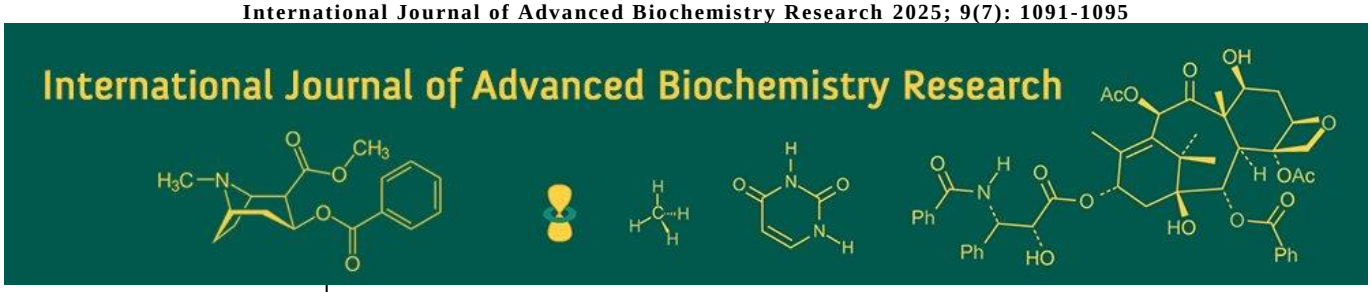

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Studies on effect of biostimulants and biomix on growth and yield of red cabbage (*Brassica oleracea* var. *capitata* f. *rubra*)

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Abstract
A field experiment was conducted during Rabbi season 2024-2025 at experimental field, Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani on "Studies on effect of biostimulants and biomix on growth and yield of red cabbage (*Brassica oleracea* var. *capitata* f. *rubra*)". The application of treatment T_4 i.e. Seaweed Extract 3 ml/L Spray (30,45 & 60 DAT) recorded higher plant growth parameter such as plant height (38.76 cm), stem height (13.21 cm), diameter of stem (14.32 mm), number of outer leaves per plant (19.56), leaf area (220.67 cm^2), days taken for head initiation (37.15), days taken for head maturity (70 days), quantitative parameter such as diameter of head (17.50 cm), length of head (17.23 cm), weight of head (1194.67 g), yield per plot (29.87 kg) and yield per hectare (442.47 q).

Keywords: Red cabbage, biostimulants, biomix, seaweed extract, humic acid, jeevamrut

Introduction
Red cabbage [*Brassica oleracea* var. *capitata* f. *rubra*] is a cool season vegetable belonging to the group of cole crops (Brassicaceae family). This crop has been recognized as modern multitasker's dream food for its numerous benefits that it provide us (Das *et al.* 2014). Red cabbage, the most prominent member of the Brassica genus, is native to the eastern coast of the Mediterranean Sea. Botanically known as *Brassica oleracea* var. *capitata* f. *rubra*, it belongs to the cruciferae or mustard family. Red cabbage flourishes in relatively cool, moist climates. The plant grows to form a head composed of twisted leaves surrounding the terminal buds. A distinctive feature of red cabbage is its deep purplish-red colour, attributed to the anthocyanin pigment which possesses antioxidant and anti-cancer properties. Additionally, red cabbage helps reduce blood cholesterol levels (AL-Ubaidy and AL-Zaidy, 2017) [3].

Red cabbage is a nutrient-dense, visually stunning vegetable with a multitude of culinary applications. This biennial crop grown annually for its vibrant purple-red heads, adds a satisfying crunch and flavour to various dishes including salads, curries and pickled vegetables. Rich in carotenoids, proteins and healthy fats. Red cabbage is an excellent source of essential minerals such as calcium, phosphorus and potassium. Additionally, it contains a range of vitamins including A, B1, B2 and C. The presence of indole-3-carbinol imparts red cabbage with anticancer properties making it a valuable addition to a healthy diet. Notably, consuming red cabbage in its raw form preserves its thermally sensitive vitamins and polyphenolic compounds. Red cabbage is cultivated globally with prominent production regions including India, Northern Europe, America and parts of China. India alone accounts for 388 thousand hectares of cabbage cultivation yielding thousands of tonnes annually (Manasa *et al.* 2017) [12].

In recent times, sourcing safe materials has become a significant challenge particularly in the current pandemic era, where enhancing human immunity and reducing environmental pollution are paramount. Biostimulants which include bio-organic materials and microorganisms offer a valuable solution by promoting nutrient uptake, growth stimulation and stress tolerance ultimately enhancing crop quality. Seaweed extract is extracted from marine brown algae *Aschophyllum nodosum*.

It is nutrient-dense, organic substance that serves as a rich source of amino acids, minerals, and vitamins, while also functioning as a vitamin precursor. The extract from seaweed is renowned as a source of plant growth regulators because it includes large quantities of cytokinin, auxin and gibberellin which might encourage cell division, elongation and differentiation. It also enhances the development of flowers and hence, overall fruit output. As a groundbreaking agri-input, seaweed extracts have captured the attention of both industrial and scientific communities, sparking innovative applications in horticulture (Mohamed *et al.* 2021) [13]. In recent years, the application of humic acid has gained popularity as a means to boost agricultural production. As a cost-effective solution, humic acid is commonly applied directly to the soil or used as a foliar spray for plants. The mode of action of humic acid on plant growth can be categorized into direct and indirect effects. Directly humic acid affects membrane function, leading to improved nutrient transport, enhanced protein synthesis and increased photosynthesis. Additionally, humic acid solubilizes micronutrients, reduces toxic element levels and enhances microbial populations (El-Hak *et al.* 2017) [6].

Jeevamrut serves as a bio-stimulant, enhancing the activity of beneficial microorganisms in the soil and phyllospheric microorganisms when applied as a foliar spray. It acts as a primer for microbial activity increasing the population of native earthworms. Jeevamrut has an acidic nature and is a rich source of primary nutrients including nitrogen (1.97%), phosphorus (0.172%) and potassium (0.29%) as well as micro-nutrients like manganese (47 ppm) and copper (50 ppm). It can be applied through irrigation water or foliar spray. Preparation takes only one day and the shelf life is approximately seven days (Lakshman *et al.* 2024) [10].

Biomix is a well balanced and unique blend of 14 selected species of microbes such as *Aspergillus niger*, *Pseudomonas striata*, *Neumoria relyi*, Gluconacetobactor, *Bacillus subtillis*, PPFM, *Tricoderma harzianum*, *Pseudomonas fluorescens*, *Beauveria bassiana*, *Metarhizium anisopliae*, *Paecilomyces lilacinus*, *Verticillium lecanii* and *Azospirillum brasilence*. In order to solubilizes soil-based minerals like iron, magnesium and residual phosphorus more accessible to plants, it also solubilizes these minerals. It stimulates sprouting and aids in improving the capacity of soil to retain water. It increases crop yields and quality, inhibits insects and plant diseases from spreading. Biomix application aim to enhancing plant tolerance to a wide range of biotic and abiotic stresses.

Application of biostimulants leads to reduction in use of recommended dose of fertilizers which eventually reduce the cost of cultivation for farmers. Gives better quality products with good taste and better storage properties. For ensuring optimum utilization of natural resources for short term benefit and conserving them for future generation. More research and development is needed in this field to achieve sustainable crop production. The effect of biostimulants on plant growth depends on the date and dose of application.

Materials and Methods

The experiment entitled "Studies on effect of biostimulants and biomix on growth, yield and quality of red cabbage (*Brassica oleracea* var. *capitata* f. *rubra*)" was conducted during Rabi season 2024-25 at Instructional-Cum-Research Farm, Department of Horticulture, College of Agriculture, V.N.M.K.V., Parbhani. The experiment was laid out in Randomized Block Design in 13 treatment with 3 replication. The experiment were T_1 i.e. Control (Water spray), T_2 i.e. Seaweed Extract 3 ml/L Spray (30 DAT), T_3 i.e. Seaweed Extract 3 ml/L Spray (30 & 45 DAT), T_4 i.e. Seaweed Extract 3 ml/L Spray (30,45 & 60 DAT), T_5 i.e. Humic Acid 5ml/L Spray (30 DAT), T_6 i.e. Humic Acid 5ml/L Spray (30 & 45 DAT), T_7 i.e. Humic Acid 5ml/L Spray (30,45 & 60 DAT), T_8 i.e. Jeevamrut 3%/L Spray (30 DAT), T_9 i.e. Jeevamrut 3%/L Spray (30 & 45 DAT), T_{10} i.e. Jeevamrut 3%/L Spray (30,45 & 60 DAT), T_{11} i.e. Biomix 1%/L Spray (30 DAT), T_{12} i.e. Biomix 1%/L Spray (30 & 45 DAT), T_{13} i.e. Biomix 1%/L Spray (30,45 & 60 DAT). There were some biostimulants such as seaweed extract, humic acid, jeevamrut and biomix applied as per treatments. Seedlings that were four weeks old were chosen for transplanting. Trasplanting was done in month of November. During land preparation, Farm Yard Manure (FYM) was incorporated into the soil. At the time of transplanting, half the recommended dose of nitrogen through urea was applied along with the full dose of phosphorus through single superphosphate and potassium through muriate of potash. The remaining half dose of nitrogen was applied 30 days after transplanting. The bistimulants spraying was done at particular day intervals as per mentioned in the treatments. Weeding was done manually at 15, 30 and 45 days after transplanting.

Observations were taken with respect to the growth parameters are plant height, stem height, diameter of stem, number of outer leaves per plant, leaf area, minimum days taken for head initiation and minimum days taken for head maturity, quantitative parameters like diameter of head, length of head, weight of head, yield per plot and yield per ha. The statistical analysis was done as per the methods suggested by Panse and Sukhatme (1985) [15].

Results and Discussion

Data on growth parameter such as plant height, stem height, diameter of stem, number of outer leaves per plant, leaf area, days required for head initiation, days required for head maturity, quantitative parameter such as diameter of head, length of head, weight of head, yield per plot and yield per hectare were statistically analysed and the means were presented in tables.

Growth parameter

The first application of biostimulants and biomix was scheduled on 30 days after transplanting, the observations recorded on that date showed nearly similar values. As a result, the plant height at 30 DAT was found to be non-significant. At 60 DAT the treatment T_3 (Seaweed extract 3 ml/L spray 30 & 45 DAT) recorded significantly maximum plant height (34.46 cm), stem height (8.62 cm), diameter of stem (12.02 mm), number of outer leaves per plant (19.56) and leaf area (146.23 cm^2). At harvest, foliar application of T_4 (Seaweed extract 3 ml/spray 30, 45 and 60 DAT) recorded significantly maximum plant height (38.76 cm), stem height (13.21 cm), diameter of stem (14.32 mm), number of outer leaves per plant (19.56) and leaf area (220.67 cm^2) as compared to lowest readings recorded in control T_1. .Minimum days taken for head initiation (37.15) and maturity (70 days) found also in T_4 (Seaweed extract 3 ml/spray 30, 45 and 60 DAT) and maximum days required in control T_1.

The enhancement in shoot characteristics can be attributed to the auxin content in seaweed extracts, which promotes cell division and enlargement, thereby increasing shoot growth, leaf area and plant dry weight. Additionally, the presence of cytokinins in these extracts stimulates physiological activities, boosting total chlorophyll content and photosynthetic activity. This, in turn, positively impacts shoot characteristics. Furthermore, the seaweed extracts' mineral content, including Zn, Cu and B also contribute to enhanced cell division, enlargement and photosynthesis, ultimately leading to improved shoot growth. The macronutrient content in the extracts may also play a role in this process (Sarhan *et al.* 2011) [16]. Early head initiation and maturity in treated plants may be attributed to the accumulation of sufficient glucose and carbohydrate reserves. The application of seaweed extract likely contributes to this process by providing cytokinins and other plant hormones, which enhance the head's ability to act as a strong sink for photoassimilates, ultimately promoting better growth and development (Selvakumari and Venkatesan 2017) [17]. Zodape *et al.* (2008) [21] discovered similar results in okra, Abdel-Mawgoud *et al.* (2010) [1] in watermelon, Sarhan *et al.* (2011) [16] in cucumber, Shehata *et al.* (2011) [18] in celeriac plant, Zodape *et al.* (2011) [20] in tomato, Zewail (2014) [19] in common bean, Mahmoud *et al.* (2019) [11] in red radish plants, Al-Bayati *et al.* (2020) [2] in eggplant, Hasan and Hussein (2020) [8] in cucumber, Ashour *et al.* (2021) [4] in hot pepper, Mohamed *et al.* (2021) [13] in sweet pepper, Elkeleny and Haffez (2023) [7] in broccoli and Selvakumari and Venkatesan (2017) [17] in tomato.

Yield parameters

Application of T_4 (Seaweed extract 3 ml/spray 30, 45 and 60 DAT) was recorded significantly maximum diameter of head (17.50 cm), length of head (17.23 cm) and weight of head (1194.67 g) as compared to control T_1. Brown algae seaweed extracts contain natural regulators such as auxin and cytokinin which enhance cell division and promote cell expansion. Extract are rich in nutrients and stimulate the absorption of minerals like N, P, K, Ca, Mg and Fe those are responsible for biomass accumulation leading to head thickening. Enhanced photosynthesis, increases biomass production result in vertical head growth (Khan *et al.* 2009) [9]. Potassium, a key component of the seaweed extract, plays a vital role in plant development, being absorbed in greater quantities than any other element. As the dominant cation, it regulates various physiological processes including membrane permeability, carbon metabolism, sugar transport and protein synthesis, ultimately leading to enhanced fruit weight (Hasan and Hussein 2020) [8]. The similar results are reported by Abdel-Mawgoud *et al.* (2010) [1] in watermelon, Nour *et al.* (2010) [14] in tomato, Sarhan *et al.* (2011) [16] in cucumber, Zewail (2014) [19] in common bean, Hasan and Hussein (2020) [8] in cucumber and Ashour *et al.* (2021) [4] in hot pepper.

Yield per plot (29.87 kg) and yield per hectare (442.47 q/ha) was recorded maximum in treatment T_4 (Seaweed extract 3 ml/spray 30, 45 and 60 DAT).Minimum yield per plot (17.05 Kg) and yield per hectare (252.45 q/ha) recorded in control T_1. Seaweed fertilizers boost agricultural production by promoting plant growth, enhancing stress tolerance, increasing nutrient uptake, and augmenting antioxidant properties. This is due to the presence of growth-promoting hormones and beneficial compounds (trace elements, vitamins, amino acids and micronutrients). Additionally, seaweed-derived polysaccharides, betaines and antioxidants help strengthen plant defenses against environmental stresses like drought, salinity and extreme temperatures (Khan *et al.* 2009) [9]. These results are consistent with the findings of Zodape *et al.* (2008) [21] in okra, Sarhan *et al.* (2011) [16] in cucumber, Zodape *et al.* (2011) [20] in tomato and Mahmoud *et al.* (2019) [11] in red radish.

Table 1: Effect of biostimulants and biomix on plant height, stem height and diameter of stem of red cabbage

Tr. No.	Treatments	Plant height (cm)			Stem height(cm)			Diameter of stem(cm)		
		30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest
T_1	Control	20.44	26.45	27.85	5.16	6.41	7.12	6.03	8.86	11.57
T_2	Seaweed extract 3 ml/L spray (30 DAT)	23.09	28.74	30.96	5.90	7.37	9.51	6.24	9.42	12.44
T_3	Seaweed extract 3 ml/L spray (30 & 45 DAT)	20.95	34.46	35.36	5.71	8.50	11.57	6.47	12.02	13.12
T_4	Seaweed extract 3 ml/spray (30, 45 and 60 DAT)	21.01	34.21	38.76	5.40	8.62	13.21	6.21	11.93	14.32
T_5	Humic acid 5 ml/L spray (30 DAT)	22.99	27.84	30.22	5.53	7.02	9.14	6.34	9.39	12.37
T_6	Humic acid 5 ml/L spray (30 & 45 DAT)	23.33	32.85	34.22	6.00	7.86	11.38	6.77	11.44	12.93
T_7	Humic acid 5 ml/L spray (30, 45 and 60 DAT)	21.43	33.07	37.67	5.80	8.01	12.56	6.53	11.65	14.03
T_8	Jeevamrut 3%/L spray (30 DAT)	19.38	27.04	29.84	5.10	7.16	8.56	5.95	9.26	12.01
T_9	Jeevamrut 3%/L spray (30 & 45 DAT)	21.73	32.26	33.95	5.98	7.73	10.32	6.62	11.32	12.79
T_{10}	Jeevamrut 3%/L spray (30, 45 and 60 DAT)	20.23	31.74	35.53	5.29	7.69	12.12	6.15	10.97	13.87
T_{11}	Biomix 1% spray/L (30 DAT)	22.22	26.74	28.01	5.10	6.80	7.99	5.89	9.14	11.95
T_{12}	Biomix 1% spray/L (30 & 45 DAT)	20.67	30.79	32.48	5.66	7.46	9.92	6.41	9.81	12.57
T_{13}	Biomix 1% spray/L (30, 45 and 60 DAT)	21.43	31.09	33.87	5.60	7.54	11.74	6.39	10.03	13.36
	SEm±	0.85	1.14	1.22	0.22	0.42	0.52	0.20	0.41	0.52
	CD at 5%	NS	3.36	3.57	NS	1.22	1.52	NS	1.21	1.53

Table 2: Effect of biostimulants and biomix on number of outer leaves per plant and leaf area of red cabbage

Tr. No.	Treatments	No. of outer leaves per plant		Leaf area (cm^2)			Days taken for head initiation	Days taken for head maturity
		30 DAT	60 DAT	30 DAT	60 DAT	At harvest		
T_1	Control	10.23	14.09	69.38	113.78	152.53	42.14	82.15
T_2	Seaweed extract 3 ml/L spray (30 DAT)	10.42	15.11	70.43	126.46	178.53	38.44	79.13
T_3	Seaweed extract 3 ml/L spray (30 & 45 DAT)	10.8	19.23	71.45	146.23	201.56	37.63	76.71
T_4	Seaweed extract 3 ml/spray (30, 45 and 60 DAT)	10.36	19.56	70.04	145.98	220.67	37.15	70.64
T_5	Humic acid 5 ml/L spray (30 DAT)	10.54	14.77	70.59	123.62	172.28	39.58	79.38
T_6	Humic acid 5 ml/L spray (30 & 45 DAT)	11.43	17.15	71.98	140.67	197.72	38.86	77.27
T_7	Humic acid 5 ml/L spray (30, 45 and 60 DAT)	10.91	17.43	71.32	141.21	217.74	39.20	73.99
T_8	Jeevamrut 3%/L spray (30 DAT)	10.11	14.53	69.12	120.34	168.52	39.83	79.33
T_9	Jeevamrut 3%/L spray (30 & 45 DAT)	11.21	16.37	69.55	137.55	192.83	40.57	77.14
T_{10}	Jeevamrut 3%/L spray (30, 45 and 60 DAT)	10.29	16.03	69.82	136.37	212.43	40.10	75.86
T_{11}	Biomix 1% spray/L (30 DAT)	9.96	14.24	68.78	116.84	161.84	41.84	80.13
T_{12}	Biomix 1% spray/L (30 & 45 DAT)	10.72	15.34	71.21	130.43	187.95	41.60	77.47
T_{13}	Biomix 1% spray/L (30, 45 and 60 DAT)	10.69	15.76	70.81	132.11	209.37	41.28	76.02
	SEm±	0.33	0.69	1.69	4.86	6.34	0.13	0.68
	CD at 5%	NS	2.02	NS	14.24	18.58	0.38	2.00

Table 3: Effect of biostimulants and biomix on number of diameter of head, length of head, weight of head. yield per plot and yield per hectare of red cabbage

Tr. No.	Treatments	Diameter of head	Length of head	Weight of head	Yield per plot	Yield per hectare
T_1	Control	10.96	10.27	682.00	17.05	252.45
T_2	Seaweed extract 3 ml/L spray (30 DAT)	14.00	12.97	874.00	21.85	323.70
T_3	Seaweed extract 3 ml/L spray (30 & 45 DAT)	14.67	14.43	987.00	24.68	365.56
T_4	Seaweed extract 3 ml/spray (30, 45 and 60 DAT)	17.50	17.23	1194.67	29.87	442.47
T_5	Humic acid 5 ml/L spray (30 DAT)	14.07	12.93	863.33	21.58	319.75
T_6	Humic acid 5 ml/L spray (30 & 45 DAT)	14.33	14.10	958.67	23.97	355.06
T_7	Humic acid 5 ml/L spray (30, 45 and 60 DAT)	16.40	16.07	1146.33	28.66	424.57
T_8	Jeevamrut 3%/L spray (30 DAT)	13.57	12.40	841.67	21.04	311.73
T_9	Jeevamrut 3%/L spray (30 & 45 DAT)	13.90	13.44	922.00	23.05	341.48
T_{10}	Jeevamrut 3%/L spray (30, 45 and 60 DAT)	15.47	15.28	1073.67	26.84	397.65
T_{11}	Biomix 1% spray/L (30 DAT)	13.23	12.21	822.67	20.57	304.69
T_{12}	Biomix 1% spray/L (30 & 45 DAT)	13.30	13.09	911.67	22.79	337.65
T_{13}	Biomix 1% spray/L (30, 45 and 60 DAT)	15.20	14.97	1031.33	25.78	381.98
	SEm±	0.21	0.20	5.17	0.13	2.05
	CD at 5%	0.61	0.59	15.17	0.38	6.01

Conclusion

This study concludes that treatment T_4 (Seaweed extract 3 ml/spray at 30, 45, and 60 DAT) significantly enhanced growth parameters including plant height, stem height, stem diameter, number of outer leaves per plant, leaf area while also reducing days to head initiation and maturity. Furthermore, T_4 treatment resulted in significantly higher quantitative parameters, such as head diameter of head, length of head, weight of head, yield per plot and yield per hectare. Overall, the application of Seaweed extract 3 ml/spray at 30, 45, and 60 DAT (T_4) outperformed other treatments in improving growth and yield parameters of red cabbage during the rabbi season in the Marathwada region.

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