



Influence of Seed Priming and Foliar Spray of Bio stimulants on Growth and Seed Yield of Bread Wheat (*Triticum aestivum* L.) under Different Sowing dates

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Abstract

A field experiment was conducted during *rabi* 2025-26 at the All India Co-ordinated Research Project on Wheat, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, to assess the effect of seed priming and foliar application of bio stimulants on growth and seed yield of wheat (cv. UAS 375) under two sowing dates. The experiment was laid out in a factorial randomised block design with three replications. Factor one comprised two sowing dates, viz., early sowing (05th November 2025) and late sowing (05th December 2025), while factor two included nine bio stimulant seed priming and foliar spray combinations, including an untreated control. Early sowing significantly improved plant height, flag leaf area, NDVI, spike length, productive tillers and seed yield (3398 kg ha⁻¹) compared with late sowing (2911 kg ha⁻¹), representing 16.7 per cent increase. Among the bio stimulant treatments, seaweed extract seed priming (100 mL kg⁻¹ for 6 h) and foliar spray at 4 mL L⁻¹ (T₉) recorded the highest values for flag leaf area, spike length, productive tillers, seeds per spike and yield (3529 kg ha⁻¹). It remained statistically on par with glycine betaine (T₈) and salicylic acid (T₅) treatments for many growth and yield attributes, whereas the control recorded the lowest values. The findings indicate that seaweed extract, glycine betaine or salicylic acid priming and foliar application can help sustain wheat productivity even under warmer late sowing conditions.

Keywords: Bio stimulant, seed priming, foliar spray, sowing dates, yield

Introduction

Wheat (*Triticum aestivum* L., 2n = 42; family Poaceae) is one of the most important cereal crops and contributes about 36 per cent of India's total food grain production (Ramadas *et al.*, 2019). India ranks second in global wheat production after China, with productivity estimated at 3593 kg ha⁻¹ during 2025-26, while Karnataka has a relatively low productivity of 1313 kg ha⁻¹ (Anon., 2026) [6]. This indicates considerable scope for improving wheat productivity, particularly in warmer and nontraditional growing regions. Worldwide, abiotic stress such as heat is the major obstructions that threaten the agricultural production (Devate *et al.*, 2023). Temperature is a major environmental factor influencing wheat phenology, growth and productivity (Bishnoi *et al.*, 1995; Tack *et al.*, 2015). In Dharwad like semi-arid areas, high temperatures lead to a significant loss of yield during the grain-filling stage (Chaya *et al.*, 2026) [9]. Delayed sowing, often due to the late harvest of preceding kharif crops, exposes wheat to elevated temperatures and terminal drought stress poses a big challenge to sustain wheat grain production (Sharada and Uday, 2021). Thereby reducing grain weight and yield (Lobell *et al.*, 2011) [17]. Plant bio stimulants have emerged as a promising and cost-effective approach for enhancing

crop growth, nutrient use efficiency and tolerance to abiotic stresses (du Jardin, 2015; Vasconcelos and Chaves, 2020). They include non-microbial substances such as seaweed extracts, chitosan, humic substances, osmolytes and antioxidants, as well as microbial products (Anon., 2012) [5]. Seed priming with bio stimulants enhances metabolic activity, germination and seedling vigour, while foliar application at critical growth stages can improve photosynthesis and stress tolerance. Their combined application may be particularly beneficial under delayed sowing, when the crop is exposed to terminal heat stress. Therefore, the present investigation was undertaken to assess the effect of seed priming and foliar application of bio stimulants on growth, seed yield and quality parameters of bread wheat under different sowing dates.

Material and Methods

The field experiment was conducted during *rabi* 2025-26 at AICRP on Wheat, MARS, UAS, Dharwad (15.49° N, 74.97° E; 678 m amsl). Bread wheat variety UAS 375 was used as test material. The experiment followed a factorial randomized block design with three replications and a net plot size of 4 × 1.8 m, comprising early (05th November, 2025) and late (05th December, 2025) sowing and nine bio

stimulant seed priming and foliar spray treatments. Seeds were primed with the respective bio stimulants at a 1:2 seed to solution ratio (v/v) for the specified durations (Tanwar *et al.*, 2023) [25]. Foliar application was carried out twice at crown root initiation (30–35 DAS) and flowering (50–55 DAS).

Treatment details of bio stimulant seed priming and foliar spray treatments imposed on bread wheat

Treatments	Seed priming	Foliar spray
T ₁	Control	-
T ₂	Hydropriming for 12 h	-
T ₃	Chitosan 0.25% for 8 h	Chitosan 100 mg L ⁻¹
T ₄	Vermiwash 6% for 8 h	Vermiwash 5%
T ₅	Salicylic acid 200 mg L ⁻¹ for 12 h	Salicylic acid 250 ppm
T ₆	Ascorbic acid 200 mg L ⁻¹ for 12 h	Ascorbic acid 100 mg L ⁻¹
T ₇	Potassium chloride 1% for 12 h	Potassium chloride 5 g L ⁻¹
T ₈	Glycine betaine 50 mM for 12 h	Glycine betaine 600 ppm
T ₉	Seaweed extract 100 mL kg ⁻¹ seed for 6 h	Seaweed extract 4 mL L ⁻¹

Growth attributes recorded on five randomly tagged plants per plot included plant height (30 DAS, 60 DAS and at harvest), flag leaf area = length × width × 0.75, normalized difference vegetation index (NDVI) at booting and anthesis using a field portable sensor. Days to 50 per cent flowering, spike length, and productive tillers per metre were recorded at the appropriate phenological stage. Yield attributes comprised number of seeds per spike and seed yield (kg ha⁻¹), the latter converted from per plot yield to per hectare.

Data were analysed using factorial RBD analysis of variance at 5 per cent significance level (Gomez and Gomez, 2010).

Results and Discussion

1. Effect of sowing date on growth, phenology and yield attributes

Sowing date significantly influenced most growth, phenological and yield attributes. Early sowing produced taller plants at harvest (88.77 cm) (Table 1), larger flag leaf area (28.81 cm²) (Table 2), NDVI at booting and anthesis (0.69) (Table 3) compared with late sowing, which recorded 86.77 cm, 25.14 cm², 45.27 and 0.66, respectively. Similar improvements in plant height, dry matter and leaf area with early sowing were reported by Alam *et al.* (2013), while Hari and Kaur (2024). recorded higher NDVI in wheat sown during early November.

Late sowing resulted in reduced days to 50 per cent flowering from 63 to 59 days (Table 2). The accelerated phenological development under delayed sowing may be attributed to faster heat unit accumulation (Sayed, 1995; Gondake *et al.*, 2024). Early sowing also recorded higher spike length (11.12 cm) (Table 4) and productive tillers m⁻¹ (122.89) (Table 4) than late sowing (10.17 cm and 120.93), consistent with Farooq *et al.* (2016) and Wahid and Al-Hilfy (2018).

Consequently, seed yield was significantly higher under early sowing (3398 kg ha⁻¹) than late sowing (2911 kg ha⁻¹) (Table 5), representing a 16.7 per cent increase, in agreement with Bagherikia *et al.* (2025) [7], Chouhan *et al.* (2017) and Shah *et al.* (2019) [22] all of whom reported a yield penalty under delayed sowing on account of terminal heat stress.

2. Effect of bio stimulant seed priming and foliar spray on growth and yield attributes

Among the bio stimulant treatments, glycine betaine seed priming (50 mM for 12 h) followed by foliar spray at 600 ppm (T₈) recorded the highest plant height at 30 and 60 DAS (33.49 and 83.79 cm) (Table 1), NDVI at booting and anthesis (0.72) (Table 3), and earliest flowering (60 days) (Table 2). It was also on par with seaweed extract treatment (T₉) for plant height at harvest (93.30 cm) (Table 1). The untreated control (T₁) recorded the lowest values. The beneficial effect of glycine betaine may be associated with its osmo protective role in maintaining membrane and photosynthetic stability under stress (Vali *et al.*, 2024; Ahmed *et al.*, 2020).

Seaweed extract seed treatment (100 mL kg⁻¹ for 6 h) with foliar spray at 4 mL L⁻¹ (T₉) recorded the highest flag leaf area (31.22 cm²) (Table 2), spike length (11.52 cm) (Table 4) (Fig. 1), productive tillers m⁻¹ (133.83) (Table 4), seeds spike⁻¹ (55.00) (Table 5) and seed yield (3529 kg ha⁻¹) (Table 5), while the control recorded the lowest yield (2513 kg ha⁻¹). Similar improvements in spikes m⁻², grain yield and grains spike⁻¹ were reported by Ali *et al.* (2019), while Lamani *et al.* (2024) observed higher grain yield with foliar seaweed extract at 4 mL L⁻¹.

Salicylic acid treatment (T₅) under late sowing recorded the highest yield (3510 kg ha⁻¹) (Table 5), comparable with T₉, supporting the findings of Chouhan *et al.* (2017) and Seadhi and Metwally (2015) who attributed the response to the role of salicylic acid in sustaining photosynthesis under heat stress. Vermiwash markedly improved flag leaf length (23.71 cm) but resulted in a shorter spike (9.97 cm), a pattern consistent with the negative source sink relationship reported by Maheswari *et al.* (2017).

3. Sowing date × bio stimulant interaction and multivariate relationships

The interaction between sowing dates and bio stimulant treatment was non-significant for plant height, days to 50 per cent flowering, spike length, productive tillers m⁻¹, seeds spike⁻¹ and seed yield, indicating largely independent effects. Nevertheless, early sowing with seaweed extract (S₁T₉) recorded the highest numerical seed yield (3580 kg ha⁻¹), whereas late sowing with the control (S₂T₁) recorded the lowest yield (2558 kg ha⁻¹) (Table 5) (Fig.2).

The interaction was significant for NDVI at booting and anthesis stage. Early sowing combined with seaweed extract (T₉) or glycine betaine (T₈) produced superior values, while late sowing with the untreated control recorded the poorest performance. Similar interaction effects for chlorophyll content under different sowing dates and bio stimulant treatments were reported by Al-Uburi and Lami (2023).

Table 1: Influence of sowing dates and bio stimulant seed priming and foliar spray on plant height(cm) at different intervals in wheat

	30 DAS			60 DAS			At harvest time		
	Sowing dates (S)		Mean	Sowing dates (S)		Mean	Sowing dates (S)		Mean
Bio-stimulants (B)	S ₁	S ₂		S ₁	S ₂		S ₁	S ₂	
T ₁	28.50	27.49	27.99	72.73	67.27	70.00	81.07	80.46	80.77
T ₂	28.63	34.13	31.38	78.38	74.87	76.63	84.85	83.08	83.96
T ₃	28.91	33.96	31.43	78.68	75.16	76.92	86.22	85.18	85.70
T ₄	27.06	32.13	29.59	79.20	74.92	77.06	89.41	88.03	88.72
T ₅	30.53	31.53	31.03	72.61	68.02	70.32	89.03	87.94	88.49
T ₆	29.30	32.43	30.86	74.18	70.01	72.09	90.22	86.36	88.29
T ₇	30.02	30.96	30.49	77.05	73.66	75.36	88.85	84.02	86.44
T ₈	34.34	32.60	33.49	83.76	83.84	83.79	94.42	92.19	93.30
T ₉	33.97	32.90	33.43	79.68	80.38	80.03	94.87	93.66	94.27
Mean	30.15	32.01		77.30	73.96		88.77	86.77	
	S	B	SxB	S	B	SxB	S	B	SxB
S.E.m ±	0.49	0.85	1.20	0.53	1.13	1.59	0.55	1.17	1.65
CD@ 5%	1.41	2.45	NS	1.53	3.25	NS	1.58	3.37	NS

S.E.m.± = standard error of mean; CD = critical difference; NS = non-significant.

S₁-Early Sowing, S₂-Late Sowing, SP – Seed Priming, FS- Foliar Spray, DAS- Days After Sowing**Table 2:** Influence of sowing dates and bio stimulants seed priming and foliar spray on flag leaf area (cm²) in wheat

Bio stimulants (B)	Flag leaf area (cm ²)			Days to 50 per cent flowering		
	Sowing dates (S)		Mean	Sowing dates (S)		Mean
	S ₁	S ₂		S ₁	S ₂	
T ₁	23.83	17.86	20.85	64	60	62
T ₂	32.45	24.26	28.36	64	59	61
T ₃	27.99	26.96	27.48	63	58	61
T ₄	33.82	25.58	29.70	64	58	61
T ₅	25.81	25.38	25.60	64	58	61
T ₆	30.13	26.73	28.43	63	60	62
T ₇	24.32	26.14	25.23	64	59	62
T ₈	27.08	24.77	25.93	62	57	60
T ₉	33.83	28.60	31.22	62	59	61
Mean	28.81	25.14		63	59	
	S	B	SxB	S	B	SxB
S.E.m ±	0.59	1.02	1.44	0.21	0.37	0.52
CD@ 5%	1.69	2.92	4.13	0.61	1.05	NS

S.E.m.± = standard error of mean; CD = critical difference; NS = non-significant.

S₁-Early Sowing, S₂-Late Sowing, SP-Seed Priming, FS- Foliar Spray**Table 3:** Influence of sowing dates and bio stimulants seed priming and foliar spray on Normalized Difference Vegetation Index (NDVI) at booting stage and anthesis stage in wheat

Bio stimulants (B)	NDVI at booting stage			NDVI at anthesis stage		
	Sowing dates (S)		Mean	Sowing dates (S)		Mean
	S ₁	S ₂		S ₁	S ₂	
T ₁	0.66	0.68	0.65	0.63	0.61	0.62
T ₂	0.72	0.70	0.71	0.68	0.66	0.67
T ₃	0.72	0.63	0.67	0.69	0.68	0.69
T ₄	0.69	0.58	0.67	0.69	0.65	0.67
T ₅	0.69	0.64	0.67	0.68	0.64	0.66
T ₆	0.68	0.66	0.67	0.66	0.60	0.63
T ₇	0.70	0.65	0.67	0.70	0.64	0.67
T ₈	0.70	0.73	0.72	0.71	0.72	0.72
T ₉	0.67	0.66	0.67	0.69	0.70	0.70
Mean	0.69	0.66		0.69	0.66	
	S	B	SxB	S	B	SxB
S.E.m ±	0.006	0.012	0.017	0.004	0.008	0.011
CD@ 5%	0.017	0.035	0.050	0.013	0.022	0.031

S.E.m.± = standard error of mean; CD = critical difference.

S₁-Early Sowing, S₂-Late Sowing, SP-Seed Priming, FS- Foliar Spray

Table 4: Influence of sowing dates and bio stimulants seed priming and foliar spray on spike length (cm), productive tillers per meter and seeds per spike in wheat

Bio stimulants (B)	Spike length (cm)			Productive tillers per meter		
	Sowing dates (S)		Mean	Sowing dates (S)		Mean
	S ₁	S ₂		S ₁	S ₂	
T ₁	10.52	9.54	10.03	115.67	114.33	115.00
T ₂	10.88	10.01	10.45	118.33	115.67	117.00
T ₃	11.23	10.02	10.62	122.00	119.67	120.83
T ₄	10.63	9.31	9.97	123.33	121.33	122.33
T ₅	11.23	10.55	10.88	120.67	118.00	119.33
T ₆	11.39	9.96	10.67	118.33	115.33	116.83
T ₇	10.96	10.37	10.66	125.67	119.00	122.33
T ₈	11.15	10.83	10.99	128.67	130.67	129.67
T ₉	12.09	10.93	11.52	133.33	134.33	133.83
Mean	11.12	10.17		122.89	120.93	
	S	B	SxB	S	B	SxB
S.E.m ±	0.11	0.23	0.33	0.60	1.04	1.47
CD@ 5%	0.32	0.68	NS	1.72	2.98	NS

S.E.m.± = standard error of mean; CD = critical difference; NS = non-significant.

S₁-Early Sowing, S₂-Late Sowing, SP-Seed Priming, FS- Foliar Spray

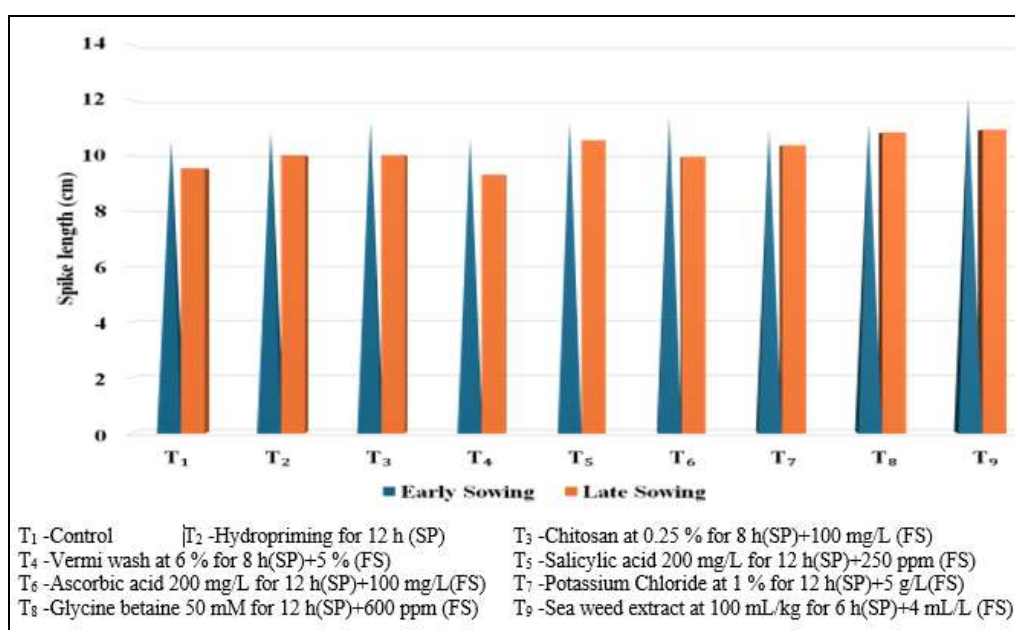


Fig 1: Effect of sowing dates and bio stimulants seed priming and foliar spray on spike length of wheat

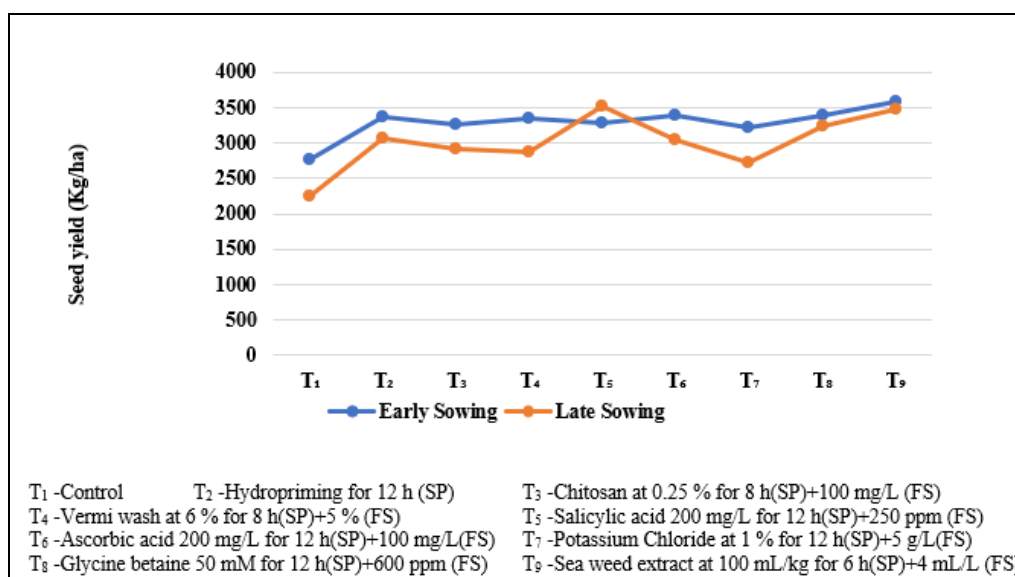


Fig 2: Effect of sowing dates and bio stimulants seed priming and foliar spray on seed yield (kg/ha) of

Table 5: Influence of sowing dates and bio stimulants seed priming and foliar spray on seed yield (kg ha⁻¹)

Bio stimulants (B)	Seeds per spike			Seed yield (kg ha ⁻¹)		
	Sowing dates (S)		Mean	Sowing dates (S)		Mean
	S ₁	S ₂		S ₁	S ₂	
T ₁	42.33	39.00	40.66	2769	2258	2513
T ₂	44.00	42.00	43.00	3358	3069	3213
T ₃	42.33	41.67	42.00	3260	2909	3085
T ₄	45.33	42.33	43.83	3338	2881	3110
T ₅	52.33	57.00	54.66	3286	3510	3398
T ₆	43.67	44.33	44.00	3395	3056	3225
T ₇	43.00	40.00	41.50	3226	2726	2976
T ₈	52.66	55.00	53.83	3389	3233	3311
T ₉	55.67	54.33	55.00	3580	3477	3529
Mean	47.37	46.18		3398	2911	
	S	B	SxB	S	B	SxB
S.E.m ±	1.03	1.78	2.52	140.47	243.30	344.08
CD@ 5%	403.72	699.26	NS	403.72	699.26	NS

S.E.m.± = standard error of mean; CD = critical difference; NS = non-significant.

S₁-Early Sowing, S₂-Late Sowing, SP-Seed Priming, FS- Foliar Spray.

Conclusion

Based on the findings of the present investigation, it can be concluded that seed priming and foliar spray of seaweed extract proved to be the single most effective priming treatment for wheat yield parameters, followed by salicylic acid and glycine betaine hastening the growth attributes. When bio stimulants seed priming was combined with foliar spray and evaluated across sowing dates, early sowing consistently outperformed late sowing, whereas late sowing hastened flowering. The additive nature of the interaction between sowing dates and bio stimulants treatment for growth and yield traits indicated that the benefits of bio stimulants application can be realised across sowing windows. Accordingly, the ill effects of delayed sowing can be alleviated by seed priming and foliar application of seaweed extract, glycine betaine or salicylic acid for enhancing growth and yield quality of wheat.

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