Environment and Ecology 42 (1) : 84—93, January—March 2024
Article DOI: https://doi.org/10.60151/envec/ZYBJ8353
ISSN 0970-0420

Impact of Organic and Inorganic Plant Growth Promoters on Growth Indices and Yield of Wheat (*Triticum aestivum* L.) Varieties

Sunil Kumar Prajapati, V. K. Verma, Naushad Khan, Shivendra Singh, Gurwaan Singh, Shivam Yadav

Received 4 June 2023, Accepted 5 December 2023, Published on 31 January 2024

ABSTRACT

The micronutrients, such as zinc, iron, copper, and boron play an important role in the physiological processes of plants. This experiment evaluate the impact of organic (GA_3, Seaweed extract solid/liquid) and inorganic (Nitrobenzene and micronutrients- Zn, Fe, B, Cu) plant growth promoters on the growth indices and yield of wheat varieties. The experiment was laid out in Split Plot Design with three replications. Three timely shown wheat varieties (DBW-187, K-1006, and K-607) allocated in the main plots and plant growth promoters (Nitrobenzene, Gibberellic acid, Seaweed extract, and a mixture of micronutrients-Zn, Fe, Cu, B) in the sub-plots comprised of 18 treatment combinations. The results revealed that significant variations in the response of wheat varieties to the different plant growth promoters. The highest growth and yield viz., plant height (85.50cm), number of tillers (451.75 m^{-2}), fresh weight (86.83 g $plant^{-1}$), dry weight (23. 39 g $plant^{-1}$), crop growth rate, test weight (40.67g) and grain yield (4764.67 kg ha^{-1}) was recorded in wheat varieties DBW-187 followed by K-1006 and minimum in variety K-607. Among plant growth promoters, the mixture of micronutrients (Zn, Fe, Cu, B) @ 0.5% foliar spray at tillering stage, show significant result in growth and yield viz., plant height (86.21cm), number of tillers (459.63 m^{-2}), fresh weight (86.96 g $plant^{-1}$), dry weight (23.92 g $plant^{-1}$), crop growth rate, test weight (41.87g) and grain yield (4813.67 kg ha^{-1}) as compared to all other treatment. The Gibberellic acid @ 2000 ppm and Seaweed extract liquid @ 625 ml ha^{-1} show significant result also. The maximum growth and yield was obtained by the variety DBW-187 and mixture nutrients (Zn, Fe, Cu, and B). The interaction effects were found non-significant.

Keywords Wheat, Micronutrients, Seaweed extract, Zn, Fe, Cu, B, GA_3, Growth, Yield.

Sunil Kumar Prajapati[1]*, V. K. Verma[2], Naushad Khan[3], Shivendra Singh[4], Gurwaan Singh[5], Shivam Yadav[6]

[2,3] Professor

[1,2,3,4,5,6] Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh 208002, India

Email: sunil01673@gmail.com
*Corresponding author

INTRODUCTION

Wheat is a critical global crop, feeding two-thirds of the world's population with 779.30 million tonnes produced annually (Anonymous 2021). Doubling production by 2050 is essential for global food security. Micronutrient deficiencies like zinc, iron, boron, and copper in soils threaten wheat production.

Soil factors like pH and texture affect micronutrient availability, with calcareous soils in arid regions often deficient (Dhaliwal *et al.* 2022). Low wheat production is due to various factors like poor seeds, salinity, waterlogging, inadequate fertilization, and limited education. In India, 49% of cultivated land lacks zinc and copper (Altaf *et al.* 2021). Relying solely on chemical fertilizers is insufficient for long-term soil health. Micronutrients are crucial for wheat growth, impacting various metabolic processes and nutrient uptake (Umair Hassan *et al.* 2020). Seaweed extracts, rich in trace elements and growth regulators like cytokinins, are renowned bio-stimulants (Panda *et al.* 2022). They enhance plant resilience to frost, drought, pests, and pathogens, while boosting crop yields and nutrient uptake (El-Desouky *et al*. 2022, Prajapati *et al.* 2022). Extraction methods vary, including high-pressure water, alcohol, alkaline, microwave-assisted, and supercritical CO_2 extraction. Notably, cytokinins can be extracted using chilled 70% ethanol with deuterium as a co-solvent. India boasts diverse marine algae species, with leading seaweed producers in Tamil Nadu, Gujarat, Maharashtra, Goa, and others. Seaweed extracts are commercially available in forms like Liquid Seaweed Fertilizer (LSF), granules, and powder, promoting growth in cereals, pulses, and flowering plants (Tandel *et al.* 2016). These extracts are weed seed and pathogen-free, making them beneficial for crops. Foliar spray of Seaweed extract accelerates growth and yield in various crops, and ongoing research explores innovative seaweed preparation methods. Brown algae liquid extracts are marketed as bio-stimulants or bio-fertilizers under different brand names like Maxicrop, Cytex, and Seacrop-16 (Prajapati *et al.* 2022).

Gibberellic acid (GA) is a vital plant growth regulator with multifaceted roles. It triggers germination, stimulates cell division, breaks seed dormancy, and enhances leaf size (Niharika *et al.* 2021). Moreover, GA plays a pivotal role in bolstering plant defense mechanisms against stress by neutralizing excess reactive oxygen species (ROS) and boosting antioxidant enzyme activity (Sabagh *et al.* 2021). Studies confirm that applying GA externally to wheat plants alleviates salt stress, bolsters nutrient absorption, and augments crop yield. GA_3 is integral to a wide array of developmental processes, spanning from seed development and germination to root growth, leaf morphology, flower formation, pollination, and fruit enlargement. Notably, germination is intricately regulated by various plant hormones, including gibberellic acid (GA), abscisic acid (ABA), auxin, and ethylene. Nitrobenzene, available as a greenish-yellow crystal or yellow oily liquid with a bitter odor, exhibits solubility in various substances such as water, acetone, benzene, diethyl ether, and ethanol. In agriculture, it serves as a potent tool when combined with nitrogen to stimulate flowering and enhance crop growth. Nitrobenzene derived from Seaweed extracts demonstrates remarkable capabilities, serving as both a flower stimulant and a deterrent against flower shedding. Essentially, it's a plant energizer and yield enhancer formed by combining nitrogen with plant growth regulators extracted from seaweed. Nitrobenzene is particularly well-suited for vegetable crops and flowering plants, offering a cost-effective alternative to traditional plant growth regulators, with a concentration of 20% w/w. This plant energizer is swiftly absorbed by plants, influencing their biochemical pathways and resulting in increased nutrient absorption from the soil and improved nutrient utilization efficiency. Moreover, it aids in retaining flowers and fruits on the plants. Notably, the application of 'Flora,' which contains nitrobenzene, contributes to improved sensory attributes and extends the shelf life of agricultural produce. Ultimately, this leads to higher yields across a range of crops. During the two growing seasons, the foliar application of macronutrients demonstrated a significant effect on various growth parameters and yield attributes. Additionally, the content of certain nutrients in wheat grains, such as Fe, Zn, Cu, and B, increased due to the foliar application of macronutrients (Aziz *et al.* 2019). Notably, significant differences were observed between varieties across most characteristics. Among the timely sown wheat varieties examined, DBW-187 exhibited the most favorable results compared to K-1006 and K-607. Furthermore, the interaction between different plant growth promoters and a micronutrient mixture significantly influenced the yield attributes and economic aspects. The objectives of the experiments were to evaluate the performance of timely sown wheat varieties, to assess the impact of plant growth promoters on the yield of wheat varieties and analyze the interaction effect between wheat varieties and plant growth promoters.

MATERIALS AND METHODS

Experimental site: The field experiment was conducted at Chandra Shekhar Azad University of Agriculture and Technology in Kanpur, Uttar Pradesh (Fig. 1). The weather data for the wheat crop during the *rabi* season of 2021-22 was obtained from the Agro-meteorological Observatory in the Department of Agronomy. Kanpur is geographically located in the central part of Uttar Pradesh, in the sub-tropical semi-arid tract of North India. It is positioned at coordinates 26° 29' 35" North latitude and 80° 18' 25" East longitude, with an elevation of approximately 125.9 meters above mean sea level in the Gangetic plain. Kanpur is situated in the central plain zone of Uttar Pradesh, on the right bank of the Ganga River, and falls within the upper Indo-Gangetic plain zone of India.

Climatic conditions: Climate refers to the collective weather conditions experienced in a particular region over an extended period. It encompasses larger areas such as zones, states, countries, and continents, and encompasses longer durations such as months, seasons, and years. The annual average rainfall in the area is approximately 885.6 mm, with a significant portion, typically around 88.70%, occurring between July and September. Detailed information about the weather conditions during the cropping period can be seen in the graph provided (Fig. 2).

Soil characteristics: The properties of the soil have a significant impact on plant growth and consequently, the final yield. The soil of experiment field is characterized as sandy clay loam, with specific measurements including Organic carbon (0.49%), Available nitrogen (148.20 kg ha^{-1}), Available P_2O_5 (20.60 kg ha^{-1}), Available K_2O (215.50 kg ha^{-1}), and a pH of 7.7.

Experimental details: The experimental was laid out in split-split plot design (SPD) with three replications. Three timely shown varieties (V_1-DBW-187, V_2-K-1006 and V_3-K-607) were allocated in the main plots and plant growth promoters (G_0- Control, G_1- Nitro-

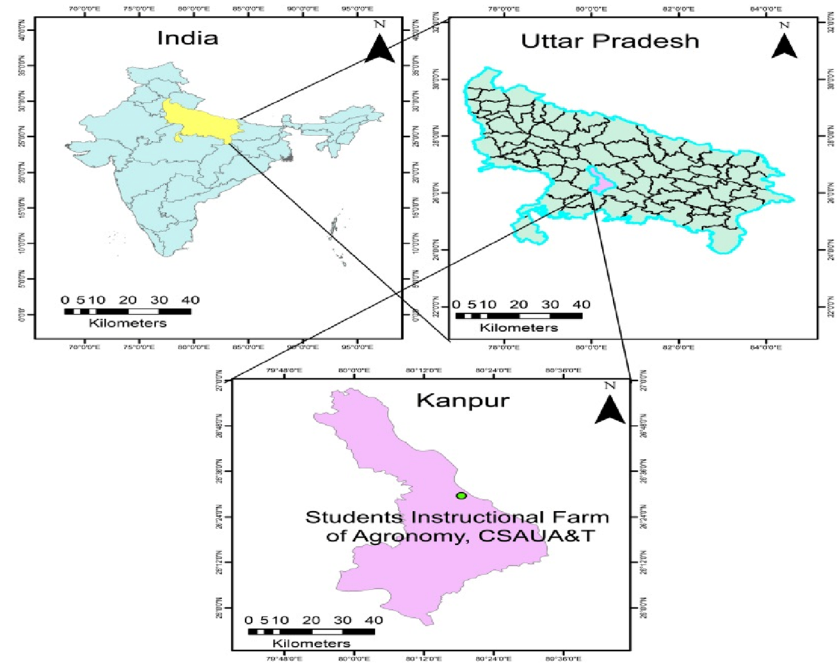

Fig. 1. Location map of the study area.

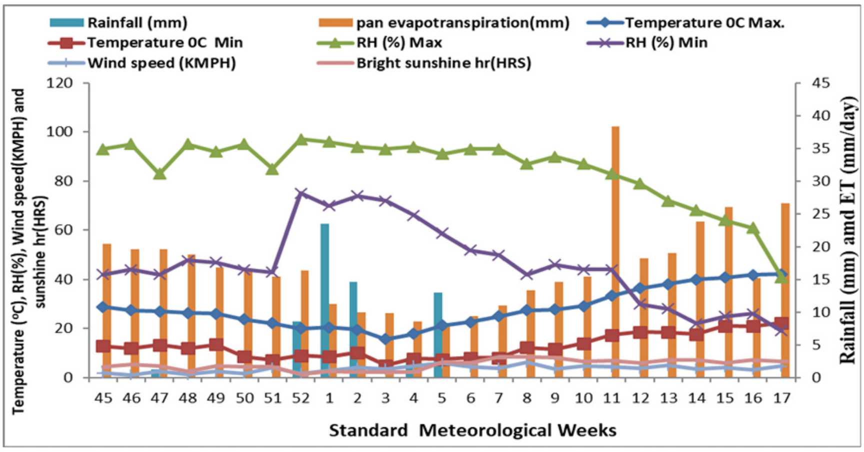

Fig. 2. Details of weather data during crop season (2021-22).

benzene @ 3ml l^{-1}, G_2-Gibberellic acid @ 2000 ppm, G_3-Seaweed extract solid @ 25 kg ha^{-1}, G_4-Seaweed extract liquid @ 625 ml ha^{-1}, G_5-Micronutrients (Zn, Fe, B, Cu) @ 0.5%) were allocated in the sub-plots accommodated in 18 treatment combinations. Each plot had dimensions of 4.0 m in length and 3.0 m in width, resulting in a total plot size of 12 m^2.

Crop varieties

(a) K-1006 (Shekhar): It was released from CS Azad University of Agriculture and Technology (UP) Kanpur in 2014. The optimum time of sowing this variety ranges from the 1st week of Nov to the 2nd week of Dec and its yield potential is 50-60 q ha^{-1}.

(b) K-607 (Azad): It was released from CS Azad University of Agriculture and Technology (UP) Kanpur in 2013. The optimum time of sowing this variety range from the 2nd week of November to the 1st week of December and its yield potential is 50-55 q ha^{-1}.

(c) DBW-187 (Karan Vandana): It was released from Indian Institute of Wheat and Barley Research, Karnal, Haryana. This variety is recommended for irrigated timely sown condition NWPZ (Punjab, Haryana, Delhi, Rajasthan and Western UP). Resistant to stripe and leaf rust, highly resistant to wheat blast, moderate resistance to karnal bunt and tolerance to loose smut with average yield of 61.3 q ha^{-1} and yield potential of 96.6 q ha^{-1}.

Agronomical practices adopted: The field was thoroughly prepared, ensuring appropriate soil moisture levels, following pre-sowing irrigation conducted approximately 10 days prior to the sowing date. The initial ploughing was performed using a rotavator attached to a tractor, followed by two cross ploughing actions using a cultivator. Subsequently, planking was carried out. On 29 November 2021, certified seeds of wheat varieties DBW-187, K-1006, and K-607 were sown in a timely manner. The sowing process was conducted manually, ensuring proper moisture levels, with a uniform seed rate of 100 kg ha^{-1}. Adequate planking was performed to cover the seeds in the furrows. The crop received a uniform fertilization of 120 kg N, 60 kg P_2O_5, and 40 kg K_2O ha^{-1}. Various plant growth promoters were applied at specific stages: Nitrobenzene at a rate of 3 ml/l during the tillering stage, gibberellic acid at a concentration of 2000 ppm also during the tillering stage, Seaweed extract (solid) @ 25 kg ha^{-1} at sowing time, Seaweed extract (liquid) @ 625 ml ha^{-1} during the tillering stage, and micronutrients (Zn, Fe, Cu, B) @ 0.5% at tillering stage. For effective weed control, Clodinafop-propargyl (Topik) @ 60-80 g a.i. ha^{-1} and Metsulfuron-methyl @ 4-8 g a.i. ha^{-1} were uniformly applied at 30-35 days after sowing (DAS) in each treatment. The experiment was conducted under irrigated conditions, with a total of five irrigations, including pre-sowing irrigation. The first irrigation was applied at the crown root initiation (CRI) stage, which occurred between

21-25 DAS in all treatments. The remaining three irrigations were scheduled at intervals of 20-25 days to meet the crop's water requirements. Harvesting took place when the ear heads turned a golden yellow color, and the leaves and stems had dried. The plants were cut near the ground and left to dry. From each treatment, the net plot area, excluding the borders, was harvested, bundled, and labeled separately. The bundles were then taken to the threshing floor, where they were weighed after complete drying in sunlight. Threshing was conducted on a plot-wise basis using a thresher, and yield data for grain and straw were carefully recorded.

Observations recorded: To ensure maximum precision at minimum cost, a proper sampling technique was employed. In accordance with this principle, observations were recorded from four tagged plants within each plot. Various growth and yield attributes of wheat, including, plant height, tillers per plant, dry weight of the plant, crop growth rate, test weight, and grain yield, were recorded on a per-plot basis (Prajapati *et al.* 2022). The collected data were then subjected to appropriate statistical analysis using the method described by Gomez and Gomez (1984) to determine if there were any significant differences among the treatment means. The LSD (Least Significant Difference) test was utilized to compare the means of the treatments at a 5% level of probability. The statistical analysis was conducted using SPSS Version 10.0, a software package developed by SPSS, Chicago, IL.

RESULTS AND DISCUSSION

Plant height: The data regarding plant height, an important growth parameter that directly affects the productivity of plants, in terms of biological and grain yield. The measurements of plant height (Table 1) for different wheat varieties were taken at various stages of crop growth, namely 30, 60, 90, 120 DAS (days after sowing), and at the harvest stage. Until 30 days after sowing, there was no significant difference observed in the height of wheat plants. However, significant variations in plant height were recorded during the 60, 90, 120 DAS stages, as well as at the harvest stage, among different varieties. The tallest plants were found in the DBW-187 variety, with a recorded height of 85.70 cm, followed by K-1006 at 82.72 cm. On the other hand, the shortest plants were observed in the K-607 variety, with a height of 81.10 cm. Among the plant growth promoters applied in the field, the mixture of micronutrients (Zn, Fe, B, Cu) at a concentration of 0.5% resulted in the maximum plant height of 86.42 cm. In contrast, the control plot, where no growth promoter was used, yielded the minimum plant height of 80.42 cm. The interaction between the varieties and plant growth promoters was found to be non-significant. However, significant variations in plant height were observed concerning the different varieties and plant growth promoters. Similar findings were also reported by (Al-Taee *et al.* 2020 and Zain *et al.* 2015).

Number of tillers: The data presented in Table 1 represents the number of tillers per square meter recorded at 45, 75, 90, 105 days after sowing (DAS), and at the harvest stage. The influence of plant growth promoters on the performance of different varieties, in terms of the number of tillers, reveals that tiller count increased until 90 DAS regardless of treatments. However, the number of tillers decreased at 105 DAS and at the maturity stage of the crop due to the conversion of tillers into yield-contributing characteristics, specifically effective tillers, which ultimately contribute to the grain yield of wheat. Significant variations in the number of tillers were observed among wheat varieties at different stages of crop growth. The highest number of tillers was recorded at 90 DAS (451.75 m^{-2}) in the DBW-187 variety, while the lowest number of tillers (428.65 m^{-2}) at 90 DAS was observed in the K-607 variety. Regarding plant growth promoters (PGPs), the application of a mixture of micronutrients (Zn, Fe, B, and Cu) resulted in the highest number of tillers (459.63 m^{-2}) at 90 DAS, followed by gibberellic acid (453.87 m^{-2}). Seaweed extract (granules) at a rate of 25 kg per hectare was comparable to Seaweed extract (liquid). Nitrobenzene at a concentration of 3ml per liter (427.45 m^{-2}) at 90 DAS showed a significant difference, while the control plot exhibited the lowest number of tillers (411.33 m^{-2}) at 90 DAS. Therefore, the interaction effect between varieties and plant growth promoters showed no significant impact on the number of tillers per plant. Similar findings were also reported by (Deepana *et al.* 2021, Gomaa *et al.* 2015 and Zain *et al.* 2015).

Table 1. Effect of organic and tnorganic plant growth promoters on growth attributes of wheat varieties.

Treatments	Plant height (cm) at 120 DAS	Number of tillers m^2 at 90 DAS	Fresh weight of plant (g plant^{-1}) 30 DAS	60 DAS	90 DAS	120 DAS	Harvesting
Varieties							
DBW-187	85.50	451.75	9.54	76.66	86.83	56.66	26.34
K-1006	82.55	440.70	9.60	75.07	85.07	55.07	25.07
K607	81.78	428.65	9.58	72.89	82.89	52.89	22.89
SE (d) ±	1.018	5.182	0.113	0.694	0.694	0.141	0.166
CD (p=0.05)	2.903	14.772	NS	1.977	1.978	0.100	0.475
Plant growth promoters							
Control	80.29	411.33	9.49	71.66	81.89	51.89	21.22
Nitrobenzene @ 3 ml/l	81.67	427.45	9.55	75.51	84.51	54.51	24.51
Gibberellic acid @ 2000 ppm	84.70	453.87	9.68	75.44	85.44	55.44	25.44
Seaweed extract (solid) @ 25kg/ha	82.76	441.24	9.48	74.87	84.87	54.87	24.87
Seaweed extract (liquid) @ 625ml/ha	84.03	448.35	9.68	75.46	85.79	55.46	25.46
Micronutrient (Zn, Fe, Cu, B) @ 0.5%	86.21	459.63	9.66	76.96	86.96	56.96	26.96
SE(d)±	1.114	4.682	0.094	0.802	1.124	0.688	0.365
CD (p=0.05)	2.286	9.609	NS	1.646	2.308	1.413	0.626
Interaction V×G							
SE(d)±	2.035	9.037	0.186	1.445	1.909	1.098	0.510
CD (p=0.05)	NS	NS	NS	NS	NS	NS	1.090
G×V							
SE (d) ±	1.930	8.110	0.162	1.389	1.948	1.192	0.528
CD (p=0.05)	NS	NS	NS	NS	NS	NS	1.129

Fresh weight of plant: The data for fresh weight (Table 1) of wheat varieties at 30, 60, 90, 120 DAS and at the harvesting stage. At 30 DAS, there was no significant difference in the fresh weight of plants. However, it was observed that the fresh weight increased until 90 DAS and then decreased at 120 DAS and the harvesting stage due to moisture loss and movement of stored food materials from source to sink. The wheat variety DBW-187 exhibited the highest fresh weight per plant (86.83g, 56.66g, and 26.38g) at 90 DAS, 120 DAS, and the harvesting stage, respectively, followed by K-1006 (85.70g, 55.07g, and 25.07g) at the same stages. The variety K-6067 recorded the lowest fresh weight per plant (82.89g, 52.89g, and 22.89g) at 90 DAS, 120 DAS, and the harvesting stage, respectively. Among the plant growth promoters, the application of a mixture of micronutrients (Zn, Fe, B, Cu) at a concentration of 0.5% resulted in the highest fresh weight at 90 DAS (86.96g), 120 DAS (56.96g), and the harvesting stage (26.96g). Seaweed extracts (liquid), seaweed extract (granules), and gibberellic acid showed comparable results. The control plot had the lowest fresh weight (81.96, 51.89 and 21.22g) at 90 DAS, 120 DAS, and the harvesting stage, respectively. The interaction effect between varieties and plant growth promoters was non-significant until 120 DAS, but significant at the harvesting stage. Similar findings were also reported by (Altındal *et al.* 2019).

Dry weight of plant: The yield of crop depends on the dry matter production per unit area; therefore the first prerequisite for high yield is related to higher production of total dry matter of plant. The data pertaining to dry matter of wheat varieties were recorded at 30, 60, 90, 120 DAS and harvesting stage are presented in Table 2. The dry weight of plant recorded at 30 DAS found non-significant difference. It is also observed that the dry weight of plant increased up to harvesting stage and maximum at harvest. The dry weight (g plant^{-1}) of different varieties DBW-187 recorded maximum dry weight of plant (8.64 g, 15.42 g, 21.26 g and 23.37 g at 60, 90, 120 DAS and harvesting stage, respectively) followed by K-1006 (8.11 g, 14.48 g, 20.14 g and 21.50 g at 60, 90, 120 DAS and harvesting stage, respectively) while K-607 recorded minimum dry weight of plant (7.98 g, 14.07 g, 20.07 g and 20.02 g at 60, 90, 120 DAS and

Table 2. Effect of organic and inorganic plant growth promoters on dry weight of wheat varieties.

Treatments	Dry Weight of plant (g $plant^{-1}$)				
	30 DAS	60 DAS	90 DAS	120 DAS	Harvesting
Varieties					
DBW-187	2.113	8.64	15.42	21.26	23.37
K-1006	2.113	8.11	14.48	20.14	21.50
K607	2.129	7.98	14.04	20.07	20.02
SE (d)±	0.029	0.040	0.176	0.125	0.136
CD (p=0.05)	NS	0.115	0.502	0.357	0.388
Plant growth promoters					
Control	1.91	7.44	13.26	19.15	19.41
Nitrobenzene @ 3 ml/l	1.96	7.77	13.83	19.76	20.73
Gibberellic acid @ 2000 ppm	2.25	8.70	15.63	21.30	22.57
Seaweed extract (solid) @ 25kg/ha	2.04	7.95	14.26	20.06	21.20
Seaweed extract (liquid) @ 625ml/ha	2.24	8.09	15.02	20.48	21.96
Micronutrient(Zn, Fe, Cu, B) @ 0.5%	2.29	9.50	15.88	22.19	23.92
SE(d)±	0.023	0.098	0.127	0.234	0.243
CD (p=0.05)	NS	0.518	0.261	0.481	0.500
Interaction V×G					
SE(d)±	0.046	0.160	0.268	0.391	0.408
CD (p=0.05)	NS	0.336	0.642	NS	0.874
G×V					
SE(d)±	0.039	0.169	0.221	0406	0.422
CD (p=0.05)	NS	0.356	0.529	NS	0.903

harvesting stage, respectively). Among plant growth promoters, the mixture of micronutrients (Zn, Fe, B, Cu) @ 0.5% recorded maximum dry weight of plant (9.5, 15.88, 22.19 and 23.92 g at 60, 90, 120 DAS and harvesting stage, respectively) followed by seaweed extract liquid and seaweed extract granules and gibberellic acid found significant at par result while minimum dry weight of plant (7.44g, 13.26g, 19.15g and 19.41g at 60, 90, 120 DAS and harvesting stage, respectively) under control plot. The interaction effect of varieties and plant growth promoters were found non-significant up to 30 DAS and at 60, 90 DAS and harvesting stage found significant. Similar findings were also reported by Deepana *et al.* (2021), Altındal *et al.* (2019) Gomaa *et al.* (2015), Manasa and Devaranavadagi (2015).

Crop growth rate: The data pertaining to Crop growth rate of wheat varieties was recorded at 30 to 60, 60 to 90, 90 to 120 and 120 DAS to harvesting stage is presented in Table 3. The crop growth rate of plant shows significant difference up to harvesting stage. It is also observed that crop growth rate increased up to harvesting stage and maximum crop growth recorded at 60 to 90 DAS followed by 30 to 60 DAS and 90 to 120 DAS while minimum at 120 DAS to harvesting stage. The wheat variety, DBW-187 (0.202, 0.226, 0.186 and 0.099 g m^{-2} day^{-1} at 30 to 60, 60 to 90, 90 to120 DAS and 120 DAS to harvesting stage, respectively) recorded maximum crop growth rate of plant followed by K-1006 while K-607(0.198, 0.202, 0.210 and 0.028 g m^{-2} day^{-1} at 30 to 60, 60 to 90, 90 to 120 and 120 to harvesting stage respectively) recorded minimum fresh weight of plant. Among plant growth promoters, the mixture of micronutrients (Zn, Fe, B, Cu) @ 0.5% recorded maximum crop growth rate (0.240, 0.212, 0.188 and 0.095 g m^{-2} day^{-1} at 30 to 60, 60 to 90, 90 to 120 and 120 to harvesting stage, respectively) followed by Seaweed extract liquid, Seaweed extract granules and gibberellic acid found significant at par result while nutrient crop growth rate (0.184, 0.194, 0.96 and 0.035 g m^{-2} day^{-1} at 30 to 60, 60 to 90, 90 to 120 and 120 to harvesting respectively) under control plant. Hence, the interaction effect of varieties and plant growth promoters was found significant in all stage of crop. Similar findings were also reported by Manasa and Devaranavadagi (2015), Amanullah *et al.* (2021).

Table 3. Effect of organic and inorganic plant growth promoters on CGR, test weight and grain yield of wheat varieties.

Treatments	CGR (g $plant^{-1}$ day^{-1}) 30 to 60 DAS	60 to 90 DAS	90 to 120 DAS	120 DAS to harvesting	Test weight (g)	Grain yield (kg ha^{-1})
Varieties						
DBW-187	0.202	0.226	0.186	0.099	40.67	4764.67
K-1006	0.200	0.212	0.189	0.068	39.66	4402.33
K607	0.198	0.202	0.210	0.028	39.28	4298.83
SE (d)±	0.002	0.002	0.001	0.0005	0.266	41.554
CD (p=0.05)	0.004	0.004	0.004	0.001	0.758	118.461
Plant growth promoters						
Control	0.184	0.194	0.196	0.035	38.16	4143.00
Nitrobenzene @ 3 ml/l	0.193	0.202	0.202	0.055	39.03	4325.33
Gibberellic acid @ 2000 ppm	0.184	0.230	0.189	0.065	40.90	4650.33
Seaweed extract (solid) @ 25 kg/ha	0.197	0.210	0.193	0.062	39.28	4444.33
Seaweed extract (liquid) @ 625 ml/ha	0.195	0.231	0.182	0.078	40.03	4539.00
Micronutrient (Zn, Fe, Cu, B)@ 0.5%	0.240	0.212	0.188	0.095	41.87	4813.67
SE(d)±	0.002	0.003	0.003	0.001	0.487	55.579
CD (p=0.05)	0.005	0.005	0.006	0.002	0.999	114.056
Interaction V×G						
SE(d)±	0.004	0.004	0.006	0.001	0.814	97.207
CD (p=0.05)	0.009	0.009	0.010	0.003	NS	NS
G×V						
SE (d) ±	0.004	0.004	0.005	0.002	0.843	96.265
CD (p=0.05)	0.009	0.009	0.010	0.003	NS	NS

Test weight: The data on 1000 grain weight (Table 3), which was significantly influenced by different varieties and plant growth promoters. The variety DBW-187 exhibited the highest test weight (40.67g), followed by K-1006 (39.66g), while the lowest test weight (39.28g) was observed in variety K-607. The superior yield attributes of DBW-187 can be attributed to its better growth characteristics compared to other varieties. Among the plant growth promoters, significant increases in test weight were recorded. The maximum test weight (41.87g) was observed with the application of micronutrients (Zn, Fe, B, Cu) at a concentration of 0.5%, followed by gibberellic acid (40.90g), Seaweed extract (liquid) (40.03g), Seaweed extract (granules) (39.28g), and nitrobenzene (39.03g). The control treatment resulted in the lowest test weight (39.16g). The application of multi-micronutrients mixture (Fe, Zn, B, and Cu) led to an increase in test weight. Although micronutrients are required in small quantities, their supplementation during crop growth enhances the utilization of other nutrients, resulting in improved wheat crop growth. The use of Seaweed extracts promotes yield attributes by providing essential plant hormones and nutrients. The interaction effect between varieties and plant growth promoters was found to be non-significant regarding test weight (g). The similar findings were also reported by Mishra *et al.* (2021, Navya *et al.* (2021), Wankhade *et al.* (2020), Deepana *et al.* (2021), Rathinapriya *et al.* (2020), Al-Taee *et al.* (2020) and Zain *et al.* (2015).

Grain yield: The grain yield performance of wheat varieties, namely DBW-187, K-1006, and K-607, showed significant results (Table 3). DBW-187 demonstrated a substantial increase in grain yield, reaching 4764.67 kg ha^{-1} (10.83%) compared to variety K-607, while K-1006 exhibited a yield increment of 4402.33 kg ha^{-1} (2.41%) compared to K-607. The superior performance of DBW-187 in terms of grain yield can be attributed to its better growth and yield attributes. Among the plant growth promoters, the application of a micronutrient mixture (Zn, Fe, B, Cu) at a concentration of 0.5% resulted in a significant increase in grain yield, reaching 4813.63 kg ha^{-1} (16.17%) compared to the control treatment. Gibberellic acid also showed promising results, with a grain yield increment of 4650.33 kg ha^{-1} (12.24%) compared to the control. Grain yield represents the culmination of physiological and metabolic activities in plants and is influenced by various factors. Seaweed extracts are known to enhance the source-sink relationship, facilitate the translocation of photosynthesis, and improve the photosynthetic ability of plants. These factors play a significant role in achieving high productivity levels and higher grain yields. Similar findings were also reported by (Navya *et al.* (2021), Chowdhury *et al.* (2018), Zain *et al.* (2015).

CONCLUSION

The result of the current investigation shows that the variety of wheat DBW-187 recorded better, growth and grain yield (4764.67 kg ha^{-1}) under timely sown (29th Nov 2021) compared to other varieties K-1006 and K-607. Among plant growth promoters, the mixture of micronutrients (Zn, Fe, B, and Cu) recorded maximum growth attributes, grain yield (4839.00 kg ha^{-1}) compared to control treatment. The interaction effect of varieties and plant growth promoters found non-significant. On the basis of observed results, farmers were instructed to grow the wheat variety DBW-187 with foliar applications micronutrients (Zn, Fe, Cu, B) @ 0.5% at tillering stage for greater growth and yield.

ACKNOWLEDGMENT

I feel golden opportunity with great pleasure in acknowledging my profound sense of veneration and gratitude to my major advisor and Chairman. The authors are thankful to the department of agronomy for providing the required research facilities I gratefully express my deep sense gratifies to my respected senior, at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, (UP) India for his keen interest, valuable guidance, and constructive criticism throughout the pursuit of the present research paper and vital suggestion during preparation of this manuscript.

REFERENCES

Al-Taee RA, Al-Juthry HW, Al-Badrani WAA (2020) Effect of inoculation of mycorrhizae, sprayed of nanoseaweeds extract and nano specific fertilizer on growth and yield of wheat. Plant cell biotechnology and molecular biology, pp 35-43.

Altaf A, Zhu X, Zhu M, Quan M, Irshad S, Xu D, Zada A (2021) Effects of environmental stresses (heat, salt, waterlogging) on grain yield and associated traits of wheat under application of sulfur-coated urea. *Agronomy* 11(11):2340.

Altındal D (2019) Effect of seaweed extract (se) on seed germination characteristics of wheat in salty conditions. *Int J Agric For Life Sci* 3 (1): 115-120.

Amanullah, Ilyas M, Nabi H, Khalid S, Ahmad M, Muhammad A, Parmar B (2021) Integrated foliar nutrients application improves wheat (*Triticum aestivum* L.) productivity under calcareous soils in drylands. Commun *Soil Sci Pl Anal* 52(21): 2748-2766.

Anonymous (2021) Crop Production Summary 2021. USDA: United State Department of Agriculture.

Aziz MZ, Yaseen M, Abbas T, Naveed M, Mustafa A, Hamid Y, Xu MG (2019) Foliar application of micronutrients enhances crop stand, yield and the biofortification essential for human health of different wheat cultivars. *J Integrative Agric* 18(6): 1369-1378.

Chowdhury B, Howlader MHK, Hossain MK, Sikder MC, Hasan MM (2018) Effect of nitrobenzene on growth and yield of boro rice. *Prog Agric* 29(4): 304-312.

Deepana P, Bama, KS, Santhy P, Devi TS (2021) Effect of seaweed extract on rice (*Oryza sativa* var. ADT53) productivity and soil fertility in Cauvery delta zone of Tamil Nadu, India. *J Appl Natural Sci* 13(3):1111-1120.

Dhaliwal SS, Sharma V, Shukla AK (2022) Impact of micronutrients in mitigation of abiotic stresses in soils and plants—A progressive step toward crop security and nutritional quality. *Adv Agron* 173:1-78. https://doi.org/10.1016/bs.agron.2022.02.001

El-Desouky HS, Zewail RM, Selim DAFH, Baakdah MM, Johari DM, Elhakem A, Yousry MY (2022) Bio-growth stimulants impact seed yield products and oil composition of Chia. *Agronomy* 12(11):2633.

Gomaa MA, Radwan FI, Kandil EE, El-Zweek SM (2015) Effect of some macro and micronutrients application methods on productivity and quality of wheat (*Triticum aestivum* L.). *Middle East J Agric Res* 4(1): 1-11.

Gomez KA, Gomez AA (1984) Statistical Procedures for Agricultural research (2nd), John Wiley and sons, New York.

Manasa LP, Devaranavadagi SB (2015) Effect of foliar application of micronutrients on growth, yield and nutrient uptake by maize! *Karnataka J Agricult Sci* 28(4): 474-476.

Mishra B, Yadav RK, Singh SP, Singh AK, Singh AK (2021) Effect of foliar application of plant growth regulators on growth and development, biochemical changes and yield of mung bean (*Vigna radiata* L.). *J Pharmacog Phytochem* 10(1): 2789-2794.

Navya PP, Akhila M, Dawson J (2021) Effect of plant growth regulators on growth and yield of *Zaid* mung bean (*Vigna-radiata* L.). *J Pharmacog Phytochem* 10 (2): 1228-1230.

Niharika, Singh NB, Singh A, Khare S, Yadav V, Bano C, Yadav RK (2021) Mitigating strategies of gibberellins in various environmental cues and their crosstalk with other hormonal pathways in plants: A review. *Pl Mol Biol Rep* 39: 34-49.

Panda D, Mondal S, Mishra A (2022) Liquid Bio-fertilizers from Seaweeds: A Critical Review. In: Ranga Rao A, Ravishankar

GA (eds). Sustainable Global Resources of Seaweeds Volume 1. Springer, Cham. https://doi.org/10.1007/978-3-030-91955-9_26

Prajapati SK, Verma VK, Singh G, Singh S, Verma S, Prajapati BK, Kumari P (2022) Effect of organic and inorganic plant growth promoters on yield attribute, yield and economics of wheat (*Triticum aestivum* L.) varieties. *Int J Pl Soil Sci* 34(23): 1798-1807.

Rathinapriya P, Satish L, Pandian S, Rameshkumar R, Bala sangeetha M, Rakkammal K, Ramesh M (2020) Effects of liquid seaweed extracts in improving the agronomic performance of foxtail millet. *J Pl Nutrition* 4319 : 2857-2875.

Sabagh AE, Hossain A, Islam MS, Iqbal MA, Amanet K, Mubeen M, Erman M (2021) Prospective Role of Plant Growth Regulators for Tolerance to Abiotic Stresses. In: Aftab T, Hakeem KR (eds). Plant Growth Regulators. Springer, Cham. https://doi.org/10.1007/978-3-030-61153-8_1

Tandel KV, Joshi NH, Tandel GM, Patel MR, Tandel JT (2016) Seaweed cultivation in India, a new opportunity of revenue generation. *Adv Life Sci* 5(7): 2487-2491.

Umair Hassan M, Aamer M, Umer Chattha M, Haiying T, Shahzad B, Barbanti L, Guoqin H (2020) The critical role of zinc in plants facing the drought stress. *Agriculture* 10(9): 396.

Wankhade RS, Kubde KJ, Sunil K, Deshmukh MR (2020) Effect of bioregulators on growth and yield of chickpea (*Cicer arietinum* L.). *J Pharmacog Phytochem* 9(4): 358-361.

Zain M, Khan I, Qadri RWK, Ashraf U, Hussain S, Minhas S, Bashir M (2015) Foliar application of micronutrients enhances wheat growth, yield and related attributes. *Am J Pl Sci* 6(07): 864.