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Performance of Nutricereals and their Varieties under Varied Sowing Windows

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ABSTRACT: A field trial was conducted during the *kharif* seasons of 2021 and 2022, at University of Agricultural Sciences, GKVK, Bengaluru, Karnataka. The aim of the study was to investigate the agronomic performance of two varieties each in foxtail millet, proso millet and little millet across three sowing windows *viz*., second fortnight of august (W_1), first fortnight of September (W_2) and second fortnight of september (W_3). There were 18 treatments with three replications each, tested in a factorial randomized design. In the study, significant variations were observed in absolute growth rate, crop growth rate and relative growth rate. Sowing during August second fortnight has recorded higher absolute growth rate (0.4810 g/day), crop growth rate (10.05 g/m^2/day), relative growth rate (0.0174 g/g/day) at 60 DAS-at harvest. Among the crops, higher absolute growth rate (0.4286 g/day), relative growth rate (0.0185 g/g /day$^-$) and crop growth rate (9.33 g/m^2/day) were recorded in foxtail millet at 60 DAS-at harvest. Among varieties DHFt 109-3, GPUP-21 and GPUL-6 recorded higher AGR, CGR and RGR than GPUF-3, GPUP-28 and DHLM-36-3 at 60 DAS-at harvest. Foxtail millet consistently displayed higher values in several parameters, with DHFt-109-3 sown during second fortnight of august was showing superior performance in terms of AGR (0.5348 g/day), CGR (10.96 g/m^2/day) and RGR (0.0207 g/g/day) at 60 DAS-at harvest. Proso millet demonstrated the early maturation, while little millet showed relatively late performance across different sowing windows.

Keywords: Absolute growth rate, growth, interaction, small millets, sowing windows, yield.

INTRODUCTION

Millet crops have long history of cultivation of more than 5000 year (Prabhakar *et al*., 2018; Sukanya *et al.* 2023). Now a days millets are called as nutricereals because they are rich nutricereals in which sorghum and pearl millet are major millets and millets such as finger millet, Foxtail millet, Proso millet kodo millet and little millet barnyard millet and Brountop millet are minor millets. These small millets have gained attention for their nutritional benefits, including being gluten-free, rich in micronutrients, and having a low glycemic index. Millets are described as "miracle crops" because of their numerous advantages, including their use as food and food products with added value, forage, contribution to agro-diversity, low nutrient requirements, greater carbon sequestration (C_4 plants), ability to prevent erosion in arid regions and confirmation of adequate supply of food and nutrition for smallholders who live in harsh environmental condition (Sukanya *et al.* 2022). They are considered important in addressing issues related to food security and nutrition, particularly in regions where they are traditionally grown. Additionally, these millets contribute to biodiversity and sustainable agriculture due to their ability to grow in diverse environmental conditions with minimal inputs. As a result, there has been a renewed interest in promoting the cultivation and consumption of small millets for both nutritional and environmental reasons. Moreover, as C_4 plant, millets sequester carbon, thereby adding to CO_2 reduction opportunities, contribute to improved agro-biodiversity by their diversity and allow mutually beneficial intercropping with other vital crops. In view of this background current research was formulated to study the growth and yield potential of foxtail millet Proso millet, little millet and their varieties in late *kharif* sowing windows.

MATERIAL AND METHODS

The field trials were conducted at Zonal Agricultural Research Station (ZARS), University of Agricultural Sciences (UAS), Gandhi Krishi Vigyan Kendra (GKVK), Bangaluru. during *Kharif* season of 2021 and 2022. The experimental site is located in Eastern Dry Zone (Zone-V) of Karnataka and found between 12º 51' N Latitude and 77º 35' E Longitude at an altitude of 930 m above Mean Sea Level (MSL). The soil of the experimental site was red sandy loam. Composite soil samples have been drawn at random from the experimental site before experimentation and analyzed for physico- chemical properties. The soil of the experimental site was slightly acidic in reaction (pH 5.95) with low electrical conductivity (0.22 ds/m) and low organic carbon content (0.36 %). The soil was low in available nitrogen (249.7 kg/ha), high in available phosphorus (71.80 P_2O_5 kg/ha) and medium in available potassium (180.40 K_2O kg/ha). The Experiment was carried out with 3 factors laid in Factorial Randomized Complete Block Design replicated thrice. Treatments were of three sowing windows (August 2nd, September 1st and September 2nd fortnight), three crops (foxtail millet, Proso millet and little millet) and two varieties (Foxtail millet: GPUF-3 and DHFt 109-3; Proso millet: GPUP-28 and GPUP-21; Little millet: GPUL-6 and DHLM 36-3).

Absolute Growth Rate AGR (g/day)

It indicates the dry weight increase per unit time and expressed in gram per day. It was calculated by using the following formula given by (Radford 1967).

AGR $=W_2-W_1/t_2-t_1$

Where,

W_1 and W_2= Total dry matter per plant (g) at time t_1 and t_2, respectively. $t_2–t_1$= Time interval

Crop Growth Rate CGR (g/m^2/day)

It is the absolute growth rate per unit ground area and expressed as gram per m^2 per day

It was worked out by adopting the formula of Watson (1952).

CGR = W_2-W_1/t_2-t_1 1/P

Where,

W_1 and W_2=Total dry matter per plant (g) at time t_1 and t_2, respectively. $t_2–t_1$= Time interval between two stages(days).

P =Ground area covered by the plant (m^2)

Relative Growth Rate RGR (g/g/day)

Relative growth rate was calculated by the formula of Radford (1967) and expressed as g/g/day

$$\text{RGR (g/g/day)} = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where,

W_1 and W_2=Total dry matter per plant (g) at time t_1 and t_2, respectively $t_2–t_1$ = Time interval between two stages(days).

Net Assimilation Rate NAR (g/dm^2/day)

NAR is the rate of increase in the dry matter per unit leaf area per unit time. NAR was calculated according to Gregory (1926) as

NAR = $W_2-W_1/t_2-t_1 \times \text{Loge}L_2-\text{Loge}L_1/L_2- L_1$

Where,

L_1 and W_1= Leaf area and dry weight of the plant respectively at the time t_1 L_2 and W_2 = Leaf area and dry weight of the plant respectively at the time t_2.

Absolute growth rate (g/day) of small millets as influenced by sowing windows and varieties.

Treatments	0 - 30 DAS			30- 60 DAS			60 DAS - harvest		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Sowing Window (W)									
W_1	0.1489	0.1538	0.2258	0.3223	0.3268	0.4880	0.3589	0.2441	0.4810
W_2	0.1131	0.1169	0.1716	0.3033	0.3101	0.4618	0.2731	0.3150	0.4306
W_3	0.0747	0.0772	0.1133	0.3009	0.3044	0.4549	0.2359	0.2336	0.3527
S.Em ±	0.0004	0.0004	0.0006	0.0072	0.0070	0.0106	0.0040	0.0031	0.0049
CD at 5%	0.0012	0.0012	0.0018	0.0208	0.0201	0.0304	0.0115	0.0088	0.0141
Crops (C)									
C_1	0.1237	0.1279	0.1877	0.3638	0.3715	0.5534	0.2975	0.2623	0.4286
C_2	0.1137	0.1175	0.1725	0.3098	0.3121	0.4670	0.2927	0.2562	0.4208
C_3	0.0992	0.1025	0.1505	0.2529	0.2579	0.3843	0.2777	0.2742	0.4148
S.Em ±	0.0004	0.0004	0.0006	0.0072	0.0070	0.0106	0.0040	0.0031	0.0049
CD at 5%	0.0012	0.0012	0.0018	0.0208	0.0201	0.0304	0.0115	0.0088	0.0141
Varieties (V)									
V_1	0.1095	0.1132	0.1661	0.3040	0.3073	0.4593	0.2902	0.2633	0.4219
V_2	0.1149	0.1188	0.1743	0.3137	0.3203	0.4772	0.2884	0.2651	0.4209
S.Em ±	0.0004	0.0004	0.0005	0.0059	0.0057	0.0086	0.0033	0.0025	0.0040
CD at 5%	0.0010	0.0010	0.0015	0.0170	0.0164	0.0249	0.0094	0.0072	0.0115
Sowing Window (W) × Crops (C)									
W_1C_1	0.1560	0.1612	0.2366	0.3784	0.3856	0.5748	0.3936	0.2517	0.5194
W_1C_2	0.1470	0.1519	0.2229	0.3124	0.3208	0.4770	0.3300	0.2408	0.4503
W_1C_3	0.1436	0.1484	0.2178	0.2760	0.2741	0.4122	0.2327	0.2192	0.3423
W_2C_1	0.1224	0.1264	0.1856	0.3688	0.3753	0.5597	0.2375	0.1974	0.3362
W_2C_2	0.1160	0.1199	0.1760	0.3004	0.3065	0.4567	0.3531	0.2400	0.4731
W_2C_3	0.1010	0.1043	0.1532	0.2408	0.2486	0.3690	0.2375	0.2841	0.3796
W_3C_1	0.0928	0.0959	0.1408	0.3442	0.3536	0.5257	0.2657	0.2978	0.4146
W_3C_2	0.0782	0.0808	0.1186	0.3167	0.3090	0.4673	0.2874	0.3313	0.4531
W_3C_3	0.0531	0.0548	0.0805	0.2419	0.2508	0.3718	0.2661	0.3159	0.4241
S.Em ±	0.0007	0.0008	0.0011	0.0125	0.0121	0.0183	0.0069	0.0053	0.0085
CD at 5%	0.0021	0.0022	0.0032	0.0361	0.0349	0.0527	0.0199	0.0152	0.0244
Sowing Window (W) × Varieties (V)									
W_1V_1	0.1473	0.1523	0.2235	0.3302	0.3329	0.4980	0.2284	0.2320	0.3444
W_1V_2	0.1504	0.1554	0.2281	0.3144	0.3208	0.4780	0.2434	0.2352	0.3610
W_2V_1	0.1115	0.1152	0.1691	0.2885	0.2985	0.4427	0.3639	0.2382	0.4830
W_2V_2	0.1148	0.1186	0.1741	0.3182	0.3218	0.4809	0.3538	0.2501	0.4789

W_3V_1	0.0697	0.0721	0.1058	0.2933	0.2905	0.4372	0.2783	0.3199	0.4382
W_3V_2	0.0797	0.0823	0.1208	0.3085	0.3183	0.4726	0.2679	0.3101	0.4229
S.Em ±	0.0006	0.0006	0.0009	0.0102	0.0099	0.0150	0.0056	0.0043	0.0069
CD at 5%	0.0017	0.0018	0.0026	0.0294	0.0285	0.0431	0.0162	0.0124	0.0199

Crops (C) × Varieties (V)									
C_1V_1	0.1229	0.1269	0.1863	0.3346	0.3307	0.4980	0.2771	0.2686	0.4114
C_1V_2	0.1246	0.1288	0.1890	0.3930	0.4122	0.6088	0.2784	0.2798	0.4183
C_2V_1	0.1100	0.1137	0.1668	0.3036	0.3076	0.4594	0.2972	0.2617	0.4281
C_2V_2	0.1175	0.1214	0.1782	0.3161	0.3166	0.4746	0.2881	0.2507	0.4135
C_3V_1	0.1027	0.1062	0.1558	0.232	0.2836	0.4205	0.2985	0.2648	0.431
C_3V_2	0.0957	0.0989	0.1451	0.2738	0.2321	0.3481	0.2964	0.2597	0.4262
S.Em ±	0.0006	0.0006	0.0009	0.0102	0.0099	0.0150	0.0056	0.0043	0.0069
CD at 5%	0.0017	0.0018	0.0026	0.0294	0.0285	0.0431	0.0162	0.0124	0.0199
Sowing Window (W) × Crops (C) × Varieties (V)									
$W_1C_1V_1$	0.1547	0.1598	0.2346	0.3776	0.3750	0.5638	0.2234	0.2760	0.3614
$W_1C_1V_2$	0.1573	0.1626	0.2386	0.3792	0.3962	0.5858	0.4118	0.2460	0.5348
$W_1C_2V_1$	0.1413	0.1460	0.2144	0.3108	0.3187	0.4741	0.2359	0.2052	0.3385
$W_1C_2V_2$	0.1526	0.1577	0.2315	0.3140	0.3229	0.4799	0.2391	0.1897	0.3340
$W_1C_3V_1$	0.1460	0.1509	0.2214	0.3021	0.3051	0.4561	0.2259	0.2147	0.3333
$W_1C_3V_2$	0.1412	0.1459	0.2142	0.2499	0.2432	0.3682	0.2395	0.2236	0.3513
$W_2C_1V_1$	0.1224	0.1264	0.1856	0.3290	0.3315	0.4960	0.3427	0.2136	0.4495
$W_2C_1V_2$	0.1223	0.1264	0.1856	0.4086	0.4191	0.6234	0.3172	0.2679	0.4512
$W_2C_2V_1$	0.1144	0.1182	0.1734	0.2815	0.2999	0.4406	0.3737	0.2437	0.4955
$W_2C_2V_2$	0.1177	0.1216	0.1785	0.3192	0.3131	0.4727	0.3325	0.2363	0.4506
$W_2C_3V_1$	0.0977	0.1010	0.1482	0.2549	0.2640	0.3914	0.3754	0.2574	0.5041
$W_2C_3V_2$	0.1043	0.1077	0.1582	0.2267	0.2333	0.3466	0.2516	0.2923	0.3977
$W_3C_1V_1$	0.0915	0.0946	0.1388	0.2972	0.2856	0.4342	0.2650	0.3162	0.4231
$W_3C_1V_2$	0.0941	0.0973	0.1428	0.3913	0.4215	0.6171	0.2664	0.2793	0.4060
$W_3C_2V_1$	0.0743	0.0768	0.1127	0.3184	0.3041	0.4634	0.2821	0.3363	0.4503
$W_3C_2V_2$	0.0821	0.0849	0.1246	0.3150	0.3138	0.4713	0.2928	0.3262	0.4559
$W_3C_3V_1$	0.0627	0.0648	0.0951	0.2644	0.2819	0.4141	0.2878	0.0627	0.0648
$W_3C_3V_2$	0.0434	0.0449	0.0659	0.2194	0.2197	0.3294	0.2444	0.0434	0.0449
S.Em ±	0.0011	0.0011	0.0016	0.0177	0.0172	0.0259	0.0098	0.0075	0.0120
CD at 5%	0.0030	0.0031	0.0045	0.0510	0.0493	0.0746	0.0281	0.0215	0.0345

Legend:
Factor A - W_1: August 2nd fortnight; W_2: September 1st fortnight; W_3: September 2nd fortnight Factor B - C_1: Foxtail millet; C_2: Proso millet; C_3: Little millet
Factor C - V_1: GPUF 3 /GPUP 28 / GPUL6; V_2: DHFt 109-3/ GPUP 21 / DHLM 36-3

Pooled data indicated that the crop sown during second fortnight of august recorded significantly higher absolute growth rate of 0.2258, 0.4880 and 0.4810g/day at 0-30 DAS, 31-60 DAS and 61 DAS-harvest, respectively followed by the crop sown at first fortnight of September (0.1716, 0.4618, 0.4306 g/day at 0-30 DAS, 31-60 DAS and 61 DAS-harvest, respectively). Significantly lower AGR was recorded in second fortnight of September (0.1133, 0.4549, 0.3527 g/day at 0-30 DAS, 31-60 DAS and 61 DAS- harvest, respectively).

Among the different small millets, higher AGR was recorded in foxtail millet (0.1877, 0.5534 and 0.4286 g/day) followed by Proso millet (0.1725, 0.4670,0. 0.4208 g/day) at 0-30 DAS, 31-60 DAS and 61 DAS-harvest, respectively. Lower AGR was observed in little millet (0.1505, 0.3843 and 0.4148 g/day) at these growth stages. Among varieties, DHFt-109-3, GPUP 21 and GPUL-6 were found significantly superior over GPUF-3, GPUP-28 and DHLM-36-3 at 0-30 DAS, 31-60 DAS and 61 DAS-harvest.

There was significant interaction found between sowing windows and crops 0-30 DAS, 31-60 DAS and 61 DAS-harvest. Among different combinations, sowing of foxtail millet during second fortnight of august has recorded significantly higher AGR (0.2366, 0.5748, 0.5194 g/day) followed by sowing of foxtail millet during first fortnight of September (0.1856,0.5597 and 0.3362 g/ day).

The interaction effect between sowing windows and varieties was found significant in which, the second fortnight of august and variety V_2 has recorded significantly higher AGR (0.2281, 0.4780 and 0.3610 g/day, respectively), which was followed by second fortnight of august and variety V_1 (0.2235, 0.4980 and 0.483 g/day) and significantly the lowest AGR was observed with second fortnight of September and V_1 (0.1058, 0.4372 and 0.361 g/day) at 0-30 DAS, 31-60 DAS and 61 DAS-harvest, respectively.

There was significant interaction between crop and variety. Among different combinations, DHFt-109-3 of foxtail millet has recorded significantly higher AGR (0.1890, 0.6088 and 0.431g/day) which was followed by GPUF 3 variety of foxtail millet (0.1863, 0.4980 and 0.4281 g/day, respectively). Significantly lower AGR (0.1451, 0.4205 and 0.4135 g/day) was recorded in GPUL-6 of little millet at 0-30 DAS, 31-60 DAS and 61 DAS-harvest, respectively

Overall interaction between sowing windows, crops and varieties found significant in all growth stages of crop. At 0-30 DAS, 31-60 DAS and 61 DAS- harvest, the combination of sowing of DHFt 109-3 variety of foxtail millet during second fortnight of august has recorded significantly higher AGR (0.2386, 0.5858 and 0.5348 g/day) which was on par with GPUF-3 of foxtail millet sown in second fortnight of august and significantly lower AGR was observed with combination of DHLM 36-3 variety of little millet during second fortnight of September (0.0659, 0.3249 and 0.0449 g/day) which was on par with combination sowing of variety of little millet during second fortnight of September GPUL-6.

Absolute growth rate (AGR) primarily depends on the total dry matter production per hill. AGR was lower during the initial crop growth stage (30 DAS), it reached maximum at 60 DAS and thereafter progressively declined towards maturity. Greater AGR was mainly attributed to increased leaf number, leaf area and vegetative growth of plant which leads to higher photosynthesis ability and higher availability of soil nutrients. These results validate the findings of Nasim *et al*. (2012); Jadipujari *et al*. (2023) ; (Sukanya *et al*. (2023) who also indicated the positive effects of nitrogen and sowing window on AGR of Quinoa crop.

CGR (g/m^2/day) crop growth of small millets as influenced by sowing windows and varieties.

Treatments	0 - 30 DAS			30- 60 DAS			60 DAS – harvest		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Sowing Window (W)									
W_1	4.96	5.13	5.04	10.74	10.89	10.82	7.86	7.79	10.05
W_2	3.77	3.90	3.83	10.11	10.34	10.22	11.96	8.14	9.80
W_3	2.49	2.57	2.53	10.03	10.15	10.09	9.10	10.50	7.82
S.Em ±	0.01	0.01	0.01	0.24	0.23	0.24	0.13	0.10	0.10
CD at 5%	0.04	0.04	0.04	0.69	0.67	0.68	0.38	0.29	0.29
Crops (C)									
C_1	4.12	4.26	4.19	12.13	12.38	12.25	9.26	9.14	9.33
C_2	3.79	3.92	3.85	10.33	10.40	10.37	9.76	8.54	9.20
C_3	3.31	3.42	3.36	8.43	8.60	8.51	9.92	8.74	9.15
S.Em ±	0.01	0.01	0.01	0.24	0.23	0.24	0.13	0.10	0.10
CD at 5%	0.04	0.04	0.04	0.69	0.67	0.68	0.38	0.29	0.29
Varieties (V)									
V_1	3.65	3.77	3.71	10.13	10.24	10.19	9.67	8.78	9.23
V_2	3.83	3.96	3.90	10.46	10.68	10.57	9.61	8.84	9.22
S.Em ±	0.01	0.01	0.01	0.20	0.19	0.19	0.11	0.08	0.08
CD at 5%	0.03	0.03	0.03	0.57	0.55	0.56	0.31	0.24	0.24
Sowing Window (W) × Crops (C)									
W_1C_1	5.20	5.37	5.29	12.61	12.85	12.73	13.12	8.39	10.75
W_1C_2	4.90	5.06	4.98	10.41	10.69	10.55	8.87	10.53	9.7
W_1C_3	4.79	4.95	4.87	9.20	9.14	9.17	7.92	9.47	8.69
W_2C_1	4.08	4.21	4.15	12.29	12.51	12.40	9.58	11.04	10.31
W_2C_2	3.87	4.00	3.93	10.01	10.22	10.11	11.00	8.03	9.51
W_2C_3	3.37	3.48	3.42	8.03	8.29	8.16	7.76	7.31	7.53
W_3C_1	3.09	3.20	3.15	11.47	11.79	11.63	11.77	8.00	9.88
W_3C_2	2.61	2.69	2.65	10.56	10.30	10.43	8.86	9.93	9.39
W_3C_3	1.77	1.83	1.80	8.06	8.36	8.21	7.92	6.58	7.25
S.Em ±	0.02	0.03	0.02	0.42	0.40	0.41	0.23	0.18	0.18
CD at 5%	0.07	0.07	0.07	1.20	1.16	1.18	0.66	0.51	0.5
Sowing Window (W) × Varieties (V)									
W_1V_1	4.91	5.08	4.99	10.48	10.69	10.59	12.13	7.94	10.04
W_1V_2	5.01	5.18	5.10	11.01	11.00	11.05	11.79	8.34	10.06
W_2V_1	3.72	3.84	3.78	9.62	9.95	9.78	8.93	10.34	9.63
W_2V_2	3.83	3.95	3.89	10.61	10.73	10.67	9.28	10.66	9.97
W_3V_1	2.32	2.40	2.36	9.78	9.68	9.73	7.61	7.73	7.67
W_3V_2	2.66	2.74	2.70	10.28	10.61	10.45	8.11	7.84	7.98
S.Em ±	0.02	0.02	0.02	0.34	0.33	0.33	0.19	0.14	0.14
CD at 5%	0.06	0.06	0.06	0.98	0.95	0.96	0.54	0.41	0.41
Crops (C) × Varieties (V)									
C_1V_1	4.10	4.23	4.16	11.15	11.02	11.09	9.91	8.72	9.32
C_1V_2	4.15	4.29	4.22	13.10	13.74	13.42	9.95	8.83	9.39
C_2V_1	3.67	3.79	3.73	10.12	10.25	10.19	9.88	8.66	9.27
C_2V_2	3.92	4.05	3.98	10.54	10.55	10.54	9.28	9.33	9.3
C_3V_1	3.42	3.54	3.48	9.13	9.45	9.29	9.24	8.95	9.09
C_3V_2	3.19	3.30	3.24	7.73	7.74	7.73	9.6	8.36	8.98
S.Em ±	0.02	0.02	0.02	0.34	0.33	0.33	0.19	0.14	0.14
CD at 5%	0.06	0.06	0.06	0.98	0.95	0.96	0.54	0.41	0.41
Sowing Window (W) × Crops (C) × Varieties (V)									
$W_1C_1V_1$	5.16	5.33	5.24	12.59	12.50	12.54	12.51	8.58	10.55
$W_1C_1V_2$	5.24	5.42	5.33	12.64	13.21	12.92	13.73	8.2	10.96
$W_1C_2V_1$	4.71	4.87	4.79	10.36	10.62	10.49	10.57	8.93	9.75
$W_1C_2V_2$	5.09	5.26	5.17	10.47	10.76	10.62	10.57	8.93	9.75
$W_1C_3V_1$	4.87	5.03	4.95	10.07	10.17	10.12	8.83	10.54	9.69
$W_1C_3V_2$	4.71	4.86	4.79	8.33	8.11	8.22	8.88	9.31	9.09

$W_2C_1V_1$	4.08	4.21	4.15	10.97	11.05	11.01	9.59	10.23	9.91
$W_2C_1V_2$	4.08	4.21	4.15	13.62	13.97	13.79	9.76	10.87	10.32
$W_2C_2V_1$	3.81	3.94	3.88	9.38	10.00	9.69	11.08	7.88	9.48
$W_2C_2V_2$	3.92	4.05	3.99	10.64	10.44	10.54	8.15	10.83	9.49
$W_2C_3V_1$	3.26	3.37	3.31	8.50	8.80	8.65	7.98	7.45	7.72
$W_2C_3V_2$	3.48	3.59	3.53	7.56	7.78	7.67	7.86	6.84	7.35
$W_3C_1V_1$	3.05	3.15	3.10	9.91	9.52	9.71	8.39	9.74	9.06
$W_3C_1V_2$	3.14	3.24	3.19	13.04	14.05	13.55	9.4	11.21	10.31
$W_3C_2V_1$	2.48	2.56	2.52	10.61	10.14	10.38	7.45	9.2	8.32
$W_3C_2V_2$	2.74	2.83	2.78	10.50	10.46	10.48	11.42	7.12	9.27
$W_3C_3V_1$	2.09	2.16	2.12	8.81	9.40	9.10	7.53	7.16	7.34
$W_3C_3V_2$	1.45	1.5	1.47	7.31	7.32	7.32	7.97	6.32	7.15
S.Em ±	0.04	0.04	0.03	0.59	0.57	0.58	0.33	0.25	0.25
CD at 5%	0.10	0.10	0.10	1.70	1.64	1.67	0.94	0.72	0.71

Legend:

Factor A - W_1: August 2nd fortnight; W_2: September 1st fortnight; W_3: September 2nd fortnight

Factor B - C_1: Foxtail millet; C_2: Proso millet; C_3: Little millet

Factor C - V_1: GPUF 3 /GPUP 28 / GPUL6; V_2: DHFt 109-3/ GPUP 21 / DHLM 36-3

Crop growth rate (CGR) was lower during the initial crop growth stage (30 DAS), it reached maximum during 31-60 DAS thereafter declined towards harvest. The data pertaining to effect of sowing windows and varieties of small millets on crop growth rate (CGR) recorded at 0-30 DAS, 31-60 DAS and 61 DAS-harvest.

Pooled data indicated that the crop sown during second fortnight of august recorded significantly higher crop growth rate (5.04, 10.82 and 10.05 g/ m^2/day at 0-30 DAS, 31-60 DAS and 61 DAS-harvest, respectively) followed by the crop sown at first fortnight of September (3.83, 10.22 and 9.80 g/m^2/day) at 0-30 DAS, 31-60 DAS and 61 DAS-harvest, respectively. Significantly lower CGR was recorded in second fortnight of September (2.53, 10.09 and 7.82 g/m^2/day, respectively) at 0-30 DAS, 31-60 DAS and 61 DAS-harvest, respectively. Among the different small millets, higher CGR was recorded in foxtail millet (4.19, 12.25 and 9.33 g/m^2/day) followed by Proso millet (3.85, 10.37 and 9.20 g/m^2/day) at 0-30 DAS, 31-60 DAS and 61 DAS- harvest, respectively. Lower CGR was observed in little millet (3.36, 9.92 and 9.15 g/m^2/day, respectively) at 30 DAS, 31-60 DAS and 60 DAS-harvest. Among varieties, DHFt-109-3, GPUP 21 and GPUL-6 were significantly superior over GPUF-3, GPUP-28 and DHLM-36-3 at 0-30 DAS, 31-60 DAS and 61 DAS-harvest, respectively.

There was a significant interaction found between sowing windows and crops 0-30 DAS, 31-60 DAS and 61 DAS- harvest. Among different combinations sowing of foxtail millet during second fortnight of august has recorded significantly higher CGR (5.29, 12.73 and 10.75 g/m^2/day, respectively) followed by sowing of foxtail millet during first fortnight of September (4.15, 12.40 and 10.31 g/m^2/day, respectively.).

The interaction between sowing windows and varieties was found significant in which second fortnight of august and V_2 has recorded significantly higher CGR (5.10, 11.05 and 10.06 g/m^2/day, respectively) which was followed by second fortnight of august and variety V_1 (4.99, 10.59 and 10.04 g/m^2/day). Significantly lower CGR was observed with second fortnight of September and variety V_2 (2.36, 9.73 and 7.67 g/m^2/day) at 0-30 DAS, 31-60 DAS and 61 DAS-harvest, respectively.

There was significant interaction between crop and variety. Among different combinations DHFt-109-3 of foxtail millet has recorded significantly higher CGR (4.22, 13.42 and 9.39 g/m^2/day, respectively) which was followed by GPUF 3 variety of foxtail millet (4.16,11.9 and 9.32 g/m^2/day, respectively). Significantly lower CGR was recorded in DHLM 36-3 variety of little millet (3.24, 7.73 and 8.98 g/m^2/day) at 0-30 DAS, 31-60 DAS and 61 DAS-harvest, respectively.

Overall interaction between sowing windows, crops and varieties found significant in all growth stages of crop. At 0-30 DAS, 31-60 DAS and 61 DAS- harvest, the combination of sowing of DHFt 109-3 variety of foxtail millet during second fortnight of august has recorded significantly higher CGR (5.33, 12.92 and 10.96 g/m^2/day, respectively) which was followed GPUF-3 of foxtail millet sown in second fortnight of august and significantly lower CGR was observed with combination of DHLM 36-3 variety of little millet during second fortnight of September (1.47, 7.32 and 7.15 g/m^2/day, respectively). Awais *et al*. (2015) opined that improvement in the CGR could be attributed to more vegetative growth due to increased photosynthesis at higher nitrogen rates in early sown crops than later sown crops. These results validate the findings of Nasim *et al*. (2012); Mondal *et al*. (2017) reported that greater LAI caused higher light interception which further enhanced CGR in mustard crop. Higher LAI was in august second fortnight therefore; larger LAI can intercept 95% of sunlight then plant gets optimum crop growth rate and also greater light interception stimulates CGR which in turn increases total dry matter and LAI. Decrease of CGR with the delay sowing might be due to reduction of total dry matter production. Similar results were reported by Vyshnavi *et al.* (2023).

Relative growth rate (g/g/day) of small millets as influenced by sowing windows and varieties

Treatments	30- 60 DAS	60 DAS – harvest

	2021	2022	Pooled	2021	2022	Pooled
Sowing Window (W)						
W_1	0.0544	0.0537	0.0541	0.0176	0.0176	0.0174
W_2	0.0431	0.0429	0.0432	0.0173	0.0173	0.0165
W_3	0.0382	0.0377	0.0379	0.0148	0.0148	0.0145
S.Em ±	0.0005	0.0005	0.0005	0.0002	0.0002	0.0001
CD at 5%	0.0015	0.0014	0.0014	0.0005	0.0005	0.0004
Crops (C)						
C_1	0.0461	0.0458	0.0460	0.0191	0.0191	0.0185
C_2	0.0448	0.0442	0.0445	0.0163	0.0163	0.0157
C_3	0.0447	0.0444	0.0443	0.0141	0.0141	0.0142
S.Em ±	0.0005	0.0005	0.0005	0.0002	0.0002	0.0001
CD at 5%	0.0015	0.0014	0.0014	0.0005	0.0005	0.0004
Varieties (V)						
V_1	0.0445	0.0441	0.0443	0.0164	0.0164	0.0160
V_2	0.0459	0.0455	0.0457	0.0167	0.0167	0.0163
S.Em ±	0.0004	0.0004	0.0004	0.0002	0.0002	0.0001
CD at 5%	0.0012	0.0011	0.0012	0.0004	0.0004	0.0004
Sowing Window (W) × Crops (C)						
W_1C_1	0.0577	0.0577	0.0577	0.0203	0.0203	0.0202
W_1C_2	0.0462	0.0458	0.046	0.0167	0.0167	0.0164
W_1C_3	0.0406	0.0406	0.0406	0.0134	0.0134	0.0143
W_2C_1	0.054	0.0525	0.0532	0.0211	0.0211	0.0198
W_2C_2	0.0425	0.0423	0.0424	0.0159	0.0159	0.0155
W_2C_3	0.038	0.0378	0.0379	0.015	0.015	0.0138
W_3C_1	0.0514	0.051	0.0512	0.0173	0.0173	0.0173
W_3C_2	0.0408	0.0405	0.0407	0.0151	0.0151	0.0148
W_3C_3	0.0357	0.0348	0.0352	0.0139	0.0139	0.0137
S.Em ±	0.0009	0.0008	0.0009	0.0003	0.0003	0.0003
CD at 5%	0.0025	0.0024	0.0025	0.0009	0.0009	0.0007
Sowing Window (W) × Varieties (V)						
W_1V_1	0.0524	0.0522	0.0523	0.0173	0.0175	0.0169
W_1V_2	0.0563	0.0553	0.0558	0.0181	0.0181	0.0182
W_2V_1	0.0425	0.0426	0.0426	0.0167	0.0167	0.0162
W_2V_2	0.0437	0.0432	0.0435	0.0178	0.0178	0.0167
W_3V_1	0.0373	0.0369	0.0371	0.0142	0.0142	0.0141
W_3V_2	0.039	0.0385	0.0387	0.0153	0.0153	0.0149
S.Em ±	0.0007	0.0007	0.0007	0.0003	0.0003	0.0002
CD at 5%	0.0021	0.0020	0.0020	0.0008	0.0008	0.0006
Sowing Window (W) × Crops (C) × Varieties (V)						
C_1V_1	0.0481	0.0485	0.0483	0.0185	0.0185	0.0177
C_1V_2	0.0485	0.0486	0.0485	0.0197	0.0197	0.0193
C_2V_1	0.0445	0.0437	0.0441	0.0159	0.0159	0.0152
C_2V_2	0.0452	0.0447	0.0449	0.0168	0.0168	0.0162
C_3V_1	0.0442	0.0431	0.0436	0.0148	0.0148	0.0150
C_3V_2	0.0409	0.0401	0.0405	0.0134	0.0134	0.0135
S.Em ±	0.0007	0.0007	0.0007	0.0003	0.0003	0.0002
CD at 5%	0.0021	0.0020	0.0020	0.0008	0.0008	0.0006
Sowing Window (W) × Crops (C) × Varieties (V)						
$W_1C_1V_1$	0.0546	0.0558	0.0552	0.0128	0.0135	0.0195
$W_1C_1V_2$	0.0653	0.0662	0.0657	0.0198	0.0198	0.0207
$W_1C_2V_1$	0.0481	0.0463	0.0472	0.0175	0.0175	0.0171
$W_1C_2V_2$	0.0501	0.0493	0.0497	0.0199	0.0199	0.0191
$W_1C_3V_1$	0.0435	0.0429	0.0432	0.0182	0.0182	0.0169
$W_1C_3V_2$	0.0408	0.041	0.0409	0.014	0.014	0.0146
$W_2C_1V_1$	0.0489	0.0487	0.0488	0.0171	0.0171	0.0175
$W_2C_1V_2$	0.0555	0.0534	0.0544	0.0223	0.0223	0.0204
$W_2C_2V_1$	0.0428	0.0428	0.0428	0.0164	0.0164	0.0167
$W_2C_2V_2$	0.0437	0.0424	0.0431	0.0172	0.0172	0.0167
$W_2C_3V_1$	0.0385	0.0384	0.0384	0.0151	0.0151	0.0142
$W_2C_3V_2$	0.0372	0.0371	0.0372	0.0149	0.0149	0.0135
$W_3C_1V_1$	0.0409	0.04	0.0405	0.0147	0.0147	0.0143
$W_3C_1V_2$	0.0525	0.0516	0.0520	0.0209	0.0209	0.0198
$W_3C_2V_1$	0.0387	0.0386	0.0386	0.0151	0.0151	0.0142
$W_3C_2V_2$	0.0414	0.0421	0.0417	0.0153	0.0153	0.0151
$W_3C_3V_1$	0.0374	0.0368	0.0371	0.0126	0.0126	0.0131
$W_3C_3V_2$	0.0339	0.0327	0.0333	0.0138	0.0138	0.0129
S.Em ±	0.0012	0.0012	0.0012	0.0005	0.0005	0.0004
CD at 5%	0.0036	0.0034	0.0035	0.0013	0.0013	0.0011

Legend:
Factor A - W_1: August 2nd fortnight; W_2: September 1st fortnight; W_3: September 2nd fortnight Factor B - C_1: Foxtail millet; C_2: Proso millet; C_3: Little millet
Factor C - V_1: GPUF 3 /GPUP 28 / GPUL6; V_2: DHFt 109-3/ GPUP 21 / DHLM 36-3

Pooled data indicated that the crop sown during second fortnight of august recorded significantly higher relative growth rate (0.0541 and 0.0174 g/g/day at 31-60 DAS and 61 DAS-harvest, respectively) followed by the crop sown at first fortnight of September (0.0432 and 0.0165 g/g/day). Significantly lower RGR was recorded in second fortnight of September (0.0379 and 0.0145 g/g/day) at 31-60 DAS and 61 DAS-harvest, respectively. Among the different small millets, higher RGR was recorded in foxtail millet (0.0460 and 0.0185 g/g/day) followed by Proso millet (0.0445 and 0.0157 g/g/day) at 31-60 DAS and 61 DAS-harvest, respectively). Lower RGR was observed in little millet (0.0443 and 0.0142 g/g/day) at 31-60 DAS and 60 DAS-harvest. Among varieties, DHFt-109-3, GPUP 21 and GPUL-6 were significantly superior over GPUF-3, GPUP-28 and DHLM-36-3 at 31-60 DAS and 60 DAS-harvest.

There was a significant interaction found between sowing windows and crops at 31-60 DAS and 61 DAS-harvest. Among different combinations, the sowing of foxtail millet during second fortnight of august has recorded significantly higher RGR (0.0577 and 0.0202 g/g/day) followed by sowing of foxtail millet during first fortnight of September (0.0532 and 0.0198 g/g/day).

The interaction effect between sowing windows and varieties was found significant in which second fortnight of august and variety DHFt 109-3 has recorded significantly higher RGR (0.0558 and 0.0182 g/g/day), which was followed by second fortnight of august and variety GPUF 3 and significantly lower RGR was observed with second fortnight of September and variety GPUL 6 (0.0523 and 0.0169 g/g/day) at 31-60 DAS and 61 DAS-harvest, respectively.

There was significant interaction between crop and variety. Among different combinations DHFt-109-3 of foxtail millet has recorded significantly higher RGR (0.0485 and 0.0193 g/g/day) which was followed by GPUF 3 variety of foxtail millet (0.0483 and 0.0177/ g/g/day). Significantly lower RGR was recorded in DHLM 36-3 of little millet (0.0405 and 0.0135 g/g/day) at 31-60 DAS and 61 DAS- harvest, respectively.

Overall interaction between sowing windows, crops and varieties found significant in all growth stages of crop. At 31-60 DAS and 61 DAS-harvest, the combination of sowing of DHFt 109-3 variety of foxtail millet during second fortnight of august has recorded significantly higher RGR (0.0657 and 0.0207g/g/day) which was on par with GPUF-3 of foxtail millet sown in second fortnight of august and significantly lower RGR was observed with combination sowing of DHLM 36-3 variety of little millet during second fortnight of September (0.0333 and 0.0129 g/g/day).

Sowing during II fortnight of august in foxtail millet, Proso millet, little millet resulted in higher RGR may be attributed to favorable climatic conditions in terms of temperature and photoperiod and rainfall like climatic factors during different growth stages. These findings were in corroboration with Patel *et al*. (2004); Reddy (2007) also opined that the growth and growth attributes among the varieties attributed to genetic potentiality of the genotypes**.**

Net assimilation rate (g m^2/d) of small millets as influenced by sowing windows and varieties.

Treatments	30-60 DAS		
	2021	2022	Pooled
Sowing Window (W)			
W_1	0.001168226	0.001121442	0.001144834
W_2	0.001028003	0.000999959	0.001013981
W_3	0.001016563	0.000933398	0.000996993
S.Em ±	6.2766	9.61533	6.02971
CD at 5%	NS	NS	NS
Crops (C)			
C_1	0.001139556	0.001088673	0.001114114
C_2	0.001081687	0.001048449	0.001065068
C_3	0.000991548	0.000917676	0.000976625
S.Em ±	2.1839	3.34559	2.098
CD at 5%	NS	NS	NS
Varieties (V)			
V_1	0.001061891	0.001025202	0.001043547
V_2	0.00107997	0.00101133	0.001060325
S.Em ±	1.78316	2.73167	1.71301
CD at 5%	NS	NS	NS
Sowing Window (W) × Crops (C)			
W_1C_1	0.000949703	0.000786523	0.00093415
W_1C_2	0.001086808	0.001059495	0.001073151
W_1C_3	0.001013178	0.000954176	0.000983677
W_2C_1	0.000986304	0.000955179	0.000970742
W_2C_2	0.001093802	0.001061027	0.001077414
W_2C_3	0.001003903	0.000983671	0.000993787
W_3C_1	0.001038638	0.001011327	0.001024983
W_3C_2	0.00123806	0.001145496	0.001191778
W_3C_3	0.00122798	0.001207501	0.001217741
S.Em ±	3.78265	5.79474	3.63384
CD at 5%	NS	NS	NS
Sowing Window (W) × Varieties (V)			
W_1V_1	0.001065672	0.000935399	0.00104456
W_1V_2	0.000967453	0.000931397	0.000949425
W_2V_1	0.001003722	0.00098954	0.000996631
W_2V_2	0.001052283	0.001010378	0.001031331
W_3V_1	0.001170514	0.001109051	0.001139783
W_3V_2	0.001165938	0.001133832	0.001149885

S.Em ±	3.08852	4.73138E	2.96702
CD at 5%	NS	NS	NS
Sowing Window (W) × Crops (C) × Varieties (V)			
C_1V_1	0.000972426	0.000826174	0.000943325
C_1V_2	0.00101067	0.001009178	0.001009924
C_2V_1	0.00117045	0.001124042	0.001147246
C_2V_2	0.001108663	0.001053303	0.001080983
C_3V_1	0.001097032	0.001083773	0.001090403
C_3V_2	0.001066342	0.001013125	0.001039733
S.Em ±	3.08852	4.73138	2.96702
CD at 5%	NS	NS	NS
Sowing Window (W) × Crops (C) × Varieties (V)			
$W_1C_1V_1$	0.00102638	0.000706986	0.000998757
$W_1C_1V_2$	0.000873025	0.000866059	0.000869542
$W_1C_2V_1$	0.001109353	0.001080384	0.001094868
$W_1C_2V_2$	0.001064263	0.001038605	0.001051434
$W_1C_3V_1$	0.001061285	0.001018826	0.001040055
$W_1C_3V_2$	0.000965071	0.000889526	0.000927299
$W_2C_1V_1$	0.000934359	0.000895887	0.000915123
$W_2C_1V_2$	0.001038249	0.001014471	0.00102636
$W_2C_2V_1$	0.00107362	0.001085747	0.001079683
$W_2C_2V_2$	0.001113984	0.001036307	0.001075145
$W_2C_3V_1$	0.001003188	0.000986986	0.000995087
$W_2C_3V_2$	0.001004617	0.000980356	0.000992487
$W_3C_1V_1$	0.00095654	0.00087565	0.000916095
$W_3C_1V_2$	0.001120736	0.001147005	0.001133871
$W_3C_2V_1$	0.001328378	0.001205996	0.001267187
$W_3C_2V_2$	0.001147741	0.001084997	0.001116369
$W_3C_3V_1$	0.001226624	0.001245509	0.001236067
$W_3C_3V_2$	0.001229336	0.001169493	0.001199415
S.Em ±	5.34948	8.195	5.13903
CD at 5%	NS	NS	NS

Legend:
Factor A - W_1: August 2nd fortnight; W_2: September 1st fortnight; W_3: September 2nd fortnight Factor B - C_1: Foxtail millet; C_2: Proso millet; C_3: Little millet
Factor C - V_1: GPUF 3 /GPUP 28 / GPUL6; V_2: DHFt 109-3/ GPUP 21 / DHLM 36-3

Net assimilation rate was recorded at 31-60 DAS. NAR has not significantly influenced by sowing windows, crops and varieties However numerically higher in early sown crops. Interactions between sowing windows and crops, windows and varieties, crops and varieties, sowing window, crops and varieties were found non-significant. This may be attributed to environmental factors such as light, temperature, water availability, and nutrient supply. If these factors are not optimal, NAR may not be significant. These findings are in line with Jadipujari *et al.* (2023).

CONCLUSIONS

Sowing during August second fortnight has recorded higher absolute growth rate, crop growth rate, relative growth rate while lower absolute growth rate, crop growth rate relative growth rate was recorded in September second fortnight sowing. Among the crops, higher AGR, RGR and CGR were recorded in foxtail millet whereas, lower absolute growth rate, crop growth rate and relative growth rate was recorded in little millet. Among varieties DHFt 109-3, GPUP-21 and GPUL-6 recorded higher AGR, CGR and RGR than GPUF-3, GPUP-28 and DHLM-36-3.

The combination of sowing of DHFt 109-3 variety of foxtail millet during second fortnight of august has recorded significantly higher AGR, CGR and RGR. Lower AGR, CGR and RGR was observed with combination sowing of DHLM 36-3 variety of little millet during second fortnight of September at 60 DAS-harvest. NAR showed non-significant responses with respect to sowing windows, crops and varieties.

FUTURE SCOPE

The optimum sowing window for nutricereals is normally June to July but rainfall is not always adequate for normal sowing window moreover, rainfall is becoming uncertain in changing climate scenarios Therefore to get remunerative returns in aberrant weather conditions need to shift on growing nutricereals. Though nutricereals are being called as contingent crops, scientific study during late *kharif* is necessary. As climate is region specific, there is need to study the response of different varieties for different climatic regions of country. Nutrient and irrigation requirement of millets is need to be studied in detail.

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Conflict of Interest. None.

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