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Growth and yield performance of late *Kharif* grain sorghum genotypes under different sowing windows in Northern dry zone of *Karnataka*

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ABSTRACT

A field experiment was conducted during late kharif 2025 at the Agricultural Research Station, Hagari, Ballari district, *Karnataka*, to evaluate the growth and yield performance of late kharif grain sorghum genotypes under different sowing windows. The experiment comprised three sowing windows, viz., first fortnight of August (W_1), second fortnight of August (W_2) and first fortnight of September (W_3), as main plot treatments, and six genotypes, viz., DSH-7, SHD-215, SHD-217, CSH-16, Pradhan and HTJH-3201, as sub-plot treatments, laid out in a split plot design with three replications. Sowing during the first fortnight of September (W_3) recorded significantly higher plant height (147.9 cm), leaf area (23.45 dm² plant⁻¹), leaf area index (3.47), total dry matter accumulation (180.93 g plant⁻¹), earhead weight (70.9 g), 1000-grain weight (31.9 g), grain yield (2608 kg ha⁻¹) and stover yield (7523 kg ha⁻¹), and it was on par with second fortnight of August (W_2). While harvest index was not significantly influenced by sowing window (0.251-0.261). Among the genotypes, HTJH-3201 recorded higher plant height (151.7 cm), leaf area (24.14 dm² plant⁻¹), leaf area index (3.58) and total dry matter accumulation (191.94 g plant⁻¹), and it was on par with SHD-215. HTJH-3201 produced higher earhead weight (77.6 g), 1000-grain weight (32.0 g), grain yield (3016 kg ha⁻¹) and stover yield (8877 kg ha⁻¹), while DSH-7 recorded the higher harvest index (0.265). The interaction between sowing windows and genotypes was non-significant for all the parameters studied. Sowing during the first fortnight of September and among genotype, HTJH-3201, or alternatively SHD-215, can be recommended for realizing higher growth and yield of grain sorghum during late kharif in the Northern dry zone of *Karnataka*.

Keywords: Grain sorghum, Sowing window, Genotypes, Late kharif, Dry matter accumulation, Grain yield

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench], an important cereal of the semi-arid tropics, is well adapted to erratic rainfall, higher temperature and limited irrigation, making it a key crop of dryland agriculture (Talwar *et al.*, 2013) [1]. Globally, it is cultivated on about 42.22 million hectares, producing 62.29 million tonnes (Anonymous, 2023) [2], with the grain valued for its carbohydrate, protein and mineral content and the stover serving as an important source of dry-season fodder (Tiware *et al.*, 2023; ICRISAT, 2011) [4, 3]. In India, sorghum is grown during both *kharif* and *rabi* seasons under predominantly rainfed condition, with an area, production and productivity of 4.00 million ha, 4.96 million tonnes and 1240 kg ha⁻¹, respectively, during 2024-25 (Anon., 2025) [5]. *Karnataka* is the second-largest sorghum-producing state in the country after Maharashtra, with cultivation concentrated mainly in the northern districts (Basavaraja *et al.*, 2005) [6]. In the Northern dry zone of *Karnataka*, sorghum is traditionally sown to coincide with the onset of the southwest monsoon. However, delayed monsoon onset and erratic rainfall in recent years have increasingly forced farmers to shift sowing to the late *kharif* window, shortening the growing period and exposing the crop to terminal moisture stress and unstable yields, a risk further compounded by the absence of genotypes specifically bred for late-sown conditions (Kumar *et al.*, 2021) [7]. Identification of optimum sowing windows together with genotypes that can sustain productivity under such truncated growth cycles is therefore essential for climate-resilient sorghum production. Keeping this in view, the present study was undertaken to evaluate the influence of different sowing windows and grain sorghum genotypes on growth and yield during the late *kharif* season.

Materials and methods

The field experiment was conducted during late *kharif* 2025-26 at the Agricultural Research Station, Hagari, Ballari district, *Karnataka*, situated in the Northern Dry Zone of *Karnataka* (Zone III). The experimental site was located at 15°13' N latitude, 77°05' E longitude and an elevation of 414 m above mean sea level. The

soil of the experimental site was a medium black *Vertisol* with clay texture. The soil had pH (7.52), electrical conductivity (0.43 dS m^{-1}) and organic carbon (5.05 g kg^{-1}), with available N, P_2O_5 and K_2O (253.20, 40.85 and $426.15 \text{ kg ha}^{-1}$, respectively).

The experiment was laid out in a split plot design with three replications. Three sowing windows were assigned to the main plots: First fortnight of August (W_1), Second fortnight of August (W_2) and First fortnight of September (W_3). Six genotypes were assigned to the sub-plots: DSH-7 (G_1), SHD-215 (G_2), SHD-217 (G_3), CSH-16 (G_4), Pradhan (G_5) and HTJH-3201 (G_6). The crop was planted with a spacing of $45 \text{ cm} \times 15 \text{ cm}$. The recommended dose of $100:75:37.5:15 \text{ kg N, P}_2\text{O}_5, \text{K}_2\text{O}$ and $\text{ZnSO}_4 \text{ ha}^{-1}$ along with FYM at 5.5 t ha^{-1} was applied uniformly to all treatments. Half of the nitrogen and the full quantities of phosphorus, potassium and zinc were applied basally, while the remaining nitrogen was side-dressed at about 30 days after sowing. Furrow irrigation was followed, with protective irrigations scheduled at critical crop growth stages. Five plants were randomly selected and tagged in each plot for recording observations. Plant height was measured from ground level to the base of the fully opened top leaf. Leaf area was estimated using the third leaf from the top and the multiplication factor of 0.747 (Sticker *et al.*, 1961) [8]. Leaf area index was calculated as leaf area per plant divided by land area occupied by a single plant (Sestak *et al.*, 1971) [9]. For total dry matter accumulation, plants were separated into leaves, stem and earhead and oven dried at 65°C to constant weight. Yield observations were recorded at harvest; grain and stover yields were expressed in kg ha^{-1} . The data were subjected to analysis of variance appropriate for split plot design. Significance of treatment effects was tested at the 5 per cent probability level following the procedure described by Panse and Sukhatme (1967) [10].

Results and discussion

Growth parameters

Growth contributing characters, viz., plant height, leaf area, leaf area index and total dry matter accumulation, recorded at 30, 60, 90 DAS and at harvest, as influenced by sowing windows and grain sorghum genotypes, are presented in Table 1 and Fig. 1 and 2.

Plant height (cm)

The data on plant height recorded at 30, 60, 90 DAS and at harvest, as affected by sowing windows and genotypes, are depicted in Table 1. Plant height varied significantly due to sowing windows and genotypes at all growth stages, whereas the interaction remained non-significant. Sowing during the first fortnight of September (W_3) recorded significantly higher plant height throughout crop growth (21.8, 110.5, 143.5 and 147.9 cm at 30, 60, 90 DAS and harvest, respectively), remaining statistically on par with the second fortnight of August (W_2) (21.1, 108.5, 141.8 and 146.1 cm), while significantly lower plant height was observed under the first fortnight of August (W_1) (19.5, 105.5, 137.9 and 141.9 cm , respectively). Among the genotypes, HTJH 3201 (G_6) recorded the maximum plant height at all stages (23.5, 113.5, 146.8 and 151.7 cm), remaining on par with SHD-215 (G_2) (22.9, 112.9, 145.8 and 150.5 cm), whereas DSH-7 (G_1) recorded the lower plant height (18.8, 104.2, 136.8 and 140.8 cm , respectively). The taller plants recorded under W_3 may be due to synchronization of the vegetative phase with favourable temperature and adequate soil moisture during late *kharif*, which promoted active cell division and internode elongation, whereas the shorter plants under W_1 reflect a less favourable early vegetative en-

vironment. The genotypic superiority of HTJH 3201 and SHD-215 indicates their inherent vigour and greater stem-elongation potential. Similar improvement in plant height under favourable, comparatively delayed sowing was reported by Hulihalli *et al.* (2016) [11] and Dakshayani *et al.* (2023) [12].

Leaf area ($\text{dm}^2 \text{ plant}^{-1}$)

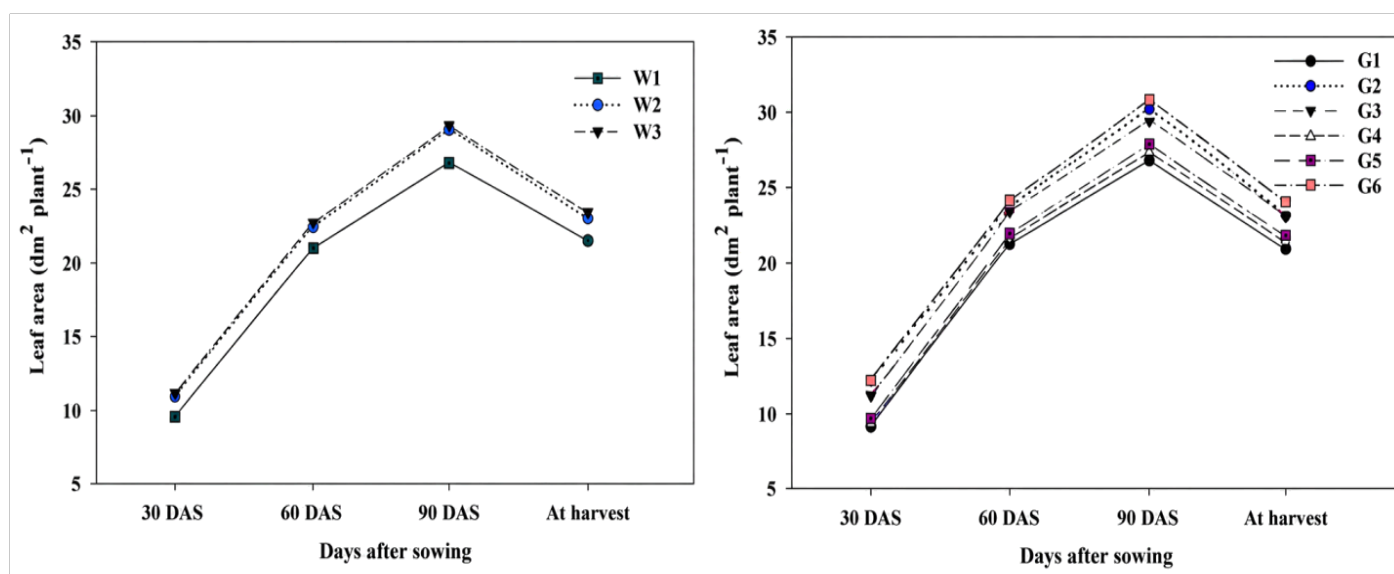
The data on leaf area recorded at 30, 60, 90 DAS and at harvest, as affected by sowing windows and genotypes, are depicted in Fig. 1. Leaf area varied significantly due to sowing windows and genotypes at all growth stages, whereas the interaction remained non-significant. Sowing during the first fortnight of September (W_3) recorded significantly higher leaf area throughout crop growth (10.75, 22.74, 29.34 and $23.45 \text{ dm}^2 \text{ plant}^{-1}$ at 30, 60, 90 DAS and harvest, respectively), remaining statistically on par with the second fortnight of August (W_2) (10.67, 22.50, 29.16 and $23.11 \text{ dm}^2 \text{ plant}^{-1}$), while significantly lower leaf area was observed under the first fortnight of August (W_1) (9.37, 20.99, 26.79 and $21.54 \text{ dm}^2 \text{ plant}^{-1}$). Among the genotypes, HTJH 3201 (G_6) recorded the maximum leaf area at all stages (11.76, 23.37, 30.56 and $24.14 \text{ dm}^2 \text{ plant}^{-1}$), remaining on par with SHD-215 (G_2) (11.67, 23.12, 29.98 and $23.68 \text{ dm}^2 \text{ plant}^{-1}$), whereas DSH-7 (G_1) recorded the lower leaf area (8.91, 20.74, 26.34 and $21.16 \text{ dm}^2 \text{ plant}^{-1}$, respectively).

Leaf area index (LAI)

Leaf area index (LAI), depicted in Fig. 2, varied significantly due to sowing windows and genotypes at 30, 60, 90 DAS and at harvest, while the interaction remained non-significant throughout. Among the sowing windows, W_3 recorded significantly higher LAI (1.59, 3.37, 4.34 and 3.47 at 30, 60, 90 DAS and harvest, respectively), remaining statistically on par with W_2 (1.58, 3.33, 4.32 and 3.42), while W_1 registered significantly lower LAI (1.39, 3.11, 3.97 and 3.19). Among the genotypes, HTJH 3201 (G_6) recorded the higher LAI at all stages (1.73, 3.46, 4.53 and 3.58), remaining on par with SHD-215 (G_2) (1.72, 3.42, 4.44 and 3.51), whereas DSH-7 (G_1) recorded the lower LAI (1.32, 3.07, 3.90 and 3.13, respectively).

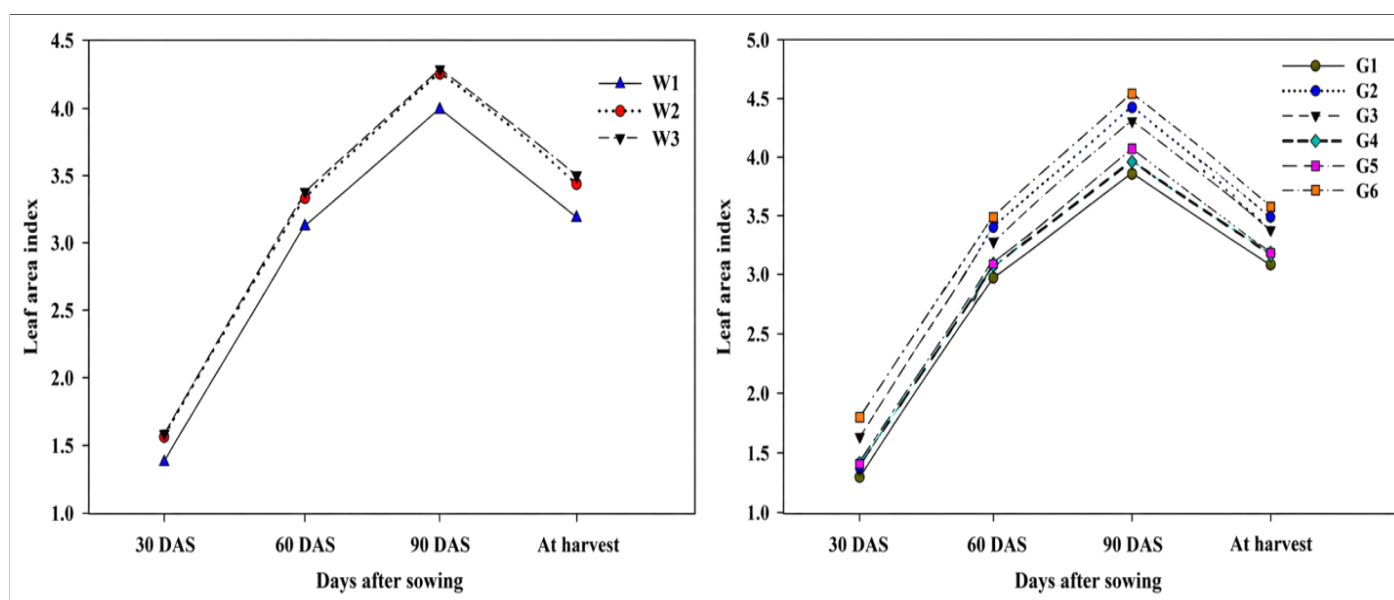
Total dry matter accumulation (g plant⁻¹)

Total dry matter accumulation, presented in Table 1, was significantly influenced by sowing windows and genotypes at 30, 60, 90 DAS and at harvest, while their interaction remained non-significant at all stages. Sowing during the first fortnight of September (W_3) recorded significantly higher total dry matter accumulation throughout crop growth (3.73, 61.60, 127.33 and $180.93 \text{ g plant}^{-1}$ at 30, 60, 90 DAS and harvest, respectively) and which was statistically on par with the second fortnight of August (W_2) (3.64, 60.27, 124.40 and $178.78 \text{ g plant}^{-1}$). Significantly lower dry matter accumulation was recorded under the first fortnight of August (W_1) (2.88, 52.29, 111.74 and $163.07 \text{ g plant}^{-1}$). Among the genotypes, HTJH 3201 (G_6) accumulated significantly higher total dry matter at all stages (4.27, 67.33, 135.34 and $191.94 \text{ g plant}^{-1}$), and was on par with SHD-215 (G_2) (4.14, 65.51, 133.03 and $190.30 \text{ g plant}^{-1}$), whereas DSH-7 (G_1) recorded the lower values (2.56, 48.77, 108.41 and $157.66 \text{ g plant}^{-1}$). The higher dry matter accumulation under W_3 may be ascribed to sustained crop growth and more efficient conversion of intercepted solar radiation into biomass throughout the season, whereas W_1 recorded comparatively lower biomass due to a less favourable early growing environment. The greater dry matter accumulation of HTJH 3201 and SHD-215 reflects their taller stature and larger leaf area, enabling more efficient partitioning of photosynthates. Similar findings were reported by Alakuntla and Likhitha (2023) [13] in sorghum.



Note: W₁: First FN of August, W₂: Second FN of August and W₃: First FN of September
 G₁: DSH-7, G₂: SHD-215, G₃: SHD-217, G₄: CSH 16, G₅: Pradhan and G₆: HTJH 3201

Figure 1. Leaf area ($\text{dm}^2 \text{ plant}^{-1}$) of grain sorghum at different stages as influenced by different sowing windows and genotypes under late *kharif* in Northern dry zone of Karnataka



Note: W₁: First FN of August, W₂: Second FN of August and W₃: First FN of September
 G₁: DSH-7, G₂: SHD-215, G₃: SHD-217, G₄: CSH 16, G₅: Pradhan and G₆: HTJH 3201

Figure 2. Leaf area index of grain sorghum at different stages as influenced by different sowing windows and genotypes under late *kharif* in Northern dry zone of Karnataka

Yield parameters

The economic yield of a crop results from the integration of growth processes occurring throughout the crop-growth cycle and is ultimately governed by the availability of light, water, temperature and nutrients. The yield components, *viz.*, earhead weight, 1000-grain weight, grain yield, stover yield and harvest index, as influenced by sowing windows and grain sorghum genotypes, are presented in Table 2.

Earhead weight (g)

Earhead weight differed significantly due to sowing windows and genotypes, while the interaction effect remained non-significant (Table 2). Among the sowing windows, first fortnight of September (W₃) recorded significantly higher earhead weight (70.9 g), statistically on par with W₂ (69.9 g), while significantly lower earhead

weight was registered under W₁ (65.4 g). Among the genotypes, HTJH 3201 (G₆) recorded significantly higher earhead weight (77.6 g), which was statistically comparable with SHD-215 (G₂) (77.0 g), and significantly lower earhead weight was observed in Pradhan (G₅) (62.2 g), and it was on par with CSH-16 (G₄) (62.7 g) and DSH-7 (G₁) (63.7 g). The higher earhead weight recorded under W₃ could be due to better synchronization between vegetative growth and reproductive development, favouring well-filled, compact earheads, whereas W₁ restricted development of reproductive structures. The heavier earheads of HTJH 3201 and SHD-215 indicate superior source-to-sink translocation of assimilates. Similar findings were reported by Dakshayani *et al.* (2023) [12] and Shaikh *et al.* (2024) [14].

Table 1. Plant height and total dry matter accumulation of grain sorghum genotypes as influenced by sowing windows at 30, 60, 90 DAS and at harvest under late *kharif* conditions in Northern dry zone of Karnataka

Treatments		Plant height (cm)				Total dry matter accumulation (g plant ⁻¹)			
		30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Main plot: Sowing windows (W)									
W ₁		19.5	105.5	137.9	141.9	2.88	52.29	111.74	163.07
W ₂		21.1	108.5	141.8	146.1	3.64	60.27	124.4	178.78
W ₃		21.8	110.5	143.5	147.9	3.73	61.6	127.33	180.93
S.Em.±		0.2	0.6	0.4	0.5	0.04	0.36	0.74	0.88
C.D. @ 5%		0.7	2.2	1.8	2	0.16	1.41	2.92	3.47
Sub plot: Genotypes (G)									
G ₁		18.8	104.2	136.8	140.8	2.56	48.77	108.41	157.66
G ₂		22.9	112.9	145.8	150.5	4.14	65.51	133.03	190.30
G ₃		21	108.5	140.9	144.9	3.74	60.63	123.51	176.73
G ₄		19	104.4	137.4	141.4	2.79	52.13	112.32	162.64
G ₅		19.5	105.6	138.7	142.4	2.99	53.93	114.33	166.28
G ₆		23.5	113.5	146.8	151.7	4.27	67.33	135.34	191.94
S.Em.±		0.2	0.5	0.5	0.7	0.11	0.93	1.74	1.70
C.D. @ 5%		0.5	2.1	1.5	1.9	0.33	2.69	5.03	4.90
Interaction (W × G)									
W at same level	S.Em.±	1.2	4.4	3.1	4	0.69	5.59	10.47	10.22
of G	C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
G at same/diff.	S.Em.±	0.3	1.3	0.9	1.1	0.2	1.61	3.01	2.94
level of W	C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS

Note: Recommended dose of fertilizers (RDF): 100:75:37.5:15 kg N : P₂O₅ : K₂O : ZnSO₄ ha⁻¹; FYM @ 5.5 t ha⁻¹ is common for all the treatments, W₁: First FN of August, W₂: Second FN of August and W₃: First FN of September, G₁: DSH-7, G₂: SHD-215, G₃: SHD-217, G₄: CSH 16, G₅: Pradhan and G₆: HTJH 3201, NS: Non-significant.

1000-grain weight (g)

The data presented in Table 2 revealed that 1000-grain weight was significantly influenced by sowing windows and genotypes, while their interaction remained non-significant. Sowing during first fortnight of September (W₃) recorded significantly higher 1000-grain weight (31.9 g), and it was statistically on par with W₂ (31.7 g), while significantly lower 1000-grain weight was recorded under W₁ (31.1 g). Among the genotypes, HTJH 3201 (G₆) recorded significantly higher 1000-grain weight (32.0 g), statistically on par with SHD-215 (G₂) (31.8 g), while significantly lower 1000-grain weight was observed in Pradhan (G₅) (31.2 g).

Grain yield (kg ha⁻¹)

Grain yield, presented in Table 2, differed significantly due to sowing windows and genotypes, whereas the interaction effect found to be non-significant. Among the sowing windows, first fortnight of September (W₃) registered significantly higher grain yield (2608 kg ha⁻¹), on par with W₂ (2561 kg ha⁻¹), while significantly lower grain yield was recorded under W₁ (2260 kg ha⁻¹). Among the genotypes, HTJH 3201 (G₆) recorded significantly higher grain yield (3016 kg ha⁻¹), which was on par with SHD-215 (G₂) (2927 kg ha⁻¹), while significantly lower grain yield was recorded in Pradhan (G₅) (2102 kg ha⁻¹).

The higher grain yield under first fortnight of September (W₃) could be due to better synchronization between vegetative growth and reproductive development, enabling more efficient utilization of available resources and translating into improved yield components, whereas W₁ reflected a less efficient conversion of growth into eco-

nomic yield. The superior grain yield of HTJH 3201 and SHD-215 reflects the cumulative advantage of their favourable growth and yield attributes. Similar improvement in grain yield was reported by Kumar *et al.* (2025) [15] and Londhe *et al.* (2022) [16].

Stover yield (kg ha⁻¹)

Stover yield, presented in Table 2, was significantly affected by sowing windows and genotypes, while the interaction remained non-significant. Sowing during first fortnight of September (W₃) recorded significantly greater stover yield (7523 kg ha⁻¹), on par with W₂ (7301 kg ha⁻¹), while significantly lower stover yield was registered under W₁ (6796 kg ha⁻¹). Among the genotypes, HTJH 3201 (G₆) recorded significantly superior stover yield (8877 kg ha⁻¹), which was on par with SHD-215 (G₂) (8651 kg ha⁻¹), while significantly lower stover yield was recorded in DSH-7 (G₁) (5891 kg ha⁻¹).

The higher stover yield under first fortnight of September (W₃) may be attributed to greater accumulation of vegetative biomass throughout the crop-growth period, consistent with the correspondingly higher dry matter accumulation recorded under this sowing window (Table 1), whereas W₁ reflected reduced vegetative biomass production. The superior stover yield of HTJH 3201 and SHD-215 reflects their greater capacity for vegetative biomass production. Similar findings were reported by Huli halli *et al.* (2016) [11] and Dera and Mativavarira (2018) [17].

Table 2. Earhead weight, 1000-grain weight, grain yield, stover yield and harvest index of grain sorghum genotypes as influenced by sowing under late *kharif* conditions in Northern dry zone of *Karnataka*

Treatments		Earhead weight (g)	1000-grain weight g)	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Harvest index
Main plot: Sowing windows (W)						
W ₁		65.4	31.1	2260	6796	0.250
W ₂		69.9	31.7	2561	7301	0.261
W ₃		70.9	31.9	2608	7523	0.258
S.Em.±		0.4	0.05	24	69	0.004
C.D. at 5%		1.7	0.2	94	272	NS
Sub plot: Genotypes (G)						
G ₁		63.7	31.3	2121	5891	0.265
G ₂		77	31.8	2927	8651	0.253
G ₃		69.2	31.5	2574	7552	0.254
G ₄		62.7	31.6	2118	6014	0.260
G ₅		62.2	31.2	2102	6253	0.251
G ₆		77.6	32	3016	8877	0.254
S.Em.±		1.1	0.2	58	220	0.005
C.D. at 5%		3.2	0.4	167	635	0.013
Interaction (W × G)						
W at same level of G	S.Em.±	6.6	0.9	347	1320	0.028
	C.D. at 5%	NS	NS	NS	NS	NS
G at same/diff. level of W	S.Em.±	1.9	0.3	100	381	0.008
	C.D. at 5%	NS	NS	NS	NS	NS

Note: Recommended dose of fertilizers (RDF): 100:75:37.5:15 kg N : P₂O₅ : K₂O : ZnSO₄ ha⁻¹; FYM @ 5.5 t ha⁻¹ is common for all the treatments, W₁: First FN of August, W₂: Second FN of August and W₃: First FN of September, G₁: DSH-7, G₂: SHD-215, G₃: SHD-217, G₄: CSH 16, G₅: Pradhan and G₆: HTJH 3201, NS: Non-significant.

Harvest index

Harvest index, presented in Table 2, exhibited non-significant differences due to sowing windows, but varied significantly among genotypes; the interaction between sowing windows and genotypes remained non-significant. Among the genotypes, DSH-7 (G₁) attained significantly higher harvest index (0.265), on par with CSH-16 (G₄) (0.260), HTJH 3201 (G₆) (0.254), and SHD-217 (G₃) (0.254), while significantly lower harvest index was recorded in Pradhan (G₅) (0.251).

Conclusion

Under the late *kharif* conditions of the Northern Dry Zone of *Karnataka*, the first fortnight of September (W₃) was the better sowing window for obtaining higher plant height, leaf area, leaf area index, total dry matter accumulation, earhead weight, 1000-grain weight, grain yield and stover yield at harvest. Among genotypes, HTJH-3201 showed superior performance for the major growth and yield traits and was on par with SHD-215. The non-significant interaction between sowing windows and genotypes indicated that the relative performance of the genotypes remained consistent across the tested sowing windows.

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