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Effect of Biostimulants and Irrigation Levels on Productivity of Wheat (*Triticum aestivum* L.)

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Abstract

A field experiment was conducted during *rabi* 2024-25 at the Irrigation and Water Management Farm of the Department of Soil Science, Choudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya (CSKHPKV), Palampur, to study the efficacy of biostimulants under different irrigation regimes with wheat cultivar, HPW-368, following split-plot design. The application of biostimulants and irrigation at critical stages resulted in significantly higher values of yield and yield attributes. The maximum grain yield under the two irrigation regimes was about 3415 kg ha^{-1}, which was greater than rainfed crop with the lowest grain yield of 2742 kg ha^{-1}. Additionally, the application of biostimulant, '*Terra sorb*', gave the higher grain yield of 3222 kg ha^{-1}, which was 15.4% more than the control with no biostimulant. The next best biostimulant was 'Sagrika' with a grain yield of 3200 kg ha-1, followed by 'Zymegold' having grain yield of 3100 kg ha^{-1}.

Keywords: Biostimulants, Irrigation Regimes, Wheat, Yield

Wheat (*Triticum aestivum* L.), belonging to the family Poaceae, attains a prominent position among all the major food crops worldwide. Being a staple diet of nearly 2.5 billion of the world, it provides almost half of all calories in the region of North Africa and West and Central Asia. Globally, wheat is cultivated in an area of about 220 million hectares with a production of 763.06 million tonnes of grain (Ramadas *et al.* 2019). India is one of the principal wheat-producing and consuming countries in the world. India contributes about 24.40% of global wheat production from an area of 31.23 million hectares with a production of 112.92 million tonnes and an average productivity of 3.62 t ha^{-1} (Anonymous 2024). It is the most important and common cereal crop of Himachal Pradesh, sown in an area of 319.476 thousand hectares with total production and productivity of 609.31 thousand tonnes and 1.9 tonnes per hectare, respectively (Anonymous 2022-23). Most of the wheat cultivation in the state is either rainfed or under limited irrigation.

The limited and unpredictable rainfall in the *rabi* season is the major production constraint in wheat. With the recession of monsoon rains and longer dry spells, especially from November to January, the crop is exposed to severe abiotic stress, especially in terms of water availability. Limited water availability, known as water stress, ranks among the most impactful environmental factors hindering plant growth and development (Rashwan *et al.* 2020). Further, climate change is a growing threat to agriculture and ecosystems worldwide (Alshammari *et al.* 2024). Agronomic, physiological, and grain quality changes are caused by water stress in wheat. Under water stress conditions in wheat, agronomic and morphological characteristics generally decrease. For realising the optimal production in any crop besides an adaptable variety and appropriate fertiliser doses, adequate soil moisture availability at critical stages is essential.

In the state, besides the biotic stresses, especially the rusts, the moisture and temperature variability at

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different growth stages are the major abiotic stress. Bringing resilience to abiotic stress through a breeding programme is highly challenging and time-consuming. To enhance crop growth and yield under stressed conditions, the use of biostimulants as an alternative has attracted the attention of researchers around the world.

Biostimulants are the materials other than fertilisers and pesticides that stimulate the nutritional process for nutrient use efficiency, resilience to abiotic stress, quality traits and availability of confined (fixed/ unavailable) nutrients in the soil (Rouphael and Colla 2020). Biostimulants are the natural bio-products derived from plant origin, sea weeds, humic and/ or synthetic substances which contain plant growth regulators like auxins, cytokinins, gibberellin, brassinosteroids (the sixth class of plant hormones, acting as steroid derivatives essential for plant growth and development by promoting cell division and elongation, regulating gene expression, and enhancing tolerance to environmental stresses) and strigolactones (a class of plant hormones derived from carotenoids that regulate a wide range of plant developmental processes, including shoot branching, root architecture, and symbiotic interactions), amino acids and other plant essential components. A plant biostimulant is any microorganism or substance administered to plants with the goal of improving nutritional effectiveness, providing tolerance against various types of abiotic stresses, and/or enhancing crop quality attributes (Jardin 2015). Biostimulants can be broadly classified into seven categories, which are a) humic and fulvic acids, b) seaweed extracts and botanicals, c) chitosan and other biopolymers, d) inorganic compounds, e) beneficial fungi, f) beneficial bacteria and g) protein hydrolysates and other N-containing compounds (Jardin 2015). They all alleviate stress by acting as plant growth regulators, which improve the growth rate by enhancing photosynthetic activity, act as natural fertilisers for improving soil health, improving nutrient uptake and most importantly, improving the plant's overall resilience under abiotic and biotic stress by avoiding yield losses.

There are various biostimulants available in the market, out of which, Terra sorb, Zyme gold complex and Sagrika are commercially available and have been evaluated in some crops in India and abroad. Terra Zorb contains a range of amino acids obtained by enzymatic hydrolysis, thereby enabling their fast incorporation into the plant metabolism. Zyme Gold is an organic manure derived biologically from sea grass, which contains cytokinin, protein complexes, enzymatic amino acids and many other minerals. Sagrika is also an organic bio-stimulant made from red and brown marine algae.

MATERIALS AND METHODS

The experiment was conducted at the Irrigation and Water Management Research Farm of the Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The area lies in 32º 06′ 05′′ N latitude and 76º 33′ 02′′ E longitude at an elevation of 1290 meters above mean sea level in the Kangra district of Himachal Pradesh, India. The twelve treatment combinations were imposed in a split-plot design and were replicated three times. Treatments consisted of three irrigation levels, *viz*., rainfed, one irrigation (Crown Root Irrigation-CRI) and two irrigations (CRI and late tillering) in main plots, and four biostimulants, *viz*, 'Terra sorb', 'Zymegold', 'Sagrika' and control (water spray) in subplots. Weekly meteorological data, *viz*., rainfall (mm), relative humidity (%), maximum and minimum temperature (°C), duration of bright sunshine (hours), were recorded from the Agrometeorological observatory, CSK HPKV, Palampur.

Before starting the experiment, a composite soil sample from 0-15 cm depth was collected at random using a stainless steel auger from the experimental site. The sample was air-dried, ground, passed through a 2mm sieve and subjected to mechanical and chemical analysis. After analysis of the soil sample, the soil of the experimental site was found to be silty clay loam in texture with a pH of 5.48 and an organic carbon content of 0.68 per cent. The soil was rated as low in available nitrogen (225kg ha^{-1}) and available potassium (140.7kg ha-1) and high in available phosphorus (31.3kg ha^{-1}).

The present study was conducted in a split-plot design with twelve treatment combinations. Three irrigation levels, *viz*. rainfed, one irrigation (CRI) and two irrigations (CRI and late tillering) in main plots and four biostimulants, 'Terra sorb', 'Zymegold', 'Sagrika' and control (water spray) in subplots were replicated three times. The dose recommended for

biostimulant spray is 2ml/L of water each for 'Terra sorb' and 'Zymegold', while 2.5ml/L for 'Sagrika' at tillering and heading stage. The experiment consisted of plots with gross and net plot sizes of $9m^2$and $4.8m^2$. Before sowing, a pre-sowing irrigation of 4cm was given uniformly to each plot. For further irrigation, the irrigation requirement was calculated based on the soil moisture deficit method of the active root zone. The irrigation water was applied through a hosepipe system. The seed rate was 100 kg/ha, with row spacing of 22.5cm. The recommended fertilisers were applied at the rate of 120, 60 and 30 kg/ha for nitrogen, phosphorus and potassium to the twice-irrigated wheat crop, while 80,40 and 40 kg/ha were applied to once-irrigated and rainfed crop. The nitrogen, phosphorus and potassium were supplied through urea (46%), Single Super Phosphate (16% P_2O_5) and Muriate of Potash (60% K_2O), respectively. One third of nitrogen and the whole of P_2O_5 and K_2O were applied at the time of sowing. The remaining two-thirds of the nitrogen dose was applied at CRI, and late jointing was divided into equal splits. The basal dose of fertilisers was placed below the seed in the open furrows made by a hand-driven plough. Weed management was carried out using Vesta at the rate of 0.4 kg/ha. The harvesting as well as threshing was carried out manually.

RESULTS AND DISCUSSION

Phenological Studies

Both the development stages of the crop were significantly influenced by irrigation levels. Significantly higher numbers of days were taken to attain 50% flowering under rainfed conditions, and they decreased consistently with the application of irrigation. The earliest flowering was observed when two irrigations were applied, followed by days observed with one irrigation regime. The physiological maturity followed the reverse trend of days taken to flowering. Significantly, a higher number of days were taken to attain physiological maturity when the crop was irrigated twice, followed by days taken with only one irrigation. Wheat raised under rainfed conditions matured significantly earlier compared to irrigated conditions. Significantly higher numbers of days were taken to attain 50% flowering under rainfed conditions, and they decreased consistently with the application of irrigation. The earliest flowering was observed when two irrigations were applied, followed by days observed with one irrigation. It could be because in rainfed plots, limited water availability during the vegetative and early reproductive phase might have caused the mild water stress, which slowed down the tillering and stem elongation, leading to delayed heading. Similar results were obtained by Kumar *et al.* (2015), who reported that water stress at CRI and tillering delayed heading due to slower leaf emergence and spike formation in wheat. Earliest flowering in irrigated plots could be due to the sufficient soil moisture, which supported continuous vegetative growth and early spike initiation, leading to earlier heading.

The effect of biostimulant application on the development stages of wheat revealed that only the days to 50% flowering were significantly influenced, while the maturity of the crop remained unaffected due to different biostimulant treatments. The application of biostimulants advanced the period taken to attain 50% flowering compared to no biostimulant application. However, there was no significant difference in the days taken to attain 50% flowering under all the biostimulants used. The interaction effect of irrigation levels and biostimulants on developmental phases, namely, 50% flowering and physiological maturity, was not significant at all stages of crop growth.

Growth Attributes

Plant height is a crucial growth parameter of wheat. In the present field study, a significant difference between irrigated plots was recorded. Significantly taller plants were recorded in twice-irrigated plots, followed by height under one irrigation, while the shortest plants were observed under rainfed plots, as shown in Table 1. Since near optimum moisture was present during tillering and stem elongation crucial for development, otherwise water stress at these stages is known to limit cell division and expansion of cell components (Kumar *et al.* 2015). The effect of biostimulants on plant height was found to be significant. Biostimulant 'Terra sorb' caused a significant increase in plant height, which was at par with 'Sagrika'. While differences due to 'Zymegold' and 'Sagrika' were found to be non-significant, but significantly higher than the control. Calvo *et al.* (2014) reported that biostimulants promote vegetative growth and root development, thus

increasing the plant height. Also, in the experiment, the biostimulants used were seaweed-based extracts containing metabolites enhanced with vitamins and nutrients, which supplemented the plant growth by supporting cell division and cell elongation.

Dry matter accumulation of the wheat crop was significantly influenced by the different irrigation treatments. It was significantly higher when two irrigations (CRI and late tillering) were applied in wheat, followed by dry matter accumulation with only one irrigation (CRI), while it was lowest under rainfed treatment plots. Irrigation at the critical growth stages of CRI and late tillering applied in the experiment played a crucial role in biomass accumulation since it is known to promote leaf expansion and photosynthetic activity (Zhan-Jiang *et al.* 2010). The limited water availability under rainfed conditions negatively impacted the leaf characters like leaf area, leaf size, number and duration, whereas the irrigation regimes enhanced these traits (Abdelaal *et al.* 2021).

The dry matter accumulation recorded at harvest did not differ significantly under application of different biostimulants, and all resulted in high dry matter production over control because of the stimulation of photosynthesis, increased nutrient uptake, enhanced stimulation of phytohormones and translocation of photosynthates due to the presence of free amino acids in the preparation. Further, the biostimulants like seaweed extract used in the experiment contain growth hormones like auxin, cytokinin, gibberellin, and betaine, which also augment leaf length growth and expansion.

Yield Attributes

All three irrigation levels exhibited significant variation in the number of effective tillers. With an increase in irrigation numbers, the number of tillers also increased significantly. The highest number of tillers was recorded when wheat was irrigated twice (at crown root initiation and flowering stages), followed by the number when one irrigation (at CRI) was applied, while the lowest effective tillers were recorded under a rainfed crop. It can be due to the fact that sufficient water availability under two irrigations has improved the photosynthetic activity, nutrient mobilisation through better root proliferation, as observed in the present experiment, leading to an increased number of tillers. Moreover, tillering in wheat largely depends on carbohydrate supply, hormonal balance and adequate soil moisture. This aligned with the results reported by Moghaddam *et al.* (2012), who found that there was a significant reduction in grain yield and agronomic parameters, including the number of effective tillers per square meter under severe stress conditions.

The effect of biostimulants was also found to be significant on tiller development (Table 1). Different biostimulants, although, did not show any significant variation from one another, but caused a significant increase over the control. However, numerically, higher effective tillers were observed with biostimulant, 'Sagrika', followed by 'Zymegold' and 'Terra sorb'. Favourable response of biostimulants to the number of effective tillers m^{-2} could be due to the efficient utilisation of nutrients applied by foliar spray of biostimulants, which have micronutrients and vitamins as additional supplements. A higher number of spikes per square meter in wheat with the foliar spray of biostimulants was also reported by El-Said and Mahdy (2016).

Application of irrigation caused a significant increase in the number of grains per ear head over the rainfed condition. The highest number of grains per ear head was obtained with the application of two irrigations, followed by grain number with one irrigation, though both were statistically at par but significantly higher than grains per ear head recorded under rainfed conditions. It can be due to the sufficient moisture in the soil profile, which improved the nutrient availability, assimilate translocation and enhanced photosynthetic efficiency, which directly supported spikelet fertility and grain setting as reported by Saini and Westgate (2000).

Application of bio-stimulants also exhibited a significant effect on the number of ear heads (Table 1). 'Terra sorb' treated plots recorded the maximum number of grains per ear head, but it was statistically at par with grains with the application of 'Sagrika'. Similarly difference due to 'Sagrika' and 'Zymegold' was not significant, but recorded significantly higher grains per ear head over the control plots. Resultant of bioactive compounds, amino acids, phytohormones and micronutrients in biostimulants would have led to better photosynthetic efficiency and hence, larger translocation of photosynthates from source to sink, as this conforms with El-Said and Mahdy (2016)

Table 1. Effect of irrigation scheduling and biostimulants on phenology stages, number of effective tillers/m^2, grain yield and straw yield of wheat

Treatment	Phenological Studies		Growth Attributes		Yield Attributes			Yield		Benefit Cost ratio
	days to 50% flowering	Days to physiological maturity	Plant Height (cm) at Physiological Maturity	Dry matter accumulation (g/m^2) at physiological maturity	No. of effective tillers/ m^2	No. of grains/ spike	1000-grain weight (g)	Grain yield (kg/ ha)	Straw yield (kg/ ha)	
Irrigation Levels										
Rainfed	122.33	168.25	82.517	660.92	227.2	31.3	38.10	2742	4228	2.13
One irrigation	116.58	173.67	87.383	728.36	241.9	33.8	40.61	3031	4603	2.43
Two irrigations	114.58	176.25	89.875	827.20	260.1	34.4	41.15	3415	4923	2.64
SEm +	0.39	0.27	0.38	6.84	2.9	0.5	0.13	45.64	72.70	-
CD (P=0.05)	1.57	0.97	1.48	25.57	11.6	2.0	184	285		-
Biostimulants										
Control	119.33	171.67	85.05	707.17	235.2	31.5	38.75	2728	4350	2.31
'Terra sorb'	117.22	173.00	87.97	760.72	247.3	34.5	40.16	3222	4644	2.44
'Zymegold'	117.66	173.44	86.41	747.01	244.7	33.1	40.08	3100	4660	2.37
'Sagrika'	117.11	173.22	86.92	739.80	244.9	34.2	40.07	3200	4683	2.42
SEm +	0.55	0.63	0.37	7.20	1.9	0.3	0.12	32.56	78.45	-
CD (P=0.05)	1.65	NS	1.12	21.56	5.8	1.1	0.38	97	233	-

A perusal of data in Table 1 indicates that an increase in irrigation levels resulted in a consistent and significant increase in the test weight of wheat. It was significantly higher in plots irrigated twice, followed by 1000-grain weight in one irrigation regime, while the lowest weight was recorded under rainfed conditions. It could be possible due to the strategic application of irrigation at critical stages. Further, at lower irrigation levels, the plants develop drought adaptation strategies to shorten their reproductive phase. Similar results were obtained by Jain *et al.* (2018), who reported that when the crop received the maximum irrigation compared to the minimum irrigation treatment, the highest 1000-grain weight was observed.

The biostimulant 'Terra sorb' recorded the highest 1000-grain weight over the control could be due to the stimulation of cytokinin by the use of biostimulant 'Terra sorb', which might have caused the Richmond Lang effect, and thus, leaves continued photosynthesising and subsequent translocation of photosynthates, thus increasing the 1000-grain weight. 'Zymegold' enhances the nutrient availability and photosynthetic efficiency, and 'Sagrika' enhances the assimilate partitioning towards developing grains. These results aligned with the findings of Rathore *et al.* (2009), who have also observed an increase in yield attributes with the use of biostimulants.

Grain Yield

Application of two irrigations (CRI and late tillering) increased the grain yield significantly over one irrigation (CRI), and the crop was raised as rainfed. Similarly, one irrigation also increased the yield significantly over a rainfed crop. The grain yield was lowest when no irrigation was applied. On average, application of two irrigations and one irrigation significantly increased yield by 24.5% and 10.5%, respectively, over the rainfed raised crop. The higher grain yield under supplemental irrigation and biostimulants can be attributed to an increase in root density and weight, resulting in better nutrient uptake, enhanced plant water content and increased photosynthesis, which culminated in higher shoot biomass, more tiller number, grains per ear head and 1000-grain weight as this aligns with the study done by Mishra and Kushwaha (2016).

The biostimulants also induced significant variation in grain yield (Table 1). Biostimulant, 'Terra sorb'

application resulted in higher grain yield, but it was statistically at par with the grain yield recorded with 'Sagrika' application. 'Zymegold' caused a significant increase in yield over the control. On average, per cent increase in grain yield due to Terra sorb, 'Sagrika' and 'Zymegold' over the control was 18.1, 17.3 and 13.6 per cent, respectively. Biostimulants stimulate the growth of the above-ground and sub-surface parts of the plant as well as the uptake of water and nutrients, resulting in higher crop yields (Kocira *et al*. 2018).

Straw Yield

Straw yield also revealed a significant and consistent increase with an increase in the irrigation levels. It was highest when the crop was irrigated twice, followed by straw yield with one irrigation, while the lowest was recorded when no irrigation was applied. There was an increase of 8.8% and 16.4% in straw yield with one and two irrigations, respectively, over control, where no irrigation was applied, and the crop was raised as rainfed. Unlike grain yield, straw yield did not differ significantly among another due to the use of different biostimulants. However, all three biostimulants, namely 'Terra sorb', 'Zymegold' and 'Sagrika', remained at par with each other and recorded significantly higher straw yield over the control. There was an increase of 6.7% to 7.6% in straw yield with the use of biostimulants over the control.

Benefit-Cost Ratio (B: C)

The highest B: C ratio was recorded under two irrigations (2.64), followed by one irrigation (2.43), while the lowest B: C ratio was observed under rainfed (2.13). Among biostimulants, the highest B: C ratio was recorded under 'Terra sorb' (2.29), followed by 'Sagrika' (2.27) and 'Zymegold' (2.22), which were higher than the control (1.96).

CONCLUSION

For higher crop yield, the wheat crop should be irrigated twice at critical stages of CRI and late tillering. Successively, for increasing the productivity and uptake in wheat, the crop should be supplied with biostimulant 'Terra sorb'@ 2 ml/L or 'Sagrika'@ 2.5 ml/L at tillering and heading stage. These combinations also provided high net returns and a B: C ratio.

Conflict of Interest: The Authors declare no competing interests.

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