



International Journal of Research in Agronomy

E-ISSN: 2618-0618

P-ISSN: 2618-060X

© Agronomy

www.agronomyjournals.com

2024; 7(8): 532-537

Received: 20-06-2024

Accepted: 28-07-2024

Kumar D Lamani

Principal Scientist, Department of
Agronomy, AICRP Wheat and
Barley, MARS, University of
Agricultural Sciences, Dharwad,
Karnataka, India

Uday G Reddy

Department of Genetics and Plant
Breeding, University of
Agricultural Sciences, Dharwad,
Karnataka, India

Nagesh Rathod

Department of Agronomy,
University of Agricultural Sciences,
Dharwad, Karnataka, India

Corresponding Author:

Nagesh Rathod

Department of Agronomy,
University of Agricultural Sciences,
Dharwad, Karnataka, India

Optimizing emmer wheat (*Triticum dicoccum* L.) yield: Strategies for lodging prevention with foliar application of plant growth regulators

Kumar D Lamani, Uday G Reddy and Nagesh Rathod

DOI: <https://doi.org/10.33545/2618060X.2024.v7.i8g.1437>

Abstract

A field trial was conducted during *Rabi* season of 2020-21 and 2021-22 to study the "Optimizing emmer wheat yield: Strategies for lodging prevention with plant growth regulators". The study was organized using a split-plot design, employing three replications. The experimental treatments included four genotypes in the main plot and five treatments in the sub-plots. The results indicated that the genotype of MACS 2971 with foliar application of ethephon @ 30 ppm l⁻¹ of water (V₁G₅) recorded significantly lower plant height (66.00 cm), lodging score (0.83%), higher number of effective tillers (391.83 m⁻²), grain yield (44.24 q/ha), straw yield (72.99 q/ha), biological yield (117.73 q/ha), gross returns (₹. 1,62,851 ha⁻¹), net returns (₹. 1,27,530 ha⁻¹) and B:C ratio (4.61) followed by V₁G₃, V₂G₃, V₂G₅, V₃G₃ and V₄G₅. Where, as significantly higher plant height, lodging score, lower number of effective tillers, grain yield, straw yield, biological yield and lower economic returns was (V₄G₅) recorded in without foliar application of plant growth regulators in gokak local genotype.

Keywords: Economics, emmer wheat, genotypes, lodging, plant growth regulators

Introduction

The emmer wheat (*Triticum dicoccum* L.) is reported to be grown on a very restricted scale in Gujarat, Maharashtra and Karnataka, where it is known under the names Popathiya, Samba and Khapli it means 'crusty' respectively. In general emmer wheat varieties are rich source of protein and complex carbohydrate (dietary fibre) as compared to bread wheat and it keeps one full for longer and hence helps in weight loss. It possesses excellent grain quality traits and is rich source of dietary fibres of more than 16 percent. It helps the digestion of carbohydrates, which slows down the release of glucose into the bloodstream maintaining a steady blood sugar level and makes it ideal for diabetic people. It contains good amount of proteins (11.8 to 15.3%), total carbohydrates (78.7 to 83.2%) and also this grain is rich in polyphenols which helps to prevent cancer, cardiovascular diseases and neurodegenerative diseases. The traditional products of emmer wheat varieties have better taste, texture and flavour (Singh, 2015) ^[10].

Globally, wheat is cultivated in an area of 222 Mha with a production of 779 Mt and having the productivity of 3510 kg/ha (Anon., 2022) ^[3]. In India, the estimated area 31.61 Mha with production of 109.52 Mt and productivity of 3464 kg/ha (Anon., 2021) ^[2]. Uttar Pradesh has the highest area (9.85 M ha) and production (35.50 Mt) followed by Madhya Pradesh (6.39 Mha, 17.62 Mt). Punjab has the highest average productivity of 4862 kg/ha followed by Haryana with 4836 kg/ha (Anon., 2021) ^[2]. Karnataka is unique in cultivation of three species, namely, bread, durum and dicoccum wheat. In Karnataka, the area under wheat is 1.67 lakh ha with annual production of 1.79 Mt and productivity of 1198 kg/ha.

Dicoccum wheat lodging was notably pronounced, resulting in a substantial yield reduction of approximately 30-40%. This lodging phenomenon is prevalent, primarily attributed to the increased plant height in local varieties when compared to newer variants. The North-West winds, known as Paduvana gali, carry higher moisture content. Consequently, the panicles absorb this moisture, becoming weightier and compelling the plants to undergo lodging.

Lodging is a complex issue influenced by factors like wind, rain, topography, soil type, previous

crop management and disease. It often occurs due to conditions promoting excessive plant growth, leading to the vulnerability of wheat stems to lodging during later stages such as heading and grain filling, causing significant yield loss. Lodging hampers light absorption, intra-plant water availability and nutrient translocation, ultimately reducing yields. To address this, dicocum is being experimented with, along with plant regulators like chlormequat chloride (CCC) and Ethephon. These regulators can modify stem stand, regulate plant growth and improve source-sink relationships, resulting in more grains per spike and increased grain yield. By preventing, delaying, or reducing lodging in cereals, the quantity and harvest ability of grains are enhanced, ensuring a favourable economic outcome. Consequently, an experiment was launched to assess the yield potential of both improved and local genotypes of emmer wheat through the application of plant growth regulators.

Materials and Methods

Description of field sites and experimental design: A field trial was conducted during *Rabi* season of 2020-21 and 2021-22 to study the “Optimizing emmer wheat yield: Strategies for lodging prevention with plant growth regulators”. The Dharwad region experiences a weather characterized by hot and dry summer along with medium cold winters. The soil type of the experimental site was medium deep black soil with clay loam texture. It was low in available nitrogen (189.74 kg/ha), high in available phosphorous (36.24 kg/ha) and potassium (368.25 kg/ha). Additionally, the soil had a neutral pH of 7.51 and EC was 0.27 dS/m. The experiment was laid out in split plot design with three replications. The experiment consists of four genotypes (V₁-MACS 2971; V₂-DDK 1029; V₃-HW-1098 and V₄-Gokak local) in main plots and five treatments (G₁-Control; G₂-CCC @ 1000 ppm l⁻¹ water; G₃-CCC @ 1500 ppm l⁻¹ water; G₄- Ethephon @ 10 ppm l⁻¹ water and G₅- Ethephon @ 10 ppm l⁻¹ water) in sub plots. The seed rate used for sowing is 150 kg ha⁻¹ with a row spacing of 20 cm. The recommended doses of fertilizer (RDF) at 120: 60: 30 kg N: P₂O₅: K₂O ha⁻¹ were applied. Nitrogen was administered in two equal splits, initially at sowing as a basal application and then 30 days after sowing. The complete amount of phosphorus and potassium was applied as a basal dose during sowing, alongside half of the nitrogen. Emmer wheat was cultivated following a specified set of agricultural practices. Irrigation was managed based on the crop's water requirements using the check basin method. The crop was sown on November 14th and harvested on March 15th in both years.

Estimating emmer wheat yield: The wheat crop underwent manual harvesting, leaving two border rows unharvested in both horizontal and longitudinal directions, with a 0.5 m gap in the longitudinal direction. Subsequently, the harvested wheat grain was gathered and subjected to oven-drying at 65–70 °C for 48 hours. The weight of the dried grain was then measured to calculate the economic yield. Harvesting was conducted from the net plot and the yield was quantified in quintals per hectare.

Lodging score

To score lodging the percent area of plant that lodged was estimated and the angle of stem lodging was estimated.

$$\text{Lodging score} = \frac{\% \text{ area lodging} \times \text{angle of lodging from vertical}}{90}$$

Statistical analysis

The investigation involved the meticulous compilation and analysis of recorded data, employing statistical techniques such as analysis of variance (ANOVA) for split plot design. Fisher's ANOVA method, as elucidated by Gomez and Gomez (1984) [5], was adopted for this purpose. Standard error of mean and coefficient of variability were computed for each set of observations pertaining to various characteristics. The mean values for the main plot, sub-plot and interaction effects were subjected to separate analysis through Duncan's Multiple Range Test (DMRT) using corresponding error mean sum of squares and degrees of freedom values, facilitated by the OP-STAT program.

Results and Discussion

The performance of different emmer wheat genotypes in terms of growth, yield and yield attributes was assessed

In this investigation, differences in plant height, lodging score and 1000-grain weight among various genotypes were not statistically significant. However, the Gokak local genotype (V₄) exhibited numerically higher values: 79.94 cm in plant height, 2.44% in lodging score and 44.18 g in 1000-grain weight, surpassing other genotypes (Table 1 & 2). These variations are likely attributed to the unique genetic characteristics of specific genotypes, aligning with the findings of Sujatha *et al.*, (2018) [13].

The results showed a significant increase in the number of effective tillers per square meter for all genotypes, except the Gokak local genotype. Particularly, the MACS 2971 genotype (V₁) exhibited the highest count of effective tillers at 349.71 m⁻², outperforming other genotypes (Table 2). These differences can be attributed to the unique genetic traits of individual genotypes, aligning with similar findings reported by Rajala and Peltonen, 2021 [19].

In the present investigation the results indicated that, among the different genotypes there is no significant difference was recorded in grain, straw and biological yields except gokak local genotype. Where, as numerically higher grain (40.45 q/ha), straw (66.75 q/ha) and biological yields (105.95 q/ha) was recorded in HW 1098 genotype (V₃) as compared to other genotypes (Table 3 & 4). These might be due to higher yield attributing character of particular genotype. Similar type of results was also obtained by Guled (1993) [16].

The findings indicate that, with the exception of the Gokak local genotype, all emmer wheat genotypes exhibited significantly higher gross returns, net returns and benefit-cost ratios. Notably, HW 1098 (V₃) displayed superior performance, registering elevated gross returns (₹. 1,48,924 ha⁻¹), net returns (₹. 1,13,061 ha⁻¹) and a benefit-cost ratio of 4.16 compared to other genotypes. This outcome is likely linked to the higher grain yield and straw yield recorded in HW 1098, (Table 4). Importantly, similar results were corroborated by Sujatha *et al.*, (2018) [13].

Effect of foliar application of plant growth regulators on growth and yield parameters of emmer wheat

The foliar application of ethephon @ 30 ppm per liter of water after 30 to 35 DAS (G₅) recorded significantly lower plant height (67.96 cm), lodging score (0.93%), higher number of effective tillers (361.17 m⁻²), thousand grain weight (44.19 g), grain yield (42.70 q/ha), straw

Table 1: Plant height and lodging score of emmer wheat as influenced by different genotypes and plant growth regulators (PGRs)

Treatment		Plant height (cm)			Lodging score (%)		
		2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Main plot: Four different genotypes (V)							
V ₁	MACS 2971	72.68 ^a	74.70 ^a	73.69 ^a	2.15 ^a	1.81 ^a	1.98 ^a
V ₂	DDK 1029	76.00 ^a	77.42 ^a	76.71 ^a	2.11 ^a	1.81 ^a	1.96 ^a
V ₃	HW 1098	73.18 ^a	74.18 ^a	73.68 ^a	2.33 ^a	2.03 ^a	2.18 ^a
V ₄	Gokak Local	79.44 ^a	80.44 ^a	79.94 ^a	2.56 ^a	2.31 ^a	2.44 ^a
S.E.m.±		1.92	1.78	1.83	0.10	0.12	0.11
Sub plot: Foliar application of plant growth regulators (PGRs) (G)							
G ₁	Control	83.80 ^a	82.45 ^a	83.13 ^a	4.22 ^a	3.90 ^a	4.06 ^a
G ₂	CCC @ 1000 ppm	78.58 ^b	80.60 ^{ab}	79.59 ^b	2.61 ^b	2.41 ^b	2.51 ^b
G ₃	CCC @ 1500 ppm	70.67 ^c	72.67 ^c	71.67 ^c	1.26 ^c	0.93 ^c	1.10 ^c
G ₄	Ethephon @ 10 ppm	76.65 ^b	78.70 ^b	77.68 ^b	2.31 ^b	1.91 ^b	2.11 ^b
G ₅	Ethephon @ 30 ppm	66.92 ^c	69.00 ^c	67.96 ^d	1.05 ^c	0.81 ^c	0.93 ^c
S.E.m.±		0.87	0.83	0.81	0.11	0.13	0.17
Interaction (V × G)							
V ₁ G ₁		80.30 ^{bc}	82.40 ^b	81.35 ^b	4.23 ^a	3.83 ^{ab}	4.03 ^{ab}
V ₁ G ₂		76.00 ^{d-f}	78.00 ^{c-e}	77.00 ^{c-e}	1.93 ^e	1.73 ^{cd}	1.83 ^{cd}
V ₁ G ₃		69.60 ^{g-i}	71.60 ^{f-h}	70.60 ^{f-h}	1.40 ^f	1.00 ^e	1.20 ^{de}
V ₁ G ₄		72.50 ^{fg}	74.50 ^{ef}	73.50 ^{ef}	2.27 ^{c-e}	1.77 ^{cd}	2.02 ^c
V ₁ G ₅		65.00 ^{jk}	67.00 ^{ij}	66.00 ^{ij}	0.93 ^f	0.73 ^e	0.83 ^e
V ₂ G ₁		82.50 ^b	81.40 ^{bc}	81.95 ^b	3.73 ^b	3.43 ^b	3.58 ^b
V ₂ G ₂		79.60 ^{b-d}	81.70 ^{bc}	80.65 ^{bc}	2.40 ^{cd}	2.20 ^{cd}	2.30 ^c
V ₂ G ₃		71.30 ^{gh}	73.30 ^{fg}	72.30 ^{fg}	1.30 ^f	1.00 ^e	1.15 ^{de}
V ₂ G ₄		78.30 ^{c-e}	80.30 ^{b-d}	79.30 ^{b-d}	2.10 ^{de}	1.60 ^d	1.85 ^{cd}
V ₂ G ₅		68.30 ^{h-j}	70.40 ^{g-i}	69.35 ^{g-i}	1.03 ^f	0.83 ^e	0.93 ^e
V ₃ G ₁		83.20 ^b	80.00 ^{b-d}	81.60 ^b	4.40 ^a	4.10 ^a	4.25 ^{ab}
V ₃ G ₂		77.60 ^{c-e}	79.60 ^{b-d}	78.60 ^{b-d}	2.47 ^{cd}	2.27 ^c	2.37 ^c
V ₃ G ₃		66.30 ^{ij}	68.30 ^{hi}	67.30 ^{hi}	1.30 ^f	1.00 ^e	1.15 ^{de}
V ₃ G ₄		77.50 ^{c-e}	79.60 ^{b-d}	78.55 ^{b-d}	2.30 ^{c-e}	2.00 ^{cd}	2.15 ^c
V ₃ G ₅		61.30 ^k	63.40 ^j	62.35 ^j	1.20 ^f	0.80 ^e	1.00 ^e
V ₄ G ₁		89.20 ^a	86.00 ^a	87.60 ^a	4.53 ^a	4.23 ^a	4.38 ^a
V ₄ G ₂		81.12 ^{bc}	83.12 ^{ab}	82.12 ^b	3.63 ^b	3.43 ^b	3.53 ^b
V ₄ G ₃		75.50 ^{ef}	77.50 ^{de}	76.50 ^{de}	1.03 ^f	0.73 ^e	0.88 ^e
V ₄ G ₄		78.30 ^{c-e}	80.40 ^{b-d}	79.35 ^{b-d}	2.58 ^c	2.27 ^c	2.43 ^c
V ₄ G ₅		73.10 ^{fg}	75.20 ^{ef}	74.15 ^{ef}	1.04 ^f	0.89 ^e	0.97 ^e
M × S							
S.E.m.±		1.74	1.65	1.62	0.20	0.27	0.34
S × M							
S.E.m.±		2.47	2.31	2.33	0.21	0.27	0.32

*Note: Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

yield (70.45 q/ha), biological yield (112.81 q/ha), gross returns (₹. 1,57,182 ha⁻¹), net returns (₹. 1,22,188 ha⁻¹) and benefit cost ratio (4.49) and it was on par with (G₃) foliar application of CCC (2-chloroethyl trimethyl ammonium chloride) at the rate of 1500 ppm per liter of water after 30 to 35 DAS. However, significantly higher plant height (83.13 cm), lodging score

(4.06%), lower number of effective tillers (301.75 m⁻²), thousand grain weight (41.98 g), grain yield (33.11 q/ha), straw yield (54.64 q/ha), biological yield (87.11 q/ha), gross returns (₹. 1,21,909 ha⁻¹), net returns (₹. 88,374 ha⁻¹) and benefit cost ratio (3.64) was recorded (G₁) in control as

Table 2: Number of effective tillers and test weight of emmer wheat as influenced by different genotypes and plant growth regulators (PGRs)

Treatment		Number of effective tillers (m ⁻²)			Test weight (g)		
		2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Main plot: Four different genotypes (V)							
V ₁	MACS 2971	342.13 ^a	357.28 ^a	349.71 ^a	41.33 ^a	43.53 ^a	42.43 ^a
V ₂	DDK 1029	324.97 ^{ab}	340.60 ^{ab}	332.79 ^{ab}	41.43 ^a	43.56 ^a	42.50 ^a
V ₃	HW 1098	328.87 ^{ab}	344.27 ^{ab}	336.57 ^{ab}	41.52 ^a	43.46 ^a	42.49 ^a
V ₄	Gokak Local	291.67 ^b	309.47 ^b	300.57 ^b	43.21 ^a	45.14 ^a	44.18 ^a
S.E.m.±		10.03	10.77	9.73	1.13	1.21	1.16
Sub plot: Foliar application of plant growth regulators (PGRs) (G)							
G ₁	Control	293.88 ^c	309.61 ^c	301.75 ^c	41.23 ^a	42.73 ^a	41.98 ^a
G ₂	CCC @ 1000 ppm	306.17 ^c	321.17 ^c	313.67 ^c	40.74 ^a	42.91 ^a	41.83 ^a
G ₃	CCC @ 1500 ppm	333.50 ^b	349.25 ^b	341.38 ^b	42.90 ^a	44.73 ^a	43.81 ^a
G ₄	Ethephon @ 10 ppm	324.25 ^b	338.92 ^b	331.58 ^b	41.47 ^a	43.89 ^a	42.68 ^a
G ₅	Ethephon @ 30 ppm	351.75 ^a	370.58 ^a	361.17 ^a	43.02 ^a	45.36 ^a	44.19 ^a
S.E.m.±		4.27	3.68	3.20	0.51	0.60	0.52

Interaction (V × G)						
V ₁ G ₁	294.00 ^{f-h}	307.43 ^{hi}	300.72 ^{fg}	41.50 ^{b-f}	43.17 ^{b-e}	42.34 ^{b-e}
V ₁ G ₂	322.67 ^d	339.00 ^{ef}	330.84 ^d	39.15 ^f	42.15 ^{de}	40.65 ^e
V ₁ G ₃	340.67 ^c	355.33 ^{cd}	348.00 ^c	41.80 ^{a-e}	43.80 ^{a-e}	42.80 ^{a-e}
V ₁ G ₄	371.00 ^{ab}	383.33 ^b	377.16 ^b	41.90 ^{a-e}	43.90 ^{a-e}	42.90 ^{a-e}
V ₁ G ₅	382.33 ^a	401.33 ^a	391.83 ^a	42.29 ^{a-e}	44.62 ^{a-e}	43.46 ^{a-d}
V ₂ G ₁	299.53 ^{e-g}	317.00 ^{gh}	308.27 ^{ef}	41.18 ^{c-f}	42.18 ^{de}	41.68 ^{c-e}
V ₂ G ₂	308.33 ^{d-f}	325.00 ^{fg}	316.67 ^{de}	39.97 ^{ef}	42.30 ^{c-e}	41.14 ^{de}
V ₂ G ₃	341.00 ^c	356.67 ^{cd}	348.84 ^c	42.66 ^{a-d}	44.66 ^{a-d}	43.66 ^{a-c}
V ₂ G ₄	322.00 ^d	336.67 ^{ef}	329.34 ^d	40.59 ^{d-f}	43.59 ^{a-e}	42.09 ^{b-e}
V ₂ G ₅	354.00 ^{bc}	367.67 ^{bc}	360.84 ^c	42.75 ^{a-d}	45.09 ^{a-c}	43.92 ^{a-c}
V ₃ G ₁	311.00 ^{d-f}	325.33 ^{fg}	318.17 ^{de}	40.05 ^{ef}	41.72 ^e	40.88 ^e
V ₃ G ₂	315.33 ^{de}	329.00 ^{e-g}	322.17 ^{de}	40.76 ^{c-f}	42.42 ^{c-e}	41.59 ^{c-e}
V ₃ G ₃	343.67 ^c	360.00 ^c	351.84 ^c	42.90 ^{a-d}	44.56 ^{a-e}	43.73 ^{a-c}
V ₃ G ₄	321.00 ^d	337.00 ^{ef}	329.00 ^d	40.80 ^{c-f}	43.14 ^{b-e}	41.97 ^{b-e}
V ₃ G ₅	353.33 ^{bc}	370.00 ^{bc}	361.67 ^c	43.11 ^{a-c}	45.44 ^{ab}	44.28 ^{ab}
V ₄ G ₁	271.00 ⁱ	288.67 ^j	279.84 ^h	42.18 ^{a-e}	43.85 ^{a-e}	43.02 ^{a-e}
V ₄ G ₂	278.33 ^{hi}	291.67 ^{ij}	285.00 ^h	43.10 ^{a-c}	44.76 ^{a-d}	43.93 ^{a-c}
V ₄ G ₃	308.67 ^{d-f}	325.00 ^{fg}	316.84 ^{de}	44.24 ^a	45.90 ^{ab}	45.07 ^a
V ₄ G ₄	283.00 ^{g-i}	298.67 ^{ij}	290.84 ^{gh}	42.60 ^{a-d}	44.94 ^{a-d}	43.77 ^{a-c}
V ₄ G ₅	317.33 ^{de}	343.33 ^{de}	330.33 ^d	43.94 ^{ab}	46.27 ^a	45.11 ^a
M × S						
S.Em.±	8.54	7.36	6.40	1.02	1.19	1.03
S × M						
S.Em.±	12.61	12.62	11.29	1.46	1.61	1.48

*Note: Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

Table 3: Grain and straw yields of emmer wheat as influenced by different genotypes and plant growth regulators (PGRs)

Treatment		Grain yield (q ha ⁻¹)			Straw yield (q ha ⁻¹)		
		2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Main plot: Four different genotypes (G)							
V ₁	MACS 2971	37.45 ^{ab}	39.71 ^a	38.58 ^a	61.79 ^{ab}	65.52 ^a	63.66 ^a
V ₂	DDK 1029	37.06 ^{ab}	39.32 ^a	38.19 ^{ab}	61.15 ^{ab}	64.89 ^a	63.02 ^{ab}
V ₃	HW 1098	39.39 ^a	41.52 ^a	40.45 ^a	64.99 ^a	68.50 ^a	66.75 ^a
V ₄	Gokak Local	34.59 ^b	35.51 ^b	35.05 ^b	57.07 ^b	58.59 ^b	57.83 ^b
S.Em.±		1.12	0.90	0.99	1.84	1.48	1.64
Sub plot: Foliar application of plant growth regulators (PGRs) (G)							
G ₁	Control	32.11 ^c	34.12 ^c	33.11 ^d	52.99 ^c	56.29 ^c	54.64 ^d
G ₂	CCC @ 1000 ppm	34.45 ^{bc}	36.39 ^b	35.42 ^c	56.85 ^{bc}	60.04 ^b	58.44 ^c
G ₃	CCC @ 1500 ppm	40.97 ^a	43.34 ^a	42.16 ^a	67.60 ^a	71.52 ^a	69.56 ^a
G ₄	Ethephon @ 10 ppm	36.37 ^b	37.53 ^b	36.95 ^b	60.01 ^b	61.93 ^b	60.97 ^b
G ₅	Ethephon @ 30 ppm	41.70 ^a	43.70 ^a	42.70 ^a	68.80 ^a	72.10 ^a	70.45 ^a
S.Em.±		0.57	0.43	0.32	0.94	0.71	0.52
Interaction (V × G)							
V ₁ G ₁		32.72 ^{f-h}	34.39 ^{gh}	33.55 ^{gh}	53.99 ^{f-h}	56.74 ^{gh}	55.37 ^{gh}
V ₁ G ₂		33.58 ^{e-g}	35.91 ^{e-g}	34.75 ^{fg}	55.41 ^{e-g}	59.25 ^{e-g}	57.33 ^{fg}
V ₁ G ₃		42.84 ^a	45.17 ^a	44.00 ^a	70.68 ^a	74.53 ^a	72.61 ^a
V ₁ G ₄		35.02 ^{ef}	37.69 ^{de}	36.36 ^e	57.78 ^{ef}	62.19 ^{de}	59.99 ^e
V ₁ G ₅		43.07 ^a	45.40 ^a	44.24 ^a	71.07 ^a	74.91 ^a	72.99 ^a
V ₂ G ₁		32.37 ^{gh}	35.04 ^{fh}	33.70 ^{gh}	53.41 ^{f-h}	57.82 ^{fh}	55.61 ^{gh}
V ₂ G ₂		33.95 ^{e-g}	36.61 ^{ef}	35.28 ^{ef}	56.02 ^{e-g}	60.41 ^{ef}	58.21 ^{ef}
V ₂ G ₃		41.03 ^{ab}	43.69 ^a	42.36 ^b	67.70 ^{ab}	72.09 ^a	69.89 ^b
V ₂ G ₄		35.91 ^{de}	37.25 ^e	36.58 ^e	59.25 ^{de}	61.47 ^e	60.36 ^e
V ₂ G ₅		42.03 ^{ab}	44.03 ^a	43.03 ^{ab}	69.35 ^{ab}	72.65 ^a	71.00 ^{ab}
V ₃ G ₁		33.18 ^{fg}	35.85 ^{e-g}	34.52 ^{fg}	54.75 ^{fg}	59.15 ^{e-g}	56.95 ^{fg}
V ₃ G ₂		38.14 ^{cd}	39.81 ^{bc}	38.98 ^d	62.93 ^{cd}	65.69 ^{bc}	64.31 ^d
V ₃ G ₃		42.50 ^a	45.16 ^a	43.83 ^a	70.13 ^a	74.51 ^a	72.32 ^a
V ₃ G ₄		39.77 ^{bc}	41.43 ^b	40.60 ^c	65.62 ^{bc}	68.36 ^b	66.99 ^c
V ₃ G ₅		43.34 ^a	45.34 ^a	44.34 ^a	71.51 ^a	74.81 ^a	73.16 ^a
V ₄ G ₁		30.18 ^h	31.18 ⁱ	30.68 ⁱ	49.80 ^h	51.45 ⁱ	50.62 ⁱ
V ₄ G ₂		32.14 ^{gh}	33.22 ^{hi}	32.68 ^h	53.03 ^{gh}	54.82 ^{hi}	53.92 ^h
V ₄ G ₃		37.50 ^{cd}	39.36 ^{cd}	38.43 ^d	61.88 ^{cd}	64.94 ^{cd}	63.41 ^d
V ₄ G ₄		34.77 ^{e-g}	33.77 ^h	34.27 ^{fg}	57.37 ^{e-g}	55.72 ^h	56.54 ^{fg}
V ₄ G ₅		38.34 ^{cd}	40.01 ^{bc}	39.18 ^d	63.26 ^{cd}	66.02 ^{bc}	64.64 ^d
M × S							
S.Em.±		1.14	0.87	0.63	1.88	1.43	1.04
S × M							
S.Em.±		1.51	1.19	1.14	2.50	1.96	1.89

*Note: Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

Compared to other treatments (Table 1, 2, 3 & 4). Ethephon (2 chloro ethyl phosphonic acid) and CCC (chlormequat chloride) were reported to be useful in reducing the plant height (Ali, 1993) [1]. Ethephon led to decrease in the length of peduncle, middle internode and to some extent.

Basal internodes (Knapp *et al.*, 1987) [7]. Ethephon application was found to increase lignin content and decrease cellulose content in lower and middle internodes. It decreased ADF (Acid detergent fibre) and prevented lodging in the basal internodes and increased potassium content of second internode (Tripathi *et al.*, 2003) [12]. The present investigation included identification of appropriate growth regulator with effective dosage in reducing the lodging and also to find out a variety which responds favourably in improving its growth and yield to plant growth. These might be a result of reduces the lodging of emmer wheat plant by foliar application of ethephon through decrease in the length of peduncle, middle internode and to some extent basal internodes (Knapp *et al.*, 1987) [7], simultaneously increased tiller numbers m^{-2} , stem wall thickness for the 1st, 2nd and 3rd internodes (Tripathi *et al.*, 2003) [12].

Interaction effect of different genotypes and foliar application of plant growth regulators on growth and yield parameters of emmer wheat

The genotypes of HW 1098, MACS 2971 and DDK 1029 with foliar application of ethephon @ 30 ppm per liter of water after 30 to 35 DAS (V_3G_5 , V_1G_5 and V_2G_5) recorded significantly lower plant height (62.35, 66.00 and 69.35 cm, respectively) and lodging score (1.00, 0.73 and 0.83%, respectively) and it was on par with V_1G_3 , V_2G_3 , V_3G_3 and V_4G_3 , respectively (Table 1). Nevertheless, a notable increase in plant height and lodging score was observed in all genotypes without foliar application of plant growth regulators. This phenomenon may be attributed to the combined positive impact of specific genotypes and the absence of plant growth regulators. These outcomes align with the observations made by Knapp *et al.* (1987) [7].

The genotype of DDK 1029 with foliar application of ethephon @ 30 ppm per liter of water after 30 to 35 DAS (V_2G_5) recorded

significantly higher number of effective tillers ($391.83 m^{-2}$) followed by V_1G_3 , V_1G_4 , V_2G_3 , V_2G_5 , V_3G_3 and V_3G_5 . However, significantly lower number of effective tillers was recorded in (V_4G_1 and V_4G_2) without foliar application of plant growth regulators and foliar application of CCC @ 1000 ppm per liter of water with gokak local genotype (279.84 and 285.00 m^{-2} , respectively) (Table 2). These could be linked to a consequence of combined positive influence of respective genotypes and plant growth regulators. Similar results were shown (Sujatha *et al.*, 2018) [13].

The genotypes of MACS 2971, DDK 1029 and HW 1098 with foliar application of ethephon @ 30 ppm per liter of water and CCC @ 1500 ppm per liter of water after 30 to 35 DAS recorded significantly higher grain yield (V_1G_3 -44.00 q/ha, V_1G_5 -44.24 q/ha, V_2G_5 -43.03 q/ha, V_3G_3 -43.83 q/ha and V_3G_5 -44.34 q/ha), straw yield (V_1G_3 -72.61 q/ha, V_1G_5 -72.99 q/ha, V_2G_5 -71.00 q/ha, V_3G_3 -72.32 q/ha and V_3G_5 -73.16 q/ha) and biological yield (V_1G_3 -117.72 q/ha, V_1G_5 -117.73 q/ha, V_2G_5 -114.49 q/ha, V_3G_3 -114.40 q/ha and V_3G_5 -116.28 q/ha) as compared to without foliar application of plant growth regulators in gokak local genotype (V_4G_1) (Table 3 & 4). These effects are likely the result of the combined positive influence of both specific genotypes and application of plant growth regulators on the growth and yield parameters of emmer wheat. These findings are consistent with the results reported.

The genotypes of MACS 2971, DDK 1029 and HW 1098 with foliar application of ethephon @ 30 ppm per liter of water and CCC @ 1500 ppm per liter of water after 30 to 35 DAS recorded significantly higher gross returns V_1G_3 (₹. 1,62,001 ha^{-1}), V_1G_5 (₹. 1,62,851 ha^{-1}), V_3G_3 (₹. 1,61,359 ha^{-1}) and V_3G_5 (₹. 1,63,238 ha^{-1}) and it was on par with V_2G_5 (₹. 1,58,415 ha^{-1}). However, significantly lower gross returns were recorded in (V_4G_1) without foliar application of plant growth regulators in gokak local genotype (₹. 1,12,953 ha^{-1}) (Table 4). These could be caused by higher grain and straw yields was recorded in respective treatments. This is in accordance with the findings of (Sujatha *et al.*, 2018) [13].

Table 4: Biological yield and economics of emmer wheat as influenced by different genotypes and plant growth regulators (PGRs)

Treatment		Biological yield (q ha^{-1})			GR (₹. ha^{-1})	NR (₹. ha^{-1})	B:C ratio
		2020-21	2021-22	Pooled	Pooled	Pooled	Pooled
Main plot: Four different genotypes (V)							
V_1	MACS 2971	99.23 ^{ab}	105.24 ^a	102.95 ^a	142028 ^a	106077 ^a	3.95 ^a
V_2	DDK 1029	98.20 ^{ab}	104.21 ^a	101.79 ^a	140601 ^a	104738 ^{ab}	3.92 ^{ab}
V_3	HW 1098	104.37 ^a	110.02 ^a	105.95 ^a	148924 ^a	113061 ^a	4.16 ^a
V_4	Gokak Local	91.65 ^b	94.10 ^b	91.36 ^b	129026 ^a	93163 ^b	3.60 ^b
S.E.m.±		2.96	2.38	1.89	3662	3746	0.10
Sub plot: Foliar application of plant growth regulators (PGRs) (G)							
G_1	Control	85.10 ^c	90.41 ^c	87.11 ^c	121909 ^d	88374 ^d	3.64 ^c
G_2	CCC @ 1000 ppm	91.30 ^{bc}	96.43 ^b	93.99 ^{bc}	130400 ^c	92929 ^d	3.48 ^c
G_3	CCC @ 1500 ppm	108.56 ^a	114.86 ^a	110.99 ^a	155198 ^a	115758 ^b	3.94 ^b
G_4	Ethephon @ 10 ppm	96.37 ^b	99.47 ^b	97.67 ^b	136035 ^b	102050 ^c	4.00 ^b
G_5	Ethephon @ 30 ppm	110.49 ^a	115.79 ^a	112.81 ^a	157182 ^a	122188 ^a	4.49 ^a
S.E.m.±		1.51	1.15	1.59	1163	1190	0.03
Interaction (V × G)							
V_1G_1		86.70 ^{f-h}	91.14 ^{gh}	88.18 ^{gh}	123531 ^{gh}	89996 ^h	3.68 ^{fg}
V_1G_2		88.99 ^{e-g}	95.16 ^{e-g}	94.41 ^{e-g}	127915 ^{fg}	90444 ^h	3.41 ^{ij}
V_1G_3		113.52 ^a	119.70 ^a	117.72 ^a	162001 ^a	122561 ^{bc}	4.11 ^{cd}
V_1G_4		92.80 ^{ef}	99.88 ^{de}	96.72 ^{d-f}	133841 ^e	99856 ^g	3.94 ^{de}
V_1G_5		114.14 ^a	120.31 ^a	117.73 ^a	162851 ^a	127530 ^{ab}	4.61 ^a
V_2G_1		85.78 ^{f-h}	92.86 ^{f-h}	89.94 ^{f-h}	124084 ^{gh}	90549 ^h	3.70 ^{fg}
V_2G_2		89.97 ^{e-g}	97.02 ^{ef}	94.73 ^{e-g}	129884 ^{ef}	92413 ^h	3.47 ^{hi}
V_2G_3		108.73 ^{ab}	115.78 ^a	112.15 ^{ab}	155949 ^b	116509 ^d	3.95 ^{c-e}
V_2G_4		95.16 ^{de}	98.72 ^e	97.63 ^{de}	134674 ^e	100689 ^g	3.96 ^{c-e}

V ₂ G ₅	111.38 ^{ab}	116.68 ^a	114.49 ^a	158415 ^{ab}	123530 ^{a-c}	4.54 ^{ab}
V ₃ G ₁	87.93 ^{fg}	95.00 ^{e-g}	90.40 ^{f-h}	127068 ^{fg}	93533 ^h	3.79 ^{ef}
V ₃ G ₂	101.07 ^{cd}	105.50 ^{bc}	102.21 ^{cd}	143486 ^d	106015 ^{ef}	3.83 ^{ef}
V ₃ G ₃	112.63 ^a	119.67 ^a	114.40 ^a	161359 ^a	121919 ^c	4.09 ^{cd}
V ₃ G ₄	105.39 ^{bc}	109.79 ^b	106.47 ^{bc}	149469 ^c	115484 ^d	4.40 ^b
V ₃ G ₅	114.85 ^a	120.15 ^a	116.28 ^a	163238 ^a	128353 ^a	4.68 ^a
V ₄ G ₁	79.98 ^h	82.63 ⁱ	79.91 ⁱ	112953 ⁱ	79418 ⁱ	3.37 ^{ij}
V ₄ G ₂	85.17 ^{gh}	88.04 ^{hi}	84.61 ^{hi}	120315 ^h	82844 ⁱ	3.21 ^j
V ₄ G ₃	99.38 ^{cd}	104.30 ^{cd}	99.68 ^{c-e}	141483 ^d	102043 ^{fg}	3.59 ^{gh}
V ₄ G ₄	92.14 ^{e-g}	89.48 ^h	89.87 ^{f-h}	126157 ^{fg}	92172 ^h	3.71 ^{fg}
V ₄ G ₅	101.60 ^{cd}	106.03 ^{bc}	102.74 ^{cd}	144223 ^d	109338 ^e	4.13 ^c
M × S						
S.Em.±	3.02	2.29	3.18	2326	2381	0.06
S × M						
S.Em.±	4.01	3.14	3.42	4212	4309	0.12

*Note: Mean followed by the same letter(s) did not differ significantly by DMRT (p= 0.05)

The foliar application of ethephon @ 30 ppm per liter of water with genotype of HW 1098 (V₃G₅) recorded significantly higher net returns (₹. 1,28,353 ha⁻¹) and it was on par with V₁G₅ (₹. 1,27,530 ha⁻¹) and V₂G₅ (₹. 1,23,530 ha⁻¹). Where, as significantly lower net returns were recorded in V₄G₁ without foliar application of plant growth regulators in gokak local genotype (₹. 79,418 ha⁻¹) (Table 4). These may be attributed to higher grain and straw yields was recorded in respective treatments. This is in accordance with the findings of (Sujatha *et al.*, 2018) [13].

The foliar application of plant growth regulators and various genotypes significantly influences the benefit-cost ratio of emmer wheat. The genotypes of MACS 2971 and HW 1098 with foliar application of ethephon @ 30 ppm per liter of water after 30 to 35 DAS (V₁G₅ and V₃G₅) recorded significantly higher benefit cost ratio (4.61 and 4.68, respectively) and it was on par with V₂G₅ (4.54). However, significantly lower benefit cost ratio was recorded in (V₄G₂) gokak local genotype with foliar application of CCC @ 1000 ppm per liter of water after 30 to 35 DAS (3.21) (Table 4). These could result from higher grain and straw yields was recorded in respective treatments. This is in accordance with the findings of (Sujatha *et al.*, 2018) [13].

Conclusion

In summary, the utilization of the plant growth regulator ethephon at 30 ppm resulted in a reduction in growth parameters such as plant height and lodging score across all genotypes. Simultaneously, it positively influenced grain yield, yield attributes and economic factors in all the genotypes.

References

1. Ali AA. Effect of nitrogen nutrition and ethephon on lodging and yield of wheat (*Triticum aestivum* L.). Monoufeya J Agric Res. 1993;18:2225-2234.
2. Anonymous. Area, production and productivity of wheat in Karnataka; c2021. Available from: www.indiastat.com. [Accessed 28 March 2021].
3. Anonymous. Agricultural statistics at a glance. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Govt. of India; c2022.
4. Farmer O. Effect of regulator application on spring barley yields. Sbornik Vysoke Skoly Zemedelske V Praze, Fakulta Agronomicka. Rada A, Rostlinna Vyroba. 1992;54:237-245.
5. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd ed. New York: Wiley-International Science Publication; c1984. p. 680.
6. Guled MB. Investigation on the performance of rice

varieties and the water requirement of rice-based cropping systems in Krishnaraja Sagar Command area. PhD Thesis, University of Agricultural Sciences, Bangalore, Karnataka, India; c1993.

7. Knapp JS, Harms CL, Volenec JJ. Growth regulator effects on wheat culm non-structural and structural carbohydrates and lignin. Crop Sci. 1987;27(6):1201-1205.
8. Lamani KD, Rathod N, Reddy UG. Efficacy of pre-emergent herbicides against diverse weed flora in wheat crop in Northern Transition Zone of Karnataka in South India. Indian J Weed Sci. 2024;56(2):151-158.
9. Rajala A, Peltonen SP. Plant growth regulator effects on spring cereal root and shoot growth. Agron. J. 2021;93(4):936-943.
10. Singh SK. Cultivation of dicoccum wheats in India. Krishisewa; c2015. p. 1-4.
11. Sliman ZT, Ghandorah MO. Response of two wheat cultivars to chlormequat (CCC) application. Agric.s Sci. 1992;4(1):57-65.
12. Tripathi SC, Sayre KD, Kaul JN. Fibre analysis of wheat genotypes and its association with lodging: effects of nitrogen levels and ethephon. Cereal Res Commun. 2003;31(3/4):429-436.
13. Sujatha ER, Sridhar V. Spatial Prediction of Erosion Risk of a small mountainous watershed using RUSLE: A case-study of the Palar sub-watershed in Kodaikanal, South India. Water. 2018 Nov 9;10(11):1608.