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Productivity and water use efficiency and nutritional composition of yellow maize fodder under hydroponic condition

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Abstract
The objective of the study was to assess the productivity, water use efficiency and nutritional composition of yellow maize fodder under hydroponic conditions. The low cost hydroponic device fabricated at TANUVAS has been utilised for the study. 6 replicates with a seed rate of 5.26 kg/m^2 have been utilized for the study. Parameters such as total fresh and dry fodder yield, seed to fodder ratio, root and shoot biomass yield, total water use, water use efficiency and nutritional composition were studied. The fresh and dry fodder yield of yellow maize fodder under hydroponic condition was found to be 240.61±1.08 ton/ha and 39.89±0.44 ton/ha. Seed to fodder yield was 4.57±0.15 and root and shoot biomass yield were 66.67±0.52% and 33.33±0.52%. The total water use was 6.99±0.25 litres/tray and 1.53±0.14 litre /kg fresh matter for the 8 day growth period. The water use efficiency was 656.55±2.99 kg fresh matter/m^3 and 108.86±1.22 kg dry matter/m^3. It is concluded that about 1.5 litres of water are required for the production of 1 kg fresh yellow maize fodder under hydroponic conditions.

Keywords: Hydroponic fodder, low cost hydroponic device, nutritional composition productivity, water use efficiency

Introduction
Agriculture was the most critical sector under global climate change impacts. Natural water resources are affected by global climate change so food production and sustainability are endangered [1]. It's expected that the global climate change causes a negative impact on the grazing lands in the arid and semi-arid regions [2]. [3] was interested in the concept of putting one kilogram of grain into a hydroponic system and producing 6 to 10 kilograms of fresh green sprouts, independent of weather and at any time of year. Hydroponic fodder production is a method of fodder production, in which fodder seeds are germinated into a high quality, highly nutritious, disease-free animal food in a hygienic environment [4, 5]. Hydroponic fodder production takes place in an intensive hydroponic growing unit in which only water and nutrients are used to produce nutrient-rich grass and root combination [6].
Reducing agricultural water use, while maintaining or improving economic productivity of the agricultural sector is a major challenge in arid and semi-arid regions. Irrigated agriculture is the major consumer of freshwater supplies in many parts of the world, particularly in relatively arid and semiarid regions [7]. [8] reported that only about 2-3% of the water used under field conditions is required for the production of the same amount of fodder under hydroponic method. 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 [9, 10]. It is of high feed quality, rich with proteins, fibre, vitamins, and minerals [11, 12, 13]. Due to these special features, the hydroponic fodder production method is now 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 [7].
The objective of this study was to assess the productivity, water use efficiency and nutritional composition of yellow maize fodder under hydroponic conditions.

Materials and Methods
Low cost hydroponic device
The study was conducted using the low cost hydroponic device fabricated by the researchers of Tamil Nadu Veterinary and Animal Sciences University (TANUVAS), India. It is a semi-automated device which has to be operated manually for watering the plants. The device is made up of 90% shade net on all sides mounted on a metal frame. It consists of two sections each in turn consist of 8 rows which correspond to the 8 days of growth period. Each row can hold 3 trays of 2 ft length, 1ft width and 1-inch depth.

Each row is fitted with 3 misting device corresponding to each tray for irrigation. A separate water tank of 500 litres capacity has been utilised for storage of water. One exhaust fan has been fitted at the rear end for air circulation.

Production of hydroponic maize fodder

6 different trays with yellow maize seed at the rate of 5.26 kg/m^2 have been utilized for the study. Good quality seeds with less than 12% moisture were selected and weighed. Seeds were washed in tap water by stirring with a wooden stick manually to remove chaffs and specks of dirt. The seeds were then soaked in tap water for 20 h. Then water was drained and the seeds were kept in gunny bags for 24 h for germination. After germination, seeds were weighed and placed onto different trays and kept on the sprout section of hydroponic green fodder machine. The trays were shifted to the next rack daily. After 8 days of the total growth period in the device, the fodder was taken out on the 9th day, weighed for productivity.

Fodder yield

The experiment was terminated after 8 days from seeding when the fodder biomass was ready for harvest. At harvest time, the following data were recorded per tray: Total fresh fodder yield and ratio of produced green fodder: initial seeds weight.

Biomass yield of hydroponic maize fodder

The shoot and root biomass of hydroponic maize fodder were quantified using a weighing balance. Six samples of 500 g each were taken. The shoots were separated from the roots and seeds by cutting at the base of the hypocotyls. The weight of root and shoot were quantified separately and the same was repeated for the remaining samples. The root and shoot biomass were calculated using the formula

$$\text{Root /Shoot biomass yield (\%)} = \frac{\text{Total root/shoot biomass (g)}}{\text{Total biomass (g)}} \text{ X } 100$$

Assessment of water use efficiency

Water was sprinkled over the trays through the misting device for 5 times a day @ rate of 900 ml/tray at a time. The water drained after irrigation has been collected to compute total water usage. The total water used by plants (litres/tray) was calculated according to the equation given by [7]:

Total water use = Total added water in irrigation − Total drained water out of rays.

Water use efficiency (WUE) in kg fresh weight/m^3 water was computed according to the equation given by [7]:

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

Nutritional composition of hydroponic maize fodder

Proximate composition, micro minerals, macro minerals and vitamin E analysis were carried out as per AOAC, (2005).

Data analysis

Data from six replicates were collected. The mean and standard error were computed using MS excel 2007.

Results and Discussion

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 hydroponics fodder or sprouted grains or sprouted fodder [14]. Hydroponics green fodders are produced under controlled environment in greenhouses within a short period [15]. In hydroponics fodder germinated were seeds embedded in the root system plants without any nutrient wastage and is highly palatable [16]. Based on the type of grains, the hydroponics fodder looks like a mat of 11-30 cm height by the end of the germination period of about 8-days consisting of germinated seeds embedded in their white roots and green shoots [17, 18, 19, 20]. Productivity, fodder yield to seed ratio and biomass yield of hydroponic maize fodder was given in Table 1.The fresh yield of 3.5- 6.0 folds in 7-8 days with DM content of 10.3-18.5% in maize fodder has been reported [20, 15]. However, 4.57 folds fresh yield of maize fodder was observed during our experiment and it is following the report of [21]who observed a biomass yield of 4.55±0.08 kg/kg of seed in hydroponic fodder maize using a low cost hydroponic device under Tamil Nadu conditions. The average green fodder yield was 240.61±1.08 ton/ha in one production cycle (8 days).

Table 1: Fresh and dry fodder yield, ratio of seed to fodder yield and biomass yield of yellow maize fodder under hydroponic conditions

Replicate	Fresh fodder yield (ton/ha)	Dry fodder yield (ton/ha)	Seed: fodder yield	Root biomass (%)	Shoot biomass (%)
1	248.95	41.28	4.73	66	34
2	237.37	39.36	4.51	68	32
3	228.95	37.96	4.35	66	34
4	241.05	39.97	4.58	68	32
5	245.79	40.75	4.67	64	36
6	241.58	40.05	4.59	68	32
Mean±SE	240.61±1.08	39.89±0.44	4.57±0.15	66.67±0.52	33.33±0.52

The root and shoot biomass yield of hydroponic maize fodder observed in the present study were in accordance with [22] and [23] who reported root biomass of 70±0.52%, 68.58% and shoot biomass of 30±0.49, 31.42%, respectively in hydroponic maize fodder. The higher root biomass in hydroponic maize fodder is due to the presence of root mat along with seeds.

Water is one of the basic requirements for seed germination and seedling growth as it is essential for enzyme activation, reserve storage breakdown, translocation, and use in seed germination and seedling growth [24]. [7] stated that hydroponically produced fodder was found to enhance the efficiency of water use (WUE). [25] reported that hydroponic green fodder production technique requires only about 10–20% of the water needed to produce the same amount of crop in soil culture. [8] reported that only 3–5% of water is needed to produce the same amount of fodder compared to that produced under field conditions. Total water use and water use efficiency of hydroponic maize fodder were given in Table 2. In this study, the total water use per tray was 6.99±0.25 litres for the 8 day growth period. In other words, 1.53±0.14 litres of water are required for the production of 1 kg of fresh yellow maize fodder under hydroponic conditions. The total water use observed for maize in the present study

was lower than that reported by [7] for alfa alfa, barley, cowpea, wheat and sorghum hydroponic fodders. The water use efficiency was 656.55±2.99 kg fresh matter/m^3 and 108.86±1.22 kg dry matter/m^3. The water use efficiency in terms of kg fresh matter/m^3 observed in the present study for yellow maize is higher than those reported by [7] for alfa alfa, barley, cowpea, wheat and sorghum hydroponic fodders. However, the water use efficiency in terms of kg dry matter/m^3 observed for yellow maize in the present study is higher than alfa alfa, wheat and cowpea and lower than barley and sorghum as reported by [7].

Table 2: Total water use and water use efficiency of yellow maize fodder under hydroponic conditions

Replicate	Total water use		Water use efficiency	
	Litres/tray*	Litres/kg fresh matter	kg fresh matter/m^3	kg dry matter/m^3
1	6.31	1.33	749.60	124.28
2	7.10	1.57	635.21	105.32
3	7.35	1.69	591.84	98.13
4	7.30	1.59	627.40	104.02
5	6.98	1.49	669.05	110.93
6	6.89	1.50	666.18	110.45
Mean±SE	6.99±0.25	1.53±0.14	656.55±2.99	108.86±1.22

Table 3: Nutritional composition of hydroponic yellow maize fodder

Parameters	Hydroponic maize fodder (%)
Moisture	83.42
DM	16.58
CP	12.44
EE	2.65
CF	9.49
TA	2.77
NFE	72.65
TDN	82.22

The nutritional composition of hydroponic yellow maize fodder (Table 3) observed in the present study was slightly lower than that reported by [26] who observed the DM content of the hydroponically sprouted maize grains as 18.30% and the CP, EE, CF, NFE, TA and AIA content (on % DM basis) as 13.30, 3.27, 6.37, 75.32, 1.75 and 0.57, respectively.

Thus, green fodders production by the hydroponic method is a highly efficient process in terms of water-saving when compared to field fodder production. Hence, the hydroponic system could play a significant role in improving water use efficiency in countries that suffer from the scarcity of water.

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