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Effect of varieties, date of sowing and foliar application of micronutrients on growth, yield attributes and yield of Barley (*Hordeum vulgare* L.)

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Abstract

A field experiment was conducted during the *rabi* seasons of 2021-22 and 2022-23 at the Agronomy Farm, S.K.N. College of Agriculture, Jobner, Rajasthan. The study aimed to evaluate the effect of sowing dates, barley varieties, and foliar application of iron and zinc on growth, yield attributes and yield of barley. The experiment revealed that normal sowing significantly improved growth parameters, yield attributes and yields compared with late sowing. On pooled basis, normal sowing increased grain yield, straw yield, and biological yield by 26.6, 26.0, and 26.3 per cent, respectively, over late sowing. It also enhanced plant height, tiller production, chlorophyll content, leaf area index, dry matter accumulation and crop growth rate. Among the varieties, RD-2552 outperformed RD-2907 and recorded 9.5, 6.5, and 7.6 per cent higher grain, straw, and biological yields, respectively. The variety also exhibited superior growth parameters and yield attributes. Grain yield of RD-2552 was 3823 kg ha⁻¹ on pooled basis. Foliar application of 0.5% FeSO₄·7H₂O + 0.5% ZnSO₄·7H₂O at tillering and flowering stages proved most effective. The treatment increased chlorophyll content by 8.2 per cent, grain yield by 13.4 per cent, straw yield by 9.5 per cent, biological yield by 11.0 per cent over control. Therefore, normal sowing of barley variety RD-2552 along with foliar application of 0.5% FeSO₄·7H₂O + 0.5% ZnSO₄·7H₂O at tillering and flowering stages is recommended for enhancing productivity under semi-arid conditions.

Keywords: barley (*hordeum vulgare* L.), date of sowing, late sowing, barley varieties, rd-2552, rd-2907, foliar application and micronutrients

Introduction

Barley (*Hordeum vulgare* L.), commonly known as “Jau” in Hindi, is one of the most important cereal crops of the world and belongs to the family Poaceae. It ranks fourth among cereal crops in terms of acreage and production after wheat, rice and maize in India (Pal *et al.*, 2012) [16]. Owing to its adaptability to diverse agro-climatic conditions, barley is cultivated for food, feed, forage and malting purposes. The grain contains about 12.5% moisture, 11.5% albuminoids, 74% carbohydrates, 1.3% fat, 3.9% crude fibre and 1.5% ash (Vaughan *et al.*, 2007; Kumari, 2015) [12, 26]. Besides its nutritional importance, barley is recognized for several health-promoting properties, including lowering blood cholesterol through β-glucans and reducing glycemic response (Pins and Kaur, 2006) [9, 18]. Globally, barley occupies an area of 49.70 million hectares with a production of 151.62 million tonnes and an average productivity of 3.05 t ha⁻¹ (Statista, 2022-2023). In India, barley is grown on 7.20 million hectares with a production of 21.50 million tonnes and productivity of 3.0 t ha⁻¹ (USDA, 2023-24). Rajasthan is one of the major barley-producing states, cultivating the crop on 2.94 million hectares with a production of 9.11 million tonnes and productivity of 3501 kg ha⁻¹ (Rajasthan Agricultural Statistics, 2021-22).

Optimum temperature for anthesis and grain filling ranges from 12 to 22 °C, while temperatures exceeding 30 °C during pre- or post-anthesis stages adversely affect grain development and yield (Prasad *et al.*, 2017) [20]. Delayed sowing exposes the crop to terminal heat stress, resulting in poor tillering, reduced growth and lower yield. Singh *et al.* (2001) [24] reported that delaying barley sowing beyond 15 December may reduce grain yield by about 50 kg ha⁻¹ day⁻¹. Furthermore, varietal response to sowing environments differs considerably, and therefore

selection of suitable genotypes adapted to normal and late-sown conditions is essential for maximizing productivity (Kumar *et al.*, 2010) ^[10]. Micronutrient nutrition has emerged as another critical factor influencing barley production. Continuous cultivation of high-yielding varieties and intensive fertilizer use have aggravated deficiencies of micronutrients, particularly zinc (Zn) and iron (Fe), in many agricultural soils. Zinc plays a key role in enzyme activation, protein synthesis, carbohydrate metabolism and stress tolerance, while iron is indispensable for chlorophyll synthesis, photosynthetic electron transport and respiration (Alloway, 2004) ^[2]. Deficiencies of these nutrients lead to impaired growth, reduced tillering, chlorosis and poor grain formation, ultimately resulting in lower yield and quality (Tahir *et al.*, 2009) ^[25]. The availability of Zn and Fe is often limited in alkaline and calcareous soils of arid and semi-arid regions due to high soil pH and bicarbonate concentrations. Foliar application has been recognized as an effective approach for correcting micronutrient deficiencies and enhancing nutrient use efficiency. Agronomic biofortification through zinc and iron fertilization not only improves crop productivity but also enhances grain nutritional quality, thereby addressing micronutrient malnutrition in cereal-based diets (Cakmak, 2008) ^[4]. Moreover, significant genetic variability exists among barley genotypes for zinc and iron uptake and accumulation, which can be exploited through suitable varietal selection and nutrient management practices (Garcia-Oliveira *et al.*, 2018) ^[6].

Considering the importance of sowing time, varietal performance and micronutrient management in barley production, the present investigation was undertaken to evaluate the effect of foliar application of zinc and iron on growth and yield of barley, assess the performance of barley varieties under normal and late-sown conditions, and study the interaction between micronutrient application and varieties under different sowing environments.

Materials and Methods

The present research work was carried out during two successive *rabi* seasons of 2021-22 and 2022-23 at Agronomy farm, S. K. N. College of Agriculture, Jobner, Jaipur. Rainfall received during the crop period was 5.00 mm to 93.00 and 6.00 to 107.4 mm during *kharif* season of 2022 and 2023, respectively. The soil of the experimental field was sandy loam in texture with low available nitrogen, medium phosphorus and potassium status. The experiment was laid out in split plot design during both the years with four replications. Date of sowing and varieties were allocated to main plot and foliar application of micronutrients to sub plots. Split plot design was used in experimentation consisting of sixteen treatment combinations (four in main plots and four in sub plots). Treatment combinations were assigned to experimental units randomly employing Fisher and Yates random table method (Panse and Sukhatme, 1985) ^[17] and allocated thrice.

Table 1: Treatment details

S.No.	Treatments	Symbols
A.	Main Plot treatments (Date of Sowing)	
1.	Normal Sown	D ₁
2.	Late Sown	D ₂
B.	Main Plot treatments (Varieties)	
1.	RD-2552	V ₁
2.	RD-2907	V ₂
C.	Sub plot treatments (Foliar Application of Micronutrients)	
1.	Control (Water spray)	N ₀
2.	0.5% FeSO ₄ .7H ₂ O at tillering and flowering stage	N ₁
3.	0.5% ZnSO ₄ .7H ₂ O at tillering and flowering stage	N ₂
4.	0.5% FeSO ₄ .7H ₂ O + 0.5% ZnSO ₄ .7H ₂ O at tillering and flowering stage	N ₃

Details of 16 treatment combinations are presented in Table2

Table 2: Treatment combinations (16)

D ₁ V ₁ N ₀	D ₁ V ₂ N ₀	D ₂ V ₁ N ₀	D ₂ V ₂ N ₀
D ₁ V ₁ N ₁	D ₁ V ₂ N ₁	D ₂ V ₁ N ₁	D ₂ V ₂ N ₁
D ₁ V ₁ N ₂	D ₁ V ₂ N ₂	D ₂ V ₁ N ₂	D ₂ V ₂ N ₂
D ₁ V ₁ N ₃	D ₁ V ₂ N ₃	D ₂ V ₁ N ₃	D ₂ V ₂ N ₃

The barley varieties RD 2552 and RD 2907 were used for the experiment

RD 2552 is a medium-statured variety with a plant height of 80 to 90 cm. It has been developed for irrigated and rainfed conditions and is suitable for normal as well as salt-affected soils. This variety is recommended for timely sown conditions. RD 2907 was developed by RARI, Durgapura for cultivation in salinity conditions. RD 2907 is a barley variety suitable for irrigated and fertile conditions.

Observation was recorded on the following parameters

Growth parameters

For all the growth and development studies during the crop growth period, five plants were selected randomly and tagged in each net plot except for that of chlorophyll content (SPAD

value), leaf area index and net assimilation ratio. Destructive sampling from border rows followed for dry matter accumulation. Initially, the growth parameters were recorded at 30 days after sowing and subsequent observations were taken at an interval of 30 days upto 90 days after sowing and lastly at harvest.

- Plant Stand (/m row length)
- Plant height (cm)
- Number of tillers
- Chlorophyll content (SPAD value)
- Dry matter accumulation (g/m²)

Yield attributes and yield

- Number of effective tillers (/m²)
- Number of grains/spike

- Grains weight/spike (g)
- Test weight (g)
- Grain yield (kg/ha)

$$\text{Grain yield (kg/ha)} = \frac{\text{Yield obtained from net plot (kg)}}{\text{Area of net plot (m}^2\text{)}} \times 10,000$$

Straw yield (kg/ha)

The straw yield was worked out by subtracting the grain yield from biological yield and expressed in kg/ha by multiplying the same conversion factor employed for grain yield.

Biological yield (kg/ha)

Total harvested above ground plant parts from each net plot were carefully bundled after sun drying, tagged and taken to threshing floor. Each bundle was weighed to record the biological yield/plot and finally converted into kg/ha.

Harvest index (%)

The ratio of economic yield to the biological yield (harvest index) was computed using the following formula given by (Nichiporovich, 1967) ^[15].

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Statistical analysis

The data obtained on various parameters was tabulated and subjected to statistical analysis in split plot design to draw a valid conclusion adopting analysis of variance technique as described by Gomez and Gomez (1984) ^[7] to identify the treatment effects. The interpretation of the treatment effects were made on the basis of least significant difference (LSD). The analysis of variance is given below.

Results and Discussion

Plant stand

Data indicated that late sowing significantly increased plant population at both 20 DAS and harvest during the two years of study. The late-sown crop recorded 30.9 and 30.3 plants per metre row length at 20 DAS and harvest, respectively, which were 8.5% and 8.99% higher than normal sowing. Barley varieties showed no significant differences in plant stand at either stage. Similarly, foliar application of micronutrients (0.5% FeSO₄·7H₂O, 0.5% ZnSO₄·7H₂O, and their combination) did not significantly affect plant population compared with the water spray control

Table 3: Effect of foliar application of micronutrients on barley varieties under normal and late sown conditions on plant stand (per meter row length)

Treatments	20 DAS			At harvest		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Date of sowing						
D ₁ : Normal Sown	27.8	28.5	28.2	27.8	27.8	27.8
D ₂ : Late Sown	30.8	31.0	30.9	30.7	29.9	30.3
SEm±	0.3	0.3	0.2	0.3	0.2	0.2
CD (P=0.05)	1.1	1.0	0.7	0.9	0.8	0.5
Varieties						
V ₁ : RD-2552	29.7	30.3	30.0	29.6	29.3	29.4
V ₂ : RD-2907	28.8	29.3	29.1	28.9	28.4	28.6
SEm±	0.3	0.3	0.2	0.3	0.2	0.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS
CV (%)	6.72	7.24		7.32	7.81	
Foliar application of micronutrients						
No: Control (Water spray)	29.0	29.1	29.1	28.9	27.5	28.2
N ₁ : 0.5% FeSO ₄ ·7H ₂ O at tillering and flowering stage	29.1	29.5	29.3	29.2	28.8	29.0
N ₂ : 0.5% ZnSO ₄ ·7H ₂ O at tillering and flowering stage	29.4	30.2	29.8	29.8	29.5	29.6
N ₃ : 0.5% FeSO ₄ + 0.5% ZnSO ₄ ·7H ₂ O at tillering and flowering stage	29.7	30.5	30.1	29.1	29.7	29.4
SEm±	0.4	0.5	0.3	0.2	0.3	0.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS
CV (%)	5.92	6.10		5.91	6.16	

*NS = non-significant

Plant height

Normal sowing resulted in significantly taller barley plants at all growth stages (30, 60, 90 DAS, and harvest) compared to late sowing. On a pooled basis, plant heights under normal sowing were 19.3, 74.0, 113.6, and 117.0 cm at 30, 60, 90 DAS, and harvest, respectively, representing increases of 5.4%, 17.2%, 12.1%, and 13.3% over late sowing. The two barley varieties did not differ significantly in plant height at 30 DAS. However, significant differences were observed at 60 DAS, 90 DAS, and harvest. Variety RD-2552 produced significantly taller plants

than the other variety, recording pooled heights of 72.1, 115.4, and 119.2 cm at 60 DAS, 90 DAS, and harvest, respectively. Micronutrient sprays had no significant effect on plant height at 30 DAS. However, significant increases were observed at 60 DAS, 90 DAS, and harvest. The combined foliar application of 0.5% FeSO₄·7H₂O + 0.5% ZnSO₄·7H₂O (N₃) produced the tallest plants, with pooled heights of 74.2, 111.5, and 117.0 cm at 60 DAS, 90 DAS, and harvest, respectively. These values were statistically at par with 0.5% ZnSO₄·7H₂O (N₂) and were 25.1%, 15.1%, and 17.5% higher than the control.

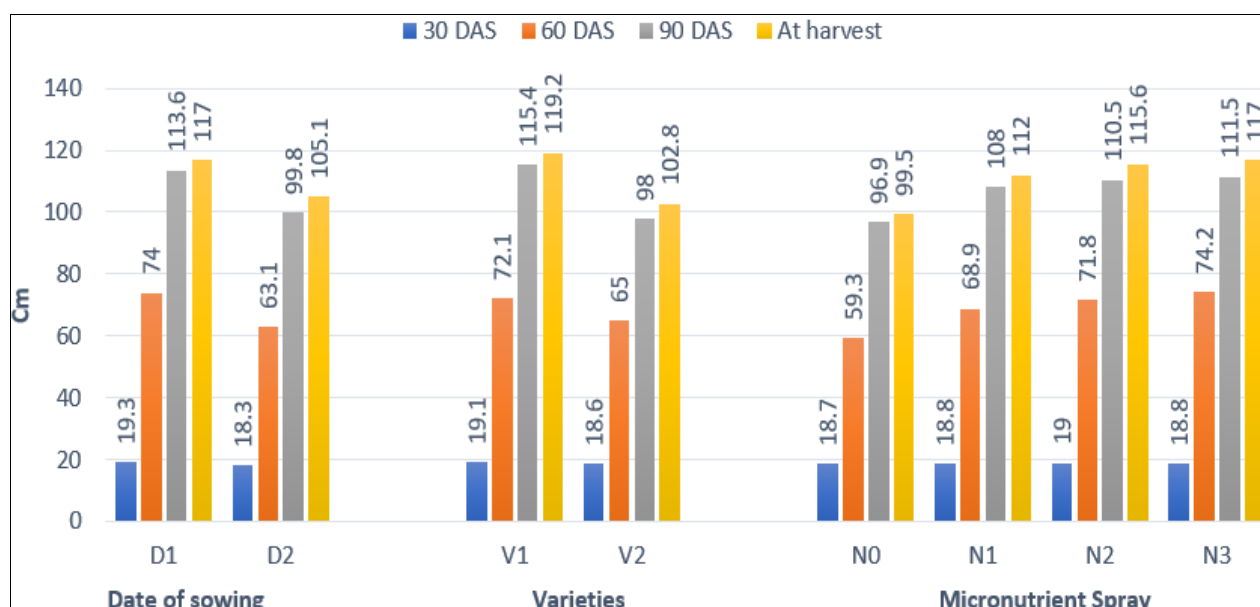


Fig 1: Effect of foliar application of micronutrients on barley varieties under normal and late sown conditions on plant height (cm)

Dry matter accumulation

Dry matter accumulation was significantly higher under normal sowing at 60 DAS, 90 DAS, and harvest. On a pooled basis, normal sowing increased dry matter accumulation by 24.7%, 14.8%, and 26.5% at these stages, respectively. The varieties showed no significant difference at 30 DAS. However, RD-2552 accumulated significantly more dry matter than RD-2907 at 60 DAS, 90 DAS, and harvest. Foliar application of micronutrients significantly increased dry matter accumulation. The combined FeSO_4 and ZnSO_4 treatment (N_3) recorded the highest values and increased dry matter by 27.0%, 14.7%, and 20.0% over the control at 60 DAS, 90 DAS, and harvest, respectively.

Number of Tillers (per m Row Length)

Normal sowing significantly increased the number of tillers at

60 DAS, 90 DAS, and harvest compared to late sowing. On a pooled basis, the normally sown crop recorded about 10% more tillers than the late-sown crop, indicating better vegetative growth and tiller production under timely sowing. The two barley varieties did not differ significantly in tiller number at 30 DAS. However, at 60 DAS, 90 DAS, and harvest, RD-2552 recorded significantly higher tiller numbers than RD-2907. On a pooled basis, RD-2552 produced about 9-10% more tillers, demonstrating its superior tillering ability. Foliar application of micronutrients significantly increased tiller production at all later growth stages. The combined application of 0.5% $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ + 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (N_3) recorded the highest tiller numbers, followed by ZnSO_4 alone. On a pooled basis, N_3 increased tiller production by about 24% over the control.

Table 4: Effect of foliar application of micronutrients on barley varieties under normal and late sown conditions on plant height (cm)

Treatments	30 DAS			60 DAS			90 DAS			At harvest		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Date of sowing												
D ₁ : Normal Sown	19.2	19.4	19.3	73.2	74.8	74.0	112.5	114.6	113.6	115.8	118.2	117.0
D ₂ : Late Sown	17.9	18.7	18.3	62.3	63.8	63.1	98.9	100.7	99.8	104.8	105.4	105.1
SEM±	0.3	0.2	0.2	0.9	1.0	0.7	1.4	1.4	1.0	1.5	1.8	1.2
CD (P=0.05)	0.9	0.8	0.5	2.9	3.3	2.1	4.6	4.6	3.0	4.8	5.8	3.5
Varieties												
V ₁ : RD-2552	18.9	19.2	19.1	71.3	72.8	72.1	114.0	116.7	115.4	117.9	120.6	119.2
V ₂ : RD-2907	18.3	18.9	18.6	64.2	65.8	65.0	97.5	98.6	98.0	102.7	103.0	102.8
SEM±	0.3	0.2	0.2	0.9	1.0	0.7	1.4	1.4	1.0	1.5	1.8	1.2
CD (P=0.05)	NS	NS	NS	2.9	3.3	2.1	4.6	4.6	3.0	4.8	5.8	3.5
CV (%)	8.34	7.26		7.71	8.57		7.74	7.59		7.67	8.14	
Foliar application of micronutrients												
N ₀ : Control (Water spray)	18.7	18.8	18.7	57.6	61.0	59.3	95.9	97.9	96.9	98.6	100.5	99.5
N ₁ : 0.5% $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ at tillering and flowering stage	18.5	19.1	18.8	68.6	69.1	68.9	107.1	108.9	108.0	111.9	112.1	112.0
N ₂ : 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ at tillering and flowering stage	18.6	19.4	19.0	71.0	72.6	71.8	109.5	111.5	110.5	114.6	116.5	115.6
N ₃ : 0.5% FeSO_4 + 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ at tillering and flowering stage	18.6	19.0	18.8	73.8	74.5	74.2	110.5	112.5	111.5	115.9	118.1	117.0
SEM±	0.2	0.3	0.2	1.0	1.2	0.8	1.3	1.3	0.9	1.4	1.5	1.0
CD (P=0.05)	NS	NS	NS	2.9	3.4	2.2	3.8	3.8	2.6	4.0	4.3	2.9
CV (%)	5.37	5.69		5.90	6.82		5.03	5.14		5.45	5.89	

*NS = non-significant

Table 5: Effect of foliar application of micronutrients on barley varieties under normal and late sown conditions on dry matter accumulation (g/ m row length)

Treatments	30 DAS			60 DAS			90 DAS			At harvest		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Date of sowing												
D ₁ : Normal Sown	8.6	8.7	8.6	97.5	99.4	98.4	292.6	294.5	293.5	351.5	356.8	354.1
D ₂ : Late Sown	8.2	8.2	8.2	78.3	79.6	78.9	254.4	257.0	255.7	282.6	288.6	285.6
SEm±	0.1	0.1	0.1	1.1	1.1	0.8	3.6	3.3	2.4	3.8	3.9	2.7
CD (P=0.05)	NS	NS	NS	3.7	3.7	2.4	11.4	10.6	7.2	12.2	12.5	8.1
Varieties												
V ₁ : RD-2552	8.6	8.7	8.7	94.7	94.6	94.6	285.5	288.3	286.9	337.2	341.7	339.5
V ₂ : RD-2907	8.2	8.2	8.2	81.1	84.4	82.7	261.5	263.1	262.3	296.8	303.7	300.3
SEm±	0.1	0.1	0.1	1.1	1.1	0.8	3.6	3.3	2.4	3.8	3.9	2.7
CD (P=0.05)	NS	NS	NS	3.7	3.7	2.4	11.4	10.6	7.2	12.2	12.5	8.1
CV (%)	7.54	7.86		7.40	7.36		7.44	7.28		6.62	6.87	
Foliar application of micronutrients												
N ₀ : Control (Water spray)	8.2	8.3	8.3	76.9	78.9	77.9	251.6	254.5	253.0	281.0	287.4	284.2
N ₁ : 0.5% FeSO ₄ .7H ₂ O at tillering and flowering stage	8.4	8.4	8.4	86.9	88.9	87.9	273.3	275.2	274.3	320.2	326.6	323.4
N ₂ : 0.5% ZnSO ₄ .7H ₂ O at tillering and flowering stage	8.4	8.4	8.4	89.4	90.4	89.9	279.7	281.9	280.8	326.6	335.3	330.9
N ₃ : 0.5% FeSO ₄ + 0.5% ZnSO ₄ .7H ₂ O at tillering and flowering stage	8.6	8.6	8.6	98.4	99.6	99.0	289.4	291.5	290.4	340.5	341.5	341.0
SEm±	0.1	0.1	0.1	1.3	1.3	0.9	4.5	4.3	3.1	4.9	5.2	3.5
CD (P=0.05)	NS	NS	NS	3.8	3.8	2.6	13.0	12.5	8.9	14.0	14.8	10.0
CV (%)	6.32	6.62		5.93	5.85		6.74	6.33		6.14	6.54	

*NS = non-significant

Table 6: Effect of foliar application of micronutrients on barley varieties under normal and late sown conditions on number of tillers (/m²)

Treatments	60 DAS			90 DAS			At harvest		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Date of sowing									
D ₁ : Normal Sown	93.4	94.7	94.1	94.6	95.5	95.1	89.4	90.1	89.8
D ₂ : Late Sown	85.1	86.0	85.6	86.1	87.1	86.6	80.9	82.4	81.7
SEm±	1.3	1.3	0.9	1.3	1.2	0.9	1.2	1.2	0.9
CD (P=0.05)	4.3	4.1	2.8	4.1	4.0	2.6	3.9	3.8	2.5
Varieties									
V ₁ : RD-2552	93.2	94.5	93.8	94.5	95.0	94.8	88.9	90.6	89.8
V ₂ : RD-2907	85.3	86.2	85.8	86.2	87.6	86.9	81.4	81.9	81.7
SEm±	1.3	1.3	0.9	1.3	1.2	0.9	1.2	1.2	0.9
CD (P=0.05)	4.3	4.1	2.8	4.1	4.0	2.6	3.9	3.8	2.5
CV (%)	8.57	8.19		8.04	7.74		8.10	7.85	
Foliar application of micronutrients									
N ₀ : Control (Water spray)	79.0	80.1	79.5	80.2	81.5	80.8	76.0	76.2	76.1
N ₁ : 0.5% FeSO ₄ .7H ₂ O at tillering and flowering stage	88.1	89.4	88.8	89.4	90.3	89.8	84.7	85.4	85.1
N ₂ : 0.5% ZnSO ₄ .7H ₂ O at tillering and flowering stage	91.5	92.7	92.1	92.3	93.5	92.9	87.0	88.3	87.6
N ₃ : 0.5% FeSO ₄ + 0.5% ZnSO ₄ .7H ₂ O at tillering and flowering stage	98.5	99.4	98.9	99.7	99.9	99.8	93.0	95.1	94.1
SEm±	1.4	1.3	1.0	1.3	1.2	0.9	1.2	1.1	0.8
CD (P=0.05)	4.1	3.7	2.7	3.7	3.4	2.5	3.4	3.0	2.2
CV (%)	6.45	5.87		5.84	5.16		5.58	5.14	

Chlorophyll content

- **Effect of date of sowing:** Normal sowing significantly enhanced chlorophyll content at 40 DAS. The pooled data showed that the chlorophyll content of the normally sown crop was 7.8% higher than that of the late-sown crop.
- **Effect of varieties:** No significant difference in chlorophyll content was observed between RD-2552 and RD-2907

during either year or in pooled analysis.

- **Effect of foliar spray of micronutrients:** Foliar application of micronutrients significantly improved chlorophyll content. The combined application of FeSO₄ and ZnSO₄ (N₃) recorded the highest chlorophyll content and increased it by 8.2% over the control, followed by ZnSO₄ alone.

Table 7: Effect of foliar application of micronutrients on barley varieties under normal and late sown conditions on chlorophyll content at 40 DAS

Treatments	Chlorophyll content (mg/g)		
	40 DAS		
	2021-22	2022-23	Pooled
Date of sowing			
D ₁ : Normal Sown	2.86	2.92	2.89
D ₂ : Late Sown	2.66	2.69	2.68
SEm±	0.04	0.03	0.02
CD (P=0.05)	0.11	0.09	0.07
Varieties			
V ₁ : RD-2552	2.79	2.84	2.82
V ₂ : RD-2907	2.73	2.77	2.75
SEm±	0.04	0.03	0.02
CD (P=0.05)	NS	NS	NS
CV (%)	7.21	7.99	
Foliar application of micronutrients			
N ₀ : Control (Water spray)	2.65	2.70	2.68
N ₁ : 0.5% FeSO ₄ .7H ₂ O at tillering and flowering stage	2.72	2.78	2.75
N ₂ : 0.5% ZnSO ₄ .7H ₂ O at tillering and flowering stage	2.79	2.82	2.81
N ₃ : 0.5% FeSO ₄ + 0.5% ZnSO ₄ .7H ₂ O at tillering and flowering stage	2.88	2.91	2.90
SEm±	0.04	0.03	0.02
CD (P=0.05)	0.10	0.08	0.06
CV (%)	5.20	5.48	

*NS = non-significant

Number of Effective Tillers per Metre Row Length

- **Effect of Date of Sowing:** Normal sowing significantly increased the number of effective tillers and recorded 13.7% more effective tillers than late sowing.
- **Effect of Varieties:** Both varieties were statistically similar during individual years, but pooled analysis showed that RD-2552 produced 6.7% more effective tillers than RD-2907.+
- **Effect of Foliar Spray of Micronutrients:** Micronutrient application significantly increased effective tillers. The combined FeSO₄ and ZnSO₄ treatment (N₃) recorded the highest number of effective tillers, about 13% higher than the control.

Number of Grains per Spike

- **Effect of Date of Sowing:** Normal sowing significantly increased grains per spike and recorded a 12.9% advantage over late sowing.
- **Effect of Varieties:** RD-2552 produced significantly more grains per spike than RD-2907, showing a 9.5% increase on a pooled basis.

- **Effect of Foliar Spray of Micronutrients:** Micronutrient application significantly improved grains per spike. The combined FeSO₄ and ZnSO₄ treatment (N₃) increased grains per spike by 14.8% over the control.

The overall growth of plants increased in terms of plant height, chlorophyll content, leaf area index, leaf area duration, dry matter accumulation and relative growth rate (Shirinzadeh *et al.* 2017) [23]. Several researchers (Kaur and Gill 2015) [9] and (Kumar, 2013) [11] also reported almost similar trend in respect of findings growth parameters of wheat under timely sown condition. The marked variations in growth and development among different cultivars have been noticed by Alam *et al.* (2013) [1] in barley as well. These findings are in a good line which obtained by Terfe *et al.* (2018). Growth of plant increased in terms of plant height, chlorophyll content, leaf area index, leaf area duration, dry matter accumulation and relative growth rate. These findings are in a good line which obtained by Harisha *et al.* (2017) [8].

Table 8: Effect of foliar application of micronutrients on barley varieties under normal and late sown conditions on number of effective tillers and grains/spike

Treatments	Number of effective tillers/ m			Number of grains/spike		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Date of sowing						
D ₁ : Normal Sown	81.69	82.54	82.12	47.16	48.07	47.62
D ₂ : Late Sown	71.13	73.32	72.22	41.76	42.56	42.16
SEm±	1.48	1.63	1.10	0.88	0.93	0.64
CD (P=0.05)	5.14	5.62	3.39	3.03	3.23	1.97
Varieties						
V ₁ : RD-2552	78.97	80.37	79.67	46.73	47.12	46.93
V ₂ : RD-2907	73.85	75.49	74.67	42.19	43.51	42.85
SEm±	1.48	1.63	1.10	0.88	0.93	0.64
CD (P=0.05)	NS	NS	3.39	3.03	3.23	1.97
CV (%)	9.52	10.22		9.66	10.09	
Foliar application of micronutrients						
N ₀ : Control (Water spray)	70.45	72.45	71.45	40.81	41.92	41.37
N ₁ : 0.5% FeSO ₄ .7H ₂ O at tillering and flowering stage	76.92	78.26	77.59	44.42	45.82	45.12
N ₂ : 0.5% ZnSO ₄ .7H ₂ O at tillering and flowering stage	78.10	79.68	78.89	45.81	45.32	45.57
N ₃ : 0.5% FeSO ₄ + 0.5% ZnSO ₄ .7H ₂ O at tillering and flowering stage	80.18	81.32	80.75	46.81	48.20	47.51
SEm±	1.18	1.24	0.86	0.95	0.98	0.68
CD (P=0.05)	3.45	3.62	2.44	2.78	2.86	1.94
CV (%)	5.36	5.84		7.41	7.65	

Grain weight per spike

- **Effect of date of sowing:** Normal sowing significantly increased grain weight per spike, recording an 8.4% increase over late sowing.
- **Effect of varieties:** RD-2552 recorded significantly higher grain weight per spike than RD-2907, with a 4.4% increase on a pooled basis.
- **Effect of foliar spray of micronutrients:** The combined FeSO_4 and ZnSO_4 treatment (N_3) significantly increased grain weight per spike and recorded a 19.6% increase over the control.

Test weight

Normal sowing significantly increased test weight and recorded a 10.9% higher value than late sowing. RD-2552 produced significantly higher test weight than RD-2907 and recorded a 9.4% increase on a pooled basis. Although individual years showed non-significant differences, pooled analysis indicated that the combined FeSO_4 and ZnSO_4 treatment (N_3) increased test weight by 3.1% over the control.

Table 9: Effect of foliar application of micronutrients on barley varieties under normal and late sown conditions on grains weight/ spike and test weight

Treatments	Grains weight/spike (g)			Test weight (g)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Date of sowing						
D ₁ : Normal Sown	1.90	1.98	1.94	41.14	41.17	41.16
D ₂ : Late Sown	1.76	1.82	1.79	36.79	37.39	37.09
SEm±	0.03	0.03	0.02	0.48	0.50	0.35
CD (P=0.05)	0.09	0.09	0.06	1.55	1.60	1.03
Varieties						
V ₁ : RD-2552	1.88	1.93	1.91	40.85	40.90	40.88
V ₂ : RD-2907	1.78	1.87	1.83	37.09	37.66	37.37
SEm±	0.03	0.03	0.02	0.48	0.50	0.35
CD (P=0.05)	0.09	0.09	0.06	1.55	1.60	1.03
CV (%)	8.37	8.55		7.03	7.21	
Foliar application of micronutrients						
N ₀ : Control (Water spray)	1.65	1.70	1.68	38.45	38.68	38.57
N ₁ : 0.5% $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ at tillering and flowering stage	1.80	1.86	1.83	38.59	39.14	38.87
N ₂ : 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ at tillering and flowering stage	1.93	1.98	1.96	39.12	39.52	39.32
N ₃ : 0.5% FeSO_4 + 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ at tillering and flowering stage	1.95	2.06	2.01	39.71	39.78	39.75
SEm±	0.03	0.04	0.02	0.47	0.46	0.33
CD (P=0.05)	0.09	0.10	0.07	NS	NS	0.93
CV (%)	6.90	7.03		5.80	5.93	

Grain yield

Grain yield of barley was significantly influenced by sowing time during both years and on a pooled basis. Normal sowing recorded 30.3%, 23.3%, and 26.6% higher grain yield during 2021-22, 2022-23, and pooled analysis, respectively, compared to late sowing. Barley varieties differed significantly in grain yield. Variety RD-2552 recorded grain yields of 3680, 3966, and 3823 kg ha^{-1} during 2021-22, 2022-23, and pooled analysis, respectively, which were 10.0%, 9.0%, and 9.5% higher than RD-2907. Foliar application of micronutrients significantly improved grain yield over the control. On a pooled basis, application of 0.5% $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, and their combination (0.5% $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ + 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) increased grain yield by 3.0%, 10.3%, and 13.4%, respectively, over water spray control.

Straw yield

Straw yield was significantly affected by sowing date. Normal sowing produced straw yields of 6400, 6716, and 6558 kg ha^{-1} during 2021-22, 2022-23, and pooled analysis, respectively. This represented increases of 25.6%, 26.5%, and 26.0% over late sowing. Variety RD-2552 produced significantly higher straw yield than RD-2907 during both years and on pooled basis, recording a 6.5% increase over RD-2907. Foliar application of micronutrients significantly enhanced straw yield. The combined application of 0.5% $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ + 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ recorded straw yields of 6014, 6260, and 6137 kg ha^{-1} during 2021-22, 2022-23, and pooled analysis, respectively, and increased straw yield by 7.3%, 8.7%, and 9.5% over the control. This treatment

remained statistically at par with 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$.

Biological yield

Biological yield was significantly influenced by sowing date. Normal sowing recorded biological yields of 10374, 10915, and 10644 kg ha^{-1} during 2021-22, 2022-23, and pooled analysis, respectively. These values were 27.4%, 25.3%, and 26.3% higher than those under late sowing. Variety RD-2552 recorded biological yields of 9614, 10161, and 9888 kg ha^{-1} during 2021-22, 2022-23, and pooled analysis, respectively, and showed increases of 7.9%, 7.3%, and 7.6% over RD-2907. Foliar application of micronutrients significantly increased biological yield. The combined spray of 0.5% $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ + 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ recorded the highest biological yield and increased it by 11.0% over the control on a pooled basis. However, this treatment was statistically at par with 0.5% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$.

Harvest index

Harvest index was not significantly affected by sowing date during either year or in pooled analysis. No significant differences in harvest index were observed between barley varieties RD-2552 and RD-2907. Foliar application of micronutrients resulted in a numerical increase in harvest index; however, the differences were non-significant during both years as well as in pooled data.

This indicated that partitioning efficiency of photosynthates between economic and vegetative yield remained almost similar under both sowing conditions. (Yadav *et al.* 2017) and (Ram *et al.* 2012) [22, 28] also observed significantly higher number of

tillers, grains/spike, grain weight/spike and test weight in barley. In an investigation conducted on barley, (Shirinzadeh *et al.* 2017) ^[23] observed higher grain and straw yield under normal sown condition. Yadav *et al.* (2017) and Ram *et al.* 2012 ^[22, 28] also observed significantly higher number of tillers, grains/spike, grain weight/spike and test weight in barley. In an investigation conducted on barley, Mona *et al.* (2013) ^[13] and Piri (2012)

^[19]observed higher grain and straw yield under normal sown condition. Yadav *et al.* (2017) and Ram *et al.* (2012) ^[22, 28] also observed significantly higher number of tillers, grains/spike, grain weight/spike and test weight in barley. In an investigation conducted on barley, by Deshmukh *et al.* (2015) ^[5] and Mukharjee, (2012) ^[14] observed higher grain and straw yield under normal sown condition.

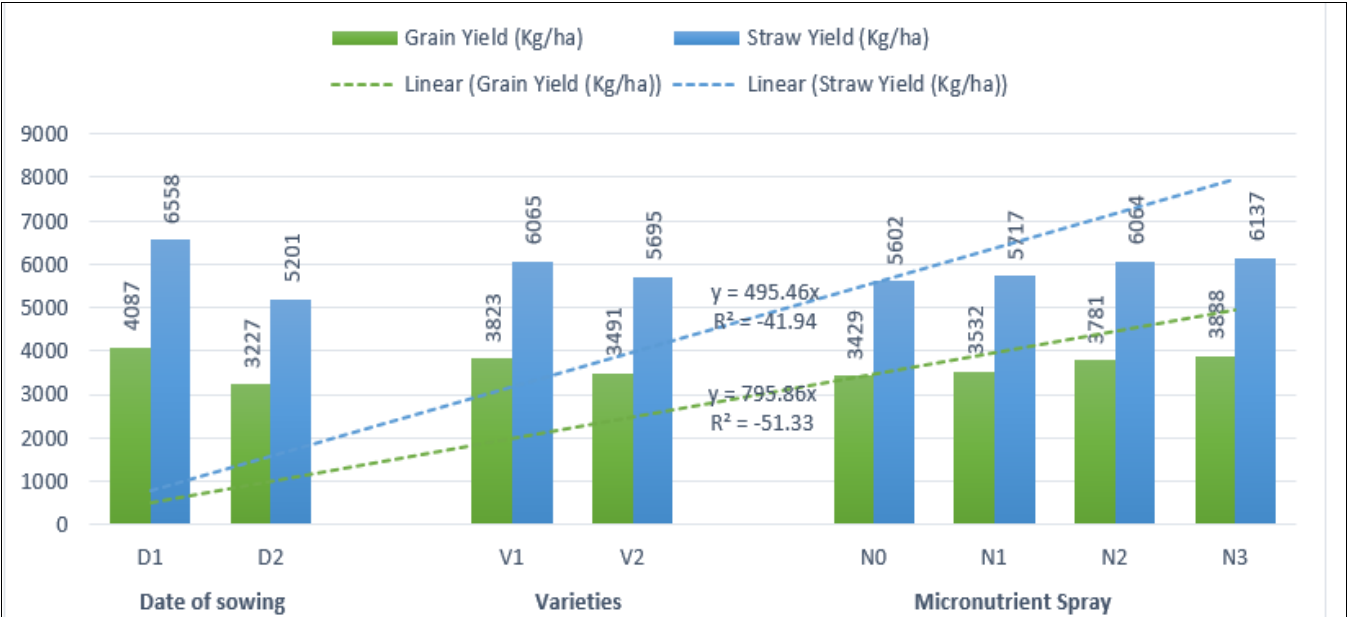


Fig 2: Effect of foliar application of micronutrients on barley varieties under normal and late sown conditions on yields

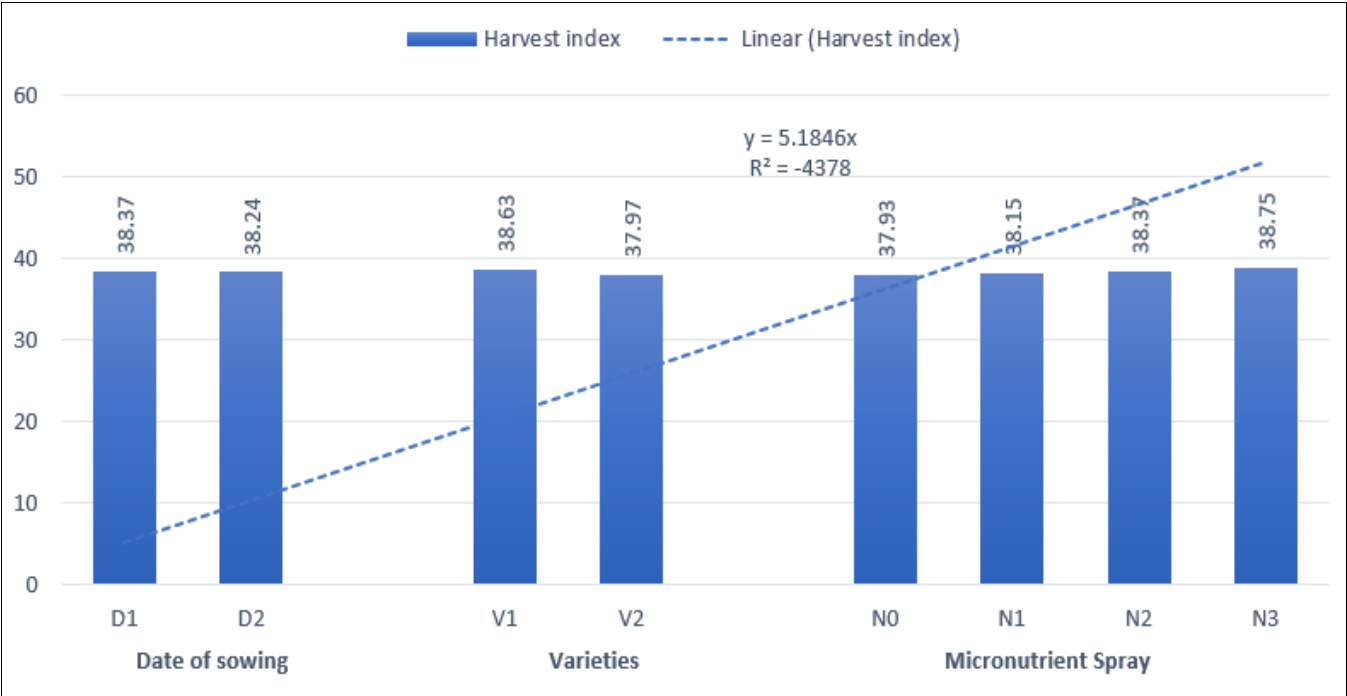


Fig. 3: Effect of foliar application of micronutrients on barley varieties under normal and late sown conditions on harvest index

Table 10: Effect of foliar application of micronutrients on barley varieties under normal and late sown conditions on yields and harvest index

Treatments	Grain yield (Kg/ha)			Straw yield (Kg/ha)			Biological yield (Kg/ha)			Harvest index (%)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Date of sowing												
D ₁ : Normal Sown	3974	4199	4087	6400	6716	6558	10374	10915	10644	38.28	38.45	38.37
D ₂ : Late Sown	3050	3405	3227	5095	5308	5201	8145	8713	8429	37.42	39.05	38.24
SEm±	60	63	43	95	92	66	143	146	102	0.59	0.61	0.42
CD (P=0.05)	192	201	129	305	296	197	458	465	303	NS	NS	NS
Varieties												
V ₁ : RD-2552	3680	3966	3823	5934	6195	6065	9614	10161	9888	38.21	39.05	38.63
V ₂ : RD-2907	3344	3638	3491	5560	5829	5695	8905	9466	9186	37.49	38.45	37.97
SEm±	60	63	43	95	92	66	143	146	102	0.59	0.61	0.42
CD (P=0.05)	192	201	129	305	296	197	458	465	303	NS	NS	NS
CV (%)	10.01	9.89	-	9.67	9.78	-	9.67	8.54	-	8.88	8.86	-
Foliar application of micronutrients												
N ₀ : Control (Water spray)	3281	3576	3429	5446	5757	5602	8727	9333	9030	37.53	38.34	37.93
N ₁ : 0.5% FeSO ₄ ·7H ₂ O at tillering and flowering stage	3395	3668	3532	5601	5832	5717	8996	9500	9248	37.67	38.63	38.15
N ₂ : 0.5% ZnSO ₄ ·7H ₂ O at tillering and flowering stage	3637	3924	3781	5928	6199	6064	9565	10123	9844	37.96	38.79	38.37
N ₃ : 0.5% FeSO ₄ + 0.5% ZnSO ₄ ·7H ₂ O at tillering and flowering stage	3736	4039	3888	6014	6260	6137	9750	10299	10025	38.25	39.24	38.75
SEm±	73	78	53	106	105	75	178	174	125	0.59	0.61	0.42
CD (P=0.05)	211	222	151	304	302	211	511	499	351	NS	NS	NS
CV (%)	8.14	8.01	-	7.45	7.58	-	8.18	7.84	-	6.25	6.27	-

*NS = non-significant

Conclusion

Based on the results of two years investigation, it may be concluded that normal sowing proved superior over late sowing in improving growth and productivity of barley under semi-arid conditions. Among the barley varieties, RD-2552 performed better with respect to growth, yield attributes and yield as compared to RD-2907. Foliar application of 0.5 per cent FeSO₄·7H₂O + 0.5 per cent ZnSO₄·7H₂O at tillering and flowering stage proved most effective in improving growth parameters, yield attributes and grain yield of barley. Normal sowing of barley significantly enhanced productivity over late sowing, recording 26.6% higher grain yield, 26.0% higher straw yield, and 26.3% higher biological yield on pooled basis. Among varieties, RD-2552 performed superiorly with pooled grain yield of 3823 kg/ha and showed 9.5%, 6.5%, and 7.6% higher grain, straw, and biological yield, respectively, over RD-2907. Foliar application of 0.5% FeSO₄·7H₂O + 0.5% ZnSO₄·7H₂O at tillering and flowering stages produced maximum yields and increased grain, straw, and biological yield by 13.4%, 9.5%, and 11.0%, respectively, over control.

References

1. Alam MP, Kumar S, Ali N, Manjhi RP, Kumari N, Lakra RK, *et al.* Performance of wheat varieties under different sowing dates in Jharkhand. *Journal of Wheat Research*. 2013;5(2):61-64.
2. Alloway BJ. Zinc in soil and crop nutrition. Brussels (Belgium): International Zinc Association; 2004.
3. Directorate of Wheat Research. Annual Progress Report 2011-12. Karnal (Haryana): Directorate of Wheat Research; 2012. p. 27.
4. Cakmak I. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification. *Plant and Soil*. 2008;302:1-17.
5. Deshmukh KM, Nayak SK, Damdari R, Wanjari SS. Response of different wheat genotypes to different sowing time in relation to GDD accumulation. *Advance Research Journal of Crop Improvement*. 2015;6(2):66-72.
6. Garcia-Oliveira AL, Chander S, Ortiz R, Menkir A, Gedil M. Genetic basis and breeding perspectives of grain iron and zinc enrichment in cereals. *Frontiers in Plant Science*. 2018;9:937.
7. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd ed. New York: John Wiley and Sons; 1984.
8. Harisha CB, Asangi H, Singh R, Meena NK, Lal G. Irrigation management for higher productivity in seed spices: A review. *International Journal of Current Microbiology and Applied Sciences*. 2017;6(6):2334-2345.
9. Kaur J, Ram H, Gill BS, Kaur J. Agronomic performance and economic analysis of soybean (*Glycine max*) in relation to growth regulating substances in Punjab, India. *Legume Research*. 2015;38(5):603-608.
10. Kumar M, Sheoran P, Yadav A. Productivity potential of wheat in relation to different planting methods and nitrogen management strategies. *Indian Journal of Agricultural Sciences*. 2010;80(5):427-429.
11. Kumar S. Performance of new wheat varieties under timely and late-sown conditions [MSc Agronomy thesis]. Ranchi (Jharkhand): Birsa Agricultural University; 2013.
12. Kumari R. Performance of wheat genotypes on growth and yield under late-sown conditions [MSc Agronomy thesis]. Ranchi (Jharkhand): Birsa Agricultural University; 2015.
13. Mona R. Effect of sulphur and zinc on growth, yield and quality of cabbage (*Brassica oleracea* var. *capitata*) under different moisture regimes [MSc Agriculture thesis]. Jobner (Rajasthan): SKN College of Agriculture, Rajasthan Agricultural University; 2012.
14. Mukherjee D. Effect of different sowing dates on growth and yield of wheat (*Triticum aestivum*) cultivars under mid-hill situation of West Bengal. *Indian Journal of Agronomy*. 2012;57(2):152-156.

15. Nichiporovich AA. Aims of research on photosynthesis of plants as a factor of soil productivity. In: Nichiporovich AA, editor. Photosynthesis of productive systems. Jerusalem: Israel Programme for Scientific Translations; 1967. p. 3-36.
16. Pal SK, Verma UN, Singh MK, Thakur R. Heat unit requirement for phenological development of wheat under different levels of irrigation, seed rate and fertilizer. Indian Journal of Agricultural Sciences. 1996;66(7):397-400.
17. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. 4th ed. New Delhi: Indian Council of Agricultural Research; 1985.
18. Pins JJ, Kaur H. A review of the effects of barley beta-glucan on cardiovascular and diabetic risk. Cereal Foods World. 2006;51(1):8-11.
19. Piri I. Effect of phosphorus fertilizer and micronutrients foliar application on sorghum yield. 2012. p. 3998-4001.
20. Prasad S, Agrawal KK, Kumar R, Prakash V. Heat unit requirement of wheat cultivars under varying thermal regimes at Jabalpur. Journal of Agrometeorology. 2017;19(3):283-285.
21. Radford PJ. Growth analysis formulae: Their use and abuse. Crop Science. 1967;7(3):171-175.
22. Ram A, Pannu RK, Dasharath P. Effect of management practices on growth, yield and quality of late-sown wheat. Indian Journal of Agronomy. 2012;57(1):92-95.
23. Shirinzadeh A, Abad HHS, Nourmohammadi G, Haravan EM, Madani H. Effect of planting date on growth periods, yield and yield components of some bread wheat cultivars in Parsabad Moghan. International Journal of Farming and Allied Sciences. 2017;6(4):109-119.
24. Singh R, Kler DS, Singh S. Effect of crop geometry and nitrogen on growth and yield of durum wheat (*Triticum durum* Desf.). Indian Journal of Environment and Ecoplan. 2001;5:173-178.
25. Tahir M, Ali A, Nadeem MM, Hussain A, Khalid F. Effect of different sowing dates on growth and yield of wheat (*Triticum aestivum* L.) varieties in district Jhang, Pakistan. Pakistan Journal of Life and Social Sciences. 2009;7(1):66-69.
26. Vaughan DA, Balazs E, Heslop-Harrison JS. From crop domestication to super-domestication. Annals of Botany. 2007;100(5):893-901.
27. Watson DJ. The physiological basis of variation in yield. Advances in Agronomy. 1947;4:101-146.
28. Yadav V, Mishra DN, Chauhan RS, Tomar P, Singh R. Performance of newly released wheat (*Triticum aestivum* L.) varieties on different sowing dates under NWPZ of Uttar Pradesh. Journal of Pharmacognosy and Phytochemistry. 2017;6(1):720-722.