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Grain Yield, Nutrient Uptake and Post-harvest Soil Properties of Browntop Millet under Varying Sowing Windows and Nitrogen levels

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Abstract

A field experiment was conducted during rainy season (June to October, 2019) at College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana State, India to find the effect of sowing windows and nitrogen levels on yield, nutrient uptake and post-harvest soil nutrient status of browntop millet. The experiment was laid out in randomized block design with factorial concept and replicated thrice. Treatments consisted of four sowing windows (June 15th, June 30th, July 15th and July 30th) and four nitrogen levels (0, 20, 40 and 60 kg ha^{-1}). Among sowing windows, June 15th recorded higher growth parameters (plant height, leaf area and dry matter production), yield attributes (panicles hill^{-1}, panicle length, weight and grains panicle^{-1}) grain, straw yield, monetary returns and nutrient uptake at harvest (nitrogen, phosphorus and potassium). Post-harvest soil properties (pH, electrical conductivity, organic carbon content, available P and K) were not significantly influenced by sowing windows, but available soil nitrogen was significantly higher with June 15th sowing. Among nitrogen levels, application of 60 kg ha^{-1} recorded significantly higher growth parameters (plant height, leaf area and dry matter production), yield attributes (panicles hill^{-1}, panicle length, weight and grains panicle^{-1}), grain, straw yield, monetary returns and nutrient uptake at harvest (nitrogen, phosphorus and potassium) but, it was comparable with 40 kg ha^{-1}. Varying nitrogen levels did not significantly influence post-harvest soil properties (pH, electrical conductivity and organic carbon content, available P and K); however, available soil N was significantly higher with the application of 40 kg ha^{-1}.

Keywords: Browntop millet, sowing windows, nitrogen, yield, nutrient status

1. Introduction

In the recent past, there has been an increasing recognition for millets as they are nutritionally superior to cereals, characterized by rich dietary fibers, resistant starches, essential amino acids, storage proteins and other bioactive compounds (Amadou et al., 2013) micronutrients and B-complex vitamins (Archana et al., 2014) and hence, aptly termed as nutri-cereals (Banerjee and Maitra, 2020). The seeds contain phyto-nutrients like phytic acid, that lowers cholesterol and phytates that reduce the risk of cancers (Gupta, 2012). They are beneficial for people suffering from diabetic and cardiac diseases (Caulibaly et al., 2011). About

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1.9 billion adults are overweight or obese and 462 million are underweight. In India malnutrition is an acute trouble (Anonymous, 2018). To tackle the threats of malnutrition and hidden hunger, inclusion of these nutrient rich crops in staple diet could be a better nutritional security option (Rao et al., 2013). Millets are climate-resilient and adaptive to a wide range of environment conditions with minimum vulnerability to environmental stresses (Kole et al., 2015). In India, millets are cultivated on an area of 818.5 thousand hectares with a production of 729.6 thousand tonnes and productivity of 817 kg ha^{-1} (Anonymous, 2020). They play pivotal role towards food security and nutrition (Maitra, 2020) amid ever-increasing agricultural costs, climate change and burgeoning mouths to feed worldwide (Tirthankar et al., 2017). Millets with C_4 photosynthetic pathway have enhanced photosynthetic rates (Brahmachari et al., 2018) at elevated CO_2 levels and warm conditions hence, called climate smart crops climate-smart crops (Maitra et al., 2020). Among the small millets, browntop millet (*Brachiaria ramosa* (L.) Stapf; *Panicum ramosum* L., *Urochola ramosa*), is one of the rarest crops commonly known as Dixie signal grass grown in Africa, Arabia, China and Australia (Clayton et al., 2006). It was introduced to the United States from India in 1915 (Oelke et al., 1990). Brown top millet is spread out from the Deccan to Tamil Nadu in the South (Cooke et al., 2005) and Gujarat in the North by the end of the second millennium BCE. It is an ideal catch, cover or crop nurse crop (Miller et al., 2007) against soil erosion. This millet is locally termed as Korale in Kannada and Andukorralu in telugu. It grows well in the drylands of Tumkur, Chitradurga and Chikkaballapura districts of Karnataka and Anantapur district of Andhra Pradesh. This millet is remarkable for its early maturing ability and harvested in about 75 to 80 days and for fodder purpose within 50 days (Sheahan, 2014). It is a rapidly maturing grass, often used as a catch crop, cover crop or nurse crop. Browntop millet represents 10–25% of the diet of terrestrial and water birds (Anonymous, 2014). This millet is a hardy crop well suited for dry land (Bhat et al., 2018) and grown on variety of soils and climates (Kimata et al., 2000). Browntop millet is not only nutritious but also delicious, gluten free and rich in essential nutrients. It is a good source of zinc, iron and fibre. It consists of 11.9 g of moisture, 8.89 g of protein, 1.89 g of fat, and 71.32 g of carbohydrate and provides 338 kcal of energy. The mineral composition constitutes 28 mg of calcium, 7.72 mg of iron, 276 mg of phosphorus, 60 mg of potassium, 94.5 mg of magnesium, 1.99 mg of manganese, 7.60 mg of sodium, 2.5 mg of zinc, and 1.23 mg of copper (Kering and Broderick, 2018). It is a rich source of natural fibre (8.5%) due to which it serves as an excellent medicine for dealing life style diseases. Lower incidence of cardiovascular diseases, duodenal ulcer and hyperglycemia (diabetes) are reported among those who regularly consume millets.

Agronomists have generated wealth of information on more efficient use of inputs such as selection of varieties and nutrient management for millet crops but very meagre information is available with regard to the agronomic practices of brown top millet. The variation in sowing time brings about varied plant environment interaction, which determines the efficiency of inherent physiological processes and ultimately the crop yield (Revathi et al., 2017). Determination of optimum nitrogen level plays an exceptional role in realizing the genetic yield potential of crops under particular geographical conditions (Mahajan et al., 2017). In view of the climate resilience, health benefits of brown top millet coupled with its hardy nature, short duration, excellent nutritive value and huge demand in the recent past, the present investigation was planned to find the ideal sowing window and optimal N dose in Southern Telangana Zone and their influence on growth, yield and nutrient uptake.

2. Materials and Methods

2.1. Study site

The experiment was carried out in browntop millet during *rainy* season from June, 2019 to October, 2019. The experimental site was at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. It is located at 17° 32′ N latitude and 78° 41′ E longitude and at an altitude of 541.6 m above mean sea level and falls under the Southern Telangana agro-climatic zone of Telangana as per Troll's classification. Pre-experiment soil samples drawn from 0-30 cm depth were analyzed for physico-chemical properties. The soil of the experimental site was sandy loam in texture (Sand 64.2%, Silt 27.3% and Clay 8.2%), pH 7.1 (neutral), electrical conductivity (0.31 dS m^{-1}), low in organic carbon (0.31%). The soil was characterized by low available nitrogen (143.0 kg ha^{-1}), medium in available phosphorus (75.0 kg ha^{-1}) and high in available potassium (313.0 kg ha^{-1}).

2.2. Method of data collection

Browntop millet variety Vizianagaram-1 (VZM-1) was used in this experiment for evaluating effect of four sowing windows (D_1-June 15th, D_2-June 30th, D_3-June 15th and D_4-July 30th) and four nitrogen levels (N_1-0 kg ha^{-1}, N_2-20 kg ha^{-1}, N_3-40 kg ha^{-1} and N_4-60 kg ha^{-1}) with 16 treatment combinations arranged in factorial concept and replicated thrice. Crop was sown on different sowing windows as per treatments by adopting inter row spacing 30 cm and intra row spacing of 10 cm. Full dose of P_2O_5 (30 kg ha^{-1}) and K_2O (20 kg ha^{-1}) along with 50 % of nitrogen (as per treatments) was applied as basal and remaining 50 % nitrogen was applied at tillering in all experiment plots except in N_1-0 kg N ha^{-1}. Thinning was done 10 days after sowing to ensure uniform population was maintained in all experimental plots.Crop was grown under rainfed conditions. A total rainfall of 682.2 mm was distributed in 43 rainy days during the crop growth period. The crop was harvested under different sowing windows at maturity stage.

The data on growth parameters and yield attributes was recorded from the five tagged representative hills selected randomly from each treatment plot. The yield from the net plot (grain and straw) was weighed separately and converted to kg ha^{-1}. The destructive plant samples collected at harvest were shade dried followed oven drying at 60°C to attain a constant weight. The grain and straw samples were finely ground and used for nutrient analysis (N, P and K content) by adopting standard procedures. After the harvest of crop, treatment wise soil samples collected from 0–30 cm were analysed for PH, electrical conductivity, organic carbon content (%) and available nutrient status (N, P and K) following standard procedures (Piper, 1966). The data on crop parameters, nutrient uptake and post-harvest soil parameters was statistically analyzed duly following the analysis of variance technique for factorial randomized block design as outlined by Gomez and Gomez, 1984.

3. Results and Discussion

3.1. Plant height

Data on plant height at 40 DAS (days after sowing) indicated significant variation due to sowing windows (Table 1). Earliest sown crop on D_1-June 15th sown crop recorded tallest plants (96.53 cm) over D_2-June 30th (90.03 cm), D_3-July 15th (83.51 cm) and the shortest plants were noticed with D_4-July 30th (77.58 cm) respectively. Improved plant height in early sowing window D_1-June 15th sowing could be ascribed to the prolonged photoperiod enhanced assimilate synthesis and translocation that enhanced the crop to express full potential over rest of sowing windows. Contrary to this, lowest plant height associated with delayed sowing D_4-July 30th could be attributed to the unfavorable weather parameters that coincided with critical crop growth stages and curtailed crop growth. These findings are in line with those of Mubeena et al. (2019).

It could be inferred that each increment in nitrogen level had significantly enhanced the plant height from N_1-0 kg ha^{-1} (77.84 cm) to N_2-20 kg ha^{-1} (86.30 cm), N_3-40 kg ha^{-1} (90.75 cm) and N_4-60 kg ha^{-1} (92.76 cm) but, N_4-60 kg ha^{-1} was comparable with N_3-40 kg ha^{-1} in terms of plant height. Improved plant height with the application of 60 and 40 kg N ha^{-1} was mainly due to the adequate availability of nutrients in soil, enhancing cell division and elongation as compared to corresponding lower levels of nitrogen application (20 and 0 kg N ha^{-1}). These findings are supported by the findings of Arshewar et al. (2018).

3.2. Leaf area

Perusal of data on plant height showed that early sown crop D_1-June 15th maintained its superiority and recorded highest leaf area at 40 DAS (1380.00 cm^2 plant^{-1}). The next best treatments were in the order of D_2-June 30th>(1320 cm^2 plant^{-1}), D_3-July 15th (1278.75 cm^2 plant^{-1})>D_4-July 30th (1302 cm^2 plant^{-1}) respectively. Higher leaf area registered with early

Table 1: Growth and yield attributes of browntop millet as influenced by dates of sowing and nitrogen levels

Treatment	Plant height (cm)	Leaf area (cm^2 hill^{-1})	Dry matter production (g m^{-2})	Days to 50 % flowering	Effective tillers hill^{-1}	Panicle length (cm)	Weight of panicle (g)	Grains panicle^{-1}	Days to maturity
Factor 1: Sowing windows									
D_1 - June 15th	96.53	1380.0	423.5	55	6.52	17.82	2.13	147.92	77
D_2 - June 30th	90.03	1320.0	392.5	53	6.02	16.03	1.81	137.42	74
D_3 - July 15th	83.51	1278.75	355.5	52	5.52	14.22	1.54	127	72
D_4 - July 30th	77.58	120.3.75	321.5	51	5.04	12.33	1.26	120.17	69
SEm±	1.48	3.17	10.39	0.01	0.14	0.38	0.06	1.96	0.69
CD (*p*=0.05)	4.28	12.18	30.00	NS	0.42	1.09	0.18	5.65	2.01
Factor 2: Nitrogen levels									
N_1 - 0 kg ha^{-1}	77.84	1110.00	290.50	50	4.84	10.29	1.30	109.58	69
N_2 - 20 kg ha^{-1}	86.30	1252.50	358.75	50	5.62	13.45	1.56	123.50	72
N_3 - 40 kg ha^{-1}	90.75	1395.00	412.25	54	6.16	17.58	1.86	147.00	74
N_4 - 60 kg ha^{-1}	92.76	1425.00	431.50	54	4.48	19.08	2.03	152.42	75
SEm±	1.48	2.18	10.39	0.01	0.14	0.38	0.06	1.96	0.69
CD (*p*=0.05)	4.28	35.17	30.00	NS	0.42	1.09	0.18	5.65	2.01
Interaction (D×N)									
SEm±	2.96	24.36	20.77	0.02	0.29	0.75	0.13	3.91	1.38
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

sowing window D_1-June 15th was due to the ambient weather parameters (temperature, solar radiation and rainfall) that resulted in higher tiller count over rest of the sowing dates. These results corroborate with those of Bashir et al. (2015).

Crop fertilized with N_4-60 kg ha^{-1} maintained its superiority (1437.50 cm^2 plant^{-1}) over sub-optimal N application *viz*., N_2-20 kg ha^{-1} (1227.25 cm^2 plant^{-1}) and N_1-0 kg ha^{-1} (1123.75 cm^2 plant^{-1}) but, N_4 was equally superior to N_3-40 kg ha^{-1} (1386.25 cm^2 plant^{-1}) in terms of leaf area. Nitrogen is the main component of the protoplasm and aid in stimulation of cell division and elongation (Ali, 2010). Improved leaf area associated with 40 kg N ha^{-1} was due to adequate availability of N, cell multiplication and enlargement over corresponding 0 and 20 kg N ha^{-1}. Similarly, results of improved leaf area with nitrogen application in finger millet were reported by Patil et al. (2015).

3.3. Dry matter accumulation

Across the sowing windows, crop sown on D_1-June 15th registered significantly higher dry matter (423.50 g m^{-2}) and it was followed by D_2-June 30th (392.50 g m^{-2}) and D_3-July 15th (355.50 g m^{-2}) while, the lowest dry matter accumulation was evidenced in D_4-July 30th (321.50 g m^{-2}). Variation in dry matter accumulation across the sowing dates was associated with differences in the amount of intercepted radiation. Further, the increase in plant height and leaf area under D_1-June 15th coupled with the extended development period also reflected in better interception and utilization of radiant energy, leading to production of higher photosynthates that ultimately resulted in higher accumulation of dry matter accumulation. Similar results in maize were earlier reported by Leela et al. (2013).

Varying levels of nitrogen fertilization depicted its significance in terms of dry matter accumulation over control plot. Among the nitrogen application, N_4-60 kg ha^{-1} maintained its superiority in terms of dry matter production (431.50 g m^{-2}) over N_2-20 kg ha^{-1} (358.75 g m^{-2}) and control (290.50 g m^{-2}). However, N_4-60 kg ha^{-1} was comparable with N_3-40 kg ha^{-1} (412.25 g m^{-2}). Enhanced dry matter accumulation with adequate supply of nitrogen, as evidenced in this investigation corroborate with the findings of Patil et al., 2015, who highlighted the positive role of N in maintenance of active leaf area that favored higher photosynthates through better assimilation of carbon from atmosphere as compared to no N application and sub-optimal dose of N.

3.4. Days to 50% flowering

In general days to 50% flowering in browntop millet varied from 51 days to 55 days among sowing dates and nitrogen levels but, it was found to be non-significant. It could be observed that crop sown on D_1-June 15th took relatively higher days to 50% flowering (55 days) followed by June 30th (53 days), July 15th (52 days) and July 30th (51 days) (Andhale et al., 2007b) observed delay in days to 50 % flowering in early sown pearl millet crop and it hastened with delay in planting date. Among nitrogen levels crop fertilized with N_4-60 kg ha^{-1} attained days to 50% flowering (54 days) relatively later than N_2-20 kg ha^{-1} (52 days) and no nitrogen application (50 days). Similar findings of delay in days to 50% flowering with N application were documented by Pradeep et al. (2014).

3.5. Panicles hill^{-1}

Number of effective tillers hill^{-1} differed significantly across sowing windows and nitrogen levels. Among the treatments, crop sown on D_1-June 15th recorded significantly higher number of effective tillers m^{-2} (6.52) over D_2-June 30th (6.02), D_3-July 15th (5.52) and lowest effective tillers was observed in plots on D_4-July 30th (5.04). Higher effective tillers in crop sown on D_1-June 15th had opportunity for longer growth period with sufficient light, temperature while, delayed sowing significantly reduced the effective tillers due to inadequate vegetative growth and dry spells at later stages. These findings are in line with those of Mubeena et al. (2019).

Among the nitrogen levels, application of N_4-60 kg ha^{-1} registered significantly higher number of effective tillers m^{-2} (6.48) over corresponding lower dose of nitrogen application viz., N_2-20 kg ha^{-1} (5.62), and N_1-0 kg ha^{-1} (4.84). However, N_4-60 kg ha^{-1} was on par with N_3-40 kg ha^{-1} (6.16). Similar findings of improved panicles with nitrogen fertilization in pearl millet were reported by Navya Jyothi et al. (2015).

3.6. Panicle length

Panicle length differed significantly among sowing windows. The crop sown on D_1-June 15th registered significantly greater panicle length (17.82 cm) over D_2-June 30th (16.03 cm) and D_3-July 15th (14.22 cm) and lowest panicle length was recorded on July 30th (12.33 cm).

Significant increase in panicle length noted with early sowing window over delayed sowings was due to the opportunity for longer growth period, higher assimilate synthesis and translocation towards panicle (Navya Jyothi et al., 2015). contradictory to this, reduced panicle length with delay in sowing was due to inadequate vegetative growth and curtailed growing season, coupled with critical dry spells and forced maturity. Similar results were earlier documented by Prathima et al. (2015).

Varying levels of nitrogen application had significantly influenced that panicle length and crop applied with N_4-60 kg ha^{-1} registered significantly higher panicle length (19.08 cm) over N_2-20 kg ha^{-1} (13.45 cm), N_1-0 kg ha^{-1} (10.29 cm) however, N_4-60 kg ha^{-1} was on par with N_3-40 kg ha^{-1} (17.58 cm) in terms of panicle length. A Progressive increase in panicle length was recorded with an increase in nitrogen level and the maximum was in N_3-40 kg ha^{-1}, which was probably due to more vigorous and luxuriant vegetative growth which favored better partitioning of assimilates from source to sink, as manifested with higher leaf area and dry matter accumulation (Nagaraju et al., 2009).

3.7. Panicle weight

Panicle weight varied was significantly with sowing windows and there was significant reduction with delay in sowing from D_1-June 15th (2.13 g) to D_2-June 30th (1.81 g), D_3-July 15th (1.54 g) and the lightest panicles were noticed in crop sown on D_4-July 30th (1.26 g). Heavier panicles in early sowing window D_1-June 15th could be attributed to the maximum light interception, reduced moisture stress in addition to effective translocation of assimilates towards higher dry matter partitioning and translocation to sink in comparison to delayed sowing. These results are in line with those of Revathi et al. (2017) who reported heavier panicles with early sowing due to exposure of crop to high light intensity in comparison to delayed sowing with shorter day length (Leila et al., 2008) reported that delaying planting beyond 15th June significantly reduced panicle weight in pearl millet and decrease under late planting dates was correlated to the low duration of light interception in comparison to the early sown crop.

Nitrogen application had significant role in improving panicle weight. There was a remarkable increase in panicle weight with graded levels of N application over control plot. Among the treatments, application of N_4-60 kg ha^{-1} recorded significantly heavier panicles (2.03 g) over N_2-20 kg ha^{-1} (1.56 g) and the lowest panicle weight (1.30 g) was observed in plots with no nitrogen application. However, N_4-60 kg ha^{-1} and N_3-40 kg ha^{-1} (1.86 g) were equally superior in terms of panicle weight. Improved panicle weight in D_1-June 15th could be attributed to the maximum light interception, reduced moisture stress in addition to effective translocation assimilates and adequate nitrogen, efficient dry matter partitioning, and better translocation to sink, leading in higher number of grains per panicle and large sized grains. Similar findings on improved panicle weight with higher N application were reported in finger millet by Apoorva et al., (2010).

3.8. No. of grains panicle^{-1}

From the data it is clear that there was a significant reduction in grains panicle^{-1} across sowing windows from D_1-June 15th (147.92) to D_2-June 30th (137.42), D_3-July 15th (127.00) and least grain number was observed with D_4-July 30th (120.17). Early sown crop had prolonged photoperiod that favored higher assimilate synthesis and translocation towards panicle that produced maximum number of grains per panicle. Similar results of improved kernels due to earlier sowing in maize were reported by Leela et al. (2013).

Nitrogen application had profound and significant effect on grains panicle^{-1}. There was a linear and significant increase in grain number from N_1-0 kg N ha^{-1} (109.58) to N_2-20 kg N ha^{-1} (123.50), N_3-40 kg N ha^{-1} (147.00) and N_4-60 kg ha^{-1} (152.42) but, N_4-60 kg ha^{-1} and N_3-40 kg ha^{-1} were statistically on par with each other. Higher grains per panicle registered with the application of 40 kg N ha^{-1} might be ascribed to the adequate amount of nitrogen that helped in improved source-sink relationship and facilitated towards sufficient space for accommodation of higher number of grains per panicle in comparison to corresponding lower levels of N application. Similar findings on positive role of N application on panicle weight were reported by Amanullah et al. (2015).

3.9. Days to maturity

From the data it is clear that days to maturity were significantly decreased with a delay in date of sowing from D_1-June 15th matured late (77 days) over D_2-June 30th (74 days), D_3-July 15th (72 days) and D_4-July 30th (69 days) and late sown crop completed its life cycle at an accelerated pace, leading to shortening of days taken to maturity in comparison to early sown crop. Delay in days to maturity registered with June 15th over June 30th, July 15th and July 30th might be due to prolonged photoperiod as a result of more assimilate translocation and favorable soil moisture, temperature that enhanced the crop to express full potential and prolonged crop production. While, delayed sowing reflected in greater biotic, dry spells, reduced and stressed reproductive phase that reduced days for maturity. As millets are short day plants, delayed sowing time towards late *kharif* will force the crop to enter into reproductive phase and hasten maturity (Detroja et al., 2018).

Crop fertilized with N_4-60 kg ha^{-1} took significantly higher number of days to maturity (75 days) over corresponding lower dose of nitrogen *i.e* N_2-20 kg ha^{-1} (72 days) and control (69 days). However, N_4-60 kg ha^{-1} was statistically comparable with N_3-40 kg ha^{-1} (74 days). Delayed maturity in crop with higher nitrogen application was probably due to prolonged availability of adequate amount of nutrients coupled with the enhanced assimilate synthesis and translocation that prolonged the duration. Contrary, to this crop applied with no nitrogen lacked sufficient nutrient availability at different crop growth stages that led to forced maturity. These results are in line with those of Pradeep et al. (2014).

3.10. Grain yield

It could be inferred from the data (Table 2) that the grain yield varied significantly among the sowing windows and there was a significant reduction in yield with delay in sowing from D_1-June 15th (2003 kg ha^{-1}) towards the last sowing window D_4-July 30th (1540 kg ha^{-1}). The deviation in yield was to the tune of 8.28, 13.23 and 23.11% respectively over earliest sowing window D_1-June 15th. Improved yield associated with early sowing window was due to the favorable abiotic factors coupled with better nutrient supply and availability due to higher rate of mobilization of nutrients. Similar findings of improved yield with early sowing window were earlier reported in maize by Leela et al. (2013). Contrary to this lower yield registered with delayed sowing window D_4-30th July was be due to the exposure of crop to dry spells, higher temperatures, reduced photosynthetic efficiency and low mobilization of nutrients that coincided with short day periods that reflected in lower biomass accumulation and yield attributes. Similar results of lower grain yield with delayed sowing in were reported by Prakash et al. (2017) in sorghum

Table 2: Grain, straw yield (kg ha^{-1}), harvest index (%) and nutrient uptake (kg ha^{-1}) of browntop millet as influenced by sowing windows and nitrogen levels

Treatment	Grain yield	Straw yield	Harvest index	N uptake		P uptake		K uptake	
				Grain	Straw	Grain	Straw	Grain	Straw
Factor 1: Sowing windows									
D_1 - June 15th	2003	3930	33.77	108.35	60.33	23.17	13.98	26.75	102.63
D_2 - June 30th	1837	3764	32.08	86.54	50.29	19.94	12.17	22.81	79.53
D_3 - July 15th	1738	3618	32.45	73.06	40.35	16.74	10.20	19.08	61.07
D_4 - July 30th	1540	3466	30.76	63.38	34.98	13.63	8.15	14.70	52.22
SEm±	27	50	0.50	1.88	1.27	1.04	0.60	1.20	2.24
CD (p=0.05)	77	143	NS	5.43	3.67	3.01	1.74	3.46	6.47
Factor 2: Nitrogen levels									
N_1 - 0 kg ha^{-1}	1569	3326	31.94	45.22	25.07	13.77	7.29	15.73	42.76
N_2 - 20 kg ha^{-1}	1773	3642	32.68	78.56	34.30	17.13	9.88	26.00	68.05
N_3 - 40 kg ha^{-1}	1855	3862	32.39	98.77	43.44	20.53	12.84	33.32	86.28
N_4 - 60 kg ha^{-1}	1921	3949	33.71	112.70	51.97	22.28	14.49	35.39	91.75
SEm±	27	50	0.50	4.88	2.67	1.04	0.60	1.20	2.24
CD (p=0.05)	77	143	NS	14.43	8.67	3.01	1.74	3.46	6.47
Interaction (D×N)									
SEm±	53	99	1.0	6.76	3.97	2.09	1.20	2.40	4.48
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

crop respectively.

Among the nitrogen treatments, there was a gradual and significant increase in grain yield with an increase in nitrogen application from N_1-0 kg ha^{-1} (1569 kg ha^{-1}) to N_4-60 kg ha^{-1} (1921 kg ha^{-1}). However, the grain yield registered with N_4-60 and N_3-40 kg ha^{-1} was statistically comparable with each other. The improvement in yield with 20 and 40 kg N ha^{-1} was to an extent of 13.00 and 18.22% respectively over N_1-0 kg N ha^{-1}. Efficient translocation of assimilates to the reproductive parts owing to adequate supply of nitrogen registered better growth, yield attributes that reflected in higher grain yield. These results are in line with those of Rurinda et al. (2014) who highlighted the beneficial role of nitrogen in improving grain yield.

3.11. Straw yield

Similar to grain yield the straw yield of brown top millet differed significantly across sowing windows and it ranged from 3930 kg ha^{-1} to 3466 kg ha^{-1} from D_1-June 15th to D_4-July 30th. Higher straw yield associated with early sowing window (D_1-June 15th) was due to the ambient weather parameters that coincided with prolonged photoperiod and reflected in higher assimilate synthesis and translocation from source to sink. Maurya et al., 2016 reported similar results of improved straw yield with early sowing in pearl millet. On the other hand, lower straw yield registered with crop sown in the last sowing window (D_4-July 30th) was due to abiotic stress factors and coincidence of short growth period with reduced vegetative phase and lower mobility of photosynthates towards sink (Nagaraju et al., 2009).

With respect to nitrogen application, the straw yield ranged from 3326 kg ha^{-1} to 3949 kg ha^{-1} with application of N_1-0 kg ha^{-1} to N_4-60 kg ha^{-1}. Higher straw yield in crop fertilized with N_3-40 kg ha^{-1} was due to the improved nutrient availability and uptake that manifested in higher photosynthetic surface towards improved assimilate synthesis and translocation. While, lower straw yield recorded in control plots was on account of lower growth due to starved conditions coupled with the low initial nutrient status of the experimental soil (Amanullah et al., 2015).

3.12. Harvest index

There was no significant effect of sowing dates in terms of harvest index of browntop millet. An overview of the data indicated that application of varying levels of nitrogen was found to be non-significant and however the interaction effect of sowing dates and nitrogen levels were found to be non-significant. The non-significant trend in harvest index in the present study could be attributed to the negligible differences in the ratio of economic to biological yield among different treatments (Table 2).

3.13. Monetary returns

Higher monetary returns *viz*; gross, net returns and B: C ratio were accrued with early sown crop; D_1-June 15th (101080, 76680 ₹ ha^{-1} and 2.79) and monetary returns declined significantly with delay in the sowing window beyond D_1-June 15th (Table 3). Higher monetary returns fetched with early sowing window D_1- June 15th were due to significantly higher grain yield over rest of the sowing windows. These results are in accordance with those of Mubeena et al. (2019).

With respect to the nitrogen levels, monetary returns significantly enhanced from N_1-0 to N_4- 60 kg ha^{-1}. However, the gross, net returns and B:C ratio fetched with N_4- 60 kg N ha^{-1} and N_4- 40 kg ha^{-1} were comparable to each other. Higher monetary returns obtained with 40 kg N ha^{-1} could be attributed to improved grain yield due to adequate nutrient availability as a resultant of improved growth and yield attributes over rest of the treatments. These findings corroborate with Arshewar et al. (2018).

Table 3: Gross, net returns and B:C ratio of browntop millet as influenced by sowing windows and nitrogen levels

Treatment	Gross returns (ha^{-1})	Net returns (ha^{-1})	B:C ratio
Factor 1: Sowing windows			
D_1 - June 15th	101080	76680	2.79
D_2 - June 30th	95562	68162	2.48
D_3 - July 15th	88515	61115	2.23
D_4 - July 30th	80239	52840	1.92
SEm±	2141	2149	0.07
CD (p=0.05)	6184	6207	0.207
Factor 2: Nitrogen levels			
N_1 - 0 kg ha^{-1}	80458	50861	1.71
N_2 - 20 kg ha^{-1}	90747	60910	2.04
N_3 - 40 kg ha^{-1}	97743	67669	2.25
N_4 - 60 kg ha^{-1}	100014	69701	2.29
SEm±	2141	2149	0.07
CD (p=0.05)	6184	6207	0.207
Interaction (D×N)			
SEm±	4282	4298	0.14
CD (p=0.05)	NS	NS	NS

3.2. Nutrient uptake

3.2.1. Nitrogen uptake

There was a decrease in the uptake of nutrients with delay in sowing window and data revealed (Table 2) that earliest sowing window D_1-June 15th registered higher N uptake by grain and straw (108.35 and 60.33 kg ha^{-1}) over rest of the treatments *viz*., D_2-30th June (86.54 and 50.29), D_3-15th July (73.06 and 40.35) D_4-30th July (63.38 and 34.98 kg ha^{-1}). Higher N uptake in early sowing window D_1-June 15th sown crop could be ascribed to the prolonged photoperiod that facilitated higher assimilatory surface that contributed and reflected in higher grain and straw yield as evident from the respective data coupled with higher N content. Similar results of improved N uptake were reported by Mubeena et al. (2019) in foxtail millet.

Among the nitrogen levels, N_4-60 kg ha^{-1} registered significantly higher nitrogen uptake by grain and straw (112.70 and 51.97 kg ha^{-1}) over other treatments N_2-20 kg ha^{-1} (78.56 and 34.30 kg ha^{-1}) N_1-0 kg ha^{-1} (45.22 and 25.07 kg ha^{-1}). However, N_4-60 kg ha^{-1} was on par with N_3-40 kg ha^{-1} (98.77 and 43.44 kg ha^{-1}). Increased nitrogen uptake with 40 kg N ha^{-1} was due to improved growth and dry matter production coupled with higher cell permeability and better absorption owing to greater availability of nutrients over corresponding lower levels of 20 and 0 kg N ha^{-1} (Nigade and More, 2013). Due to increase in nitrogen application, there was an increase in the root exudates that act as a substrate for the micro-organisms and mineralize the organic nitrogen, thus, increasing the nitrogen status of the soil (Navya jyothi et al., 2016).

3.2.2. Phosphorus uptake

Highest uptake of phosphorus by grain and straw was registered with earliest sowing window D_1-June 15th (23.17 and 13.98 kg ha^{-1}) and there was a significant reduction in P uptake *i.e*, D_2-June 30th (19.94 and 12.17 kg ha^{-1}), D_3-July 15th (16.74 and 10.20 kg ha^{-1}) and D_4-July 30th (13.63 and 8.15 kg ha^{-1}). These findings are in line with those of Andhale et al., 2007a.

Among the nitrogen levels, Phosphorus uptake by grain was significantly higher with N_4-60 kg ha^{-1} (22.28 and 14.49 kg ha^{-1}) and N_3-40 kg ha^{-1} (20.53 and 12.84 kg ha^{-1}) which were equally superior to each other but superior to rest of the treatments *viz*., treatments N_2-20 kg ha^{-1} (17.13 and 9.88 kg ha^{-1}) and N_1-0 kg ha^{-1} (13.77 and 7.29 kg ha^{-1}). Higher P uptake by crop sown on D_1-15th June and N_3-40 kg ha^{-1} could be ascribed to the ambient weather parameters throughout crop growth period that favored relatively higher grain and straw yield and P content over rest of the treatments as evident from the respective data. Similarly, Mubeena et al. (2019) documented higher P uptake with early sowing and higher RDF application over delayed sowing and lower RDF application.

3.2.3. Potassium uptake

With respect to the sowing windows, highest potassium uptake was registered with D_1-June 15th (26.75 and 102.63 kg ha^{-1}) and it reduced significantly thereafter with D_2 -June 30th (22.81 and 79.53 kg ha^{-1}), D_3-July 15th (19.08 and 61.07 kg ha^{-1}) and lowest uptake was recorded with D_4-July 30th (14.70 and 52.22 kg ha^{-1}) respectively (Deshmukh et al., 2013).

Among the nitrogen levels, crop supplied with N_4-60 kg ha^{-1} registered significantly higher Potassium uptake by grain and straw (35.39 and 91.75 kg ha^{-1}) over other treatments N_2-20 kg ha^{-1} (26.00 and 68.05 kg ha^{-1}) and N_1-0 kg ha^{-1} (15.73 and 42.76 kg ha^{-1}). However, N_4-60 kg ha^{-1} was comparable with N_3-40 kg ha^{-1}(33.32 and 86.28 kg ha^{-1}) in terms of potassium uptake. Significantly higher dry matter production (grain and straw) coupled with K content in early sowing window D_1-15th

June reflected in higher K uptake as compared to rest of the sowing windows. Similarly, improved K uptake with higher N application (40 and 60 kg ha^{-1}) could be attributed to the improved grain and straw yield and K content as evident from the respective data (Table 3). Improvement in K uptake due to application of optimum dose of nitrogen over suboptimal dose was also reported by El Hamdy et al. (2010).

3.3. Post-harvest available soil nutrient status

Perusal of data on post-harvest soil properties (Table 4) indicated soil pH, electrical conductivity and organic carbon after the harvest of browntop millet crop were not significantly influenced by sowing windows, nitrogen levels or due to their interaction. Further, the data indicated that the post-harvest pH, electrical conductivity and organic carbon did not differ over initial values. The basic properties like pH electrical conductivity and organic carbon did not vary significantly change due to sowing windows, application of varying levels of nitrogen as well due to their interaction. A significant change in soil properties *viz*; pH, EC and OC is a long-term process and within a short period of experimentation the differences are non-significant and hence, the magnitude of change is inconspicuous (Thakur et al., 2013).

Table 4: Post-harvest soil properties of browntop millet as influenced by sowing windows and nitrogen levels

Treatment	pH	EC (dS m^{-1})	OC (%)	N	P	K
				(kg ha^{-1})		
Factor 1: Sowing windows						
D_1 - June 15th	6.97	0.29	0.49	149.75	73.81	319.84
D_2 - June 30th	6.98	0.30	0.48	141.21	73.20	318.19
D_3 - July 15th	6.93	0.30	0.49	133.00	72.20	316.01
D_4 - July 30th	6.97	0.32	0.48	124.50	71.38	313.99
SEm±	0.03	0.01	0.01	2.83	2.14	5.83
CD (p=0.05)	NS	NS	NS	8.18	NS	NS
Factor 2: Nitrogen levels						
N_1 - 0 kg ha^{-1}	6.97	0.30	0.49	122.75	70.22	311.29
N_2 - 20 kg ha^{-1}	6.96	0.29	0.49	134.83	72.18	315.44
N_3 - 40 kg ha^{-1}	6.94	0.31	0.49	142.67	73.74	318.70
N_4 - 60 kg ha^{-1}	6.98	0.31	0.47	148.21	74.45	322.60
SEm±	0.03	0.01	0.01	2.83	2.14	5.83
CD (p=0.05)	NS	NS	NS	8.18	NS	NS
Interaction (D×N)						
SEm±	NS	NS	NS	5.66	4.28	11.65
CD (p=0.05)	NS	NS	NS	NS	NS	NS

3.3.1. Available soil nitrogen

It is clearly evident from the data that there was significant and pronounced effect of sowing windows on available soil nitrogen status**.** Early sown crop on D_1-June 15th registered higher available N status (149.75 kg ha^{-1}) in comparison to D_2-June 30th (141.21 kg ha^{-1}), D_3-July 15th (133.00 kg ha^{-1}) and D_4-July 15th (124.50 kg ha^{-1}) respectively. Crop sown on D_1-June 15th had exposure to ambient weather parameters that favored better crop growth and development owing to higher photosynthetic surface and dry matter accumulation which might have added relatively higher leaf and root biomass to the soil (Amanullah et al., 2015).

There was a significant improvement in post-harvest available soil nitrogen status with each increment in N level. Among the treatments, N_4-60 kg ha^{-1} recorded significantly higher available N (148.21 kg ha^{-1}) over N_2-20 kg ha^{-1} (134.37 kg ha^{-1}) and control (122.75 kg ha^{-1}) respectively. However, N_4-60 kg ha^{-1} was comparable with treatment N_3-40 kg ha^{-1} (142.67 kg ha^{-1}). Higher post-harvest N in plots applied with N_4-60 kg N ha^{-1} and N_3-40 kg ha^{-1} was probably due to adequate supply and availability of nutrients to crop that favored higher dry matter production and might have added relatively higher leaf and root biomass to soil and higher nitrogen application in comparison to rest of the treatments. The results corroborate with those of (Dwivedi et al., 2016).

3.3.2. Available soil phosphorus

It could be inferred from the data that the post-harvest available phosphors status was not significantly influenced either by sowing windows or by varying nitrogen levels. This might be probably due to the uniform application of Phosphatic fertilizer to all experiment plots, coupled with the fixation of P–a common phenomenon in soils. Similarly in foxtail millet Navya Jyothi et al. (2016) reported that the activity of phosphatase enzymes declined towards crop maturity and lead to higher fixation of phosphorous in the soil.

3.3.3. Available soil potassium

An overview of the data on post-harvest available potassium status indicated that it was not significantly influenced by sowing windows and nitrogen levels. This might be probably due to the uniform addition of potashic fertilizer and high initial content of the available soil potassium. These results find support from (Jagathjothi et al., 2010).

4. Conclusion

On sandy loam soils of Southern Telangana region, browntop millet sown on June 15th and fertilized with 40 kg N ha^{-1} recorded significantly higher growth parameters, yield attributes, grain, straw yield monetary returns and nutrient uptake (N, P and K) at harvest. Among Post-harvest soil available nutrients nitrogen was significantly higher with 15th June sowing and application of 40 kg ha^{-1} and pH, soil electrical conductivity and organic carbon were not significantly influenced by sowing windows and N levels.

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