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RESEARCH PAPER

Optimizing sowing windows and nutrient levels for higher productivity of browntop millet (*Brachiaria ramosa* L.)

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Abstract: An experiment was conducted to optimize sowing windows and nutrient levels for higher productivity of browntop millet (*Brachiaria ramosa* L.) at ARS, Hanumanamatti, during *kharif* 2023-24. Among the varied sowing windows, sowing of browntop millet on second fortnight of June (D_1) recorded significantly higher growth parameters *viz.,* plant height (101.06 cm), number of tillers (156.70 m^{-1} row length), total dry weight (13.69 g $plant^{-1}$), leaf area per plant (480.06 cm^2) and leaf area index (1.60) and yield attributes *viz*., effective tillers (326.56 m^{-2}), ear length (14.91 cm), grain weight per ear (0.72 g), test weight (3.50 g), grain yield (1577 kg ha^{-1}) and straw yield (2726 kg ha^{-1}) over delayed sowing windows. Among the varied nutrient levels, browntop millet fertilized with 125% RDF (N_3) recorded significantly higher growth parameters *viz.,*plant height (101.86 cm), number of tillers (154.90 m^{-1} row length), total dry weight (13.72 g $plant^{-1}$), leaf area per plant (470.05 cm^2) and leaf area index (1.57) and yield attributes *viz.,* effective tillers (322.77 m^{-2}), ear length (14.92 cm), grain weight per ear (0.70 g), grain yield (1584 kg ha^{-1}) and straw yield (2731 kg ha^{-1}) compared to lower levels of nutrient application.

Key words: Browntop millet, Growth parameters, Nutrient levels, Sowing windows, Yield attributes

Introduction

Browntop millet (*Brachiaria ramosa* L.), a minor cereal grain, has garnered increasing attention for its adaptability and nutritional benefits. Native to the semi-arid regions of Southeast Asia, browntop millet has a long history of cultivation (Sheahan, 2014). Historically, it was a staple food for rural communities across India, particularly in Karnataka and Andhra Pradesh due to its yield resilience in low-fertility soils and drought-prone areas.

Millets are believed to have evolved between 5,000 and 8,000 years ago, with browntop millet being one of the earliest domesticated species. Its evolution reflects the agricultural practices of early agrarian societies, that needed robust crops capable of thriving under erratic weather conditions. Browntop millet requires less water than crops like rice and wheat and performs well in marginal soils, making it an ideal crop for regions facing water scarcity. Moreover, it matures within 85-90 days, allowing for multiple cropping cycles annually. Presently, browntop millet is being promoted as a nutritious and eco-friendly alternative to main stream cereals. Browntop millet contains around 8.98, 1.89, 3.9 and 71.32% of protein, fat, minerals and carbohydrate, respectively. Each 100 g of browntop millet provides 338 Kcal of energy (Maitra, 2020). In recent years, there has been renewed interest in browntop millet as part of a broader movement towards sustainable agriculture. Rising concerns over food security, nutritional security, soil health and climate resilience have driven efforts to reintroduce traditional and climate-smart crops like browntop millet.

The timing of sowing and nutrient management are critical factors influencing crop productivity. Planting at the right time can enhance yields without additional costs by optimizing the interaction between plant and its environment. This interaction affects, how efficiently physiological processes operate, which in turn influences crop yield. Both, sowing schedules and fertilizer application should be adjusted based on local soil fertility, environmental conditions and crop variety. Poor yields in brown top millet are often attributed to unfavorable conditions, late planting, inadequate cultivation practices and insufficient fertilizer use. Effective management of sowing times and nutrients can significantly improve both the quality and quantity of the harvest (Vishwanatha *et al*., 2024).

Material and methods

The field experiment was conducted during *kharif,* 2023-24 at Agricultural Research Station, Hanumanamatti, UAS, Dharwad which is situated at 14.39' N latitude, 75°33' E longitude and at an altitude of 594.36 m above mean sea level (MSL) and it falls within the Northern Transition Zone (Zone VIII) of Karnataka to study the influence of varied sowing windows and nutrient levels on browntop millet. The soil of the experimental site was red sandy loam in texture having acidic pH (5.91), low in available N (230.70 kg ha^{-1}), high in available phosphorus (26.32 kg ha^{-1}) and high in available potassium (329.50 kg ha^{-1}) and low organic carbon content (0.38%). A field experiment was laid out in Split-plot design comprised of three main plots (sowing windows *viz.*, D_1: second fortnight of June, D_2: first fortnight of July, D_3: second fortnight of July) and four sub plots (nutrient levels *viz.,* N_1: 100% RDF, N_2: 75% RDF, N_3: 125% RDF, N_4: 75% RDF + 2% DAP spray at 30 and 60 DAS) which was replicated three times. The crop was supplied with basal dose of FYM @ 6 t ha^{-1} commonly for all the plots. Half the dose of nitrogen and entire dose of phosphorous and potassium in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP), respectively were applied as per the treatments at the time of sowing. Remaining 50% of nitrogen was applied at 30 and 60 DAS. Sowing was done on five different dates (D_1: 30th June 2023, D_2: 13th July 2023, D_3: 30th July 2023).

Results and discussion

Growth parameters, yield and yield attributes

Influence of sowing windows

Browntop millets own during second fortnight of June (D_1), registered remarkably higher growth parameters *viz*., plant height (101.06 cm), total dry weight (13.69 g plant^{-1}), number of tillers (156.70 m^{-1} row length), leaf area per plant (480.06cm^2) and leaf area index (1.60) and yield attributes *viz.,* effective tillers (326.56 m^{-2}), ear length (14.91 cm), grain weight per ear (0.72 g), test weight (3.50 g), grain yield (1577 kg ha^{-1}) and straw yield (2726 kg ha^{-1}) (Table 1).

Early sown crop benefited from a longer photo period for vegetative growth, allowing it to reach a greater height compared to the late-sown crop.These findings are in line with Amanullah *et al*. (2015) who reported higher plant height in early sown pearl millet (20th June) as compared to delayed sowing (10th July and 30th July). Higher number of tillers per meter row length might be due to the fact that, length of day light in late June could be more favorable for the vegetative growth phase of browntop millet, encouraging more tillers production. On the other hand, delayed sowing might coincide with shorter days or a transition towards reproductive growth, leading to fewer tillers. These finding are in conformity with those of Srikanya *et al.* (2020). Higher leaf area and leaf area index registered with crop sown on second fortnight of June was due to the ambient weather parameters (temperature, solar radiation, relative humidity, sunshine hours and rainfall) that resulted in higher photosynthetic potential for prolonged period which reflected into better growth and development over rest of the sowing dates. These findings corroborate with those of Nandini *et al.* (2018). Increase in dry matter production during second fortnight of June may be attributed to higher dry matter accumulation in leaves, stem and reproductive parts. This might have resulted in higher photosynthesis and growth rate which may be due to increased uptake of available nutrients from soil, which are supplied through fertilizers. The combined functions brought about the increased plant height, tillers up to the maximum extent and thereby increased dry matter accumulation per plant which had been previously revealed by Patel and Patel (2012) in pearl millet.

The early-sown crop (second fortnight of June) experienced a longer photo period, which allowed more assimilates to accumulate in the ear and resulted in the maximum number of grains in the ear and delayed sowing reduces yield components because less moisture in late sown conditions which decreases cell division and expansion. This affects the development of

Table 1. Effect of varied sowing windows and nutrient levels on growth parameters of browntop millet at harvest (Except leaf area and LAI at 60 DAS)

Treatments	Plant height (cm)	Number of tillers (m^{1} row length)	Total dry weight (g plant^{-1})	Leaf area per plant (cm^2)	Leaf area index
Main plot- Sowing window (D)					
D_1 : Second fortnight of June	101.06^{a}	156.70^{a}	13.69^{a}	480.06^{a}	1.60^{a}
D_2 : First fortnight of July	96.88^{b}	145.48^{b}	12.53^{b}	452.77^{b}	1.51^{b}
D_3 : Second fortnight of July	92.40^{c}	136.84^{c}	11.55^{c}	415.94^{c}	1.39^{c}
S. Em ±	1.03	1.84	0.20	3.13	0.02
Sub plot- Nutrientlevels (N)					
N_1: 100% RDF	98.80^{ab}	148.90^{ab}	13.16^{a}	458.78^{a}	1.53^{a}
N_2: 75% RDF	89.12^{d}	135.59^{b}	10.83^{b}	417.96^{c}	1.39^{b}
N_3: 125% RDF	101.86^{a}	154.90^{a}	13.72^{a}	470.05^{a}	1.57^{a}
N_4: 75% RDF + 2% DAP spray at 30 and 60 DAS	97.33^{a-c}	145.96^{ab}	12.64^{ab}	451.58^{ab}	1.50^{a}
S. Em ±	2.20	3.06	0.37	7.32	0.02
Interaction- (D×N)					
D_1N_1	103.33^{ab}	160.47^{ab}	14.41^{ab}	498.34^{ab}	1.66^{a}
D_1N_2	89.90^{c}	140.22^{de}	11.29^{de}	427.56^{d-f}	1.43^{cd}
D_1N_3	110.33^{a}	168.00^{a}	15.09^{a}	507.13^{a}	1.69^{a}
D_1N_4	100.66^{a-c}	158.11^{a-c}	13.96^{a-c}	487.22^{a-c}	1.62^{ab}
D_2N_1	99.40^{a-c}	149.22^{b-e}	13.09^{a-d}	460.76^{b-d}	1.54^{b}
D_2N_2	89.50^{c}	135.22^{e}	10.84^{e}	417.44^{ef}	1.39^{d}
D_2N_3	100.60^{a-c}	154.24^{a-d}	13.61^{a-c}	477.76^{a-c}	1.59^{ab}
D_2N_4	98.00^{a-c}	143.22^{b-e}	12.56^{b-e}	455.12^{c-e}	1.52^{bc}
D_3N_1	93.66^{bc}	137.00^{de}	11.97^{c-e}	417.24^{ef}	1.39^{d}
D_3N_2	87.96^{c}	131.33^{e}	10.35^{e}	408.87^{f}	1.36^{d}
D_3N_3	94.66^{bc}	142.46^{c-e}	12.47^{b-e}	425.26^{d-f}	1.42^{cd}
D_3N_4	93.33^{bc}	136.55^{de}	11.41^{de}	412.40^{f}	1.37^{d}
S. Em±	3.79	5.31	0.65	12.70	0.03

*Note: Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

** RDF- 30:15:15 kg N, P_2O_5, K_2O ha^{-1}, ***6 t ha $^{-1}$ FYM was common for all the plots yield components, leading to lower photosynthate production due to a shorter growing period. These results support the findings of Maurya *et al.* (2016). The higher grain and straw yield from early-sown crops could be attributed to favorable weather conditions, such as optimum rainfall, temperature, relative humidity, bright sunshine hours and solar interception, which enhance growth factors like leaf area, dry matter accumulation and yield attributes, directly impacting grain and straw yield (Nandini *et al.,*2018).

Effect of nutrient levels

Among different doses of fertilizers, browntop millet fertilized with 125% RDF (N_3), registered notably higher growth parameters *viz*., plant height (101.86 cm), number of tillers (154.90 m^{-1} row length), total dry weight (13.72 g $plant^{-1}$), leaf area per plant (470.05 cm^2) and leaf area index (1.57) and yield attributes *viz.,* effective tillers (322.77 m^{-2}), ear length (14.92 cm), grain weight per ear (0.70 g), grain yield (1584 kg ha^{-1}) and straw yield (2731 kg ha^{-1}). However, it was on par with both 100% RDF (N_1) as well as 75% RDF with 2% DAP spray at 30 and 60 DAS (N_4). Test weight was not significantly affected with application of different nutrient levels. Application of 125% RDF provides sufficient nutrient to plant which leads to anatomical changes such as increase in size of cells, intercellular spaces, thinner cell walls and lower development of epidermal tissue resulting into increased plant height. Similar findings were reported by Soutade and Raundal (2022). (Table 2).The rate of production and number of tillers in millets are dependent upon nutrient supply. Number of tillers per meter row length increased with increase in the fertility level. The increased tiller production with increased fertilizer may be related to the extra nutrients provided by increased dose of fertilizer for the growth of tiller primordial. Similar findings were observed by Sukanya *et al.* (2022). Increase in total dry weight with 125% RDF may be attributed to higher dry matter accumulation in vegetative and reproductive parts like leaves, stem and ear heads. This might have resulted in higher photosynthesis and growth rate which may be caused due to increased uptake of available nutrients from soil and supplied through fertilizers. Significantly, higher leaf area and leaf area index was recorded with 125% RDF at harvest and is mainly credited to the supply of sufficient nutrients up to the harvest of grains.

Higher yield attributes with application of 125% RDF might be due to, increased doses provides sufficient nutrient to plant which leads to high chlorophyll synthesis and dehydrogenase activity, also it affects source to sink relationship which reflects in higher yields. Triveni *et al.* (2017) also opined that productive tillers per plant, fingers per ear and ear length were found maximum in 125% RDF followed by 100% RDF. The increase in grain and straw yields are reasoned for prolonged supplying ability of nutrients in the red soil conditions at the higher quantity which also coincided with need of the crop. The increase in yield due to N, P and K application could be ascribed

Table 2. Effect of varied sowing windows and nutrient levels on yield and yield attributes of browntop millet

Treatments	Effective tillers (m^{-2})	Ear length (cm)	Grain weight per ear (g)	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Main plot- Sowing window (D)						
D_1 : Second fortnight of June	326.56^{a}	14.91^{a}	0.72^{a}	3.50^{a}	1577^{a}	2726^{a}
D_2 : First fortnight of July	301.26^{b}	13.86^{b}	0.62^{b}	3.29^{b}	1414^{b}	2417^{b}
D_3 : Second fortnight of July	261.89^{c}	13.57^{c}	0.54^{c}	3.10^{c}	1280^{c}	2245^{c}
S. Em±	3.20	0.17	0.002	0.04	36.52	20.86
Sub plot- Nutrientlevels (N)						
N_1: 100% RDF	300.40^{ab}	14.31^{a}	0.65^{b}	3.32^{a}	1522^{ab}	2633^{ab}
N_2: 75% RDF	265.92^{b}	13.33^{c}	0.53^{c}	3.17^{a}	1113^{c}	1910.^{c}
N_3: 125% RDF	322.77^{a}	14.92^{a}	0.70^{a}	3.43^{a}	1584^{a}	2731^{a}
N_4: 75% RDF + 2% DAP spray at 30 and 60 DAS	297.17^{ab}	13.87^{ab}	0.63^{b}	3.25^{a}	1475^{ab}	2578^{ab}
S. Em±	9.42	0.38	0.006	0.05	37	52
Interaction- (D×N)						
D_1N_1	337.20^{ab}	15.15^{ab}	0.74^{b}	3.52^{ab}	1686^{ab}	2908^{a}
D_1N_2	280.47^{c-f}	13.48^{b}	0.60^{e}	3.27^{b-e}	1236^{ef}	2102de
D_1N_3	358.00^{a}	16.74^{a}	0.82^{a}	3.74^{a}	1756^{a}	3018^{a}
D_1N_4	330.55^{a-c}	14.25^{b}	0.72^{b}	3.47^{a-c}	1633^{a-c}	2877^{ab}
D_2N_1	302.78^{b-e}	13.96^{b}	0.65^{d}	3.35^{b-e}	1487^{b-d}	2550^{c}
D_2N_2	274.30^{d-f}	13.42^{b}	0.52^{f}	3.21^{b-e}	1168^{f}	1986^{e}
D_2N_3	326.78^{a-d}	14.14^{b}	0.69^{c}	3.38^{b-d}	1542^{b-d}	2624^{bc}
D_2N_4	301.17^{b-e}	13.90^{b}	0.62^{e}	3.20^{c-e}	1460^{cd}	2508^{c}
D_3N_1	261.22^{ef}	13.83^{b}	0.55^{f}	3.08^{de}	1394de	2440^{c}
D_3N_2	242.98^{f}	13.10^{b}	0.47^{g}	3.03^{e}	936^{g}	1642^{f}
D_3N_3	283.55^{b-f}	13.88^{b}	0.59^{e}	3.18^{c-e}	1456^{cd}	2552^{c}
D_3N_4	259.80^{ef}	13.47^{b}	0.54^{f}	3.09^{de}	1334^{d-f}	2348^{cd}
S. Em±	16.32	0.65	0.01	0.09	64	90

*Note: Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

** RDF- 30:15:15 kg N, P_2O_5, K_2O ha^{-1}

***6 t ha $^{-1}$ FYM was common for all the plots.

to better plant growth and dry matter production due to higher photosynthetic area. This was further corroborated by the fact that, soil of the experimental field was low in nitrogen (230.70 kg ha^{-1}) and medium range in phosphorus (26.32 kg ha^{-1}). Increased grain and straw yield of little millet due to higher levels of nutrients have also been reported by Raundal and Patil (2017).

Combined effects of sowing windows and nutrient levels

Sowing of browntop millet on second fortnight of June with 125% of RDF (D_1N_3) recorded significantly higher plant height (110.33 cm), number of tillers (168.00 m^{-1} row length), total dry weight (15.09 g $plant^{-1}$), leaf area per plant (507.13 cm^2) and leaf area index (1.69). Early sowing provided optimal rainfall, temperature and sunlight during critical growth stages, while the increased nutrient availability (125% RDF) provides sufficient nutrient to plant which leads to anatomical changes that led to increased plant height. Similar findings were reported by Dimple *et al*. (2022). Longer daylight hours in late June can be more beneficial for the vegetative growth phase of browntop millet, promoting total biomass and greater tiller production. The number of tillers per meter of row length also increased with higher fertility levels. Early sowing of brown top millet with higher fertilizer doses resulted in higher leaf area and leaf area index while, lower was recorded for late sowing with reduced fertilizer doses. The broader leaf area could be due to early sowing of crop which has a greater number of leaves and leaf area duration due to plenty of solar availability and higher solar units along with presence of optimum nutrients in soil for the whole growing season. Similar outcomes were reported by Muhammad and Basit (2019).

The increase in grain and straw yield might be due to the synergistic effect of the sowing time and nutrient levels which is likely provided optimal environmental conditions during the critical growth stages, while the increased nutrient supply supported enhanced plant development, leading to a substantial boost in yield and increased yield attributes *viz*., number of effective tillers (358 m^{-2}), ear length (16.47 cm), grain weight per ear (0.82 g) and test weight (3.74 g).

Conclusion

Brown top millet sown early during second fortnight of June recorded significantly higher growth parameters, yield attributes and yield. Application of 125% of RDF is beneficial in achieving better plant potential. Among the interactions, sowing of browntop millet on second fortnight of June with application of 125% of RDF recorded higher growth parameters and yield attributes.

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