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RESEARCH ARTICLE

Impact of seed priming and foliar nutrition on horse gram and pearl millet as an alternate for maize in hydroponic cultivation

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Abstract

Soil-based agriculture faces challenges from various human activities like deforestation, urbanization and industrialization. In response, scientists have introduced hydroponic cultivation, a soil-less farming method completed within 7-8 days in a nutrient-rich aqueous medium. To address this shift, an experiment was conducted at V.O.C. Agricultural College and Research Institute, Killikulam, between February and April 2022 during summer. Using a factorial completely randomized design (FCRD) with 15 treatments and three replications, to study the effects of seed priming and foliar nutrition on the growth, yield and quality of horse gram and pearl millet as best alternative for regular maize under hydroponics. Seed priming treatments including hydro-priming, 2 % humic acid priming and 1 % moringa leaf extract priming, while foliar nutrition treatments included control, 0.1 % humic acid, 20 % vermiwash, 1 % Azophos and 1 % 19:19:19 WSF (Water Soluble Fertilizer) applied at 5 days after sowing (DAS). Results indicate that combining effect of seed priming with 2 % humic acid and foliar nutrition of humic acid @ 0.1 % significantly influenced growth parameters, the higher green fodder yield of 11 and 13.7 kg m^{-2}, water use efficiency, superior proximate fodder quality *viz.,* crude protein (29.5 and 15.4 %), crude fibre (15.5 and 11.8 %), crude fat (2.9 and 4.32 %), total ash (3.26 and 2.49 %) and NFE (Nitrogen Free Extract) (48.83 and 66.9 %). Ultimately, combining seed priming with 2 % humic acid and foliar nutrition with 0.1 % humic acid emerged as the most effective strategy for promoting growth, yield and superior fodder quality of horse gram and pearl millet as the best alternate to regular maize.

Keywords: foliar nutrition; horse gram and pearl millet; hydroponics; seed priming; yield and quality

Introduction

Livestock is integral to Indian agriculture, vital for food security, economic prosperity and rural livelihoods. The total livestock population in the country stands at 535.82 million, reflecting a 4.64 % increase compared to the 20th Livestock Census of 2019. However, the population of indigenous cattle has declined by 6 %. Additionally, the milk production of indigenous cattle is significantly lower (2.93 kg/day) than that of exotic or crossbred cows, which produce 7.71 kg/day. As the population grows, so does the demand for milk, meat and dairy products. Meanwhile, fodder availability is significantly decreasing. Additionally, the land allocated for food crops is shrinking due to urbanization and industrialization. The declining area for cereals and fodder crops has led to a fodder shortage, which is being offset by a greater reliance on commercial cattle feed, ultimately driving up the cost of milk production (1). However, meeting the current demand for green fodder has become a major challenge for livestock farmers. Green fodder plays a crucial role in enhancing the productive and reproductive performance of animals. Providing green fodder can significantly improve livestock productivity (2). Various efforts have been undertaken to identify alternative sources of cattle feed. Hydroponics is regarded as the most cost-effective and efficient substitute, providing a sustainable option for livestock nutrition.

Hydroponic fodder is produced without soil as soil-less cultivation wherein, seeds utilize tap water or nutrient-enriched solutions for plant nourishment and its further growth. This method provides nutrient-rich green fodder to animals, particularly benefiting dairy farmers in areas with limited land and labour. The resulting fodder boasts superior nutrition, digestibility and palatability, leading to increased milk production and improved animal health and reproductive efficiency. It is suitable for various animals including buffaloes, cows, sheep and goats. Hydroponic fodder encompasses roots, stems, leaves and grains, offering a more comprehensive diet compared to conventionally grown fodder. Its year-round cultivation, regardless of seasonal constraints, ensures consistent employment and returns. Various crops such as cowpea, bajra, jowar, maize, barley, sunnhemp, ragi and horse gram can thrive using hydroponic techniques.

The primary challenge in hydroponic fodder production is the quality and cost of seeds. Seed quality significantly impacts success, as poor germination can lower yields and contaminate the entire production system. Moreover, seeds are a costly input that requires effective management for profitable production.

Seed priming is a cost-effective technique involving treatment of seeds with chemicals in varied temperatures, enhancing germination speed, uniformity and water efficiency while enabling germination in dormant seeds (3). Nutrition significantly affects crop growth, yield and quality. Optimal nutrient proportions are essential for maximum dry matter production. Hydroponic fodders, grown for a short duration of up to eight days, benefit from foliar nutrition, enabling efficient nutrient absorption through stomata or cuticles. Thus, an experiment was conducted to explore the impact of foliar nutrient sources on the growth, yield and quality of hydroponic fodders of horse gram and pearl millet as the best alternate to regular maize.

Materials and methods

Location, weather and climatic condition of the experimental site

The experimental site situated at the research farm (B-block) of VOC Agricultural College and Research Institute, Killikulam, located in the southern region of Tamil Nadu. This area is positioned at 80°46' N latitude and77°42' E longitude, with an elevation of 40 meters above sea level, falling under the East Coast Plains and Hills agroclimatic zone of India. The hydroponic experimental setup was housed within a shaded net, providing controlled environmental conditions for protected cultivation. The average daytime temperatures inside the net house ranged from 23 to 28 ˚C, while nighttime temperatures ranged from 18-23 °C. Relative humidity levels varied between 80-85 %.

Structure of treatments

The experiment was arranged in a Factorial Completely Randomized Design (FCRD) comprising two factors (seed priming and foliar nutrition) and replicated twice. Factor A comprised of hydro priming (S_1), seed priming with 2 % humic acid (HA) (S_2) and seed priming with 1 % Moringa Leaf Extract (MLE) (S_3) and Factor B comprised of no foliar spray as control (F_1), foliar spray of HA @ 0.1 % (F_2), foliar spray of Vermiwash @ 20 % (F_3), foliar spray of Azophos @ 1 % (F_4) and foliar spray of 19:19:19-WSF @ 1 % (F_5). Foliar spray was given at 5 days after sowing (DAS) for all crops. Hydropriming (seeds were soaked in water for 24 hrs and then shade dried for a day), seed priming with 2 % humic acid (seeds were soaked in 2 % humic acid solution for 24 hrs and then shade dried for a day), seed priming with 1 % mMLE (seeds were soaked in 1 % MLE solution for 24 hrs and then shade dried for a day). In horse gram, seed priming was done only for 12 hrs. Moringa leaf extract (MLE) was prepared by washing healthy moringa leaves, freezing them overnight and then grinding them to extract the juice. This juice was mixed with water to create a 1 % MLE solution (4). Vermiwash, drained from the vermiculture tank, was diluted with water to create a 20 % solution (5).

Crop management

A hydroponic system, constructed from PVC pipes with concrete bases was shielded by a high-density polyethylene shade net, offering 50 % shading and protection from environmental elements. Water was sprayed through a system comprising a 0.5 hp water pumping motor, supreme PVC pipes, 16 mm poly connector black lateral pipes, 6 mm micro connector and jet spray (30 LPH). Automatic watering was achieved using a cost-effective timer with 16 on/off cycles per day. The perforated plastic trays with a dimension of 0.12 m^2 (40 cm length, 30 cm width) were used for this hydroponic experiment (Fig. 1). The good quality seeds were purchased from local market. The seed rate for hydroponic fodder production was fixed based on several preliminary experiments (for horse gram (1.25 kg m^{-2}), pearl millet (3 kg m^{-2})). The floated broken and ill filled seeds were completely removed by stirring in clean tap water and this process was repeated twice. Then the seeds were cleaned by soaking in 0.1 % sodium hypochlorite solution for 30 min to prevent fungal contamination and then washed with clean tap water for 2-3 times to remove the adhering sodium hypochlorite. The primed seeds were incubated in moist gunny bags at dark

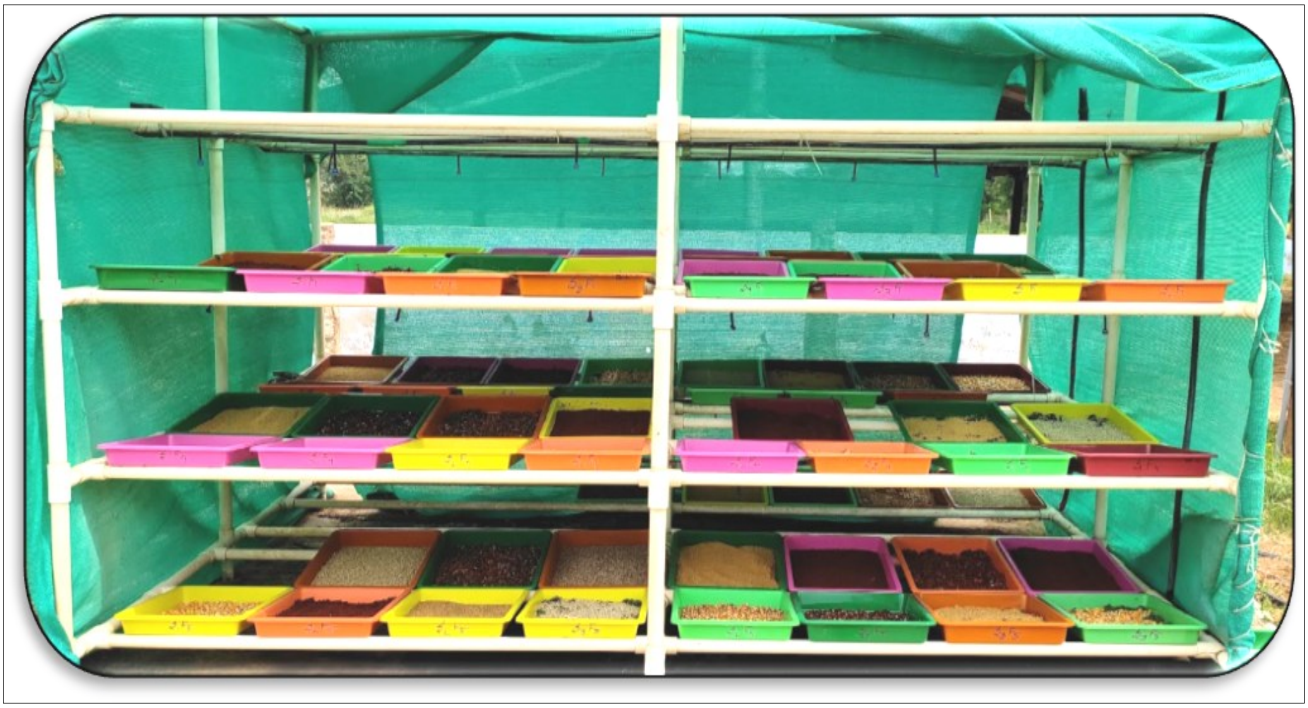

Fig. 1. Experimental unit.

condition for 24 hrs. The gunny bag was repeatedly moistened by sprinkling water for 3 to 4 times in 24 hr duration for uniform germination of seeds. The pre-germinated seeds were sown in trays of above-mentioned dimension and spread evenly. The trays with seeds were labelled on four sides with permanent markers and arranged in the topmost rack of hydroponic system. The underlying racks were kept free to avoid drainage of water from treated trays which might cause treatment errors. The trays were irrigated by using half hp water pumping motor, automatic timer and jet sprayer of 30 LPH. The irrigation water used for hydroponic fodder production had a pH of 7.85 and an EC (dS m^{-1}) of 0.67. The number of irrigations and irrigation interval varies for each crop based on their water requirement which was mentioned in Table 1. As per the treatment schedule of Factor B, the spray solutions were prepared and sprayed on the respective treatments on 5 DAS in each crop using hand sprayer of 5 L capacity (Fig. 2). After foliar nutrition, the irrigation was stopped for 4 hrs to allow the plants to absorb the sprayed nutrient solution. The hydroponic fodder crops were grown for eight days. The fodder crops were harvested at 8 DAS.

Recorded observations

Germination percentage

The germination percentage was recorded by roll towel method. Seeds were primed and placed on germination paper individually. They were rolled in labelled towels, dipped in water and left for 7 days. After unrolling, germination percentage was calculated using the following formula and expressed in percentage.

$$\text{Germination (\%)} = \frac{\text{No. of seed germinated}}{\text{Total number of seeds kept for germination in roll towel}} \times 100$$

Seedling vigour

The seedling vigour was obtained by multiplying the germination percentage with shoot length and root length.

$$\text{Seedling vigour} = \text{Germination (\%)} \times (\text{Shoot length (cm)} + \text{Root length (cm)})$$

Dry matter production

After harvest, the plant samples were dried in hot air oven at 65 ˚C until the plant attain constant weight which removes all the moisture present in the plants. After drying, the dry matter of the plant sample was weighed and expressed in mg $plant^{-1}$.

Water use efficiency

The total amount of water used during the crop growth cycle was recorded and the water use efficiency was calculated by using the following formula and expressed in kg m^{-3}.

$$\text{Water use efficiency (kg m}^{-3}\text{)} = \frac{\text{Total green fodder produced (kg m}^{-2}\text{)}}{\text{Total water (L m}^{-2}\text{)}} \times 1000$$

Green fodder yield

The crops were harvested on 8 DAS from each tray separately as per the treatments. Immediately after the harvest, fresh weight was recorded and expressed in kg m^{-2}.

Proximate analysis

The fodder samples were collected treatment-wise and crop-wise at harvest, then dried and ground. After grinding, samples were analysed for crude protein, crude fat (ether extract), crude fibre, total ash, acid insoluble ash, nitrogen free extract and total carbohydrates. For proximate analysis the standard methods of AOAC. (2005) were adopted (6).

Crude protein (CP) : The nitrogen content of the sample was estimated from diacid digestion by micro kjeldahl method. The crude protein content of the plant was estimated by multiplying the nitrogen content of the plant sample with the factor 6.25 and expressed in percentage.

$$\text{Crude protein (\%)} = \text{Percent nitrogen} \times 6.25$$

Crude fat/Ether extract (EE) : Ether extract (EE) is nothing but the crude fat content present in the plant sample. The ether extract was calculated by using the following formula and expressed in percentage (%).

$$\text{Ether extract (\%)} = \frac{\text{Weight of ether extract (g)}}{\text{Weight of the sample taken (g)}} \times 100$$

Crude fiber (CF) : Crude fiber content was estimated gravimetrically by successive digestion of the plant sample with dilute acid and alkali. The loss in weight after ignition considered as crude fiber and expressed in percentage.

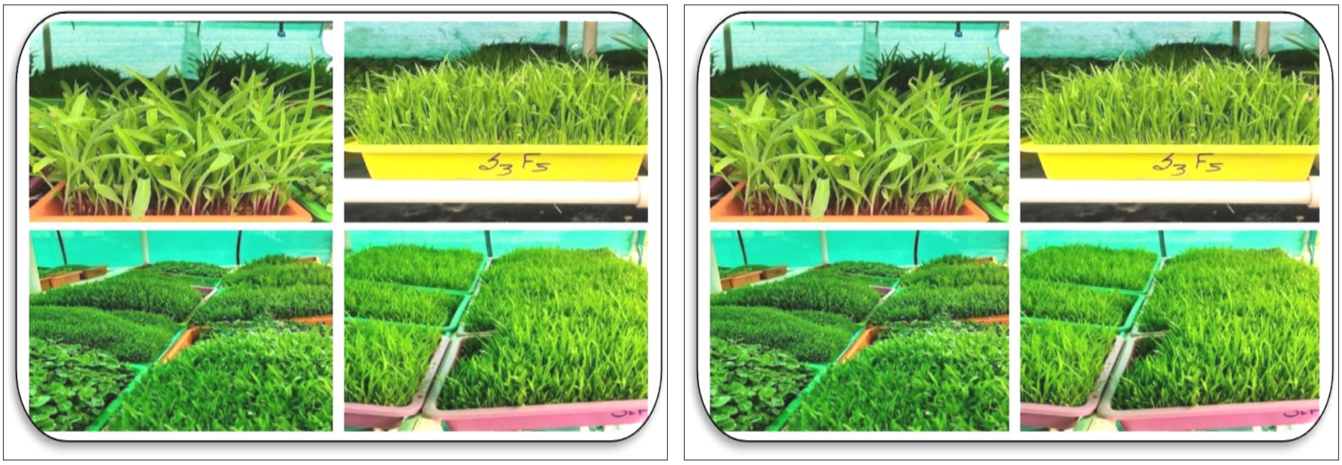

Fig. 2. Foliar nutrition at 5 DAS.

$$\text{Crude fiber (\%)} = \frac{\text{Weight before washing (g) - Weight after washing (g)}}{\text{Weight of the sample (g)}} \times 100$$

Total ash (TA) : The total ash content is measured by ingestion of the dried material in a muffle furnace at 600 °C for 4 hrs.

$$\text{Total ash (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of plant sample (g)}} \times 100$$

Nitrogen free extract (NFE) : This includes nutrients which were not assessed by the prior methods of proximate analysis and consist mainly of digestible carbohydrates, vitamins and other non-nitrogen soluble organic compounds. The nitrogen free extract was calculated by subtracting the percentages calculated for each nutrient excluding moisture content from 100 and expressed as percentage.

$$\text{NFE (\%)} = 100 - (\text{crude protein \%} + \text{crude fat \%} + \text{crude fiber} + \text{total ash \%})$$

Statistical analysis

The experimental data collected on various growth, yield and quality parameters were subjected to statistical analysis based on standard procedures to find out the treatment differences (7). Critical differences were calculated at five percent probability level where the treatments differed significantly. Non-significant treatments are indicated as "NS".

Results and Discussions

Germination

Among the different seed priming, seed priming with 1 % MLE (S_3) recorded significantly higher germination of 92.5 % for horse gram, 91.0 % for pearl millet and this was followed by seed priming with 2 % HA (S_2) recorded germination of 86.0 % (horse gram), 80.5 % (pearl millet). The main reason might be that the MLE and HA transports the necessary water and nutrients required for germination and growth (8). Lowest germination was recorded in hydropriming (S_1) *viz.,* 81.0, 70.3 for horse gram and pearl millet respectively (Table 1). This is likely because water lacks specific minerals, vitamins, enzymes and growth regulators that are present in MLE and HA. Hydropriming did, however, enhance crop germination, though not to the same extent as MLE and HA. The results were consistent with the findings of previous studies (9, 10) (Table 2).

Table 1. Number of irrigation and irrigation intervals for different hydroponic fodder.

S. No	Crops	Irrigation interval		Number of irrigations in 24 hrs
		Day	Night	
1.	Pearl millet	3 hrs once	4 hrs once	8
2.	Horse gram	2 hrs once	3 hrs once	10

Seedling vigour

Seedling vigour of hydroponic fodders at 4 DAS and 8 DAS were significantly influenced by seed priming and foliar nutrition. At 4 DAS, seed priming with 2 % HA (S_2) resulted in significantly higher seedling vigour of 1377 for horse gram and 1000 for pearl millet followed by 1 % MLE (S_3) (Table 3). This might be because of the high zeatin content, which boosted metabolic activity and active cell division, promoting shoot and root growth as well as an increase in seedling vigour (11). Hydropriming (S_1) showed the lowest seedling vigour of 918 and 650 in horse gram and pearl millet respectively. A similar trend was observed at 8 DAS. Foliar nutrition was applied on 5 DAS, which began to significantly influence seedling vigour from that point onward. At 8 DAS, foliar nutrition with 0.1 % HA (F_2) significantly recorded higher seedling vigour of 1731 (horse gram) and 1378 (pearl millet). It was followed by foliar nutrition of 20 % vermiwash (F_3). The phosphorous in humic acid and vermiwash was used effectively, which efficiently carried the phosphorous to the root's developing organs and encouraged root growth (12). The interaction of seed priming and foliar nutrition were also found to be significant. Among various combination, seed priming with 2 % HA coupled with foliar nutrition of HA @ 0.1 % (S_2F_2) significantly recorded the higher seedling vigour of 1941 for horse gram and 1553 for pearl millet. It was followed by seed priming with 1 % MLE coupled with foliar nutrition of HA @ 0.1 % (S_3F_2). Lower seedling vigour was recorded in hydropriming with no foliar spray (S_1F_1).

Table 2. Effect of seed priming on germination of hydroponic fodders.

Seed priming	Germination (%)	
	Horse gram	Pearl millet
S_1	81.0	70.3
S_2	86.0	80.5
S_3	92.5	91.0
SEd	0.9	0.9
CD (p = 0.05)	2.9	3.0

Dry matter production

Dry matter of hydroponic fodders at 4 DAS were influenced by seed priming. Seed priming with 2 % HA (S_2) recorded significantly higher dry matter of 18.5 mg plant^{-1} for horse gram and 10.44 mg plant^{-1} for pearl millet. The humic acid solution contained vital nutrients like carbon, hydrogen, nitrogen, phosphorous and sulphur, which improved nutrient uptake and produced higher dry matter (13). It was followed by seed priming with 1 % MLE (S_3). Lowest dry matter of 16.7, 7.58 mg plant^{-1} in horse gram and pearl millet respectively were observed in hydropriming (S_1). Similar trend was observed at 8 DAS.

Regarding, foliar nutrition, 0.1 % HA (F_2) foliar nutrition significantly recorded higher dry matter of 25.4 mg plant^{-1} (horse gram) and 15.3 mg plant^{-1} (pearl millet) followed by foliar nutrition of 20 % vermiwash (F_3) at 8 DAS. It might be related to growing leaves and improved photosynthesis, which led to more photosynthates being stored as dry matter (14). Among various treatment combination, seed priming of 2 % HA coupled with foliar nutrition of HA @ 0.1 % (S_2F_2) significantly recorded higher dry matter of 28.3 mg plant^{-1} for horse gram and 18.3 mg plant^{-1} for pearl millet followed by seed priming with 2 % HA coupled with foliar nutrition of verminwash @ 20 % (S_2F_3) recorded dry matter of 25.8 mg plant^{-1} (horse gram) and 15.7 mg plant^{-1} (pearl millet). Lower dry matter was recorded in hydro priming with no foliar spray (S_1F_1) (Table 4).

Table 3. Effect of seed priming and foliar nutrition on seedling vigour for horse gram and pearl millet under hydroponic.

	4 DAS												At harvest											
	Horse gram						Pearl millet						Horse gram						Pearl millet					
	Foliar nutrition												Foliar nutrition											
Seed priming	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**Mean**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**Mean**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**Mean**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**Mean**
S_1	923	919	916	913	918	918	655	652	649	646	651	650	1103	1456	1419	1165	1341	1297	793	1035	1002	849	930	922
S_2	1378	1378	1371	1381	1378	1377	995	1007	1000	994	1007	1000	1483	1941	1790	1541	1696	1690	1062	1553	1480	1242	1391	1345
S_3	1183	1178	1183	1189	1187	1184	975	969	975	980	978	975	1302	1796	1734	1493	1620	1589	1053	1547	1486	1243	1369	1339
Mean	1161	1158	1157	1161	1161		875	876	875	873	878		1296	1731	1648	1400	1552		969	1378	1323	1111	1230	
	S	**F**	**S×F**				**S**	**F**	**S × F**				**S**	**F**	**S × F**				**S**	**F**	**S×F**			
SEd	7	10	17				6	7	12				13	17	29				8	10	17			
CD (p=0.05)	16	NS	NS				12	NS	NS				28	36	63				16	21	36			

Table 4. Effect of seed priming and foliar nutrition on DMP (mg $plant^{-1}$) for horse gram and pearl millet under hydroponic.

	4 DAS												At harvest											
	Horse gram						Pearl millet						Horse gram						Pearl millet					
	Foliar nutrition						Foliar nutrition						Foliar nutrition						Foliar nutrition					
Seed priming	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**Mean**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**Mean**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**Mean**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**Mean**
S_1	16.6	16	16.4	16.8	16.7	16.7	7.48	7.68	7.48	7.68	7.58	7.58	17.1	23.7	22.9	19.3	20.7	20.7	7.8	13.6	12.8	9.2	10.6	10.8
S_2	18.6	18.6	18.4	18.2	18.6	18.5	10.51	10.51	10.3	10.41	10.51	10.44	21.2	28.3	25.8	22.9	25.4	24.7	11.1	18.2	15.7	12.8	15.3	14.6
S_3	17.4	17.8	17.4	17.3	18	17.6	8.28	8.39	8.28	8.39	8.39	8.34	18.6	24.3	24.2	20	22	21.8	8.8	14.2	14.1	9.9	11.9	11.8
Mean	17.2	17.4	17	17.1	17.4		8.75	8.86	8.69	8.82	8.82		19.3	25.4	24.3	20.7	22.7		9.2	15.3	14.2	10.6	12.6	
	S	**F**	**S × F**				**S**	**F**	**S×F**				**S**	**F**	**S × F**				**S**	**F**	**S×F**			
SEd	0.1	0.1	0.2				0.06	0.07	0.12				0.1	0.2	0.3				0.07	0.1	0.18			
CD (p = 0.05)	0.2	NS	NS				0.12	NS	NS				0.3	0.4	0.7				0.2	0.2	0.4			

Water use efficiency (WUE)

Seed priming with 2 % HA (S_2) significantly recorded higher WUE in horse gram (154.98 kg m^{-3}) and pearl millet (251 kg m^{-3}) followed by 1 % MLE (S_3) seed priming recorded WUE of 141.53 and 234 kg m^{-3} for horse gram and pearl millet respectively. This might be due to humic acid seed priming increasing cell wall permeability, allowing greater nutrient uptake from humic acid foliar nutrition, which in turn accelerated growth and development. Despite the amount of water consumed, higher biomass was produced due to increased nutrient uptake from humic acid seed priming and foliar nutrition (15). Lowest WUE of 114.55 and 200 kg m^{-3} for horse gram and pearl millet respectively were observed in hydropriming (S_1). Regarding foliar nutrition 0.1 % HA (F_2) significantly recorded higher WUE of 154.42 kg m^{-3} in horse gram and 250 kg m^{-3} in pearl millet. It was followed by foliar nutrition of 20 % vermiwash (F_3) recorded WUE of 144.28 kg m^{-3} for horse gram, 237 kg m^{-3} for pearl millet. The control (F_1) treatment which did not received any foliar spray recorded lower WUE of 117.42 and 204 kg m^{-3} in horse gram and pearl millet respectively. On interactions, seed priming with 2 % HA coupled with foliar nutrition of HA @ 0.1 % (S_2F_2) recorded higher WUE of 182.84 kg m^{-3} for horse gram, 285 kg m^{-3} for pearl millet. It was followed by seed priming with 2 % HA coupled with foliar nutrition of vermiwash @ 20 % (S_2F_3) recorded WUE of 160.92 kg m^{-3} in horse gram and 258 kg m^{-3} in pearl millet. Lower WUE was recorded in hydropriming with no foliar spray (S_1F_1) (Table 5).

Green fodder yield

The observations regarding green fodder yield are presented in Table 5 and the yields of horse gram and pearl millet were significantly influenced by seed priming and foliar nutrition. Seed priming with 2 % HA significantly recorded higher green fodder yield (9.3 and 12 kg m^{-2}) and it was followed by 1 % MLE seed priming. Regarding foliar nutrition, foliar spraying of humic acid @ 0.1 % at 5 DAS recorded the higher green fodder yield of 9.3 and 12 kg m^{-2} and it was followed by 20 % Vermiwash spray. On interaction, combining effect of seed priming with 2 % HA and foliar nutrition of HA @ 0.1 % significantly influenced the higher green fodder yield of 11 and 13.7 kg m^{-2} and it was followed by seed priming with 2 % HA and foliar spray of 20 % vermiwash. The results were in accordance with a previous study that evaluated the effect of humic substances on corn seeds under hydroponic conditions (16). The higher green fodder yield might be attributed to humic acid-primed seeds, which can utilize nutrients and water more efficiently than other seed priming agents. Additionally, humic acid is rich in essential nutrients and capable of stimulating growth hormones, which facilitate active physiological processes (17). Furthermore, combining seed priming with humic acid foliar nutrition in maize fodder enhanced nutrient and water use efficiency, resulting in higher green fodder yield.

Proximate quality of fodder

The observations regarding proximate fodder quality were presented in Fig. 3-7. The proximate qualities of hydroponically grown horse gram and pearl millet were significantly influenced by seed priming and foliar nutrition. Seed priming with 2 % humic acid significantly influenced proximate fodder quality and recorded superior proximate quality *viz.,* crude protein (28.06 and 13.1 %), crude fibre (13.83 and 10.1 %),

Table 5. Effect of seed priming and foliar nutrition on water use efficiency (WUE) (kg m^{-3}) and green fodder yield (kg m^{-2}) for horse gram and pearl millet under hydroponic.

	WUE (kg m^{-3})												Green fodder yield (kg m^{-2})											
	Horse gram						Pearl millet						Horse gram						Pearl millet					
	Foliar nutrition						Foliar nutrition						Foliar nutrition						Foliar nutrition					
Seed priming	F_1	F_2	F_3	F_4	F_5	Mean	F_1	F_2	F_3	F_4	F_5	Mean	F_1	F_2	F_3	F_4	F_5	Mean	F_1	F_2	F_3	F_4	F_5	Mean
S_1	98.17	125.92	122.08	108.75	117.84	114.55	179	214	209	193	204	200	5.9	7.6	7.3	6.5	7.1	6.9	8.6	10.3	10.1	9.3	9.8	9.6
S_2	131.00	182.84	160.92	144.42	155.75	154.98	221	285	258	237	251	251	7.9	11.0	9.7	8.7	9.4	9.3	10.6	13.7	12.4	11.4	12.1	12.0
S_3	123.08	154.50	149.83	135.00	145.25	141.53	211	250	244	226	238	234	7.4	9.3	9.0	8.1	8.7	8.5	10.1	12.0	11.7	10.8	11.5	11.2
Mean	117.42	154.42	144.28	129.39	139.61		204	250	237	219	231		7.1	9.3	8.7	7.8	8.4		9.8	12.0	11.4	10.5	11.1	
	S	F	S × F				S	F	S×F				S	F	S×F				S	F	S×F			
SEd	0.9	1.1	1.9				1.4	1.9	3.2				0.05	0.07	0.12				0.07	0.09	0.15			
CD (p = 0.05)	1.9	2.4	4.2				3.1	4.0	6.9				0.11	0.14	0.25				0.15	0.19	0.33			

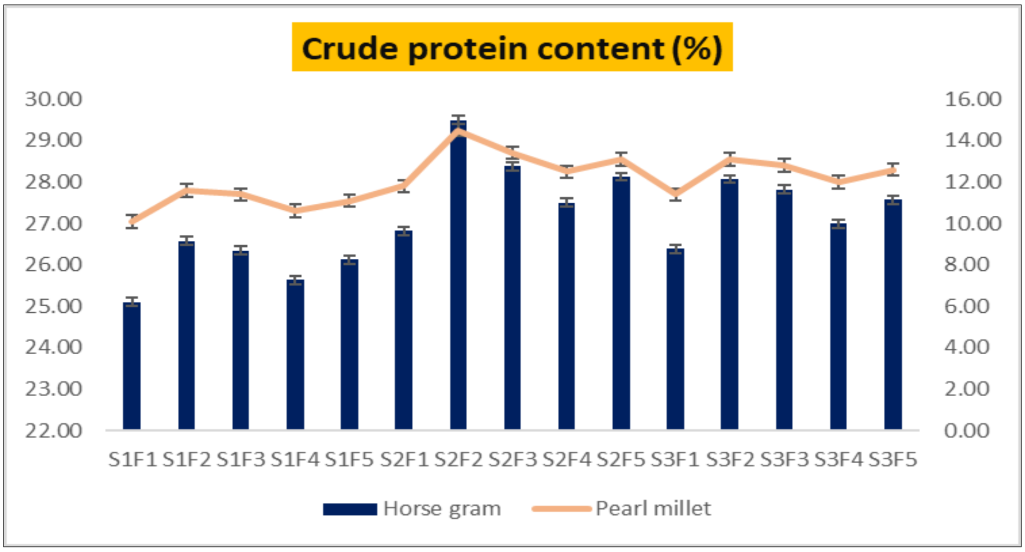

Fig. 3. Effect of seed priming and foliar nutrition on crude protein and fat content (%) for horse gram and pearl millet under hydroponic.

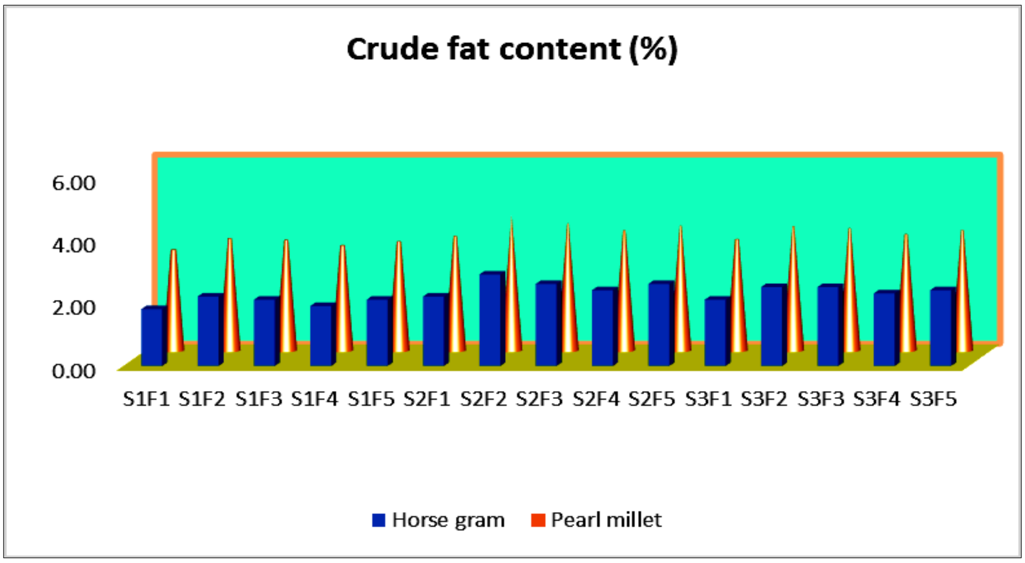

Fig. 4. Effect of seed priming and foliar nutrition on fat content (%) for horse gram and pearl millet under hydroponic.

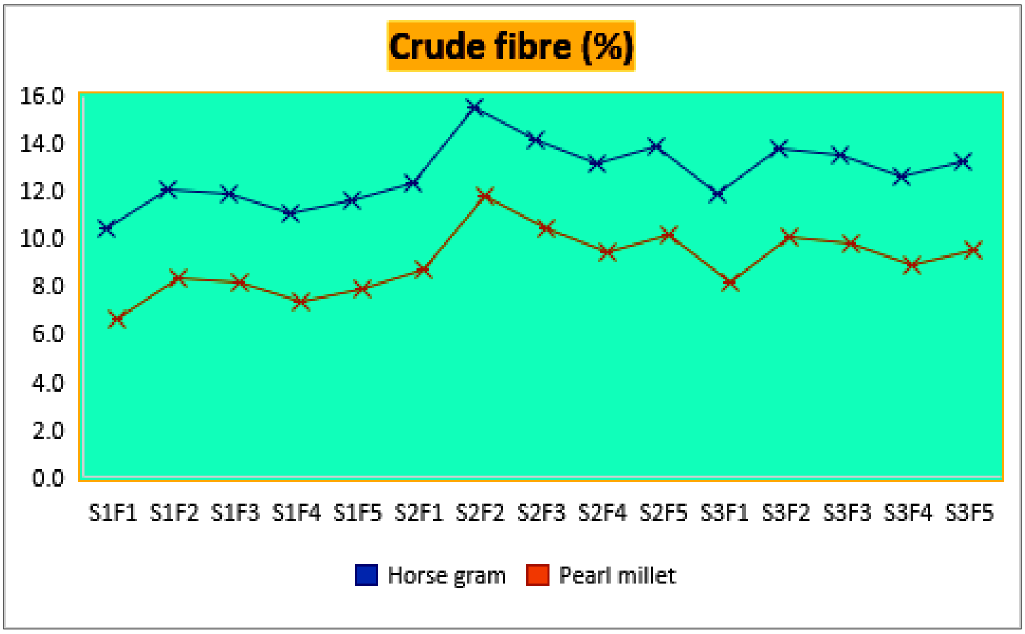

Fig. 5. Effect of seed priming and foliar nutrition on crude fibre (%) for horse gram and pearl millet under hydroponic.

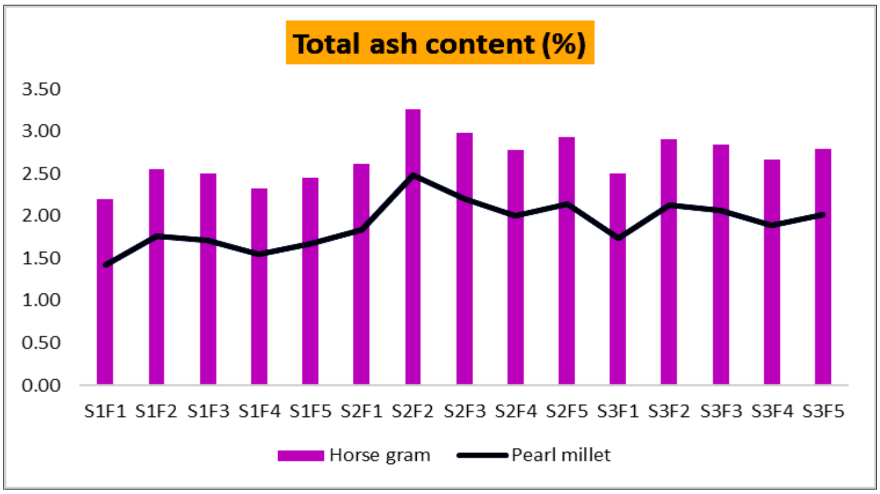

Fig. 6. Effect of seed priming and foliar nutrition on total ash content (%) for horse gram and pearl millet under hydroponic.

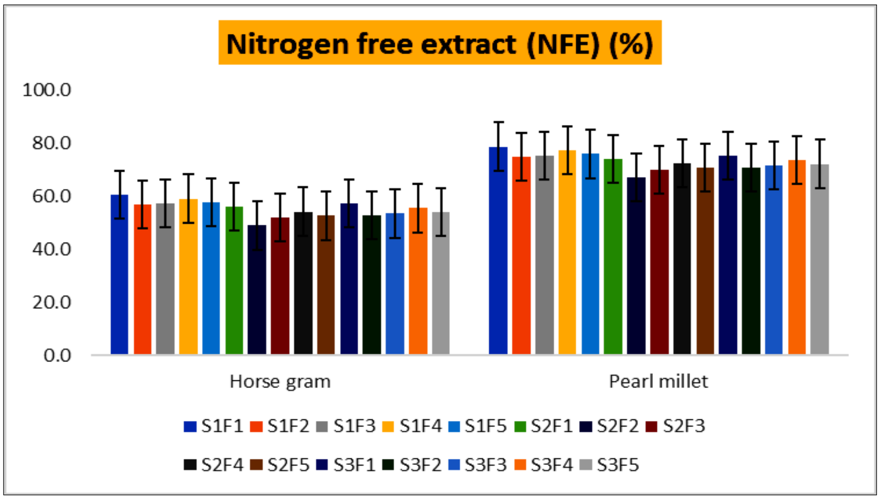

Fig. 7. Effect of seed priming and foliar nutrition on nitrogen free extract (%) for horse gram and pearl millet under hydroponic.

crude fat (2.6 and 3.95 %), total ash (2.91 and 2.14 %) and NFE (58.22 and 76.3 %) and it was followed by 1 % MLE seed priming. Regarding foliar nutrition, foliar spray of 0.1 % humic acid at 5 DAS significantly recorded superior proximate quality viz., crude protein (28.04 and 13 %), crude fibre (13.8 and 10.1 %), crude fat (2.5 and 3.94 %), total ash (2.9 and 2.13 %) and NFE (52.72 and 70.8 %) it was followed by 20 % vermi wash spray. On interaction, combination of 2 % humic acid seed priming with 0.1 % foliar nutrition of humic acid significantly influenced the superior proximate fodder quality viz., crude protein (29.5 and 15.4 %), crude fibre (15.5 and 11.8 %), crude fat (2.9 and 4.32 %), total ash (3.26 and 2.49 %) and NFE (48.83 and 66.9 %) and it is followed by seed priming with 2 % humic acid with foliar spray of 20 % vermiwash. The superior fodder quality observed in the treatment with 2 % humic acid seed priming combined with 0.1 % humic acid foliar spray at 5 DAS may be attributed to more efficient nutrient utilization. A previous study also reported that foliar application of nutrients enhances both yield and quality in cereal crops (18).

Conclusion

The experiment examined the impact of seed priming and foliar nutrition on the growth, yield and quality of hydroponic fodders. Seed priming with 1 % moringa leaf extract notably enhanced germination percentages across all five hydroponic fodder crops, including horse gram and pearl millet. Meanwhile, priming with 2 % humic acid boosted various growth parameters such as seedling vigor and dry matter production resulting in superior proximate fodder quality and increased yield. Foliar application of 0.1 % humic acid was effective in enhancing crop growth, yield and quality, while 20 % vermiwash and 1 % 19:19:19 WSF also performed well, though slightly less effectively than humic acid. Ultimately, combining seed priming with 2 % humic acid and foliar nutrition with 0.1 % humic acid emerged as the most effective strategy for promoting growth, yield and superior fodder quality of horse gram and pearl millet as alternate source of maize.

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Authors' contributions

EM, MJ and MH contributed to the research activities, field establishment and drafting of the research article. NV and GK reviewed and proofread the manuscript, performed statistical analyses on the collected data, assisted with analysis process and participated in sequence alignment. All authors reviewed and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no conflicts of interest.

Ethical issues: None

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