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Short communication

Assessment of yield and quality of moringa (*Moringa oleifera*) as a perennial forage crop under varying sowing patterns and cutting heights

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Abstract

An experiment was conducted at ICAR-CIRG, Makhdoom, from 2021 to 2023, to study the effects of sowing patterns and cutting heights on the green fodder yield, nutrient uptake, and production cost of forage moringa. The experiment consisted of three sowing patterns (30×15 cm, 45×15 cm and 60×15 cm) and four cutting heights (15, 30, 45 and 60 cm) in a split-plot design with three replications. Results showed that sowing at 30×15 cm produced the highest green fodder yield (209.57 kg ha^{-1}), crude protein, nutrient uptake, net returns (Rs 244,056 ha^{-1}) and B:C ratio (2.39), with the lowest production cost (Rs 0.84 kg^{-1}). Harvesting of moringa at 30 cm height from the ground yielded the highest fodder (199.12 kg ha^{-1}), net returns (Rs 238,763 ha^{-1}), and B:C ratio (2.49) with the lowest cost (Rs 0.81 kg^{-1}). However, cutting height had no significant effect on nutrient content, uptake, or crude protein content.

Keywords: Cost of production, Crude protein, Forage moringa, Green fodder yield, Nutrient uptake

Moringa oleifera, commonly referred to as drumstick or sahjan, stands out as a rapid growing tree with high value attributed to its exceptional nutritional profile (Foidl *et al*., 2001) and robust biomass production. As a perennial multi-cut fodder crop, moringa can produce good quality green fodder for animals, and can be grown under harsh conditions in hot, humid, and dry tropical and subtropical regions (Nouman *et al*., 2014). Its leaves serve as a rich source of vital minerals such as calcium, potassium, magnesium, iron, zinc, and copper. Additionally, they boast significant levels of crude protein, crude fat, and carbohydrates, all of which play crucial roles in enhancing livestock production and overall productivity (Arif *et al*., 2020). Effective agronomic management is crucial for the successful cultivation of moringa as a perennial fodder crop, as maximizing the production of high-quality biomass hinges on various factors, such as the timing of the initial cut, the height of cutting, and the density of the plants (Knoop and Walker, 1985; Paterson *et al*., 1998). It has been reported that closer spacing of moringa plants results in higher fodder yields compared to wider spacing (Adegun and Ayodele, 2015), and the height at which harvesting is conducted significantly impacts moringa yield (Sidhdharth *et al*., 2022). Thus, the development of suitable agronomic practices for forage moringa production is need of the hour. Therefore, the experiment was designed to optimize suitable sowing patterns and cutting heights for the production of high-quality biomass from forage moringa.

The experiment was conducted from 2021 to 2023 at the agriculture farm of ICAR-Central Institute for Research on Goats, Makhdoom (Lat 27.100 N, Lon 78.020 E, 169.2 m above mean sea level), Mathura, India. The soil of the experimental field was neutral in reaction (pH 7.0) with EC of 0.27 dS m^{-1}. The soil was low in organic carbon (0.29%), medium in available nitrogen (253 kg ha^{-1}) and potassium (161 kg ha^{-1}); and high in available phosphorus (40 kg ha^{-1}). The treatments consist of three sowing patterns (crop geometries) *viz.* 30 cm x 15 cm, 45 cm x 15 cm and 60 cm x 15 cm; and four cutting heights (harvesting from ground level) *viz.* 15 cm, 30 cm, 45 cm and 60 cm. The experiment was laid out in split plot design with three replications. The field was divided into 36 plots, each measuring 3.6 m x 4.5 m in size.

Moringa oleifera variety PKM-2 was sown on 3rd July

2021 by using the seed rates of 75, 50 and 37.5 kg ha^{-1} in 30 cm x 15 cm, 45 cm x 15 cm and 60 cm x 15 cm sowing patterns, respectively. The seeds were soaked overnight and treated with carbendazim @ 5 g/kg. Harvesting of moringa was done as per the treatments up to 8 cuttings; the first cut was taken at 90 days after sowing and the subsequent cuts were taken at the intervals of 60 days (approx.) except during severe winter.

Analysis of nutrients was carried out by using the digested samples by following methods: nitrogen by using micro Kjeldahl method (AOAC, 2005), phosphorus by yellow colour method (Richards, 1968) and potassium by flame photometer method (Richards, 1968). The crude protein (%) of the sample was calculated by multiplying the N content with the factor 6.25. The economics of different treatments was worked out in terms of net return (Rs ha^{-1}) and B: C ratio; Net return= Gross return (Rs ha^{-1}) – Cost of cultivation (Rs ha^{-1}) and B: C ratio = Gross return (Rs ha^{-1})/Cost of cultivation (Rs ha^{-1}).

All the data were subjected to statistical analysis using the appropriate method of analysis of variance, as described by Gomez and Gomez (1984). The replicated means were subjected to ANOVA using MS Excel. The critical difference (CD) was calculated at P=0.05.

The maximum green fodder yield across all the cuttings *i.e.* I cut (23.89 t ha^{-1}), II cut (25.77 t ha^{-1}), III cut (21.64 t ha^{-1}), IV cut (26.94 t ha^{-1}), V cut (28.90 t ha^{-1}), VI cut (30.36 t ha^{-1}), VII cut (25.18 t ha^{-1}), VIII Cut (26.89 t ha^{-1}) and total of all cuts (209.57 t ha^{-1}) were recorded at the spacing of 30 x 15 cm, which was significantly higher over 45 cm x 15 cm and 60 cm x 15 cm by 19.50 and 34.03 percent, respectively (Table 1). The higher yield at 30 cm x 15 cm spacing might be due to a higher plant population. Siddharth *et al.* (2022) reported that dense population in moringa produced more compound leaves. Hence, a higher yield of compound leaves was obtained when moringa was sown in closer spacing. Mabapa *et al.* (2017) reported that an increase in plant density leads to increased biomass production in moringa. Mubeena *et al.* (2024) also reported that growing agathi at a narrow spacing recorded significantly higher green fodder yield. A similar finding was also reported by Adegun and Ayodele (2015), who noted that closer spacing of moringa resulted in higher fodder yield compared to wider spacing. Further, among the treatments of different cutting height, harvesting at the height of 30 cm from ground level recorded highest green fodder yield in II cut (21.04 t ha^{-1}), III cut (20.11 t ha^{-1}), IV cut (24.96 t ha^{-1}), V cut (28.59 t ha^{-1}), VI cut (30.91 t ha^{-1}), VII cut (24.56 t ha^{-1}), VIII Cut (27.47 t ha^{-1}) and total of all cuts (199.12 t ha^{-1}). Harvesting at 15 and 30 cm cutting height was recorded at par value of green fodder yield at I cut. The higher green fodder yield at the cutting height of 30 cm might be due to the harvesting of more side branches at this cutting height. Siddharth *et al.* (2022) reported that the harvesting height significantly influenced the yield of moringa; cutting heights of 30 cm above ground level had the greatest yield, followed by 45 and 60 cm. According to El-Morsy (2009) the harvesting of Sesbania at 10 cm above the ground level produced the highest green yield, followed by the 20 and 30 cm cutting. The positive response to lower cutting levels was because the meristematic region in the perennial shrub is located at soil level which can grow rapidly into new tissues once being harvested. These results were in close confirmation with Zheng *et al.* (2016), who reported that the highest fresh biomass yield of forage moringa was recorded when it was harvested at a 30 cm cutting height during the rainy season.

Different sowing patterns significantly influenced the

Table 1. Effect of sowing pattern and cutting height on green fodder yield of *Moringa oleifera*

Treatment	Green fodder yield (t ha^{-1}) in different cuts								
	I Cut	II Cut	III Cut	IV Cut	V Cut	VI Cut	VII Cut	VIII Cut	Total
Sowing pattern									
30 cm x 15 cm	23.89	25.77	21.64	26.94	28.90	30.36	25.18	26.89	209.57
45 cm x 15 cm	20.21	17.17	17.67	22.36	25.58	26.87	21.30	24.21	175.36
60 cm x 15 cm	18.16	15.36	15.85	19.70	22.89	23.72	18.89	21.70	156.27
SEM±	0.63	0.66	0.55	0.69	0.75	0.78	0.67	0.74	3.42
CD (P<0.05)	2.46	2.59	2.17	2.73	2.94	3.05	2.62	2.89	13.42
Cutting height									
15 cm	22.24	18.97	17.38	21.22	23.48	23.88	19.32	20.97	167.47
30 cm	21.48	21.04	20.11	24.96	28.59	30.91	24.56	27.47	199.12
45 cm	20.32	19.81	19.05	23.80	26.71	27.97	22.82	25.75	186.24
60 cm	18.97	17.91	17.00	22.01	24.37	25.19	20.44	22.88	168.78
SEM±	0.53	0.56	0.54	0.67	0.66	0.71	0.64	0.68	3.75
CD (P<0.05)	1.57	1.66	1.62	1.98	1.96	2.10	1.90	2.03	11.15

Table 2. Effect of sowing pattern and cutting height on nitrogen content of *Moringa oleifera*

Treatment	Nitrogen content (%) in whole plant in different cuts							
	I Cut	II Cut	III Cut	IV Cut	V Cut	VI Cut	VII Cut	VIII Cut
Sowing pattern								
30 cm x 15 cm	3.45	3.21	3.08	2.99	2.92	2.79	2.87	2.82
45 cm x 15 cm	3.30	3.07	2.95	2.83	2.75	2.61	2.71	2.64
60 cm x 15 cm	3.16	2.93	2.82	2.68	2.59	2.47	2.57	2.50
SEM±	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04
CD (P<0.05)	0.21	0.20	0.18	0.17	0.17	0.16	0.17	0.17
Cutting height								
15 cm	3.22	2.99	2.86	2.76	2.66	2.55	2.63	2.57
30 cm	3.27	3.04	2.93	2.82	2.73	2.61	2.71	2.63
45 cm	3.35	3.11	2.99	2.86	2.79	2.65	2.74	2.67
60 cm	3.38	3.14	3.02	2.89	2.83	2.68	2.78	2.73
SEM±	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS: Non-significant

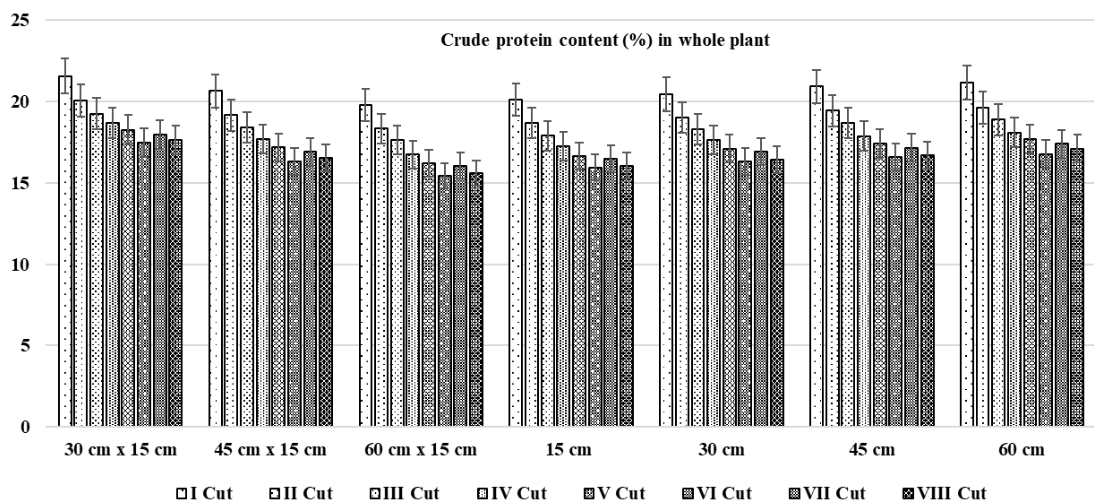

Fig 1. Effect of sowing pattern and cutting height on crude protein content in whole *Moringa oleifera* plant

crude protein content in whole moringa plants, whereas cutting height had a non-significant effect on crude protein content (Fig. 1). Significantly highest crude protein content in I cut (21.56%), II cut (20.04%), III cut (19.24%), IV cut (18.70%), V cut (18.25%), VI cut (17.47%), VII cut (17.97%) and VIII cut (17.61%) were recorded when forage moringa was sown at the spacing of 30 x 15 cm. However, sowing patterns 30 x 15 cm and 45 x 15 cm were recorded statistically at par values of crude protein content in all the cuttings except in VI and VIII cuts of forage moringa. The higher crude protein content in narrow-spaced moringa as compared to wider-spaced moringa might be due to a higher leafy portion of moringa, as moringa leaves contain higher crude protein content as compared to other plant parts. The results were in close confirmation with Zheng *et al.* (2016), who reported that the crude protein content consistently increased as the planting density increased from 80 x 80 cm to 20 x 20 cm during the rainy season. Different treatments of cutting height showed no significant variation in crude protein content of the whole moringa plant. These results were in close confirmation with Nouman *et al.* (2013), Moyo *et al.* (2011) and Sanchez *et al.* (2006), who reported no changes in the chemical composition of moringa leaves in respect of cutting height or cutting frequency.

Nitrogen, phosphorus and potassium content in whole moringa plant was significantly influenced by different sowing patterns, whereas cutting height had non-

Table 3. Effect of sowing pattern and cutting height on phosphorus content of *Moringa oleifera*

Treatment	Phosphorus content (%) in whole plant in different cuts							
	I Cut	II Cut	III Cut	IV Cut	V Cut	VI Cut	VII Cut	VIII Cut
Sowing pattern								
30 cm x 15 cm	0.479	0.426	0.379	0.326	0.300	0.258	0.289	0.307
45 cm x 15 cm	0.461	0.411	0.368	0.317	0.293	0.254	0.283	0.297
60 cm x 15 cm	0.438	0.385	0.347	0.299	0.277	0.239	0.267	0.280
SEM±	0.008	0.007	0.006	0.005	0.004	0.004	0.004	0.005
CD (P<0.05)	0.030	0.026	0.024	0.019	0.017	0.014	0.016	0.018
Cutting height								
15 cm	0.449	0.395	0.356	0.306	0.282	0.243	0.273	0.286
30 cm	0.455	0.404	0.362	0.310	0.288	0.248	0.277	0.291
45 cm	0.461	0.409	0.366	0.317	0.291	0.252	0.282	0.297
60 cm	0.472	0.421	0.375	0.325	0.299	0.258	0.288	0.305
SEM±	0.007	0.006	0.005	0.005	0.004	0.004	0.004	0.005
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS: Non-significant

Table 4. Effect of sowing pattern and cutting height on potassium content of *Moringa oleifera*

Treatment	Potassium content (%) in whole plant in different cuts							
	I Cut	II Cut	III Cut	IV Cut	V Cut	VI Cut	VII Cut	VIII Cut
Sowing pattern								
30 cm x 15 cm	1.66	1.45	1.22	1.11	1.02	0.92	1.00	0.97
45 cm x 15 cm	1.58	1.38	1.16	1.06	0.99	0.89	0.95	0.92
60 cm x 15 cm	1.46	1.28	1.06	0.96	0.88	0.80	0.83	0.79
SEM±	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02
CD (P<0.05)	0.14	0.13	0.12	0.11	0.09	0.08	0.10	0.09
Cutting height								
15 cm	1.51	1.33	1.11	1.01	0.93	0.85	0.90	0.87
30 cm	1.55	1.35	1.14	1.04	0.96	0.86	0.91	0.89
45 cm	1.58	1.39	1.15	1.06	0.98	0.88	0.94	0.90
60 cm	1.63	1.42	1.19	1.07	0.99	0.89	0.95	0.91
SEM±	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS: Non-significant

significant effect on N, P and K content (Tables 2-4). The highest value of nitrogen, phosphorus and potassium content in I cut (3.45, 0.479 and 1.66%), II cut (3.21,0.426 and 1.45%), III cut (3.08, 0.379 and 1.22%), IV cut (2.99, 0.326 and 1.11%), V cut (2.92, 0.300 and 1.02%), VI cut (2.79, 0.258 and 0.92%), VII cut (2.87, 0.289 and 1.00%) and VIII cut (2.82, 0.307 and 0.97%), respectively were recorded when forage moringa was sown at the spacing of 30 cm x 15 cm. However, sowing patterns 30 x 15 cm and 45 x 15 cm were recorded statistically at par values of N, P and K content in all the cuttings except in VI and VIII cut of forage moringa in case of nitrogen content only. The higher nutrient content in narrow-spaced moringa as compared to wider-spaced moringa might be due to higher leafy portion of moringa, as moringa leaves contain higher nutrients as compared to other plant parts. These results were in close agreement with Basra et al. (2015), who reported that moringa plants planted at a narrow spacing (15 x 30 cm) provided higher N, P, and K content compared to those planted at a wider spacing (15 x 60 cm). Newton *et al.* (2006) reported that planting density affected the leaf mineral composition of moringa. Sanchez *et al.* (2006) also reported that mineral composition of moringa plants decreased with increasing planting density. Different

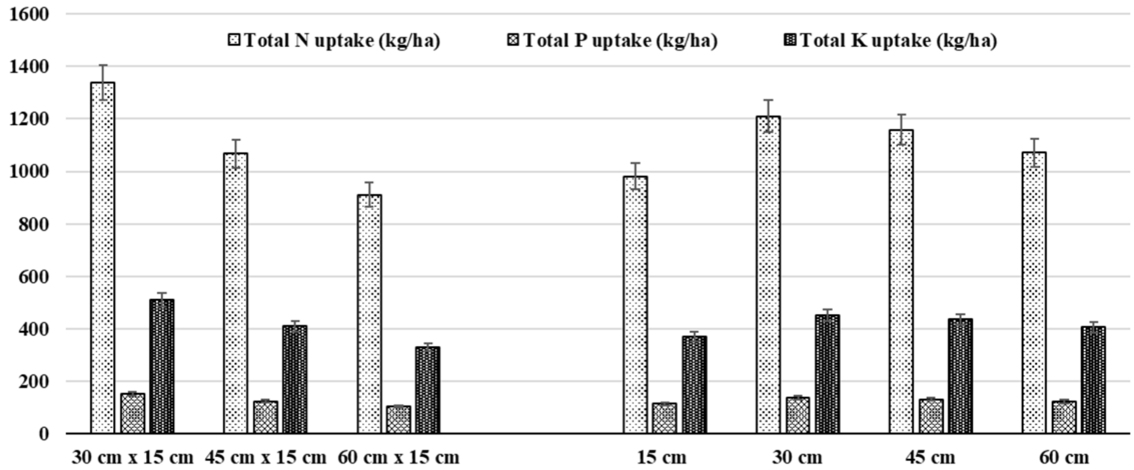

Fig 2. Effect of sowing pattern and cutting height on nutrient uptake of *Moringa oleifera*

treatments of cutting height showed no significant variation in nutrient content of whole moringa plant. These results were in close confirmation with Nouman *et al.* (2013), Moyo *et al.* (2011) and Sanchez *et al.* (2006) who reported no changes in the chemical composition of moringa leaves in respect of cutting height or cutting frequency. Further, uptakes of nitrogen, phosphorus and potassium were also significantly influenced by different sowing patterns and cutting height of forage moringa (Fig 2). Among the different sowing patterns, the maximum uptake of total N, P, and K was recorded with a crop geometry of 30 x 15 cm, followed by 45 cm x 15 cm. Among the treatments with different cutting heights for forage moringa harvested at 30 cm, followed by 45 cm from the ground level, the highest uptake of these macro-nutrients was recorded. The higher uptake of nutrients with the sowing of moringa at 30 x 15 cm sowing patterns; and at the cutting of 30 cm from ground level might be due to higher values of N, P and K content, and yield potential with these treatments as uptake of these nutrients were calculated by multiplying the nutrient content with respective dry matter yield. Rajeshkumar *et al.* (2017) reported that nutrient content was also significantly influenced by different crop geometries in *Vigna mungo*.

Table 5. Effect of sowing pattern and cutting height on economics of *Moringa oleifera*

Treatment	Net returns (Rs/ha)	B:C ratio	Cost of green moringa production (Rs/kg)
Sowing pattern			
30 cm x 15 cm	244056	2.39	0.84
45 cm x 15 cm	194381	2.24	0.90
60 cm x 15 cm	165568	2.13	0.95
SEM±	6835	0.04	0.02
CD (P<0.05)	26838	0.17	0.07
Cutting height			
15 cm	175470	2.09	0.96
30 cm	238763	2.49	0.81
45 cm	213010	2.33	0.86
60 cm	178098	2.11	0.96
SEM±	7507	0.05	0.02
CD (P<0.05)	22303	0.14	0.05

The economics of forage moringa production was significantly influenced by different sowing patterns and cutting height of moringa (Table 5). Among the different sowing patterns, the highest net returns (Rs 244056 ha^{-1}) and benefit: cost ratio (2.39); and the lowest cost of green moringa production (Rs 0.84 kg^{-1}) was obtained when forage moringa was sown at the spacing of 30 x 15 cm followed by sown at 45 x 15 cm. Further, among the treatments of different cutting heights, harvesting of forage moringa at the height of 30 cm from ground level recorded the highest net returns (Rs 238763 ha^{-1}) and benefit: cost ratio (2.49); and the lowest cost of green moringa production (Rs 0.81 kg^{-1}) followed by harvesting at 45 cm from the ground level. It was evident due to the higher total green fodder yield achieved with the treatment of 30 x 15 cm sowing and 30 cm cutting height from ground level, compared to other treatments of sowing patterns and cutting heights, which consequently resulted in a higher net return and benefit-cost ratio. These results were in close confirmation with Verma *et al.* (2023), who reported that the net returns and B:C ratio of forage moringa were significantly influenced by different sowing patterns.

The study recommends sowing of forage moringa at 30 cm x 15 cm spacing, and harvesting at 30 cm from ground level for obtaining the higher green fodder yield, crude protein content, macronutrient content, net returns and benefit: cost ratio from forage moringa.

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