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Biomass Production, Yield Attributing Characteristics and Nutritive Value of Maize Hydroponics in Rampur, Chitwan

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Abstract

This study examined the biomass production, yield attributing characteristics and nutritive value of maize hydroponics at Chitwan, Nepal from 23, March 2021 to 4, April 2021. Five improved varieties of maize were arranged in Completely Randomized Design (CRD) with five treatments as T1 (Manakamana6), T2 (ZM 401), T3 (Manakamana 3), T4 (Arun 2) and T5 (Deuti), each replicated five times. Sample were collected on the 12th day for proximate nutrient analysis. Morphological characteristics assessment and Biomass yield analysis was performed at the day of harvesting. Data were subjected to analysis of variance by Minitab 2017 and Duncans Multiple Range Test was used for mean separation at 5% level of significance. The whole plant green and dry biomass yield (Kg/m^2) was significantly higher ($p<0.01$) in ZM 401 than other varieties while Manakamana-03 was the tallest ($p<0.001$) maize variety. Similarly, ZM 401 was superior in terms of nutrient composition too with CP (10.44%), CF (29.55%), OM (94.64%) and total ash (5.36%). Specifically, Arun 2 contained higher CP (11.31%) but were poor from biomass yield view point. The result showed that the crude protein content of root and shoot of different maize varieties were similar while crude fibre and total ash were higher ($p<0.01$) in shoots but organic matters in root (($p<0.05$). Therefore, these findings collectively underscore ZM 401 as a standout choice for maize hydroponics due to its superior biomass yield and favorable growth attributes, potentially informing cultivation decisions for optimized hydroponic maize production.

Keywords: hydroponics, maize, biomass production, yield

INTRODUCTION

Green fodder are the vital inputs in livestock husbandry as it provides required nutrients for milk and meat production and helps maintain the health of the animals (Erickson & Kalscheur, 2020)). Green fodder and forages are the natural feeding materials for animals which improves the fat percentage of milk through rumen digestion and production of volatile fatty acids (VFAs). Further, the green leaves are enriched with beta-carotene that helps in vitamin-A synthesis and plays greater role on animal reproduction. Livestock sector contributes about 11.5 % of the total GDP (MoALD, 2019) and 25.7 % of the agricultural GDP (MoAD, 2014) and plays a major role in the lives of small and marginal farmers and of landless labours agriculture-based economy. Feeding cost in livestock husbandry impacts the farmers profit so results in successful livestock farming, if concentrates are saved. At this context, green fodders are reported to constitute 13 to 35 % of the total input cost, out of total feed cost of about 70 to 75% of the farming ((Ramteke *et al.*, 2019)). Thus, availability and supply of green fodder round the year is required for good dairy practices.

The National Dairy Development Board (NDDB) recommends that a cow yielding 8 to 10 litres of milk per day must be fed 25 to 30 kg of green fodder, 4 to 5 kg of dry fodder and 4.0 to 4.5 kg of concentrate daily during the complete lactation (Jahagirdar & Saha, 2007). The unavailability of quality green fodder adversely affects the productive and reproductive efficiency of the livestock. Besides, the less availability of land, more labour for cultivation (sowing, earthing up, weeding, harvesting etc.), more time for harvesting, shortage of same quality around the year, requirement of manure and fertilizer; the uncertainty of rain fall, water scarcity and natural calamities due to climate change are the major constraints for green fodder production encountered by the livestock farmers.

Due to the aforementioned constraints and short comings in green fodder production, the hydroponics technology is coming up as a revolutionized alternative to produce and supplement fodder for farm animals. Further, hydroponics technology for fodder production had been very effective for rearing small ruminants (sheep and goats) as these animals have lesser DM requirement and could be being shifted from extensive to intensive rearing system. It is a science of growing plants in nutrient broth under controlled environment conditions without soil (Bakshi *et al.*, 2017) and can be efficiently used to take pressure off the land to grow green feed for the livestock. This green source claims an increment of 8-13% in milk production and are the best alternative technology for livestock and dairy animals with low-cost materials in places where conventional green fodder production is limited (Prafulla *et al.*, 2015). There is renewed interest in this technology due to shortage of green fodder in most of the Asian, Middle East, and African countries.

The history of hydroponic green is not a novel concept but dates back to the 1800s (Kerr *et al.*, 2014), when European farmers fed sprouted grains to their cows during winter to maintain milk production and improve fertility. The two Greek words: ‘hydro’ meaning water and ‘ponos’ meaning labour or water working rooted out the hydroponic. It is a sustainable and eco- friendly alternative for smallholder farmers for fodder production without soil. Fresh fodder biscuits, sprouted fodder or sprouted grain or alfa-culture are the alternative names for this hydroponic (Dung *et al.*, 2010a). Fodder crops like maize, barley, oats, sorghum, rye, alfalfa, jowar and triticale can be produced by hydroponic technology (Rachel Jemimah *et al.*, 2015). This fodder seems like a mat with probably a height of 20-30 cm consisting of roots, seeds and plants with highly palatable, digestible and nutritious for animals. In high-cost hydroponics, fresh water is used for irrigation of the hydroponic fodder by using manual or automatic micro-sprinklers or a sprayer at frequent intervals. In low-cost hydroponic systems, the internal environment of the greenhouse is more influenced by the outside climatic conditions (Bakshi *et al.*, 2017).

Hydroponics is growing of cereal grains with necessary moisture, nutrient without solid growing medium. Germination is a response for the supplied moisture and nutrient and produce 20-30 cm long forage green shoot with interwoven roots within 7-10 days. Different cereal grains i. e., maize, bajra, millets, etc. can be used for fodder production with varied chemical and structural changes throughout the growing processes. Grain variety, quality, treatments like nutrient supply, pH, water quality, soaking time etc are influencing factors for the amount of sprouted and quality fodder (Sneath & McIntosh 2003). Under hydroponic system, this equates to only 2-5% of water used in traditional fodder production (Al-Karaki & Al-Momani, 2011; Naik, 2014).

Maize is the second most important crop after rice in terms of area and production in Nepal and a traditional crop grown for food, feed, and fodder. Demand maize has been constantly growing by about 5% annually in the last decades (Sapkota & Pokhrel, 2010) in Nepal. Per capita maize consumption in Nepal was 98 g/person/day (Ranum *et al.*, 2014). Therefore, total quantity of maize requirement for food per year is around 2.9 million mt and the production during 2014 was 2.283million mt, hence the deficit was 0.67 million mt. The feed demand is also increasing at the rate of 11% per annum. There is a need of about 6.46 million mt. feed to run smoothly the existing livestock and poultry industries in Nepal, but just about 0.5 million mt. of feed has been produced annually by the feed industries in Nepal (114, registered in NFEA). Thus, the demand for maize is also shifting from food to feed for livestock and poultry. For foods, new types of maize-based products such as soups, vegetables, edible oils are in demand. Under such circumstances, the import substitution can only be done by increasing the productivity of maize with the available shrunken land. Winter maize under rice-wheat system has been emerging as a new intervention and it can be an option to increase the maize production in Nepal. The area under winter maize in eastern and central Terai is increasing year after year. It is due to the increasing demand of maize for livestock and poultry feed. Similarly, winter maize yields are higher due to lower risk of pests and diseases and higher production of CHO/day/unit land among the cereals. Furthermore, the farmers are solely dependent on multinational hybrids. If the international suppliers fail to supply the hybrid seeds, farmers will be prone to leave growing maize during winter

Due to seasonality, less availability and quality issue, the maintenance of production and productivity of animals cannot be maintained year-round. Availability of green fodder is getting weakened due to severe climate change, unavailability of enough land, deterioration of fertile soil and water resources, competition between fodder and cereal crops, but green fodder demand among the farming community is continuously increasing bringing about rise in its cost. Therefore, it is important to explore and develop the possibility of improved fodder production technique. In this context, hydroponic cultivation is an eco-friendly method of growing green fodder as hydroponically grown cereals grow up to 50% faster and produce higher yields of better-quality. Hydroponic growing is a privilege and free of soil, chemical fertilizer, herbicides and pesticides, producing 10 times the amount of conventional fodder as a traditional farming. It has been reported that about 1.5-2 L of water is needed to produce 1 kg of green fodder through hydroponic in comparison to 73, 85, and 160 L to produce 1 kg of green fodder of barley, alfalfa, and Rhodes grass under field conditions, respectively which equates to only 2-5% of water used in traditional fodder production.

Nutritional value of hydroponic fodder was reported finer due to the modification of heterogeneous compounds into intelligible and essential form by minimizing the effect of antinutritional factors while sprouting. Sprouting of grains results increase in quantity and quality of protein, sugars, minerals and vitamin whereas total starch and dry matter had been reduced. There is a great nutritional benefit provided by hydroponic fodder to optimize the general health and performance of young animals while minimizing feed costs. A hydroponic system allows the cultivator to target the root system very easily, precisely and directly while producing quality fodder. The interference of soil-borne adulterants and compounds is totally eliminated in a hydroponic cultivation system. This technology is especially important in areas suffering from chronic water shortages or where the infrastructure for irrigation does not exist. Therefore, the types of fodder to be grown hydroponically depend upon the season and climatic condition of the locality/region. The seeds sprout within 24 h and grow up to 20-30 cm in 7-8 days, when they are ready for harvest and feeding. Thus, the study was designed to evaluate the biomass production, yield attributing characteristics and nutritive value of maize hydroponics in Rampur, Chitwan in an attempt to work out the alternative green mass production potential for livestock feeding.

MATERIALS AND METHODS

Study area and seeds

The study was conducted in National Cattle Research Programme (NCRP), Rampur, Chitwan (at geographical coordinates 27.5291^{0}N to 84.3542^{0}E) from 23, March 2021 to 4, April 2021, after approval from the Nepal Agriculture Research Council, Kathmandu, Nepal. The five improved varieties of maize used in the study were with purity 92% having 12% moisture and 95% germination capacity.

Experimental Design

The experimental trial was conducted in Completely Randomized Design (CRD) having 5 treatments as T1 (Manakamana6), T2 (ZM 401), T3 (Manakamana 3), T4 (Arun 2) and T5 (Deuti) which was replicated 5 times.

The Hydroponic System

The experiment was conducted in semi-closed hydroponic unit, established in NCRP facility. The unit consists of the straight line or parallel type tray racks having the capacity to cover 100 metallic trays (3.4ft × 1.18ft × 0.15ft). This system was constructed as semi- intensive facility using 75% shed net and the remaining 25% was used for proper aeration. To manage and control internal temperature and humidity of the green house, proper spraying of water was carried out 3 times daily manually and a range of 22 – 27^{o} C and up to 70% relative humidity was maintained for full experimental duration.

Seed treatment, Planting and Irrigation

The seeds were treated and cleaned from common debris and other foreign materials. The germination trays were also cleaned and disinfected thoroughly using clean tap water and kept dry. The seeds were then washed well from residues and soaked in tap water overnight (about 12 hours) before sowing. Seeds were weighed properly and were sown in the planting trays which have holes at the bottom to allow drainage of excess water from irrigation. Thereafter, soaked seeds were spread on the hydroponic tray to 1.5 – 2.0 cm thickness at the rate of 3 Kg seeds per tray. Trays were irrigated manually with automatic sprinkles thrice a day (early in the morning, afternoon, and evening)

Morphometrics and Proximate Nutrient Analysis

Five plants were selected from each tray for the purpose of data collection and morphometric measurement of plant height, number of leaves, leaf length and leaf width and was carried out as described by Easlon & Bloom (2014). Whole biomass, shoot biomass, root biomass was measured and fresh samples (250 gm) were taken from each tray for proximate nutrient analysis. Physical parameters like plant height, no. of leaves, leaf length, leaf width, whole biomass, shoot biomass were recorded on the 12th day. The proximate nutrient analysis was carried out according to AOAC (1990).

Statistical Analysis

The data collected from the field was entered in Microsoft excel 2010 and were subjected to analysis of variance by Using Minitab 2017. Means were separated by using Duncans Multiple Range Test at 5% level of significance.

RESULTS

Biomass yield of different maize varieties in hydroponics

The green and dry biomass yield (kg/m^2) of root, shoot, and whole plants of maize hydroponics is presented in Table 1. The whole plant green biomass yield (Kg/m^2) was significantly higher (p<0.01) in ZM 401 (12.62) than that of other varieties. In same way, Deuti (10.95) was found to produce higher (p<0.01) than that of Manakamana 6 and Arun 2 but was similar with Manakamana 3 in terms of whole green biomass yield. Arun 2 performed worst in terms of green mass total yield. In terms of root and shoot green biomass yield, ZM 401 (9.00 and 3.36) was found to outperform (p<0.01) all other verities; Deuti and Manakamana 3 were the next good yielders whereas Arun 2 and Manakamana 6 were observed to produce the least green biomass. The whole plant dry biomass yield (Kg/m^2) is significantly higher

($p<0.01$) in ZM 401 (3.24) than that of other varieties, except with Deuti (3.10), proving the best candidate for maize hydroponics. In same way, dry biomass yield of Manakamana 3 was found similar to Manakamana 6 but were observed higher ($p<0.01$) than that of Arun 2. In terms of root and shoot dry biomass yield, ZM 401 (2.71 and 0.53) was found to have the significant performance ($p<0.01$) than all other verities; Deuti and Manakamana 3 were the next good candidate for maize hydroponics technology whereas Manakamana 6 and Arun 2 were observed to produce the least.

Table 1. Biomass Yield (mean±SE) of different varieties of maize hydroponics at NCRP, Rampur Chitwan

Varieties	Green Biomass Yield (Kg/m^2)			Dry Biomass Yield (Kg/m^2)		
	Shoot	Root	Whole	Shoot	Root	Whole
Manakamana 6	0.66 ± 0.06^{c}	5.77 ± 0.08^{d}	6.53 ± 0.15^{c}	0.11 ± 0.01^{c}	2.16 ± 0.06^{ab}	2.27 ± 0.06^{bc}
ZM 401	3.36 ± 0.17^{a}	9.00 ± 0.30^{a}	12.62 ± 0.50^{a}	0.53 ± 0.02^{a}	2.71 ± 0.18^{a}	3.24 ± 0.09^{a}
Mankamana 3	2.54 ± 0.19^{b}	7.12 ± 0.20^{c}	9.77± 0.36^{b}	0.38 ± 0.02^{b}	2.55 ± 0.21^{ab}	2.94 ± 0.22^{ab}
Arun 2	0.09 ± 0.01^{c}	4.49 ± 0.06^{e}	4.66 ± 0.05^{d}	0.02 ± 0.00^{d}	1.86 ± 0.09^{b}	1.88 ± 0.09^{c}
Deuti	2.73 ± 0.17^{b}	8.04 ± 0.24^{b}	10.95 ± 0.35^{b}	0.44 ± 0.02^{b}	2.66 ± 0.29^{a}	3.10 ± 0.29^{a}
F value	99.24	78.69	99.43	143.20	3.79	9.31
P value	0.000	0.000	0.000	0.000	0.019	0.000
Sig. level	**	**	**	**	*	**

Means in the column with different superscripts differ significantly. ^{ns} not significantly different, * significant at 5% ($p<0.05$) and ** significant at 1% ($p<0.01$).

Dry matter content of root and shoot of maize hydroponics

The dry matter content of root was documented the highest in Arun 2 (37.4 %) and the lowest (30.2%) in ZM 401 while that of shoot was maximum in Arun 2 (18.2%) and minimum in Manakamana 3 (15.2%) (Table 2). Mankamana 6 maize variety was also observed to be appropriate from root (37.4%) and shoot (16.8) dry matter yield view point for fodder production through the maize hydroponics.

Table 2. Dry matter content of root and shoot of different maize varieties in hydroponics at NCRP, Rampur Chitwan

Varieties	DM (%) Root	DM (%) Shoot
Manakamana 6	37.4	16.8
ZM 401	30.2	15.8
Mankamana 3	35.8	15.2
Arun 2	41.6	18.2
Deuti	33.4	16.4

Proximate nutrient composition of different parts of maize hydroponics

The result showed that Deuti (11.31%) and ZM401 (10.44%) maize varieties were rich in term of the shoot crude protein content and Manakamana 3 (7.97%) was observed to have lowest CP content (Table 3). Similarly, CF content was observed highest in Manakamana 3 (30.40%) and ZM 401 (29.55%) and lowest in Deuti variety (20.96%). Interestingly, Arun 2 variety was observed to contain the highest amount of organic matter (98.69%) with minimum ash content (1.31%), others were found to have almost similar properties in term of OM and ash content in shoot of maize hydroponics.

Table 3. Proximate nutrient composition of shoot of different maize varieties in hydroponics at NCRP, Rampur Chitwan

Varieties	CP (%)	CF (%)	OM (%)	Total Ash (%)
Manakamana 6	8.98	21.93	91.80	8.20
ZM 401	10.44	29.55	94.64	5.36
Mankamana 3	7.97	30.40	94.18	5.82
Arun 2	9.03	22.27	98.69	1.31
Deuti	11.31	20.96	91.05	8.97

The result showed that Manakamana 3 (11.51%) and Deuti (9.64%) maize varieties were of high quality in term of root crude protein content and Manakamana 6 (7.26%) was observed to have lowest crude protein content (Table 4). Similarly, CF content was documented highest in ZM 401 (10.43%) and lowest in Manakamana 6 (3.69%) and Arun 2 (4.30%) maize variety. Interestingly, Arun 2 (98.96%) and Manakamana 6 (98.89%) were observed to contain the highest amount of organic matter with lowest ash content (1.31%) in root of maize hydroponics. The lowest organic matter content was evident in ZM 401 (97.91%) in root of maize hydroponics.

Table 4. Proximate nutrient composition of root of different maize varieties in hydroponics at NCRP, Rampur Chitwan

Varieties	CP (%)	CF (%)	OM (%)	Total Ash (%)
Manakamana 6	7.26	3.69	98.89	1.11
ZM 401	9.05	10.43	97.91	2.09
Mankamana 3	11.51	9.50	98.45	1.55
Arun 2	8.04	4.30	98.96	1.04
Deuti	9.64	9.33	98.48	1.52

The result showed that the crude protein content of root and shoot of different maize varieties in maize hydroponics were statistically similar while crude fibre content was observed significantly higher

($p<0.01$) in shoots but organic matters in root (($p<0.05$; Table 5). Similarly, the shoots were documented to have higher ($p<0.05$) amount of the total ash as compared to root in maize hydroponics.

Table 5. Proximate nutrient composition of different parts of maize varieties in hydroponics at NCRP, Rampur Chitwan

Plant parts	CP (%)	CF (%)	OM (%)	Total Ash (%)
Shoot	9.45 ± 0.59	25.02 ± 2.04^{a}	94.07 ± 1.34^{b}	5.93 ± 1.34^{a}
Root	9.10 ± 0.73	7.25 ± 1.37^{b}	98.54 ± 0.19^{a}	1.46 ± 0.19^{b}
F-value	0.23	52.30	10.88	10.88
p-value	0.647	0.000	0.011	0.011
Sig-level	Ns	**	*	*

Means in the column with different superscripts (^{abc}) differ significantly. ^{ns}not significantly different, * significant at 5% ($p<0.05$) and ** significant at 1% ($p<0.01$).

Morphological character of different maize varieties in hydroponics

The morphological character of different maize varieties in hydroponics at National Cattle Research Programme, Rampur Chitwan is portrayed in Table 6. The plant height was observed significantly higher ($p<0.01$) in the Manakamana 3 (22.06 cm) than all other varieties except for Deuti (19.55 cm). The plant height of Mankamana 6, ZM 401, Arun 2 and Deuti were non- significantly different, though the lowest height was documented in ZM 401. Interestingly, the higher number of leaves ($p<0.05$) was documented in the Mankamana 6 (3.24) as compared to Deuti and Arun 2 but was similar with Manakamana 3 and ZM 401. The lowest number of leaves was observed in Arun 2 and Deuti signalling the poor performances in term of green biomass production in maize hydroponics. The leaf width was found significantly broader ($p<0.05$) in Deuti (1.37 cm) as compared to Manakamana 3 but was comparable with other three maize varieties in hydroponics.

Table 6. Morphological character of different maize varieties in hydroponics at NCRP, Rampur Chitwan

Varieties	Plant height (cm)	Leaf Number	Leaf length (cm)	Leaf width (cm)
Manakamana 6	18.78 ± 0.69^{b}	3.24 ± 0.11^{a}	11.88 ± 0.43	1.23 ± 0.03^{b}
ZM 401	18.54 ± 0.65^{b}	3.00 ± 0.60^{ab}	12.84 ± 0.51	1.27 ± 0.04^{ab}
Mankamana 3	22.06 ± 0.54^{a}	3.04 ± 0.04^{ab}	14.77 ± 0.39	1.29 ± 0.03^{ab}
Arun 2	19.39 ± 0.71^{b}	2.92 ± 0.05^{b}	12.72 ± 0.51	1.25 ± 0.03^{ab}
Deuti	19.55± 0.62^{ab}	2.92 ± 0.08^{b}	16.14 ± 2.74	1.37 ± 0.03^{a}
F. value	4.67	3.41	1.79	2.52
P. value	0.002	0.01	0.134	0.04
Sig. level	**	*	Ns	*

Means in the column with different superscripts (^{abc}) differ significantly. ^{ns}not significantly different, * significant at 5% (p<0.05) and ** significant at 1% (p<0.01).

DISCUSSION

The fresh biomass yield productivity (4.21 to 2.29/Kg) per initial seed used observed in the present study was lower to that reported by Naik & Singh (2013) and Jemimah *et al.* (2018) who obtained 5 to 6 kg and 4.6 kg of hydroponic maize fodder per kg seed used, respectively. Al-Ajmi *et al.* (2009) also reported 2.76 and 5.7 kg green fresh fodder yield per kg of barley seed, which is similar with the result obtained in the present work. It was also lower to the value (6 to 10 kg of fodder per kg of maize seed) reported by Sneath & McIntosh (2003). The variation in fodder yield could be attributed to the differences in the varieties of maize used or differences in the extents to which the environmental factor such as humidity and temperature might have been fully controlled since they had used commercial fodder units. In hydroponics, fodder production is accelerated bringing the nutrients directly to the plants, without developing large root systems to seek out food. Plants mature faster and more evenly under a hydroponic system than a conventional soil-based system (Baksi *et al.*, 2017). 1 kg of unsprouted seed yields 8-10 kg green forage in 7-8 days (Sneath & McIntosh, 2003; Naik *et al.*, 2013b; Reddy, 2014; FAO, 2015; Kamanga, 2016). Thus, hydroponics maize fodder yield on fresh basis is 5-6 times higher than that obtained in a traditional farm production, and is more nutritious (Naik *et al.*, 2014).

Considering the total net productive area of the shade (1.03×0.36m area with 3 floor shelves that accommodate 100 trays of 0.37 m^2) and 12 days cycle of hydroponic fodder production at a productivity potential of 11.38 to 6.18 kg/m^2, a total of 0.26 to 0.14 tons of fresh hydroponic fodder can be harvested from the present hydroponic system in 9 dry months of the area. Under conventional farming, the average fresh forage biomass produced from maize was reported to be 28.43 to 30.67 tons/ha at planting space of 75 and 35.5 cm, respectively (Dicu *et al.*, 2016), which is equivalent to 2.24 to 3.07 kg/m^2 of land area. With 3 cycles year production, only about 6.84 to 9.21 kg fresh fodder can be produced per m^2 of land under conventional farming indicating high efficiency of hydroponic fodder production in terms of land utilization. Based on the observed productivity in the present experiment, an area of 0.5 to 0.6 m^2 land is sufficient to produce 10 kg fresh fodder required for a cow per day indicating even such a small size hydroponic fodder units are enough for saving expense on material depreciation and opportunity cost of the space. The area requirement can be reduced if production per unit area is more maximized. In this regard, Kamanga (2016) reported that 1 m^2 space was enough to produce fodder for 2 cows per day.

The dry matter content of hydroponic maize fodder in this experiment was comparable with the values of 16.8%,15.8%,15.2%,18.2% and 16.4% to 23.25 % DM content of maize hydroponic fodder reported by Gebremedhin (2015), Dadhich (2016) and Jemimah *et al.* (2018). Varieties differ in DM content, and the reason for variation among varieties in DM percentage of hydroponic fodder may be due to the difference in growth rate which is also related to the rate of conversion of starch stored in the seed into a simple sugar, which produces energy and gives off carbon dioxide and water (Bakshi *et al.*, 2017).

Several authors reported that the type of crops mainly influence the fresh yield and dry matter (DM) content of the hydroponic fodder. Besides, days of harvesting, degree of drainage of free water before weighing, type and quality of seed, seed rate, seed treatment, water quality, irrigation frequencies, growing period, temperature, humidity, hygienic condition of the greenhouse also affect the fresh yield and dry matter (Trubey & Otros, 1969; Sneath & McIntosh 2003; Dung *et al.*, 2010b; Fazeli *et al.*, 2012).

The CP content of shoot hydroponic maize fodder in this study was found to be 7.97% to 11.31% and 7.26% to 11.51% was of root which was comparable with the value (8.72 to 17.55) reported by Jemimah *et al.* (2018) but lower than the 13.3% reported by Naik *et al.* (2014) and 14.56 % reported by Gebremedhin (2015). The variation may be due to the differences in variety of maize used for hydroponic fodder production. The reduction in dry biomass yields due to changing the grain to hydroponic fodder was also reported by Sneath & McIntosh (2003), Dung *et al.* (2010a) and Putnam *et al.* (2013) for different crops. The loss in weight may be due to leaching of soluble carbohydrates and respiration. The conversion of starch stored in the seed by soaking activated enzymes in endosperm to a simple sugar produces energy and gives off carbon dioxide and water (Assefa *et al.*, 2020). This process leads to loss of DM with a shift from starch in the seed to fiber and pectin in the roots and green shoots (Bakshi *et al.*, 2017). Moreover, the crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and Ca content increased, but organic matter (OM) and non-fibrous carbohydrates (NFC) content decreased in the hydroponic green forage compared with the original seed on a DM basis (Abdullah, 2001; Fazaeli *et al.*, 2012; Kide *et al.*, 2015; Mehta & Sharma, 2016). Naik *et al.* (2014) described that hydroponic fodder is also a rich source of bioactive enzymes, with the highest activities in sprouts being generally between germination and 7 days of age (Chavan *et al.*, 1989). Besides, helping in the elimination of the anti-nutritional factors such as phytate in the grains, hydroponic fodders are good sources of chlorophyll and contain a grass juice factor that improves the performance of livestock (Naik *et al.*, 2015).

The plant height was observed significantly higher in the Manakamana 3 variety than all other varieties except for Deuti. The plant height of Mankamana 6, ZM 401, Arun 2 and Deuti were non-significantly different, though the lowest height was documented in ZM 401. This finding might be related to the specific varietal characteristics like temperature, light and nutrient requirement for growth and development. Moreover, Manakamana 3 is the popular maize variety recommended for mid hill regions for production during rainy season having the higher average plant height. The number of leaves was documented significantly higher in the Mankamana 6 and the lowest number of leaves was observed in Arun 2 and Deuti signalling the poor performances in term of green biomass production in maize hydroponics. Similarly, the leaf length was found non-significantly different among the different varieties of maize, though it was observed the longest in Deuti and the shortest in Mankamana 6. Likewise, the leaf width was found statistically higher in Deuti as compared to Manakamana 3 but was non-significantly different with other three maize varieties in hydroponics. The present findings on morphological characteristics were in accordance with that described by Krishna Murthy *et al.* (2017) at Andra Pradesh, India in the study of performance of different fodder crops under low-cost greenhouse hydroponic fodder production system.

CONCLUSION

ZM 401 emerges as the most promising variety, exhibiting significantly higher green and dry biomass yields compared to others, establishing its suitability for maize hydroponics. Deuti also demonstrates competitive yields, particularly in green biomass, alongside Manakamana 3. Conversely, Arun 2 and Manakamana 6 exhibit comparatively lower biomass yields, indicating less suitability for hydroponic cultivation. Additionally, morphological traits such as plant height and leaf number further emphasize the performance variations among varieties, with ZM 401 and Manakamana 3 showcasing notable characteristics. These findings collectively underscore ZM 401 as a standout choice for maize hydroponics due to its superior biomass yield and favorable growth attributes, potentially informing cultivation decisions for optimized hydroponic maize production.

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