Low-cost hydroponic fodder production technology for sustainable livestock farming during fodder scarcity

Availability of quality green fodder has always been a challenge to livestock farmers. The green fodder deficit in India is reported to be 24.81%, which is mainly due to the decline in pasture lands in the urbanization era and vagaries in monsoon[1]. Conventional fodder crops are grown in soil which involves large land area, more manpower and huge amounts of water[2]. Alternative means to ensure fodder production for feeding livestock is an urgent priority. Hydroponic fodder production is one such technology to increase green fodder production by vertical farming which requires less land, water as well as manpower. The term 'hydroponics' was derived from the Greek word 'hydro' meaning water and 'ponos' meaning labour. This system helps overcome the challenges of climatic change and also helps in production system management for efficient utilization of natural resources and mitigating malnutrition[3]. Hence, the present study was envisaged to assess the feasibility of low-cost techniques using six experiments in a low-cost hydroponic fodder unit for the production of hydroponic green fodder for sustainable livestock farming during fodder scarcity.

A low-cost hydroponic fodder unit was designed in an area of 100 ft^2 with metal sheet as roofing material and shade net on all the sides to produce hydroponic fodder maize at the Institute of Animal Nutrition, Kattupakkam, Tamil Nadu Veterinary and Animal Sciences University. The unit consists of a four-tier system with iron angles for holding 48 plastic trays, each of dimension 60 × 40 × 8 cm and holding capacity of 1.25 kg maize seed. Fodders were cultivated in plastic trays for 9–10 days and irrigated manually with tap water six times a day.

The study was carried out at the Institute of Animal Nutrition which is located 83.2 m amsl, at 12.98°N and 79.71°E and this region generally experiences hot and humid climatic conditions throughout the year. An average of 1064 mm of rainfall is received annually, 68% of which is during the northeast monsoon. Relative humidity between 58% and 84% prevails throughout the year. Temperatures reach an average maximum of 37.5°C (99.5°F) between April and July, and an average minimum of 20.5°C (68.9°F) between December and February.

The study for customization of low-cost hydroponic techniques for fodder maize was carried out using six experiments. Experiment I was conducted to study the effect of different base materials for hydroponic fodder maize growth. Experiment II was conducted to study the effect of different roofing systems for hydroponic fodder maize growth. Experiment III was conducted to optimize the inclusion level of biogas slurry for hydroponic fodder maize growth. Experiment IV was conducted to study the effect of fluorescent lighting on hydroponic fodder maize growth. Experiment V was conducted to study the seed rate of maize on hydroponic fodder growth. Experiment VI was conducted to compare the hydroponic fodder growth from maize seeds obtained from machine and manually shelled.

Fodder maize seeds required for the experiment were procured from the local market. The seeds were subjected to germination test in seed germination trays to determine their germination potential prior to the start of each trial. During the experiment, in all the trials conducted, temperature and relative humidity inside the hydroponic fodder production unit were recorded using a thermo-hygrometer.

In experiment I, the effect of different base materials on the growth of hydroponic fodder maize was studied with

Table 1. Effect of base materials on mean fodder biomass yield per kilogram maize seed

Treatment	Fodder yield (kg)
Control (without base material)	$4.35^{b} \pm 0.12$
Paddy husk	$5.45^{e} \pm 0.06$
Wood shavings	$4.79^{cd} \pm 0.16$
Gada cloth	$4.78^{cd} \pm 0.18$
Coir pith	$4.73^{c} \pm 0.14$
Bagasse	$5.20^{de} \pm 0.12$
Uneatable leftover stems of bajra Napier grass	$4.24^{b} \pm 0.19$
Wilted *Gliricidia sepium* leaves	$2.59^{a} \pm 0.02$

Mean of six samples.
Mean values within a column bearing different superscripts vary significantly ($P < 0.05$).

Table 2. Effect of roofing systems on mean fodder biomass yield of hydroponic fodder maize

Treatments	Mean biomass yield (kg fodder/kg of maize seed)
Concrete roof	$3.20^{b} \pm 0.10$
70% shade net as roof	$3.50^{b} \pm 0.40$
Thatched roof	$3.15^{b} \pm 0.15$
Asbestos roof	$1.55^{a} \pm 0.05$

Mean of six samples.
Mean values with different superscripts within a column differ significantly ($P < 0.05$).

Table 3. Effect of graded level of biogas slurry on mean biomass yield of hydroponic fodder

Nutrient solution	Biomass yield (kg/kg of seed)
Control (without biogas slurry)	$2.56^{c} \pm 0.10$
2.5% biogas slurry	$4.48^{a} \pm 0.01$
5.0% biogas slurry	$3.56^{b} \pm 0.11$
7.5% biogas slurry	$3.53^{b} \pm 0.08$

Mean of five samples.
Mean values within a coloum bearing different superscripts vary significantly ($P < 0.05$).

Table 4. Effect of biogas slurry on nutrient composition of hydroponic fodder (maize) (% dry matter basis)

Nutrient solution	Crude protein	Crude fibre	Ether extract	Total ash	Nitrogen-free extract
Control	$9.72^{a} \pm 0.53$	$9.96^{a} \pm 0.09$	$3.30^{a} \pm 0.05$	$1.87^{a} \pm 0.05$	$74.65^{c} \pm 0.55$
Biogas slurry at 2.5%	$11.35^{ab} \pm 0.46$	$10.72^{ab} \pm 0.90$	$4.37^{b} \pm 0.07$	$3.97^{b} \pm 0.10$	$69.59^{b} \pm 0.42$
Biogas slurry at 5.0%	$13.28^{bc} \pm 0.03$	$11.44^{bc} \pm 0.63$	$4.25^{ab} \pm 0.06$	$5.23^{c} \pm 0.07$	$65.80^{a} \pm 0.80$
Biogas slurry at 7.5%	$13.72^{c} \pm 0.59$	$12.48^{c} \pm 0.62$	$4.71^{b} \pm 0.09$	$3.92^{b} \pm 0.11$	$65.72^{a} \pm 0.55$

Mean of six samples. Mean values within a column bearing different superscripts vary significantly ($P < 0.05$).

Table 5. Effect of fluorescent lighting (5 W) on mean biomass yield of hydroponic fodder (maize)

Parameter	Natural illumination	Natural illumination with additional fluorescent lighting during night
Fodder yield (kg)	4.54 ± 0.04	4.57 ± 0.10

Mean of six samples. Mean values within a row show no significant variation.

Table 6. Effect of seed rate (g/ft^2) on mean fodder biomass yield of hydroponic maize

	Seed rate (g/ft^2)		
Parameter	300	400	500
Biomass yield (kg/kg seed)	$4.16^{b} \pm 0.06$	$4.14^{b} \pm 0.08$	$3.75^{a} \pm 0.06$
Dry matter	$16.5^{a} \pm 0.50$	$17.5^{ab} \pm 0.50$	$19.0^{b} \pm 0.00$

Mean of six samples. Mean values with different superscripts within a row differ significantly ($P < 0.05$).

Table 7. Effect of mechanically and manually separated maize seeds on mean hydroponic fodder biomass

Parameter	Machine shelled	Manually shelled
Biomass yield (kg)	4.00 ± 0.20	4.41 ± 0.05
Plant height (cm)	29.25 ± 0.61	25.0 ± 0.81

Mean of six samples. Mean values within a row show no significant variation.

paddy husk, wood shavings, gada cloth, coir pith, bagasse, wilted *Gliricidia sepium* leaves, uneatable leftover stems of bajra Napier grass; Table 1 presents the results of the experiment.

Though better biomass is obtained in hydroponic fodder maize with base materials, the growth of hydroponic fodder maize resulted in entangled root portion with base materials which resulted in wastage of fodder for feeding the livestock. From this experiment, it was concluded that base materials are not needed for the growth of hydroponic fodder maize. Kide *et al.*[4] used plastic trays without base material to place the sprouted barley seeds for hydroponic fodder barley cultivation.

In experiment II, hydroponic growth trial for maize was carried out under different roofing systems, viz. concrete roof, 70% shade net as roof, thatched roof and asbestos roof. Biomass yield (kg) of hydroponic fodder maize was recorded during this study period with six replications; Table 2 presents the results.

Among the above treatments, 70% shade net as roof yielded the maximum biomass of 3.50 kg of hydroponic fodder maize. In case of thatched roof and concrete roof fodder biomass is low compared to 70% shade net, which could be due to lack of sufficient sunlight essential for photosynthesis. The least biomass yield was recorded in the asbestos roof treatment due to high maximum room temperature (40.1°C) which inhibited the hydroponic fodder maize growth.

Experiment III was conducted with biogas slurry as nutrient solution at 2.5%, 5.0% and 7.5% levels for hydroponic fodder maize production by foliar spraying method with six replications. The effect of graded levels on the mean biomass yield on hydroponic fodder maize growth was studied; Table 3 presents the results.

The recorded biomass yield at the dilution of 2.5% biogas slurry as nutrient was statistically higher compared to other treatments (4.48 kg). In contrast to this study, Nugroho *et al.*[5] produced hydroponic fodder maize with higher level of biogas slurry (25%) as nutrient solution for feeding dairy cows.

Samples (200 g) of hydroponic fodder maize in this experiment were evaluated for their moisture[6], dried to constant weight in a hot-air oven at 90°C, ground to pass through 1 mm sieve and stored in air-tight containers for analysis. The proximate compositions of the dried samples were determined according to standard methods[6] and results presented on % dry matter basis (DMB) in Table 4.

The crude protein content was higher in 5.0% and 7.5% biogas slurry compared to control and 2.5% biogas slurry. This could be due to the high level of protein/nitrogen content in nutrient solution of 5.0% and 7.5% biogas slurry group and subsequently better growth resulted in higher crude fibre in 5.0% and 7.5% biogas slurry group. The total ash content was found to increase in biogas slurry group.

Experiment IV was conducted to study the effect of fluorescent lighting (5 W) wavelength range 360–950 nm, which provided luminance of 135 lux for 12 h during night-time for the entire growth period on the biomass yield of hydroponic fodder maize (Table 5).

The biomass yield and fodder colour on visual appearance were found to be similar in both the groups. There was no effect of light observed in this trial. Morgan *et al.*[7] suggested that photosynthesis is not important for the metabolism of the seedlings until the end of day 5, when the chloroplasts are activated.

Experiment V was designed with the objective of identifying minimum seed required to obtain maximum biomass yield. Hence, different seed rates at 300, 400 and 500 g/ft^2 were tested to produce hydroponic fodder maize; Table 6 presents the results.

The biomass yield recorded after nine days was found to be significantly higher in 300 and 400 g/ft^2 compared to 500 g/ft^2. This study reveals that increasing the seed rate affects the biomass yield. Thus, 300 g/ft^2 was found to be the optimum seed rate for hydroponic fodder maize cultivation. Naik *et al.*[8] have reported that high seed density increases the chances of microbial contamination in the root mat, which in turn affects the growth of the sprouts.

Experiment VI was conducted to compare the machine and manual shelled maize seeds for biomass yield of hydroponic fodder maize; Table 7 provides the results.

The biomass yield recorded after nine days was found to be higher in manually harvested maize seeds (9%). This may be because of poor germination due to damaged seeds during machine shelling.

The optimized conditions for the growth of hydroponic fodder maize are: (i) base materials are not required; (ii) 70% shade net as roof material; (iii) 2.5% biogas slurry as a nutrient; (iv) no additional night light required; (v) seed rate of 300 g/ft^2 and (vi) usage of manual shelled maize seeds. Hence by adopting these optimized conditions, hydroponic fodder maize can be produced during fodder scarcity for sustainable livestock farming.

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Enhancing the efficiency of detached leaf method for resistance breeding in apple by considering leaf emergence phenology

Apple (*Malus × domestica* Borkh.) is the most important fruit crop of temperate regions. Jammu and Kashmir (J&K), Uttarakhand, Himachal Pradesh, Arunachal Pradesh and Nagaland are apple-producing states in India. Apple industry provides livelihood to millions of people of these states. J&K contributes about 60–65% of the total production in the country, providing livelihood security to a large section of the people of the state[1]. However, people associated with the apple industry face heavy losses (up to 70% reduction in crop production in severe cases) every year as the crop is prone to various diseases resulting in huge economic losses[2]. Alternaria leaf blotch caused by *Alternaria alternata* and apple scab caused by the fungal pathogen *Venturia inaequalis* are the two important diseases of the fruit crop. Alternaria leaf blotch of apple results in irregular light-brown spots on the leaves bordered by dark brown to purple margins[3]. The *V. inaequalis* infection results in undesirable changes in the shape and size of the fruits, affecting both appearance and quality of the infected fruits. It also leads to premature fruit fall and defoliation, besides making the tree sensitive to freezing and chilling injuries[4]. For managing these two diseases, several fungicide sprays are applied every year, which is not only expensive but also ecologically hazardous. Furthermore, residues get accumulated in the fruits, which have ill-effects on the consumers' health[5]. Consumers prefer fresh, blemish-free fruits devoid of any harmful chemicals. Resistance breeding is the best strategy to manage these diseases. The development of high-quality disease-resistant varieties is a major objective of apple breeding projects worldwide. European project HIDRAS (www.hidras.com) is a prime example. Once a disease-resistant variety is identified, it can be directly distributed to farmers provided it has fruit quality attributes that meet the demands of consumers. On the other hand, if the variety fails in terms of fruit quality attributes, it can be used in breeding programmes to transfer resistance in an otherwise susceptible variety having better fruit qualities through various breeding methods. However, the first step is the identification of disease-resistant varieties (sources). This calls for screening of the germplasm. Such screening is carried out at both phenotypic as well as genotypic levels. For genotypic screening, markers closely linked to disease resistance genes are used[6]. Phenotypic screening is carried