DM (18.30 vs 15.12 %), CP (13.30 vs 11.14 %), EE (3.27 vs 2.20 %), NFE (75.32 vs 53.54 %) and lower CF (6.37 vs 22.25 %), TA (1.75 vs 9.84 %) and AIA (0.57 vs 1.03 %).

2.3 Effect of foliar application of WSF on growth, biomass yield and quality of fodder crops

Massantini and Magnani (1980) noted a positive response to added nutrient solution which was temperature dependent.

Duncan *et al.* (1994) reported the nitrogen content of a stand of heather (*Calluna vulgaris*) was increased and the fibre content decreased by adding ammonium nitrate fertilizer.

Sneath and Mclntosh (2003) noted that absorption of nitrates facilitates the metabolism of nitrogenous compounds from carbohydrate reserves thus increasing CP level.

Snow *et al.* (2008) hydroponically grew wheat, barley and oats and examined their ability to remove nutrients from aquaculture wastewater and found a fairly uniformly and rapid growth. He experimented by activation of lighting, cooling and waste water application systems on 8^{th} day of 21 day growing period.

Akhtar *et al.* (2014) reported that by applying ½ recommended dose of nitrogen along with foliar spray to oat crop @ 1.5 % urea 60DAS , fodder yield components like plant height, number of plants per square meter after germination, number of tillers per plant, number of leaves per tiller etc., are increased compared to the non-treated or non -foliar applied oat crops.

Naik *et al.* (2014) experimented by spraying a solution of liquid fertilizer (25 % bio-slurry and 75 % solution of mineral fertilizers) on the fifth day until harvesting period by using pressure sprayer evenly on each surface of corn kernels, and it was kept moist, not dried or flooded.

Nugroho and Idat (2015) harvested after 13 days and fertilizer solution which was applied from fifth day onwards were retrieved two days before harvesting and replaced with water to remove the liquid fertilizer that attached to plant, so it was safe when it was fed to cattle.

Surve and Bhosale (2015) reported a significantly higher protein content (12.81%) due to the foliar spray of 0.5 % NPK(19-19-19)

2.4 Water requirement of hydroponic fodder crop

Calder Bill (2002) reported that the hydroponic system requires a fraction of the water usage of conventional farming while still supplying high quality stock feed. It takes between 1 to 2 liters of water to produce one kg of fodder as compared with 80 – 90 liters of water to grow a kg of green grass.

Gatti *et al* (2002) reported that the water which was not used by the growing fodder, was not wasted, as it could be reused to water small areas of pasture or collected and used on gardens, lawns or vegetable patches because those water contained no chemicals (only natural supplements) it can be recycled or filtered for use within the shed without harming the environment.

Carruthers (2003) reported that nutrient film technique minimizes wastage and optimizes efficiency of water use within the system where nutrient solution that is not absorbed by the sown grains flows into a recirculating system that returns the solution back to the solution storage tank.

In an experiment conducted by Dung *et al.* (2010), spray watering was applied for 3min in every 2 h for the 7days period of sprouting.

High water use efficiency is, however, a major advantage of this technique which saves about 95-97 % of used water in comparison to conventional agriculture with small piece of land. The hydroponics forage production requires only about 3-5 % of water needed to produce same amount of forage produced under field condition (Al- Karaki *et al.,* 2012).

Naik *et al.* (2013) reported that to produce one kg of fresh hydroponic maize fodder (7-d) about 1 liter (if water is reused) to 3 (if water is not reused) liters of water is required in hi-tech green house system

2.5 Economics of different hydroponic crops

Reddy *et al.* (1988) reported that the cost of feed per kg milk production increased by 20 % on the ration containing artificially grown fodder; but in spite of the cost variations, it was concluded that being superior fodder than NB-21.

Arano (2003) estimated that the costs of insecticides, fertilizers, machinery and their running costs for cultivation and harvesting and labour of field grown feeds are 10 times greater than that of hydroponically grown feed. Evidence is also given by Prof. C.A. Arano that hydroponic grass units produces animal feed at about one-half the cost of the produce conventionally. This is based on the larger amounts of fuel needed in the production and transportation of traditional animal feeds.

A farmer at Mandrem village in Pernem Taluka of Goa also observed that on daily feeding of 10 kg hydroponics fodder maize per cow, 1.0 kg concentrate mixture per cow per day was saved and experienced enhancement of approximately 1.0 litre (from 8 liters to 9 liters) milk per cow per day, earning additional net profit of 10/ cow/ day (Anonymous, 2012).

Hydroponics fodder can be grown in low cost green houses with locally available or home-grown grains (Naik *et al.*, 2013). To produce one kg of fresh hydroponics Maize fodder (7 day) requires about1 litre water (if water is reused) to 3 (if water is not reused) in high-tech green house system. Many farmers revealed fresh yield up to 8-10 folds can be obtained. The cost of production of the hydroponics fodder was about Rs. 2-3/kg fresh fodder if seed was home grown, however, if seed was purchased from market, the cost of production was a bit higher as Rs3-3.50 (Naik *et al.*, 2013).

Naik *et al.* (2013) revealed feeding of hydroponic fodder to milking cows indicated an increase in milk yield by 0.5-2.5 liters per animal per day and earned a net profit of Rs. 25-50 due to feeding of hydroponic fodder to their dairy animals. In addition, increases the Fat and SNF content of the milk, improvement in health and conception rate of the dairy animals, reduction in cattle feed requirement by 25 per cent, increase in taste (sweetness) of the milk, requirement of less space and water, freshness and high palatability of the hydroponic fodder. The green houses used for growing hydroponics fodder can be fabricated from bamboo, wood, MS or GI pipes and brick masonry. It can also be made as a lean to structure using one side wall of the house, which reduces the cost of fabrication. The irrigation of hydroponics fodder can be through micro-sprinklers (manually or automatic controlled), knapsack sprayer or a rose can at frequent intervals.

Morsy *et al.* (2013) presented the average physical characteristics of barely germination under net house (40 % shade) and cooling room. The net house system recorded the higher values of total fresh weight, total dry weight, shoot fresh weight, root fresh weight and shoot dry weight while control cooling room gave the higher value of root dry weight. The net house system gave superior significant effect on the quality characteristics compared to control cooling room. The higher determinations of dry mater, fiber, protein, carbohydrates (%), Ca, K and energy (Kcal/kg) were recorded by using net house system. On the other hand control cooling room presented higher results of oil content (%) and kg. This source of light under the net is the sun (zero cost) while under control cooling room is high cost florescent lamps offered constant ranges light all the study period 800 – 70 (Lux). The construction cost of control cooing room (100000 Le) equal more than 6 times of net house system (15000) for the same areal unit. Thus, environmental and economic efficiencies of the use and operating hydroponic green forage tended strongly to favor the net house system.

Naik *et al.* (2014) conducted a research on effect of feeding hydroponics maize fodder on digestibility of nutrients and milk production in lactating cows. There was higher net profit of Rs. 12.67 per cow/d on feeding HMF. They concluded feeding of HMF to lactating cows increased the digestibility of nutrients and milk production leading to increase in net profit.

The higher cost of the hydroponics maize fodder (Rs.4/kg) than the conventional green fodder (Rs.1.50/kg) might be the reason for the higher cost of the feed in the HF group than the CF group (Naik *et al.*, 2012c) as cited by Naik *et al.* (2014). Reddy *et al.* (1988) and Naik *et al.* (2014) also reported that the cost of feed per kg milk production increased by 20 per cent on the ration containing artificially grown fodder; but in spite of the cost variations, it was concluded that being superior fodder than NB-21, it could be a good feed component of high yielding cows stationed in hilly areas.

Anonymous, (2014) indicated cost benefit analysis of cultivating hydroponic and conventional fodder as labour (1 person/365 tonnvs 10 person/365 Tonn), land (365 Tonn/400 sq feet Vs 150 Tonn/Acre (Napier), Water (1-2 Lt/kg/8 day Vs 80 Lt/kg/60 day), Power (53 Paise/kg Vs NA) and concluded that open field fodder requires 200 times more lands, 80 times more water, 10 times more labour. In addition he reported that cost of one kg seed Rs. 2.33 assuming Rs. 15/kg, electricity Rs. 0.53, nutrient salts Rs. 0.06, farm labour Rs. 0.00 (assuming that existing labour will manage), water Rs. 0.11 and total cost Rs. 3.04 required.

Anonymous (2014) fed 10 cattle and compared conventional feed cost vs sprouted fodder supplemented feed cost as below. He offered 10 Cattle 10 kg of concentrate feed (16 Rs. x 10), 6 kg of green fodder (2.5 Rs. x 6), 19 kg of dry fodder (5.5 Rs. x 19) Vs 10 Cattle 7 kg of concentrate feed (7 x 16 Rs.), 10 kg of GauChar fodder (3Rs. x 10), 18 kg of dry fodder (5.5 Rs. x 18) then reported 35-40 per cent reduction in concentrate feed. Original feed amount was 6-8 kg, after sprouted fodder it is reduced to 3-5 kg. He concluded 10 per cent increase in Milk production and daily milk is assumed to be around 10 liters. Assumed milk cost is Rs. 35 (conservative estimates)

3. MATERIAL AND METHODS

The present investigation entitled "Influence of foliar spray of water soluble fertilizers on growth, yield and quality of hydroponic fodder crops" was carried out at Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri during summer season, 2016.

The details of material used and methods adopted during the course of investigation are as follows.

3.1 Details of Experimental Material

3.1.1 Experimental site

The experiment was conducted at the Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri-413 722, District Ahmednagar (Maharashtra), India. Rahuri is situated in the Ahmednagar district at western coast of India. It is at an altitude of 495-555 meters above mean sea level (MSL). It is located in the subtropical region.

3.1.2 Agro climatic condition

3.1.2.1 General

Geographically, the Central Campus of Mahatma Phule Krishi Vidyapeeth, Rahuri is situated between $19^0 47'$ and $19^0 57'$ N latitude and between $74^0 19'$ and $74^0 32'$ E longitude. The altitude varies from 495 to 555 m above the mean sea level. The average annual rainfall is 520 mm which is mostly concentrated during monsoon months from June to October from South-West monsoon which is nearly 80 per cent of the total rainfall. The distribution of rainfall is erratic with 15 to 45 rainy days. The tract is under the rain shadow area lying on

Eastern sides of Western Ghats. Agroclimatically falls under Scarcity Zone of Maharashtra.

The annual mean maximum temperature is 39.2^{0}C ranging from 34 to 43.5^{0}C whereas, annual mean minimum temperature is 18.8^{0}C ranging from 7.5 to 24^{0}C. The mean relative humidity during the morning and evening are 57 and 34 per cent, respectively.

3.1.2.2 Nature of season during experimental period

The weather data during the period of experimentation (April, 2016 to May, 2016) was obtained from Meteorological Observatory located at Water Management Project, Mahatma Phule Krishi Vidyapeeth, Rahuri and presented in Appendix- II and depicted in Fig.2.

Data revealed that the mean maximum temperature ranged from 37.5-40.6^{0}C while minimum temperature from 19.9 to 24.9^{0}C. The mean relative humidity ranged from 18 to 49 per cent in the morning and 11-24% in evening. There was no rainfall during period of experimentation

3.2 Experimental methods

3.2.1 Experimental details

1.	Design	:	Factorial completely randomized design
2.	Number of replications	:	3
3.	No. of treatment	:	18
4.	Tray Size	:	50 cm x 30 cm x 5 cm
5.	Variety	:	Locally harvested grain of pearl millet, Yellow maize, oat, barley, wheat and white maize
6.	Year of Start	:	April, 2016
7.	Seed rate	:	As per seed size of crop

3.2.2 Treatment Details

a. Factor A: Hydroponic crops

C_1 - Pearl millet

C_2 - Maize

C_3 - Oat

C_4 - Barley

C_5 - Wheat

C_6 - White maize

b. Factor B: Foliar spray of water soluble fertilizers

F_1 - No foliar application

F_2 - Foliar spray of N-Urea 0.5% spray

F_3 - Foliar spray of NPK-19:19:19 WSF spray at 0.5%

Table 4 Standardization of seed rate of different hydroponic crops per tray

Sr. No.	Crop	Seed rate(g $tray^{-1}$)
1.	Pearl millet	700
2.	Yellow maize	1100
3.	Oat	600
4.	Barley	600
5.	Wheat	800
6.	White maize	1200

3.2.3.1 Structure for hydroponic fodder production

A hydroponic cultivation plan was prepared and a hydroponic unit was installed at Post Graduate Research Farm in optimum shed surrounded by white shade net. It was conducted in agronomy department farm office to give the effect of a simple house construction and see if it can be grown in available spaces without further construction. Many of the research so far had been conducted in green house. The structure we have used was cheap. The structure was fully surrounded in three sides and in one side only half covered keeping an opening for movement. A ultraviolet poly vinyl chloride rack with three shelves was installed inside it. It has the capacity of holding 54 trays of size 50 cm x 30 cm x 5 cm. The height of the rack was 1.5 m and the area of the rack being 2.55 m x 1.7 m. The gap between one layer/shelf to another was 50 cm. For water supply automated sprayer irrigation/jet sprayer system is used. A timer was connected to irrigation system and it was activated for 1 min in every 2 hr interval. The distance between two emitter was 60 cm and total 24 jets were used in the whole set up. The trays with holes at the base were to allow drainage of excess water from irrigation. Water used was tap water free from any additives. The temperature and humidity inside the green house was controlled through jet sprayers for irrigation to maintain a range of 22-27^{0}C temperature and up to 70 % relative humidity.

3.2.3.2 Standardization of seed quantity in tray and sprouting of seed

Soaking of seeds and the rapid uptake of water for facilitating the metabolism and utilization of reserve materials of the seeds for growth and development of the plant is very important step for the production of hydroponic forage. Number of hours of soaking for all crops was 6 hr. The water was then drained and the seeds were wrapped in wet gunny bags and kept for few more hours. It varies with different crop. Pearl millet and wheat was kept wrapped in gunny bag for 7 hr. In yellow maize and white maize it was kept for 14 hours while in oat and barley for 6hr. Water was sprinkled in the gunny bags from time to time making sure it is always kept wet. The germinated seeds were then transferred in the trays. The seeds were filled in the trays to the level of the ridges and were soaked separately for each tray. When the absorbed water and bulged out they a slightly above the ridges and become the perfect seed layer for growth. When the seeds were too low they do not grow well and when there were too much seed they began to show root rotting symptoms, mould growth etc. before reaching the targeted harvesting day.

3.2.3.3 Water and fertilizer management in hydroponic production system

The seeds were kept in the tray and water was sprinkled on tray at an interval of every three hours till the third day and from 4th day onwards water was supplied at an interval of every 2hrs during day time (1 min irrigation after every 2 hr) and after 6 PM till early morning at 6 AM, water was sprinkled on tray at an interval of 4hr. On the 5th day from early morning the automatic system was switch off. Water mixed with urea @ 0.5 % was foliar sprayed with the help of hand sprayer and water mixed with 19-19-19 starter grade of water soluble fertilizer @ 0.5 % was sprayed. As control three trays of each crop was sprayed with tap water only. Water or the mixer was foliar sprayed at every 3 hr interval 3 times and after the last spray automatic system of irrigation was activated again.

3.3 Observation

3.3.1. Sampling of hydroponic fodder

A random sampling was done from three replication trays each of pearl millet, yellow maize, oat, barley, wheat and white maize. The sampling was done on 4th day (i.e., before foliar application), 7th day and on 10th day performed at approximately the same time over the entire study period to determine dry matter and fodder quality changes. At the time of daily sampling, the sprouts' were removed from the trays and allowed to drain the surface water at least for 30 minutes and weighed and transferred for storage and dry matter estimation in an oven (65^0C).

3.3.2 Water requirement in hydroponic fodder

A 200 liter drum was installed near the structure for water supply. The water level was marked before activation of the Jet sprayer system and after irrigation water level was also marked, the reduction/ the difference between the two marked levels were the water used per irrigation.

3.3.3 Growth studies

Five plants on easy to remove site usually on the outer side were selected and tagged in each replication of all the treatment combination. Plant height, number of leaves, stem diameter, root and shoot length (to find the root; shoot ratio) were taken from 3rd day onward till 10th day. To measure plant height, a measuring scale with clear markings (in centimeter as well as in millimeter) were used. While for stem diameter, thread were used and then the values were recorded by measuring the length of the thread which was wrapped around the plant making sure that the end points of the thread touch each other completing a single round. For root length also, thread were used. The thread was placed over the root perfectly matching the curves and turns and later measured the length of the thread used to match the root through a measuring scale. Visual counting was followed to count number of leaves.

3.3.3.1 Dry matter

Wet Samples were collected on 4th, 7th and 10th day and their weight was recorded. The moisture of sample was lost by the evaporation caused due to heat. The amount of material left after the evaporation of moisture (keeping in an oven) was the dry matter and the weight was taken. Similarly for grains before soaking the fresh weight were taken before and after oven drying and the dry matter content in % was found out using the following formula.

$$\text{DM (\%)} = \frac{\text{Weight of sample after drying (g)}}{\text{Weight of sample before drying (g)}} \times 100$$

3.3.4 Analysis of quality parameters in hydroponic fodder production system

The samples of the hydroponic pearl millet, yellow maize, oat, barley, wheat and white maize were analyzed for the proximate principles viz., crude protein, acid detergent fiber and neutral detergent fiber (A.O.A.C., 1970). Samples of seed before soaking, 4th Day, 7th Day and 10th Day were analyzed.

Table 5 Methods used for chemical analysis as quality parameters of hydroponic fodder crops

Sr. No.	Quality parameter	Method	Reference(s)
1	Crude protein	Kjeldahl method of nitrogen analysis	AOAC (1970)
2	ADF	Van Soest method of analysis of feeds and forages	Van Soest (1965)
3	NDF	Van Soest method of analysis of feeds and forages	Van Soest (1965)

3.3.4.1 Crude protein

The crude protein was estimated by micro Kjeldahl method. Nitrogen of protein was converted into Ammonium sulphate with Sulphuric acid digestion. The acid digest was made strongly basic with Sodium hydroxide and ammonia released was distilled into a boric acid solution titrated with standard Sulphuric acid solution.

$$\text{Crude protein (\%)} = V \times 0 \; \frac{0.014 \times D \times 100}{W \times A} \times \text{Correction factor}$$

Where,

V = Volume of 0.01 N H_2SO_4 used for titration (ml)

D = Dilution factor [volume made in volumetric flask (ml)]

W = Weight of sample (g)

A = Aliquot taken (ml)

Correction factor may be 6.25 for white maize, yellow maize, 5.83 for pearl millet, oat, barley and wheat.

3.3.4.2 Acid detergent fiber

An acidified quaternary detergent solution is used to dissolve cell solubles, hemicellulose and soluble minerals leaving a residue of cellulose, lignin, and heat damaged protein and a portion of cell wall protein and minerals (ash). ADF is determined gravimetrically as the residue remaining after extraction.

$$\text{ADF \%} = \frac{\text{Weight of crucible + Fiber - Empty weight of crucible}}{\text{Weight of sample on dry matter basis}} \times 100$$

Reagents used to prepare 1 lit. Acid detergent solution:

1. 1.00 N Sulfuric acid- 27.7ml of 98% purity sulfuric acid in 973.3 ml water.
2. 20g – Cetyl trimethyl ammonium bromide (CTAB)
3. Acetone, reagent grade

3.3.4.3 Neutral detergent fiber

The process of determining NDF content involves a neutral detergent that involves a neutral detergent that dissolves plant pectins, proteins, sugars and lipids. This leaves behind the fibrous parts such as cellulose, lignin and hemicellulose. These parts are not easily digestible and so are often not desired within a feedstuff.

$$\text{NDF \%} = \frac{\text{Weight of crucible + Fiber – Empty weight of crucible}}{\text{Weight of sample on dry matter basis}} \times 100$$

Reagents used to prepare 1 lit Neutral detergent solution:

1. 0.99 ml distilled water
2. 30g sodium lauryl sulphate
3. 18.61 g Ethylene diamine tetraacetic acid (EDTA)
4. 6.8 g Sodium borate, decahydrate
5. 4.5 g sodium phosphate

6. 10 ml Triethylene glycol

Procedure to prepare ND Solution:

1. Pour one half of distilled water into mixing container
2. Place on stir plate in hood and begin stirring
3. Add remaining reagents – except Triethylene glycol
4. Slowly add remaining distilled water into the container
5. Add Triethylene glycol when three-fourth of distilled water was added to the container
6. Allow to stir overnight.

3.3.5 Yield studies

To find the biomass yield, fodders were weighed along with trays (tray weighs 625 g). After subtracting the tray weight, we get the biomass yield per tray. Likewise readings were recorded on 9th day, 10th day, 11th day and 12th day.

3.3.6 Water Productivity

To find the physical water productivity, the yield of fodder per tray and the water used per tray was taken into consideration while for economic water productivity economic return per tray and water requirement per tray was taken into consideration. The water requirement was different for different crops and was found out by keeping a record of water sprayed during each spray. It is calculated by using the following formula:

$$\text{Physical Water Productivity } (\text{kg lit}^{-1}) = \frac{\text{Biomass yield per tray (kg)}}{\text{Water requirement (lit)}}$$

$$\text{Economic Water Productivity (` lit}^{-1}\text{)} = \frac{\text{Net return per tray (`)}}{\text{Water requirement per tray (lit)}}$$

Table 6 Observations recorded during the experiment

Sr. No.	Particulars	Frequency period
a.	**Growth Studies**	
1	Plant height (cm)	4, 5, 6, 7, 8, 9, 10 DAS
2	No. of leaves	At harvest
3	Stem diameter (mm)	At harvest
4	Root length(mm)	5, 6, 7, 8, 9, 10 DAS
5.	Dry matter content (%)	Grain before soaking, 4, 7, 10 DAS
b.	**Yield studies**	
1	Green biomass yield (kg tray^{-1})	8, 9, 10 DAS
c.	**Quality studies**	
2	Crude protein (%)	Grain before soaking, 4, 7, 10 DAS
3	Neutral detergent fibre (%)	Grain before soaking, 4, 7, 10 DAS
4	Acid detergent fibre (%)	Grain before soaking, 4, 7, 10 DAS
d.	**Irrigation observation**	
1	Water requirement (lit tray^{-1})	Growing period
2	Water productivity (kg lit^{-1})	At harvest
e.	**Economics**	
1	Cost of cultivation (` ha^{-1})	At harvest
2	Gross Monetary Returns (` ha^{-1})	At harvest
3	Net Monetary Returns (` ha^{-1})	At harvest
4	Benefit : Cost ratio	At harvest

3.3.7 Economics

To calculate the economics of the different treatments we consider the total cost and return in 6 months of dry period (Jan- June). Considering total no. of days required in each cycle as 10, the total no. of cycle in 6 months was 18. In regard to the area, the rack was considered to be sheltered inside 5R shade net (20 m x 25 m). So, the number of rack accommodated in the shade net was 50 racks.

3.3.7.1 Gross monetary returns (`)

The gross monetary returns were obtained by multiplying prevailing market price (per kg) with total yield of each hydroponic fodder crop.

3.3.7.2 Cost of cultivation (`)

The total cost of cultivation of hydroponic crops was estimated by considering the different system charges, wages, irrigation charges, input cost etc.

3.3.7.3 Net monetary returns (`)

The treatment wise net monetary returns were worked out by subtracting treatment actual cost from the gross monetary returns.

3.3.7.4 Benefit cost ratio (B : C)

The treatment wise B:C ratio was worked out by dividing the gross monetary returns with the actual cost of respective treatment.

Gross monetary returns (` per unit)

B:C ratio = --

Cost (` per unit)

3.3.8 Statistical analysis

The experiment data were statistically analyzed by the Factorial Completely randomized design, using General Linear Model (GLM) procedure of SAS (SAS, 2013), based on the critical p-value of 0.05 and the difference and interaction between treatments were tested for significance using least significance difference (LSD).

4. RESULTS AND DISCUSSION

The results of the study are presented in the tables in appropriate form after the necessary statistical analysis. The results obtained are interpreted in an integrate manner to draw the broad conclusions in succeeding chapter.

4.1 Morphological studies/Growth parameters

4.2 Quality parameters

4.3 Green fodder yield (GFY)/Green Biomass Yield

4.4 Water requirement and water productivity

4.5 Economics

4.1 Morphological studies/ growth parameter:

4.1.1 Plant height

The data in respect of the plant height (cm) with increasing plant growth period are presented in Table 7 and depicted in Fig. 6.

The increase in plant height had been gradual on 4^{th} and 5^{th} day but there had been a sudden increase on 6^{th} day after foliar application in case of pearlmillet, yellow maize, oat, barley, wheat and white maize. From 7^{th} day to 9^{th} day there had been a gradual increase again.

Table 7 Periodical plant height as influenced by different treatments

Treatment		Plant height (cm)						
		4th day	5th day	6th day	7th day	8th day	9th day	10th day
C_1F_1:	Pearlmillet + Control	3.8	4.6	6.3	7.3	7.5	8.1	9.6
C_1F_2 :	Pearlmillet + Urea foliar spray @ 0.5 %	-	-	6.6	7.8	8.1	9.4	11.4
C_1F_3 :	Pearlmillet + 19-19-19 WSF spray @ 0.5 %	-	-	6.7	7.8	8.1	9.2	10.6
C_2F_1 :	Yellow maize + Control	7.6	9.8	10.6	16.5	19.7	22.0	24.5
C_2F_2 :	Yellow Maize + Urea foliar spray @ 0.5 %	-	-	12.1	17.9	20.8	23.9	26.6
C_2F_3:	Yellow Maize + 19-19-19 WSF spray @ 0.5 %	-	-	13.8	18.0	21.2	24.5	26.9
C_3F_1 :	Oat + Control	5.3	6.9	9.3	9.4	11.0	13.7	13.9
C_3F_2:	Oat + Urea foliar spray @ 0.5 %	-	-	10.3	10.3	14.4	16.3	16.7
C_3F_3 :	Oat + 19-19-19 WSF spray @ 0.5 %	-	-	10.5	10.5	15.2	16.8	17.0
C_4F_1 :	Barley + Control	6.1	6.9	8.2	8.2	10.1	15.1	15.8
C_4F_2 :	Barley + Urea foliar spray @ 0.5 %	-	-	8.4	10.3	14.9	17.2	18.1
C_4F_3 :	Barley +19-19-19 WSF spray @ 0.5 %	-	-	8.5	10.6	14.7	17.6	18.3
C_5F_1 :	Wheat + Control	6.9	7.8	11.5	13.5	14.2	15.3	15.6
C_5F_2 :	Wheat + Urea foliar spray @ 0.5 %	-	-	12.3	15.3	16.0	19.6	19.8
C_5F_3 :	Wheat + 19-19-19 WSF spray @ 0.5 %	-	-	12.5	15.5	16.0	20.0	20.2
C_6F_1:	White Maize + Control	7.6	9.9	11.6	15.6	19.4	22.2	24.7
C_6F_2 :	White Maize + Urea foliar spray @ 0.5 %	-	-	12.3	17.3	20.6	24.5	25.5
C_6F_3 :	White Maize + 19-19-19 WSF spray @ 0.5 %	-	-	12.8	17.5	20.4	25.0	25.7
	S.Em $\pm$	-	-	0.11	0.17	0.20	0.14	0.12
	CD at 5%	-	-	0.31	0.48	0.57	0.41	0.35
	Mean	-	-	10.27	12.77	15.18	17.84	18.96

4th day

The maximum plant height was seen in maize both yellow and white maize with 7.6 cm each. The plant height was least for pearl millet while oat and barley had an average of 5.3 cm and 6.1 cm respectively with wheat growing upto 6.9 cm. No foliar application was done so the plants had no external influence besides their natural growth.

5th day

Like on 4th day, pearl millet had the lowest plant height (4.6 cm) followed up by oat and barley (6.9 cm each). However the maximum plant height was observed in white maize (9.9 cm) which was close to plant height of yellow maize which was noted as 9.8 cm. A tremendous growth was observed in both the yellow maize and white maize. It may be due to more stored material in maize grain as compare to other crops.

6th day

In the observation taken in the next day of foliar spray, slight but not wide differences were observed. Maximum height was attained by 19-19-19 WSF sprayed yellow maize (13.8 cm). Urea @ 0.5 % treated yellow maize (12.1 cm), urea @ 0.5 % treated white maize (12.3 cm) were at par. As in earlier days minimum height was seen in pearl millet including control and treated i.e. urea foliar sprayed WSF foliar sprayed @ 0.5 % moving at par.

7th day

Height differences among the foliar treatment of pearl millet were not prominent and attained least height of all the other crops. Differences were noted in foliar treated pearl millet

(7.8 cm in urea @ 0.5 % foliar sprayed while it was 7.8 cm in case of 19-19-19 WSF foliar sprayed) and observed higher than control (6.3 cm). Superiority in height was seen in yellow maize and maximum height in case of 19-19-19 WSF @ 0.5 % foliar sprayed (18.0 cm). Other subplot treatment attained higher than 10 cm except control of barley (8.2 cm) and control of oat (9.4 cm).

8th day

The sequence of growth remains the same as on 7th day. Maximum height being 21.2 cm in 19-19-19 WSF foliar sprayed yellow maize. Among the different crops yellow maize and white maize performance was good. In oat and barley performance was better in 19-19-19 WSF @ 0.5 % foliar treated one then urea foliar treated. Moreover in pearl millet and wheat the measured heights of urea treated and 19-19-19 WSF @ 0.5 % were at par. The growth rate of pearl millet was still slow but compared to control and 19-19-19 WSF @ 0.5 % sprayed treatment, urea foliar sprayed pearl millet was better (9.4 cm).

The results are in conformity to the data given by Snow *et al.* (2008) stating that by the end of the growing period (day 8), the wheat, barley and oats seedlings were approximately 11.0, 14.0 and 11.5 cm respectively though little more value was observed in wheat even in control. The other values of oat and barley were near to control were no foliar application was performed.

9th day

On these day, many treatment crossed 20 cm height like in yellow maize both treated and untreated was above 20 cm. Maximum height was observed in yellow maize 19-19-19 WSF @ 0.5 % foliar sprayed. Also among white maize, 19-19-19 WSF @ 0.5 % foliar sprayed reach a height of 25 cm. Likewise in wheat, barley, pearl millet show better result in 19-19-19 WSF sprayed @ 0.5 %. But in pearl millet though shorter than other crops manages to reach 9.4 cm in urea foliar sprayed treatment.

10th day

Those were the height achieved by each treatment at the time of harvest. As per expected seeing the previous days growth data, yellow maize 19-19-19 WSF @ 0.5 % sprayed attained maximum height of 26.9 cm which was at par with urea treated yellow maize. The successful crop next to it based on plant height is white maize. The height of pearl millet even in treated ones was less (9.4 cm in urea treated and 9.2 cm in 19-19-19 WSF sprayed @ 0.5 %). The height attained by barley was not satisfying in comparison with the results provided by Snow *et al.* (2008) conducted in temperate regions of Canada which claimed that it reached 22 cm at 10th day. Whereas in our Indian situation of May month, it reached only 18.3 cm that too in 19-19-19 WSF treated barley which was considered better than urea treated barley (18.1 cm).

4.1.2 Root length

The root length of the sub plot treatment i.e. crops and the influenced due to foliar application of WSF on different hydroponically grown fodder crops shown in Table 8 and Fig. 7

From the Table 8 it was observed that more than half of the final root length on day 10 had been grown on the 5th day itself and these was the reason why we foliar spray on that day. On 5th day, mat formation became perfect though formation already started from the 3rd day itself. The root length of yellow maize was highest among the different crops grown hydroponically, so they had a very thick root-mat structure.

The root length of foliar treated yellow maize was more than of control in all observation days i.e. 5th, 6th, 7th, 8th, 9th and 10th day. Foliar spray seemed to influence root length of oat and barley but the type of foliar spray fertilizer did not create any differences as they hold almost same root length even at the time harvest i.e. on 10th day. In case of wheat the root length was highest in case of urea treated but there was not much difference with that of 19-19-19 WSF foliar treatment. A higher growth in root length was observed in foliar treated maize but it was difficult to differentiate which foliar treatment was better as they increased to an almost equal length throughout the growing period. Statistically pearl millet had shortest root-length throughout the growing period. Until the 9th day there was gradual increase in root length. But the root length dropped from 9th day (33 mm) to 10th day (31 mm) in case of control where no foliar application was done due to drying of roots. No such drying

Table 8. Periodical root length as influenced by different treatments

Treatment		Root length (mm)					
		5th day	6th day	7th day	8th day	9th day	10th day
C_1F_1:	Pearlmillet + Control	18	21	24	27	33	31
C_1F_2 :	Pearlmillet + Urea foliar spray @ 0.5 %	-	20	24	28	31	34
C_1F_3 :	Pearlmillet + 19-19-19 WSF spray @ 0.5 %	-	19	25	27	31	32
C_2F_1 :	Yellow Maize + Control	56	75	82	91	98	102
C_2F_2 :	Yellow Maize + Urea foliar spray @ 0.5 %	-	78	91	102	109	112
C_2F_3:	Yellow Maize + 19-19-19 WSF spray @ 0.5 %	-	79	94	105	112	113
C_3F_1 :	Oat + Control	33	40	46	51	59	60
C_3F_2:	Oat + Urea foliar spray @ 0.5 %	-	44	55	64	73	75
C_3F_3 :	Oat + 19-19-19 WSF spray @ 0.5 %	-	46	56	64	73	75
C_4F_1 :	Barley + Control	34	38	45	47	48	49
C_4F_2 :	Barley + Urea foliar spray @ 0.5 %	-	40	48	51	53	55
C_4F_3 :	Barley +19-19-19 WSF spray @ 0.5 %	-	40	49	55	57	55
C_5F_1 :	Wheat + Control	24	27	31	34	37	36
C_5F_2 :	Wheat + Urea foliar spray @ 0.5 %	-	30	35	39	43	43
C_5F_3 :	Wheat + 19-19-19 WSF spray @ 0.5 %	-	32	36	40	42	42
C_6F_1:	White Maize + Control	73	82	90	99	104	108
C_6F_2 :	White Maize + Urea foliar spray @ 0.5 %	-	84	92	102	11	114
C_6F_3 :	White Maize + 19-19-19 WSF spray @ 0.5 %	-	84	93	104	111	115
	S.Em±	-	0.40	0.44	0.59	0.64	0.91
	CD at 5%	-	1.15	1.27	1.69	1.86	2.63
	Mean	-	49.3	56.68	63.06	67.75	69.83

up was observed in foliar treated (both urea @ 0.5 % treated and 19-19-19 WSF treated @ 0.5 %) pearl millet.

Overall we can observed that the influence of foliar spray i.e. urea @ 0.5 % and 19-19-19 WSF @ 0.5 % were equally effective on growth of root.

4.1.3 Number of leaves

Foliar spray seemed not to play any role in increasing no. of leaves as it remained same in all the foliar spray treatment in different hydroponically grown crops as displayed in Table 9 and Fig. 8.

Table 9 Average number of leaves on 10th day

Treatment	Number of leaves
C_1F_1: Pearlmillet + Control	2
C_1F_2 : Pearlmillet + Urea foliar spray @ 0.5 %	2
C_1F_3 : Pearlmillet + 19-19-19 WSF spray @ 0.5 %	2
C_2F_1 : Yellow Maize + Control	3
C_2F_2 : Yellow Maize + Urea foliar spray @ 0.5 %	3
C_2F_3: Yellow Maize + 19-19-19 WSF spray @ 0.5 %	3
C_3F_1 : Oat + Control	2
C_3F_2: Oat + Urea foliar spray @ 0.5 %	2
C_3F_3 : Oat + 19-19-19 WSF spray @ 0.5 %	2
C_4F_1 : Barley + Control	2
C_4F_2 : Barley + Urea foliar spray @ 0.5 %	2
C_4F_3 : Barley +19-19-19 WSF spray @ 0.5 %	2
C_5F_1 : Wheat + Control	2
C_5F_2 : Wheat + Urea foliar spray @ 0.5 %	2
C_5F_3 : Wheat + 19-19-19 WSF spray @ 0.5 %	2
C_6F_1: White Maize + Control	3
C_6F_2 : White Maize + Urea foliar spray @ 0.5 %	3
C_6F_3 : White Maize + 19-19-19 WSF spray @ 0.5 %	3

Different crops had different no. of leaves. But in most crops 2 leaves in each plant was common. In yellow maize and white maize, the average number of leaves was three in both the crops. Here crop type counted and in that case both yellow maize and white maize were best with maximum number of leaves.

4.1.4 Stem diameter

The stem diameter of the hydroponic plants on the 10^{th} day is shown in Table 10 and Fig.9

The stem diameter in pearl millet was almost same even in all the foliar sprayed treatments also. So, foliar spray had no influenced on increasing the plant diameter.

In yellow maize there was a slight difference in stem diameter between foliar sprayed treatments and no foliar spray treatment but the diameter was same in both urea @ 0.5 % foliar spray treatment and 19-19-19 WSF @ 0.5 % foliar spray treatment.

The stem diameter of oat was disproportionate compared to plant height and so, there was a problem of lodging. The problem of lodging was lesser in case of foliar treatments as the stem diameter was higher than no foliar sprayed treatment. In both urea treated and 19-19-19 WSF @ 0.5 % treated oat, there was equal stem diameter and the type of fertilizer did not seem to affect much to this parameter.

In barley and wheat, effectiveness of foliar treatment was observed but the type fertilizer sprayed did not bother the increased in stem diameter. In white maize maximum stem diameter (30 mm) was observed in 19-19-19 WSF @ 0.5 % treated one so in this case it was better than that of urea @ 0.5

% treated white maize (25 mm). Foliar spray had influenced on stem diameter which is a parameter indicating better growth in all the crops taken.

Table 10 Average stem diameter on 10th day

Treatment	Stem Diameter(mm)
C_1F_1: Pearl millet + Control	10
C_1F_2 : Pearl millet + Urea foliar spray @ 0.5 %	10
C_1F_3 : Pearl millet + 19-19-19 WSF spray @ 0.5 %	10
C_2F_1 : Yellow Maize + Control	25
C_2F_2 : Yellow Maize + Urea foliar spray @ 0.5 %	30
C_2F_3 : Yellow Maize + 19-19-19 WSF spray @ 0.5 %	30
C_3F_1 : Oat + Control	10
C_3F_2: Oat + Urea foliar spray @ 0.5 %	15
C_3F_3 : Oat + 19-19-19 WSF spray @ 0.5 %	15
C_4F_1 : Barley + Control	15
C_4F_2 : Barley + Urea foliar spray @ 0.5 %	20
C_4F_3 : Barley +19-19-19 WSF spray @ 0.5 %	20
C_5F_1 : Wheat + Control	10
C_5F_2 : Wheat + Urea foliar spray @ 0.5 %	15
C_5F_3 : Wheat + 19-19-19 WSF spray @ 0.5 %	15
C_6F_1: White Maize + Control	25
C_6F_2 : White Maize + Urea foliar spray @ 0.5 %	25
C_6F_3 : White Maize + 19-19-19 WSF spray @ 0.5 %	30
S.Em.$\pm$	21.59
CD at 5%	NS
Mean	22.731

4.1.5 Dry matter

Grain/Seed before soaking

The dry matter content is generally high in initial stages. In the crops selected the dry matter was high in all the crops at first observation day i.e. seed/ grain before soaking. Highest was in pearl millet (90.1 %) and the lowest of all was in barley recording a value of 88.7 per cent as shown in Table 11. All other remaining crop had an average value near around 89 per cent.

The dry matter content of wheat as cereal grain before soaking was 89.00 per cent which is in conformity with the findings of Mooney (2005) in which he mentioned that the dry matter of wheat as cereal grain was 90.0 per cent. All other values found is in conformity with CCOF (2015) data of average dry matter percentages for various livestock feed.

4th day

There was reduction in dry matter content in all the treatments as shown in Table 11. Maximum reduction was observed in pearl millet (63.28 %). It was followed by the two maize types yellow and white (70.62 % and 69.54 % respectively). Wheat showed maximum dry matter content or minimum reduction (78.94 %) on 4th day compared to other treatment.

Table 11 Dry matter content as influenced by different treatments

Treatment		Dry matter content (%)			
		Seed	4th day	7th day	10th day
C_1F_1:	Pearl millet + Control	90.10	63.28	13.27	8.27
C_1F_2 :	Pearl millet + Urea foliar spray @ 0.5 %	-	-	15.11	10.63
C_1F_3 :	Pearl millet + 19-19-19 WSF spray @ 0.5 %	-	-	15.46	10.64
C_2F_1 :	Yellow Maize + Control	89.40	70.62	22.39	15.24
C_2F_2 :	Yellow Maize + Urea foliar spray @ 0.5 %	-	-	23.15	16.58
C_2F_3:	Yellow Maize + 19-19-19 WSF spray @ 0.5 %	-	-	24.68	18.82
C_3F_1 :	Oat + Control	90.00	74.72	14.47	11.36
C_3F_2:	Oat + Urea foliar spray @ 0.5 %	-	-	15.53	13.10
C_3F_3 :	Oat + 19-19-19 WSF spray @ 0.5 %	-	-	11.92	11.59
C_4F_1 :	Barley + Control	88.70	76.72	18.33	13.60
C_4F_2 :	Barley + Urea foliar spray @ 0.5 %	-	-	19.27	15.16
C_4F_3 :	Barley +19-19-19 WSF spray @ 0.5 %	-	-	18.63	17.55
C_5F_1 :	Wheat + Control	89.91	78.94	29.90	25.15
C_5F_2 :	Wheat + Urea foliar spray @ 0.5 %	-	-	32.12	26.67
C_5F_3 :	Wheat + 19-19-19 WSF spray @ 0.5 %	-	-	32.24	28.21
C_6F_1:	White Maize + Control	89.8	69.54	21.13	18.21
C_6F_2 :	White Maize + Urea foliar spray @ 0.5 %	-	-	22.76	19.06
C_6F_3 :	White Maize + 19-19-19 WSF spray @ 0.5 %	-	-	24.76	20.53
	S.Em.$\pm$	-	-	0.09	0.07
	CD at 5%	-	-	0.26	0.20
	Mean	-	-	18.91	14.99

7th day

The dry matter content as depicted in Table 11 and Fig. 10 was lowest in control of pearl millet (13.2 %) where no foliar application was done followed by urea @ 0.5 % treated pearlmillet (15.11 %) and then 19-19-19 WSF @ 0.5 % treated pearlmillet (15.46 %). 19-19-19 WSF @ 0.5 % treated yellow maize and 19-19-19 WSF @ 0.5 % treated white maize which were par with values around 24-25 per cent. In oat and barley, urea sprayed treatments had higher dry matter content than 19-19-19 WSF @ 0.5 % treated and control. However in wheat, it was higher in 19-19-19 WSF @ 0.5 % treated wheat than urea treated or control with maximum retention of dry matter content.

The dry matter content of barley had already been reported by Naik *et al.* (2015) that DM content of hydroponic barley be 8.00-19.7 per cent in 6-8 days. The value found in these research on 7th day was 18.33 per cent in control and 19.27 per cent in urea treated barley which is in conformity with the reports of Naik *et al.* Mooney (2005) reported that dry matter content on 7th day was 31.6 % in hydroponic wheat grown with only water which is around the values of these research where the dry matter content of wheat was 29.9 per cent.

Lorenz (1980) also reported that sprouting reduces the dry matter (%) content of grains.

10th day

The dry matter content in all treatments(Fig. 10) of pearl millet were low 8.27 per cent in control, 10.63 per cent in urea @ 0.5 % treated and 10.64 per cent in 19-19-19 WSF @ 0.5

% treated pearl millet. Maximum dry matter content was observed in 19-19-19 WSF @ 0.5 % treated wheat (28.21 %).

Usually without any foliar treatment the dry matter content was slightly less than in foliar treated treatments.

4.2 Quality parameters

4.2.1 Crude protein (CP)

The influence of foliar spray in different crop is shown in Table 12.

Grain/Seed (before soaking)

The crude protein content in grains was generally high in barley and oat with 13.10 and 13.06 per cent, respectively. The value of wheat and pearl millet are almost equal. But the crude protein content of yellow maize and white maize was quite low i.e. 9.19 and 10.5 per cent, respectively. Crude protein in feeding stuffs includes the true protein containing a number of amino acids and non-protein nitrogenous compound such as amides. Cuddeford (1989) found that the crude protein content of barley seed was 12.7 per cent whereas in the current research it was found as 13.10 per cent. The reason for difference in protein content may be due to difference in varieties.

Another research performed by Mooney (2005) found the crude protein content as 11.1 per cent in wheat grain while in the current research it was found as 12.08 per cent. Abdelrahman and Hoseney (1984) reported that the crude protein content of pearl millet was 13.3 % which is in agreement with the values of this research i.e. 12.68 %.

Table 12 Crude protein content as influenced by different treatments

Treatment		Crude Protein (%)			
		Seed	4 days	7 days	10 days
C_1F_1:	Pearlmillet + Control	12.68	16.18	17.88	19.37
C_1F_2 :	Pearlmillet + Urea foliar spray @ 0.5 %	-	-	23.60	25.38
C_1F_3 :	Pearlmillet + 19-19-19 WSF spray @ 0.5 %	-	-	22.28	23.23
C_2F_1 :	Yellow Maize + Control	9.187	10.06	10.91	16.81
C_2F_2 :	Yellow Maize + Urea foliar spray @ 0.5 %	-	-	16.61	21.06
C_2F_3:	Yellow Maize + 19-19-19 WSF spray @ 0.5 %	-	-	12.41	18.93
C_3F_1 :	Oat + Control	13.06	13.15	13.92	14.23
C_3F_2:	Oat + Urea foliar spray @ 0.5 %	-	-	14.53	16.72
C_3F_3 :	Oat + 19-19-19 WSF spray @ 0.5 %	-	-	14.27	15.95
C_4F_1 :	Barley + Control	13.10	13.56	14.00	15.52
C_4F_2 :	Barley + Urea foliar spray @ 0.5 %	-	-	17.49	19.64
C_4F_3 :	Barley +19-19-19 WSF spray @ 0.5 %	-	-	15.24	17.81
C_5F_1 :	Wheat + Control	12.08	14.43	16.62	17.65
C_5F_2 :	Wheat + Urea foliar spray @ 0.5 %	-	-	17.51	18.39
C_5F_3 :	Wheat + 19-19-19 WSF spray @ 0.5 %	-	-	17.89	20.28
C_6F_1:	White Maize + Control	10.5	11.12	14.16	14.84
C_6F_2 :	White Maize + Urea foliar spray @ 0.5 %	-	-	14.33	17.93
C_6F_3 :	White Maize + 19-19-19 WSF spray @ 0.5 %	-	-	14.47	17.23
	S.Em.±	-	-	0.05	0.12
	CD at 5%	-	-	0.14	0.36
	Mean	-	-	15.97	18.23

4th day

The increase in crude protein was highest in pearl millet (16.18 %) followed by wheat with 14.43 per cent. The lowest content was found in yellow maize (10.06 %).

The crude protein in barley was 13.56 per cent which is in conformity with the findings of Cuddeford (1989) depicting 13.4 per cent crude protein content in sprouted barley grain on 4th day.

7th day

Highest crude protein content as shown in table 12 and Fig. 11 was obtained in urea @ 0.5 % treated pearl millet (23.60 %) while the lowest was in control yellow maize (10.91 %). In pearl millet, yellow maize, oat and barley superiority influenced of urea treatment were observed however, in wheat and white maize better content of crude protein were observed in 19-19-19 WSF @ 0.5 % treatments. The influence was different in different treatments. According to Mooney (2005) crude protein content of wheat was 17.4 per cent on 7th day and the content in wheat turns out as 16.62 per cent. In another case Cuddeford (1989) reported a crude protein content of 15.5 per cent in barley on 7th day which is higher than the value revealed in this research (14.00 %)

10th day

Influence of foliar application of water soluble fertilizers was shown clearly by lower crude protein content of control (no foliar application) in all hydroponically grown crops as depicted in Table 12 and Fig. 11. The crude protein content on 10th day i.e. harvesting day was found to be lowest in oat with 14.23 per cent in control. Among the foliar sprayed treatments 19 -19 -19 WSF sprayed @ 0.5 % in oat had least crude protein content (15.95 %) than other treatments. Maximum crude protein content was found in urea treated pearl millet with 25.38 per cent. In all crops urea @ 0.5 % treated ones had higher crude protein content than 19-19-19 WSF @ 0.5 % foliar sprayed treatment except in wheat where 19-19-9- WSF @ 0.5 % applied wheat (20.28 %) showed better result than urea @ 0.5 % applied (18.39 %). Naik *et al* (2012) reported that the CP content of the maize seed was 8.60 % which remained similar up to 2nd day (9.14%) of growth in hydroponics system. The CP content of the sprouted maize showed an increasing trend with germination time and remained highest on 7th day (13.57 %) of growth. The increase in protein content may be attributed to the loss in dry weight, particularly carbohydrates, through respiration during germination and thus longer sprouting time was responsible for greater losses in dry weight and increasing trend in protein content (Chavan and Kadam, 1989).

Up to 3rd day of growth of the hydroponic fodder maize, CP content was lower than CP content (10.67 %) of fodder maize harvested at about 60 days under conventional practices; but from the 4th day onwards, values of the former remained higher than the later. So the increasing trend in CP content of the results is in conformity with the results of Naik *et al* (2012)

4.2.2 Acid detergent fibre

Grain/Seed (before soaking)

The ADF content in grains as shown in Table 13 was low, the lowest being 7.2 per cent in wheat cereal grains followed by pearl millet (7.4 %) while the highest value was noted in white maize (9.8 %). Yellow maize, oat and barley had near to equal values i.e. 8.0, 8.6 and 8.6 per cent, respectively.

4thday

Barley had lowest content of ADF with 10 % while oat had the highest (12.4 %). The value for yellow maize and wheat were equivalent (11.2 %). Similarly, pearl millet and white maize had almost equal values i.e. 10.7 and 10.5 per cent, respectively.

7thday

The lowest ADF content as shown in Table 13 and Fig. 12 was found in control of pearl millet and among foliar sprayed treatments lowest was observed in 19-19-19 WSF treated @ 0.5 % in pearl millet (12.81 %). The highest ADF content was found in 19-19-19 WSF treated @ 0.5 % in oat (21.40 %) followed by urea treated oat (20.07 %). In pearl millet and wheat, ADF per cent was higher in urea @ 0.5 % treatment than 19-19-19 WSF @ 0.5 % treatment whereas in yellow maize, oat, barley and white maize, ADF content was higher in 19-19-19 WSF @ 0.5 % treatments than in urea @ 0.5 % treatments.

These results are in conformity with Ajmi *et al.* (2009) and he reported that barley had a ADF content of 13.33 per cent on 7th day which is in similar with the findings in this research which observed a value of 12.9 per cent on the 7th day.

Table 13 Acid detergent fibre (ADF) as influenced by different treatments

Treatment		Acid detergent fibre (%)			
		Seed	4 days	7 days	10 days
C_1F_1:	Pearlmillet + Control	7.4	10.7	12.65	14.03
C_1F_2 :	Pearlmillet + Urea foliar spray @ 0.5 %	-	-	14.13	15.14
C_1F_3 :	Pearlmillet + 19-19-19 WSF spray @ 0.5 %	-	-	12.81	15.25
C_2F_1 :	Yellow Maize + Control	8	11.2	16.06	18.33
C_2F_2 :	Yellow Maize + Urea foliar spray @ 0.5 %	-	-	17.20	19.12
C_2F_3:	Yellow Maize + 19-19-19 WSF spray @ 0.5 %	-	-	18.08	19.56
C_3F_1 :	Oat + Control	8.6	12.4	18.70	20.31
C_3F_2:	Oat + Urea foliar spray @ 0.5 %	-	-	20.07	21.30
C_3F_3 :	Oat + 19-19-19 WSF spray @ 0.5 %	-	-	21.40	23.14
C_4F_1 :	Barley + Control	8.6	10	12.9	14.01
C_4F_2 :	Barley + Urea foliar spray @ 0.5 %	-	-	13.51	15.09
C_4F_3 :	Barley +19-19-19 WSF spray @ 0.5 %	-	-	13.72	15.34
C_5F_1 :	Wheat + Control	7.2	11.20	15.92	19.20
C_5F_2 :	Wheat + Urea foliar spray @ 0.5 %	-	-	15.65	19.40
C_5F_3 :	Wheat + 19-19-19 WSF spray @ 0.5 %	-	-	15.57	19.15
C_6F_1:	White Maize + Control	9.8	10.5	17.78	20.62
C_6F_2 :	White Maize + Urea foliar spray @ 0.5 %	-	-	18.00	21.60
C_6F_3 :	White Maize + 19-19-19 WSF spray @ 0.5 %	-	-	18.20	20.21
	S.Em.$\pm$	-	-	0.04	0.22
	CD at 5%	-	-	0.12	0.63
	Mean	-	-	17.32	21.30

10th day

Maximum ADF content as displayed in Table 13 and Fig 12 was noticed in 19-19-19 WSF @ 0.5 % treated oat (23.14 %) and are superior to other treatments. The lowest ADF in per cent was noticed in control of pearl millet but among the foliar applied treatments, urea @ 0.5 % treated barley had lowest ADF content (15.09 %).

4.2.3 Neutral Detergent Fiber (NDF)

Grain/Seed (before soaking)

At the start as shown in Table 14, when the samples were taken as grains, pearl millet had the lowest NDF content (20.81 %). Oat grain had highest content of NDF (23.76 %) followed by barley, yellow maize and white maize, numerically they are closed to each other. While the NDF content of wheat was 21.9 per cent which was little above that of pearl millet (20.81 %) and lower than white maize (22.44 %).

4th day

The NDF content was lowest white maize (26.07 %) which was closed to wheat containing 26.11 per cent. Maximum value was noticed in oat (29.2%) while remaining hydroponic crops had an average value very close to each other i.e. pearl millet had 28.2 per cent, with a difference of 0.2 per cent next to pearl millet was yellow maize (28.4 %) so also barley with a value of 28.61 per cent.

Table 14 Neutral detergent fibre (NDF) as influenced by different treatments

Treatment		Neutral detergent fibre (%)			
		Seed	4 days	7 days	10 days
C_1F_1:	Pearlmillet + Control	20.81	28.2	30.39	31.77
C_1F_2 :	Pearlmillet + Urea foliar spray @ 0.5 %	-	-	31.60	32.66
C_1F_3 :	Pearlmillet + 19-19-19 WSF spray @ 0.5 %	-	-	32.37	32.13
C_2F_1 :	Yellow Maize + Control	22.49	28.4	30.33	32.56
C_2F_2 :	Yellow Maize + Urea foliar spray @ 0.5 %	-	-	33.20	34.18
C_2F_3:	Yellow Maize + 19-19-19 WSF spray @ 0.5 %	-	-	34.30	35.27
C_3F_1 :	Oat + Control	23.76	29.2	34.61	37.23
C_3F_2:	Oat + Urea foliar spray @ 0.5 %	-	-	36.47	38.15
C_3F_3 :	Oat + 19-19-19 WSF spray @ 0.5 %	-	-	36.59	37.21
C_4F_1 :	Barley + Control	22.58	28.61	31.28	33.63
C_4F_2 :	Barley + Urea foliar spray @ 0.5 %	-	-	31.27	33.65
C_4F_3 :	Barley +19-19-19 WSF spray @ 0.5 %	-	-	31.01	34.24
C_5F_1 :	Wheat + Control	21.9	26.11	28.95	30.57
C_5F_2 :	Wheat + Urea foliar spray @ 0.5 %	-	-	29.43	31.49
C_5F_3 :	Wheat + 19-19-19 WSF spray @ 0.5 %	-	-	29.68	31.11
C_6F_1:	White Maize + Control	22.44	26.07	32.46	33.70
C_6F_2 :	White Maize + Urea foliar spray @ 0.5 %	-	-	34.31	35.57
C_6F_3 :	White Maize + 19-19-19 WSF spray @ 0.5 %	-	-	34.34	35.72
	S.Em.±	-	-	0.36	0.22
	CD at 5%	-	-	1.03	0.63
	Mean	-	-	17.32	21.30

7th day

As depicted in Table 14 and Fig. 13, the treatments in wheat including both control as well foliar sprayed yield lowest NDF content among all other treatments. The NDF content in control wheat was 28.95 per cent while urea @ 0.5 % treated wheat content 29.43 per cent and 19-19-19 WSF @ 0.5 % treated wheat yielded 29.68 per cent and so they are at par. Maximum percentage of NDF was observed in 19-19-19 WSF @ 0.5 % treated oat (36.59 %). In pearl millet, yellow maize, oat, barley, wheat and white maize, the treatment done by foliar spray of 19-19-19 WSF @ 0.5 % had higher NDF content than treatment done with by foliar spray of urea @ 0.5 %.

Ajmi *et al.* (2009) reported that the NDF content in barley treated with tap water was 30.43 per cent while that of treatments sprayed with sewage water was 32.77 per cent Likewise in these research, the NDF content of control barley was 29.01 per cent while those of foliar treated barley was 29.56 and 29.56 per cent. So, the two results are near to each other.

10th day

As shown in Table 14 and Fig. 13 Control of wheat (30.57 %) where no foliar spray was done content lowest NDF of all treatments. 19-19-19 WSF @ 0.5 % treated wheat (31.11 %), urea @ 0.5 % treated wheat (31.49 %) and control of pearl millet (31.77 %) were at par. Highest NDF content was observed in Urea @ 0.5 % treated oat (38.15 %). Among high NDF containing treatments, control of oat (37.23 %) and 19-19-19 WSF @ 0.5 % (37.21 %) was also included. In pearl millet, oat and wheat the NDF value were higher in urea @ 0.5 % treated than 19-19-19

WSF @ 0.5 % foliar sprayed treatments. While in yellow maize, barley and white maize the 19-19-19 WSF @ 0.5 % treatments had higher NDF content than urea @ 0.5 % treatments.

In the comparison Table 14 given above, the NDF content of 7th day was increased on 10th day. With advancing maturity, plants develop xylem tissue for water transport, accumulate cellulose and other complex carbohydrates, and these tissues become bound together by a process known as lignification. Maximum NDF value was observed in urea @ 0.5 % treated oat (C_4F_3) and 19-19-19 WSF @ 0.5 % treated oat, C_3F_3 treatment combination. Minimum was seen in 19-19-19 WSF treated wheat (C_5F_3), urea @ 0.5 % treated wheat (C_5F_2), control of wheat (C_5F_1). The NDF content white maize i.e. C_6 was higher than the minimum value but below average. Control of white maize (C_6F_1), control of pearl millet (C_1F_1), urea @ 0.5 % treated white maize (C_6F_2) and 19-19-19 WSF @ 0.5 % treated white maize (C_6F_3) are in par with each other. The lower the NDF content, the better the quality of hydroponic fodder.

4.3 Yield

4.3.1 Green Fodder Yield

The average yield of different green fodder on consecutive 8th, 9th and 10th days are given in Table 15 and depicted in Fig. 14.

It is one of the most important parameter of this experiment to know the influence of foliar spray and the type of crops suitable in an uncontrolled environment because the conclusion will mainly depend on yield.

Table 15 Periodical biomass yield as influenced by different treatments

Treatment		Seed (kg) tray^{-1}	Biomass yield (kg tray^{-1})				
			8th day	9th day	% reduced	10th day	% reduced
C_1F_1:Pearlmillet + Control		0.7	4.69	4.64	1.1	4.59	2.0
C_1F_2:Pearlmillet + Urea foliar spray @ 0.5 %		0.7	5.06	5.01	0.9	4.97	1.7
C_1F_3:Pearlmillet +19:19:19 WSF spray @ 0.5 %		0.7	5.55	5.53	0.3	5.51	0.7
C_2F_1:Yellow Maize + Control		1.1	5.34	5.30	0.7	5.24	1.8
C_2F_2 :Yellow Maize + Urea foliar spray @ 0.5 %		1.1	6.43	6.40	0.4	6.39	0.6
C_2F_3: Yellow Maize + 19-19-19 WSF spray @ 0.5 %		1.1	6.96	6.94	0.2	6.92	0.5
C_3F_1 :Oat + Control		0.6	2.82	2.81	0.3	2.76	2.1
C_3F_2:Oat + Urea foliar spray @ 0.5 %		0.6	3.23	3.22	0.3	3.18	1.5
C_3F_3 :Oat + 19-19-19 WSF spray @ 0.5 %		0.6	3.84	3.80	1.0	3.77	1.8
C_4F_1 :Barley + Control		0.6	2.79	2.74	1.7	2.71	2.8
C_4F_2 :Barley + Urea foliar spray @ 0.5 %		0.6	3.42	3.40	0.5	3.34	2.3
C_4F_3 :Barley +19-19-19 WSF spray @ 0.5 %		0.6	3.60	3.57	0.8	3.52	2.2
C_5F_1 :Wheat + Control		0.8	5.41	5.16	4.6	5.12	5.3
C_5F_2 : Wheat + Urea foliar spray @ 0.5 %		0.8	5.53	5.50	0.5	5.43	1.8
C_5F_3 :Wheat + 19-19-19 WSF spray @ 0.5 %		0.8	5.62	5.59	0.5	5.51	1.9
C_6F_1:White Maize + Control		1.2	5.28	5.37	-	5.11	3.2
C_6F_2 :White Maize + Urea foliar spray @ 0.5 %		1.2	6.29	6.47	-	6.14	2.3
C_6F_3 : White Maize + 19-19-19 WSF spray @ 0.5 %		1.2	6.85	6.82	0.4	6.74	1.6
	S.Em.$\pm$		0.03	0.02		0.02	
	CD at 5%		0.10	0.06		0.06	
	Mean		5.01	4.95		4.84	

The periodical biomass yield was recorded at 8th, 9th and 10th day and it was observed that the maximum biomass yield was obtained from different hydroponically grown crop was at 8th day later on there was reduction in biomass yield. At 8th

among the different hydroponically grown crop maximum yield per tray was obtained in yellow maize followed by wheat crop.

In all the crops taken treatment influence of foliar spray was observed. Maximum yield was shown in 19-19-19 WSF @ 0.5 % sprayed treatments followed by treatments with urea @ 0.5 % applied.

Yellow maize and white had maximum yield with an increase of 6 folds from its initial seed taken. But higher yield was observed in yellow maize compared to white maize. Among the foliar spray treatment in both the crops, 19-19-19 WSF @ 0.5 % produced better result than urea @ 0.5 % treated yellow maize and white maize.

The best treatment combination among all on 10th day was 19-19- WSF @ 0.5 % treated yellow maize (6.92 kg tray^{-1}) followed by 19-19-19 WSF @ 0.5 % treated white maize. Meanwhile the least yield was observed in control of barley and for among foliar sprayed treatments urea @ 0.5 % sprayed oat.

The mould growth increased on 9th and 10th day and some rotting and drying up of roots was seen in some cases. These could be reason for its reduction in yield after 8th day. If we consider only yield then the fodder should be harvested on 8thday rather on farmers practiced duration of 9th and 10th days and even more. At the same time the fodder was fresher on 8th day, with negligible mould growth and browning of leaves.

4.4.1 Water requirement

The water requirement of hydroponically grown crops was equal initially till 3rd day. The difference came from 4th day in which pearl millet required lesser water compared to other crops taken. The water requirement in yellow maize, oat, barley, wheat and white maize was equal in all the growing period (28.77 L $tray^{-1}$) while in pearl millet it was recorded as 20.40 L $tray^{-1}$.

Table 16 Average water requirement during hydroponic crop growing period

Treatment	Water requirement (litre)		
	1 to 3 Day (Lit. $tray^{-1}$)	**4 to 10 Day (Lit. $tray^{-1}$)**	**Total Per Crop (Lit. $tray^{-1}$)**
C_1 : Pearl millet	7.42	12.98	20.40
C_2 : Yellow maize	7.42	21.35	28.77
C_3 : Oat	7.42	21.35	28.77
C_4 : Barley	7.42	21.35	28.77
C_5 : Wheat	7.42	21.35	28.77
C_6 : White maize	7.42	21.35	28.77

4.4.2 Water productivity

The physical water productivity was highest at 8th day and was decline as the growth period increases. Among the different hydroponic crops the maximum physical water productivity was noticed in pearl millet with foliar application of 19-19-19 water soluble fertilizers @ 0.5 % (0.272 kg lit^{-1}) followed by yellow maize (0.242 kg lit^{-1}). The lowest water productivity was noticed in the treatment oat with no foliar application (0.098 kg lit^{-1}).

Table 17 Periodical physical water productivity as influenced by different treatments

Treatment	Physical water productivity (kg lit^{-1})		
	8th day	9th day	10th day
C_1F_1: Pearlmillet + Control	0.230	0.227	0.221
C_1F_2: Pearlmillet + Urea foliar spray @ 0.5 %	0.248	0.245	0.243
C_1F_3: Pearlmillet + 19-19-19 WSF spray @ 0.5 %	0.272	0.271	0.270
C_2F_1: Yellow Maize + Control	0.185	0.184	0.182
C_2F_2: Yellow Maize + Urea foliar spray @ 0.5 %	0.223	0.222	0.222
C_2F_3: Yellow Maize + 19-19-19 WSF spray @ 0.5 %	0.242	0.241	0.240
C_3F_1: Oat + Control	0.098	0.097	0.086
C_3F_2: Oat + Urea foliar spray @ 0.5 %	0.112	0.111	0.110
C_3F_3: Oat + 19-19-19 WSF spray @ 0.5 %	0.133	0.132	0.130
C_4F_1: Barley + Control	0.097	0.095	0.094
C_4F_2: Barley + Urea foliar spray @ 0.5 %	0.119	0.118	0.114
C_4F_3: Barley +19-19-19 WSF spray @ 0.5 %	0.125	0.124	0.122
C_5F_1: Wheat + Control	0.188	0.179	0.177
C_5F_2: Wheat + Urea foliar spray @ 0.5 %	0.192	0.191	0.188
C_5F_3: Wheat + 19-19-19 WSF spray @ 0.5 %	0.195	0.194	0.191
C_6F_1: White Maize + Control	0.183	0.186	0.177
C_6F_2: White Maize + Urea foliar spray @ 0.5 %	0.218	0.225	0.213
C_6F_3: White Maize + 19-19-19 WSF spray @ 0.5 %	0.238	0.237	0.234
S.Em.$\pm$	0.069	0.004	0.011
CD at 5%	0.009	0.012	0.010
Mean	0.200	0.193	0.178

Table 18 Economic water productivity as influenced by different treatments

Treatment	Economic water productivity (` lit^{-1})
C_1F_1: Pearlmillet + Control	16.63
C_1F_2: Pearlmillet + Urea foliar spray @ 0.5 %	18.84
C_1F_3: Pearlmillet + 19-19-19 WSF spray @ 0.5 %	20.73
C_2F_1: Yellow Maize + Control	16.03
C_2F_2: Yellow Maize + Urea foliar spray @ 0.5 %	17.53
C_2F_3: Yellow Maize + 19-19-19 WSF spray @ 0.5 %	20.19
C_3F_1: Oat + Control	4.71
C_3F_2: Oat + Urea foliar spray @ 0.5 %	6.54
C_3F_3: Oat + 19-19-19 WSF spray @ 0.5 %	9.07
C_4F_1: Barley + Control	4.48
C_4F_2: Barley + Urea foliar spray @ 0.5 %	7.25
C_4F_3: Barley +19-19-19 WSF spray @ 0.5 %	7.97
C_5F_1: Wheat + Control	14.11
C_5F_2: Wheat + Urea foliar spray @ 0.5 %	14.65
C_5F_3: Wheat + 19-19-19 WSF spray @ 0.5 %	14.79
C_6F_1: White Maize + Control	13.15
C_6F_2: White Maize + Urea foliar spray @ 0.5 %	16.13
C_6F_3: White Maize + 19-19-19 WSF spray @ 0.5 %	18.70

The economic water productivity of 10th day among the different hydroponic crops was noticed in pearl millet with foliar application of 19-19-19 water soluble fertilizers @ 0.5 % (20.73 ` $lit^{-1}$) followed by yellow maize (20.19 ` lit^{-1}). The lowest water productivity was noticed in the treatment barley with no foliar application (4.48 ` lit^{-1}).

4.5 Economics

The economics of hydroponic crop per unit as influenced by different foliar sprays was assessed by considering the prevailing market price (Appendix -1) in terms of cost of cultivation , gross monetary returns , net monetary returns and B:C ratio are presented in Table 19.

4.5.1 Gross monetary returns

The data (Table 19) computed for gross monetary returns differed due to various treatments under study. Among the treatments of different fertilizer levels, the maximum gross monetary returns (` 2352143 $unit^{-1}$) was recorded in 19-19-19 WSF sprayed yellow maize treatment due to maximum yield. In all the treatments minimum gross returns (` 922282 $unit^{-1}$) were obtained from control of barley followed by control of oat (` 940312 $unit^{-1}$).

4.5.2 Cost of cultivation

With reference to the data given in the table 4.13 the maximum cost of cultivation was observed in 19-19-19 WSF treated white maize (` 841470 $unit^{-1}$) and urea treated white

Table 19 Economics under different treatment

Treatment		Gross monetary return (` Unit^{-1})	Cost of production (` Unit^{-1})	Net monetary return (` Unit^{-1})	B: C ratio
C_1F_1:	Pearlmillet + Control	1563219	646800	916419	2.42
C_1F_2 :	Pearlmillet + Urea foliar spray @ 0.5 %	1686371	647097	1039274	2.61
C_1F_3 :	Pearlmillet + 19-19-19 WSF spray @ 0.5 %	1794215	651930	1142285	2.75
C_2F_1 :	Yellow Maize + Control	2023849	778020	1245830	2.60
C_2F_2 :	Yellow Maize + Urea foliar spray @ 0.5 %	2140198	778317	1361881	2.75
C_2F_3:	Yellow Maize + 19-19-19 WSF spray @ 0.5 %	2352143	783150	1568993	3.00
C_3F_1 :	Oat + Control	940312	573900	366413	1.64
C_3F_2:	Oat + Urea foliar spray @ 0.5 %	1082516	574197	508319	1.89
C_3F_3 :	Oat + 19-19-19 WSF spray @ 0.5 %	1282554	579030	703524	2.22
C_4F_1 :	Barley + Control	922282	573900	348382	1.61
C_4F_2 :	Barley + Urea foliar spray @ 0.5 %	1137628	574197	563432	1.98
C_4F_3 :	Barley +19-19-19 WSF spray @ 0.5 %	1198524	579030	619495	2.07
C_5F_1 :	Wheat + Control	1741824	719700	1022124	2.42
C_5F_2 :	Wheat + Urea foliar spray @ 0.5 %	1816668	719997	1096671	2.52
C_5F_3 :	Wheat + 19-19-19 WSF spray @ 0.5 %	1874502	724830	1149672	2.59
C_6F_1:	White Maize + Control	1740463	836340	904123	2.08
C_6F_2 :	White Maize + Urea foliar spray @ 0.5 %	2090189	836637	1253552	2.50
C_6F_3 :	White Maize + 19-19-19 WSF spray @ 0.5 %	2294649	841470	1453179	2.73

maize (` 836637 unit$^{-1}$ ) and was lowest in control of barley and oat (` 573900 unit^{-1}) but among foliar sprayed treatments urea treated oat and barley (` 574197 unit^{-1}) incurred least cost of production.

4.5.3 Net monetary returns (`)

The data regarding net monetary returns from various treatments are reported in Table 19. The maximum net monetary returns (` 1568993 unit$^{-1}$) was obtained in 19-19-19 WSF @ 0.5 % treated yellow maize followed by 19-19-19 WSF @ 0.5 % treated white maize (` 14,53,179 unit^{-1}). The lowest net monetary returns (` 348382 unit^{-1}) was obtained in barley hydroponically grown crop with no foliar application treatment which was due to lower yield. The reason for lower yield may be due to the unsuitability of the crop to the weather condition and also unavailability of sufficient nutrient sources to increase growth.

4.5.4 Benefit : cost ratio

The B:C ratio in various treatments ranges from 1.61 to 3.00. Amongst all the treatments the highest B:C ratio was obtained in 19-19-19 WSF treated yellow maize (3.00) followed by 19-19-19 treated pearl millet and urea treated yellow maize (2.75). The B:C ratio of oat and barley because of unsuitability to the region and weather. The treatments with B:C ratio above 2.00 were the ones suitable to the treatment.

5. SUMMARY AND CONCLUSIONS

5.1 Summary

The field experiment was conducted at Post Graduate Institute research farm, Department of Agronomy, M.P.K.V., Rahuri during April-May, 2016. The experiment entitled "Influence of foliar spray of water soluble fertilizer on growth, yield and quality of hydroponic fodder crops" was laid out in factorial completely randomized block design with 18 treatment combination and 3 replications. The trays used in the trial had small holes at the bottom and the size was 50 cm x 30 cm x 5 cm. The water used was tap water. The plastic rack structure of size 2.55 m x 1.7 m x 1.5 m had three shelves with a capacity of 18 trays in each shelf. The atmospheric humidity was dry but the moisture around the structure was maintained through the regular released of water through fitted jet/micro sprinklers. The temperature and humidity of the atmosphere at the trial period was around 39^0C and 48-50% respectively. The water soluble fertilizers viz., urea @ 0.5 % and 19-19-19 @ 0.5 % were used for foliar application according to treatment. They were sprayed on fifth day to 18 tray each with the help of hand sprayer and remaining 18 trays were irrigated with tap water , no foliar application of fertilizer were done. There was regular sprinkling of water at every 2hrs interval during day time and 4hrs interval during night.

The data in respect of growth, biomass yield, quality and water productivity attributes of hydroponic fodder crops were recorded periodically. The most important findings emerging from this investigation are summarized as below.

5.1.1 Morphological parameter

Maximum plant height (cm) was attended by 19-19-19 WSF @ 0.5 % sprayed yellow maize followed by white maize. The influence of 19-19-19 WSF on growth was more compared to urea. In all the hydroponically grown crops, the influence of foliar spray of water soluble fertilizers on growth was observed.

The foliar spray of water soluble fertilizers also influences root growth of different hydroponically grown crops. Highest growth in root length was observed in foliar spray of 19-19-19 WSF @ 0.5 % white maize (115 mm) and yellow maize (113 mm). Similar result also noticed in urea spray @ 0.5 % in white maize (114 mm) and yellow maize (112 mm).

The 19-19-19 WSF treated white maize and yellow maize recorded maximum plant diameter (30 mm) and followed by urea @ 0.5 % sprayed yellow maize (30 mm) and white maize (25 mm).

The more number of leaves was recorded in maize crop at 10^{th} day (3 leaves) than other hydroponically grown crops. It was also observed that the application of water soluble fertilizers not seem to play any more role in increasing number of leaves in hydroponically grown crops.

The dry matter content show a steep decline from sprouting to harvesting but still the dry matter content on 10^{th} day was improved by foliar application. The 19-19-19 WSF @ 0.5 % sprayed wheat (28.20 %) had highest content of dry matter content while the lowest was in no foliar applied pearlmillet (8.27 %)

5.1.2 Quality parameters

Foliar spray with water soluble fertilizer influenced the chemical composition of the crop and so its quality. The range of CP content for all the treatment combination was from 14.23-25.38 per cent on 10th day. In the 10th day samples of all treatment combination, CP content was significantly superior in urea @ 0.5 % foliar treated pearl millet (25.38 %) and 19-19-19 WSF @ 0.5 % foliar treated pearl millet (23.23%). Minimum CP content was found in no foliar sprayed oat and 19-19-19 WSF @ 0.5 % foliar sprayed oat.

Among the treatment combination, no foliar sprayed pearl millet (14.03%) and urea sprayed barley (15.09 %) hold minimum value of ADF content while maximum ADF content was evaluated in 19-19-19 WSF@ 0.5 % sprayed oat (23.14 %).

Maximum NDF value was observed in urea @ 0.5 % foliar sprayed oat (38.15 %) while minimum was seen in no foliar sprayed wheat (30.57 %). So, analyzing quality wise foliar spray increase the ADF and NDF content where a fodder is better the lower its content. But a fodder still comes under good quality if its ADF content is within 35 per cent and NDF content does not cross 50 per cent.

5.1.3 Yield

In yellow maize, white maize and wheat crops, there were around 5-6 folds increase in green biomass yield. The Maximum green biomass yield was obtained from application of 19-19-19 WSF @ 0.5 % to yellow maize (6.92 kg tray^{-1}) followed by white maize (6.85 kg $tray^{-1}$). The maximum green biomass obtained at 8^{th} day, thereafter reduction in biomass yield.

Among the hydroponic crops the maximum green biomass was noticed in both maize followed by wheat and pearl millet while among foliar spray treatment 19-19-19 WSF @ 0.5 % found superior over other foliar treatments.

5.1.3 Water requirement and water productivity

Hydroponically grown pearl millet required less quantity of water (20.40 lit) as compared to other crops while the other crops were supplied with same quantity of water (28.77 lit) during the growing period.

The water productivity viz., physical water productivity was highest in foliar application of 19-19-19 WSF @ 0.5 % in pearl millet (0.272 kg lit^{-1}) at 8^{th} day as age of hydroponically grown crop increases the physical water productivity decreases. The physical water productivity is more in pearl millet because it requires less water and in less water it gives more green biomass.

Similarly in economic water productivity, 19-19-19 WSF @ 0.5 % treated pearl millet (20.73 %) had highest followed by urea.

5.1.5 Economics

Maximum net monetary returns were obtained in 19-19-19 WSF @ 0.5 % treated yellow maize (` 1568993 $unit^{-1}$). Maximum B:C ratio of 3.00 and 2.75 were recorded in 19-19-19 WSF @ 0.5 % treated yellow maize and 19-19-19 WSF @ 0.5 % treated pearl millet.

5.2 Conclusions

Based on the findings emerged out from this investigation the following conclusions could be drawn.

1. Considering mainly green biomass yield, the crop with maximum biomass yield was yellow maize followed by white maize. But if we consider from quality point of view pearl millet was also suitable for Indian condition.
2. Influence of foliar sprays of 19-19-19 WSF @ 0.5 % was more than other foliar spray treatment in different hydroponically grown crops.
3. 19-19-19 WSF @ 0.5 % foliar spray treatment on yellow maize crop had highest biomass yield followed by 19-19-19 foliar spray treatment @ 0.5 % on white maize. The biomass yield of wheat with 19-19-19 WSF @ 0.5 % foliar spray treatment combination, wheat with Urea @ 0.5 % foliar spray treatment combination and pearl millet with 19-19-19 WSF @ 0.5 % foliar spray treatment combination were in par with each other. There was 3-6 folds increase in yield in all the crops in spite of growing in uncontrolled environment.
4. The nutrient content or crop quality was improved by applying foliar spray and better result was found in pearl millet with 19-19-19 WSF foliar spray @ 0.5 % treatment combination where CP content was highest compared to other treatment combination falling in the range 19-24 %. Yellow maize sprayed with 19-19-19 WSF @ 0.5 % had an average crude protein, ADF and NDF content. The result of

white maize in respect to quality was similar to that of yellow maize.

6. Plants which were foliar sprayed had a much healthier growth with more plant growth and larger diameter as compared to no foliar sprayed treatments. The DM content show a gradual decline but was improve by foliar application compared to no foliar sprayed treatments.
7. Foliar sprayed yellow maize both urea treated and 19-19-19 WSF @ 0.5 % treated were most economical of all the crops taken and it had high potential in India.

Based on one trial of experimentation, it could be concluded that yellow maize with foliar application of 19-19-19 water soluble fertilizer @ 0.5 % concentration was found most suitable for achieving maximum green biomass yield and net monetary returns during summer season. But it needs further confirmation.

6. LITERATURE CITED

Abdelrahman, A.A., and Hoseney, 1984. Basis for hardness in pearl millet, grain sorghum and corn. *Cereal Chem.* **61**:232-235

Akhtar, N., Javed Iqbal, Muhammad Arshad, Arbab Jahangeer and Zahid Ashfaq Ahmad. 2014. Effect of foliar application of Urea on Oat forage productivity. *J. Agric. Res.,* **52**(1) : 91-96.

Al-Ajmi,A.A.,Salih, I.K. and Othman, Y.(2009). Yield and water use efficiency of barley fodder produced under hydroponic system in GCC countries using tertiary treated sewage effluents. *J.Phytology* **1**(5):342-348

Al-Karaki Ghazi, N. and Al-Hashmi, M. 2012. Green fodder production and water use efficiency of some forage crops under hydroponic conditions. *ISRN Agronomy*, article ID- 924672.

Al-Saadi, M.J., Ibrahim, A.H. and Al-Zubiadi. 2015. Effects of substitution barley by 10 %, 30 % of Sprouted barley on rumen characters, digestibility and feed efficiency in diet of Awassi Male Lambs. *International J. Sci. and Research : ISBN (online)*. pp. 2319-7064.

Amal, B.K., Aurang, Z., Nizakat, B., Shahid, A.K. and Mohammad, S.K. 2007. Influence of germination techniques on phytic acid and polyphenols content of chickpea (*Cicer arietinum L.*) sprouts. *Food Chem.* **104***:* 1074-1079.

Anonymous, 2012. Hydroponics green fodder feeding technology in Goa.www.icar.org.in/en/node/6737

Anonymous, 2013. Hydroponics fodder feeding system for Chickens, Goats, Pigs, Sheep. Sidney. http://dayton. ebayclassifieds.com

Anonymous, 2014. Gau Char hydroponic fodder production unit. http://www.emaarfarm.com/Services_Fodder_Machine. html. 12/02/2014-India.

Arano.C.A.(2003).'How to produce green fodder' Fodder solution international: *www. foddersolutions-org/live-stock/beef*

A.O.A.C. 1970. Official Methods of Analysis 12th Edn. Association of Analytical Chemists, Washington, D.C

Azila Abdullah. 2001. Nutritive value of barley fodder grown in a hydroponics system. Thesis submitted in fulfillment of the requirement for the Degree of Master of Science in the Faculty of Agriculture (Unpub.), University Putra, Malaysia.

Burton, G.W., Wallace, A.T. and Rachie, K.O. 1972. Chemical composition and nutritive value of pearl millet (*Pennisetum typhoides* (Barn.) Stap F., and E.C. Hubbard) grain. *Crop Sci.* **12** : 187.

Calder Bill. 2002. Simple Shed Company, Morayfield, Queensland, Australia.

Carruthers, S. 2003. The way nature intended to grow barley' Fodder factory version 2.0-03-2014.*www.fodder-factory.co.za*

CCOF, 2015. Average dry matter percentages for various livestock feeds. ccof@ccof.org or www.ccof.org

Chavan, J. and Kadam, S.S. 1989. Nutritional improvement of cereals by sprouting. *Food Sci. Nutri.* **28**(5) : 401-437.

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

Duncan, A.J., Hartley, S.E. and Iason, T. 1994. Fine-scale discrimination of forage quality by sheep offered a soybean meal or barley supplement while grazing a nitrogen-fertilized heather (*Calluna vulgaris*) mosaic. *J. Agric. Sci.* **123** : 363-370.

Dung, D.D., Godwin, I.R. and Nolan, J.V. 2010. Nutrient content and in sacco digestibility of barley grain and sprouted barley. *J. Anim. and Vet. Advances.* **9**(1–9) : 2485–2492.

ESNC, 2010. Egypt second national communication under the united nations framework convention on climate change, UNFCCC, Published by Egyptian Environmental Affairs Agency.

F.A.O. 2012. Food and Agriculture Organization of the United Nation. Production year book. pp. 19-20.

Fayed, A.M. 2011. Comparative study and feed evaluation of sprouted barley grains on rice straw versus *Tamarix mannifera* on performance of growing Barki lambs in Sinai. *J. of American Science,* **7**(1) : 954-961.

Fazaeli, H., Golmohammadi, H.A., Tabatabayee, S.N. and Asghari, T.M. 2012. Productivity and nutritive value of barley green fodder yield in hydroponic system. Iran. *World Appl. Sci. J.* **16** (4): 531-539

Fazaeli, H., Golmohammadi, H.A., Shoayee, A.A., Montajebi, N. and Mosharraf, S. 2011. Performance of feedlot calves fed hydroponics fodder barley. *Agr. Sci. Tech. J.* **13**: 367-375.

Finney, P.L. 1982. Effect of germination on cereal and legume nutrient changes and food or feed value: *A comprehensive review. Recent Advanc in Phytochemistry.* **17**: 229-305

Freeman, J.E. and Bocan, B.J. 1973. Pearl millet: A potential crop for wet milling. Cereal Sci. Today 18:69.

Gatti, S.T., Chris, P. and Liz, V. K. 2002. The Daily News, Friday, August 23rd, 2002.

Hassan, G.H. and Mona, M.H. 2013. Sprouted Zea Mays on date palm leaves and potatoes peel waste mixture and its effects on performance of desert goats under dry season in Sinai. *(Pub), Desert Res. center, Mataria, Cairo, Egypt.*

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.

Intissar , F.A. and Eshtayeh, S.P. 2004. A new source of fresh green feed (*Hydropnic barley*) for Awassi sheep. Master in environmental sciences, faculty of graduate studies, at An-Najah National Uni., Nablus, Palestine.

Koehler, P., Hartmann, G., Weirser, H. and Rychlik, M. 2007. Changes of folates, dietary fibre and proteins in wheat as affected by germination. *J. Agric. Food Chem.,* **55** : 4678-4683.

Lewis, P. 1951. The metabolism of nitrate and nitrite in the sheep. *Biochem J.,* **49**(2) : 149-153.

Lorenz, K. 1980. Cereal sprouts composition, nutritive value, food applications. *Critical Reviews in Food Sci. Nutri.* **13**(4): 353-385.

MacKenzie, C.A. 1990. Purification of partially treated dairy manure through the intensive production of forage crops. M.Sc. Thesis, Technical University of Nova Scotia, Halifax, Nova Scotia.

Massantini, F. and Magnani, G. 1980. Hydroponic fodder growing: use of cleaner separated seed. Proceeding of 5th International congress on soil less culture.

Morsy, A.T., Abul, S.F. and Emam, M.S.A.2013. Localized hydroponic green forage technology as a climate change adaptation under Egyptian condition. *J. Agri. and Bio. Sci.* **9**(6) : 341-355.

Naik, P.K., Dhuri, R.B. and Singh, N.P. 2011. Technology for production and feeding of hydroponics green fodder. ICAR Research Complex for Goa. Extension folder. No. 45/2011.

Naik, P. K. 2012. Hydroponics technology for fodder production. I.C.A.R. News **18** (3): 4

Naik, P.K., 2012. Nutrient changes with the growth of hydroponics fodder maize. *Indian J. Anim. Nutr.***29**(2):161-163

Naik, P.K., Dhuri, R.B., Swain, B.K. and Singh, N.P. 2012c. Cost of production of hydroponics fodder maize. Proceedings of 8th Biennial Animal Nutrition Association Conference on Anim. Nutri. Res. Strategies for Food Security. **12** : 28–30

Naik, P.K., Gaikwad, S.P., Gupta, M.J., Dhuri, R.B., Ghumal, G.M. and Singh, N.P. 2013. Low cost devices for hydroponics fodder production, I.C.A.R. Research complex for Goa, Old Goa, India.

Naik P.K., Dhuri, R.B., Karunakaran, M. Swain, B.K. and Singh, N.P. 2014. Effect of feeding hydroponics maize fodder on digestibility of nutrients and milk production in lactating cows. *India J. Anim. Sci.,* **84**(8) : 880-883.

Naik, P.K., Swain B.K. and Singh N.P. 2015. Production and Utilization of Hydroponics fodder. *Indian J. Anim. Nutrition,* **32**(1) : 1-9.

Naik. P.K., Dhawaskar, B.D., Fatarpekar, Chakurkar E.B., Swain, B.K. and Singh, N.P., 2016. Nutrient changes with the growth of hydroponic cowpea sprouts. *Indian J. Anim. Nutrition,* **33** (3):357-359

Nugroho, H.D. and Idat Galih Permana. 2015. Utilization of bioslurry on maize hydroponic fodder as a corn silage supplement on nutrient digestibility and milk production of diary cows. *J. Anim. Sci. and Technology,* **38**(1) : 135-140.

Peer, D.J. and Leeson, S. 1985. Feeding value of hydroponically sprouted barley for poultry and pigs. *Anim. Feed Sci. Tech.* **13** : 83-190.

Pettersen, B.W. 1987. Ability of lettuce, rye grass and barley to reduce nutrient salt content of waste water from fish farming. *Water Sci. Technology,* **19** : 129-138.

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

Rodriguez Muela, C., Rodriguez, H.E., Ruiz, O., Flores, A., Grado, J.A. and Arzola, C. 2004. Use of green fodder produced in hydroponic system as supplement for lactating cows during the dry season. In the Proceeding of the American Society of Animal Science. pp. 271-274.

SAS. 2013. Statistical Analysis Systems, Version 9.10, SAS Institute, ICAR, New Delhi.

Scott, 2002. Nerang Hydroponic centre. *www.hydrocentre. com.au*

Shah, V.D., Makwana, M. and Sharma, S. 2011. Economics of production, processing and marketing of fodder crops in Gujarat, India *Res. Study No*. 144.

Shipard, I. 2005. How can I grow and use sprouts as living food. *Stewart Publishing.*

Singh, N.P. 2011. Technology for production and feeding of hydroponics green fodder, I.C.A.R. research complex for Goa, Old Goa

Sinsinwar,S. and Teja C., 2012. Development of cost effective , energy sustainable Hydroponic fodder production device. Project report of Agricultural Engineering Interns, IIT Kharagpur:pp.1-12

Sneath, R. and McIntosh, F. 2003. Review of hydroponic fodder production for beef cattle. Queensland Government, Department of primary Industries, Dalby, Queensland 84. McKeehen, pp. 54.

Snow, A.M., Ghaly, A.E. and Snow, A. 2008. A comparative assessment of hydroponically grown cereal crops for the purification of aquaculture waste water and the production of fish feed. *American J. Agri. and Biological Sci.* ***3*** *(1)*: 364–78.

Surve, U.S and Bhosale D.S., 2015.Effect of foliar sprays of fertilizers on growth, yield and quality of wheat. *Bioinfolet* **12**(12b):452-453

Terrill, T., Gelaye, S., Amoah, A., Miller, S., Kouakou, B., Gates, R. and Hanna, W. 1998. Protein and energy value of pearl millet grain for mature goats. *J. Anim. Sci.*, **76** : 1964-1969.

Thadchanamoorthy, S., Jayawardena, V.P. and Pramalal, C.G.C. 2012. Evaluation of hydroponically grown maize as a feed source for rabbits. Proceedings of the 22ndAnnual Student Research Session. Department of Anim. Sci. Univ. of Peradeniya, Sri Lanka.

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. *Agronomy J.* **61** : 663-665.

Ueno, M.T., Yamada, T., Hashizume, T., Mashubuchi, T. and Abe, M. 1966. Yield and nutritive values of barley seedlings grown in the grass incubator. *Bull. Natl. Inst. Anim. Ind.*, **10** : 46-48.

Van Soest, P.J.1965. Proximate analysis : Van Soest Fibre analysis. *J. Anim. Sci.* **24** : 834-843.

www.indiastat.com. Demand, supply and fodder deficit. 1995-2025.

7. APPENDICES

Appendix-I: Economic of hydroponic system

No foliar spray

Sr. No.	Operations	Treatments					
		Pearl millet (C_1)	**Yellow Maize (C_2)**	**Oat (C_3)**	**Barley (C_4)**	**Wheat (C_5)**	**White maize (C_6)**
A.	**Material cost**						
1.	Seed cost @ Rs/ kg	15	12	15	15	15	12
2.	Seed required, kg/tray	0.7	1.1	0.6	0.6	0.8	1.2
3.	Seed cost per tray @ Rs/ tray	10.5	13.2	9	9	9.6	14.4
4.	Total seed cost @ (Rs. 2825 Trays	28350	35640	24300	24300	25920	38880
5.	Soluble fertilizer applied @ Rs/ tray	-	-	-	-	-	-
6.	Total soluble fertilizer applied	-	-	-	-	-	-
B.	**Labour cost**						
7.	Soaking, cleaning spraying and maintenance	1875	1875	1875	1875	1875	1875
C.	**Electricity charges (1HP) Per season**	400	400	400	400	400	400
D.	**Land revenue, per season**	25	25	25	25	25	25
	Total (Rs)	30625	37915	26575	26575	34675	41155

Sr. No.	Operations	Treatments					
		Pearl millet (C_1)	**Yellow Maize (C_2)**	**Oat (C_3)**	**Barley (C_4)**	**Wheat (C_5)**	**White maize (C_6)**
1.	**Fixed cost**						
a.	Cost of structure	100000	100000	100000	100000	100000	100000
b.	Life of structure/ (year)	12	12	12	12	12	12
c.	Depreciation / season	1800	1800	1800	1800	1800	1800
g.	Cost of racks (Rs)	900000	900000	900000	900000	900000	900000
h.	Life of rack (years)	12	12	12	12	12	12
i.	Depreciation per season	33750	33750	33750	33750	33750	33750
2.	Repair and maintenance per season @ 2%	10000	10000	10000	10000	10000	10000
3.	Interest cost @ 10%	50000	50000	50000	50000	50000	50000
4.	Total operational cost (Rs)	95550	95550	95550	95550	95550	95550
5.	Cost of cultivation (Rs)	551250	682470	478350	478350	624150	740790
6.	Total cost of cultivation (4+5), Rs.	646800	778020	573900	573900	719700	836340
7.	Av. Yield produce, kg/ tray	4.595	5.949	2.764	2.711	5.120	5.116
8.	Total yield produce, kg	223317	289121	314330	131755	248832	248638
9.	Av. Market price (Rs/kg)	7	7	7	7	7	7
10.	Revenue, Rs. (8 x 9)	1563219	2023849	940312.8	922282.2	1741824	1243188
11.	Net profit, Rs. (10-6)	916419	1245830	366413	348382	1022124	80508
12.	B:C ratio (10/6)	2.42	2.60	1.64	1.61	2.42	1.07
13.	Payback period (years)	1.09	0.80	2.73	2.87	0.98	16.15

Urea sprayed:

Sr. No.	Operations	Treatments					
		Pearl millet (C_1)	**Yellow Maize (C_2)**	**Oat (C_3)**	**Barley (C_4)**	**Wheat (C_5)**	**White maize (C_6)**
A.	**Material cost**						
1.	Seed cost @ Rs/ kg	15	12	15	15	15	12
2.	Seed required, kg/tray	0.7	1.1	0.6	0.6	0.8	1.2
3.	Seed cost per tray @ Rs/ tray	10.5	13.2	9	9	12	14.4
4.	Total seed cost @ (Rs. 2825 Trays	28350	35640	24300	24300	32400	38880
5.	Soluble fertilizer applied @ Rs/ tray	0.01	0.01	0.01	0.01	0.01	0.01
6.	Total soluble fertilizer applied	16.50	16.50	16.50	16.50	16.50	16.50
B.	**Labour cost**						
7.	Soaking, cleaning,spraying and maintenance	1875	1875	1875	1875	1875	1875
C.	**Electricity charges (1HP) Per season**	400	400	400	400	400	400
D.	**Land revenue, per season**	25	25	25	25	25	25
	Total (Rs)	30641.50	37931.50	26591.50	26591.50	34691.50	41171.50

Sr. No.	Operations	Treatments					
		Pearl millet (C_1)	Yellow Maize (C_2)	Oat (C_3)	Barley (C_4)	Wheat (C_5)	White maize (C_6)
1.	**Fixed cost**						
a.	Cost of structure	100000	100000	100000	100000	100000	100000
b.	Life of structure/ (year)	12	12	12	12	12	12
c.	Depreciation / season	1800	1800	1800	1800	1800	1800
g.	Cost of racks (Rs)	900000	900000	900000	900000	900000	900000
h.	Life of rack (years)	12	12	12	12	12	12
i.	Depreciation per season	33750	33750	33750	33750	33750	33750
2.	Repair and maintenance per season @ 2%	1000	1000	1000	1000	1000	1000
3.	Interest cost @ 10%	50000	50000	50000	50000	50000	50000
4.	Total operational cost (Rs)	95550	95550	95550	95550	95550	95550
5.	Cost of cultivation (Rs)	551547	682767	478647	478647	624447	741087
6.	Total cost of cultivation (4+5), Rs.	647097	778317	574197	574197	719997	836637
7.	Av. Yield produce, kg/ tray	4.957	6.291	3.182	3.344	5.340	6.144
8.	Total yield produce, kg	240910	305743	154645	162518	259524	298598
9.	Av. Market price (Rs/kg)	7	7	7	7	7	7
10.	Revenue, Rs. (8 x 9)	1686371	2140198	1082516	1137628	1816668	2090189
11.	Net profit, Rs. (10-6)	1039274	1361881	508319	563432	1096671	1253552
12.	B:C ratio (10/6)	2.61	2.75	1.89	1.98	2.52	2.50
13.	Payback period (years)	5.04	3.19	-17.10	-35.48	3.17	0.80
14.	Net more profit than control (%)	20	11.4	-85.7	-320.3	6.8	27.9

19:19:19 WSF foliar sprayed

Sr. No.	Operations	Treatments					
		Pearl millet (C_1)	**Yellow Maize (C_2)**	**Oat (C_3)**	**Barley (C_4)**	**Wheat (C_5)**	**White maize (C_6)**
A.	**Material cost**						
1.	Seed cost @ Rs/ kg	15	12	15	15	15	12
2.	Seed required, kg/tray	0.7	1.1	0.6	0.6	0.8	1.2
3.	Seed cost per tray @ Rs/ tray	10.5	13.2	9	9	12	14.4
4.	Total seed cost @ (Rs. 2825 Trays	28350	35640	24300	24300	25920	38880
5.	Soluble fertilizer applied @ Rs/ tray	0.11	0.11	0.11	0.11	0.11	0.11
6.	Total soluble fertilizer applied	285	285	285	285	285	285
B.	**Labour cost**						
7.	Sowing, spraying and maintenance	1875	1875	1875	1875	1875	1875
C.	**Electricity charges (1HP) Per season**	400	400	400	400	400	400
D.	**Land revenue, per season**	25	25	25	25	25	25
	Total (Rs)	30910	38200	26860	26860	34960	41440

Sr. No.	Operations	Treatments					
		Pearl millet (C_1)	Yellow Maize (C_2)	Oat (C_3)	Barley (C_4)	Wheat (C_5)	White maize (C_6)
1.	**Fixed cost**						
a.	Cost of structure	100000	100000	100000	100000	100000	100000
b.	Life of structure/ (year)	12	12	12	12	12	12
c.	Depreciation / season	1800	1800	1800	1800	1800	1800
g.	Cost of racks (Rs)	900000	900000	900000	900000	900000	900000
h.	Life of rack (years)	12	12	12	12	12	12
i.	Depreciation per season	33750	33750	33750	33750	33750	33750
2.	Repair and maintenance per season @ 2%	10000	10000	10000	10000	10000	10000
3.	Interest cost @ 10%	50000	50000	50000	50000	50000	50000
4.	Total operational cost (Rs)	95550	95550	95550	95550	95550	95550
5.	Cost of cultivation (Rs)	556380	687600	483480	484380	629280	745920
6.	Total cost of cultivation (4+5), Rs.	651930	783150	579030	579030	724830	841470
7.	Av. Yield produce, kg/ tray	5.274	6.914	3.770	3.523	5.510	6.745
8.	Total yield produce, kg	256316	336020	183222	171218	267786	327807
9.	Av. Market price (Rs/kg)	7	7	7	7	7	7
10.	Revenue, Rs. (8 x 9)	1794215	2352143	1282554	1198524	1874502	2294649
11.	Net profit, Rs. (10-6)	1142285	1568993	703524	619495	1149672	1453179
12.	B:C ratio (10/6)	2.75	3.00	2.22	2.07	2.59	2.73
13.	Payback period (years)	0.88	0.64	1.42	1.61	0.87	0.69
14.	Net more profit than control (%)	19.8	20.6	47.9	43.8	11.1	37.8

Appendix-II: Details of meteorological data during experimental period

Date	Temperature (^0C)		Relative humidity (%)		Wind velocity (km hr^{-1})	Mean evaporation (mm day^{-1})	Rainfall (mm)
	Maximum	Minimum	Morning	Evening			
30	39.6	20.9	28	11	1.3	10.6	0.0
1	40.5	19.9	18	14	1.3	10.5	0.0
2	40.2	21.9	24	15	2.8	10.8	0.0
3	39.4	21.4	31	19	2.2	10.2	0.0
4	40.6	20.9	30	11	1.6	10.8	0.0
5	40.4	24.9	34	27	1.1	11.2	0.0
6	38.4	22.4	49	21	1.4	9.6	0.0
7	37.5	22.9	36.9	20	1.3	10.8	0.0
8	37.8	23.4	35.7	22	1.4	11.6	0.0
9	38.8	22.9	35.9	24	2.4	9.4	0.0
10	39.0	23.5	37.7	28	2.1	8.2	1.4

8. VITA

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2017

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