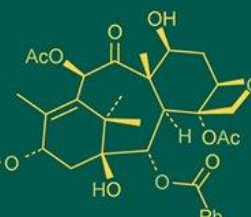
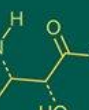
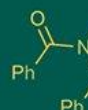


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Effect of bio-fertilisers and bio-stimulants on growth, yield and quality of Turmeric (*Curcuma longa* L.) var. IISR-Pragati under gangetic alluvial zone of West Bengal

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Abstract

A two-year field experiment was conducted during 2021-22 and 2022-23 to evaluate the effects of bio-fertilizers and bio-stimulants on growth, yield, and quality of turmeric (*Curcuma longa* L.) var. IISR-Pragati under the Gangetic Alluvial Zone of West Bengal. Eighteen treatment combinations involving recommended fertilizer levels, *Azotobacter*, Phosphorus-Solubilizing Bacteria (PSB), Potassium-Mobilizing Bacteria (KMB), humic acid, and chitosan were evaluated in a randomized block design. Pooled results showed that treatment S2, comprising 75% RDF + *Azotobacter* + PSB + KMB + humic acid, consistently produced superior growth and yield attributes. It recorded the highest pooled plant height at 90, 120, and 150 days after planting (98.95, 128.47, and 156.24 cm, respectively), along with superior clump and finger characteristics. The highest projected rhizome yield was 30.96 t ha⁻¹ under S2. Quality parameters also improved, with S2 recording 6.16% curcumin, while S6 produced the highest oleoresin content (14.33%). Overall, the study identified S2 as the most promising nutrient-management combination for improving growth, rhizome productivity, and quality of turmeric under the Gangetic plains of West Bengal.

Keywords: Turmeric, bio-fertilizers, bio-stimulants, *Azotobacter*, PSB, KMB, humic acid, rhizome yield, curcumin, IISR-pragati

Introduction

Turmeric (*Curcuma longa* L.; Family: Zingiberaceae), commonly known as “*Haldi*” (in Bengali and Hindi) is an ancient most valuable and sacred spice of India and also known as “Indian Saffron” or “Golden Spice”. Commonly it is known as the “golden spice” because of the golden yellow colour due to presence of curcumin, a primary bioactive compound. Turmeric is mainly regarded as triploid (2n = 63). It is a dried underground rhizome giving rise to primary and secondary rhizomes called fingers. Turmeric accounts for approximately 6% of the total area under spices and condiments cultivation in India and plays a significant role in the Indian economy (Choudhary and Rahi, 2018) [5]. India is the world’s leading producer and exporter of turmeric, contributing over 50% of global trade and meeting nearly 90% of worldwide demand (APEDA, 2018; Olojede *et al.*, 2009) [16].

Bio-fertilizers generally improve the fertility status of soil, provide better crop yield and uptake of plant nutrients. The application of bio-fertilizers in combination with the inorganic fertilizer substitutes the required quantity of the fertilizers.

Azotobacter belongs to the family *Azotobacteraceae*. The first species of the genus *Azotobacter*, named *Azotobacter chroococcum*, was isolated from the soil in Holland in 1901 by Beijerinck.

Phosphorus-Solubilizing Bacteria (PSB) serve as biofertilizers that can convert insoluble inorganic phosphorus into forms accessible to plants. Phosphorus is an essential macronutrient for plant growth and is typically supplied to soils through phosphorus fertilizers, although its natural concentration in soil is only around 0.05%.

KMB biofertilizer, also called potassium-mobilizing bacteria, is a liquid biofertilizer that enhances soil fertility and boosts crop yield. Plant bio-stimulants are the substances and/or

microorganisms, whose function, when applied to plants or the rhizosphere, is to stimulate natural processes to enhance or benefit in nutrient uptake.

Chitosan is a sugar that comes from the outer skeleton of shellfish, including crab, lobster, and shrimp. Chitosan is basically biopolymers substances, used in drug manufacturing.

Humic acid is a group of molecules that bind to, and help plant roots receive, water and nutrients. Humic acid deficiency can prevent farmers and gardeners from growing crops with optimum nutrition.

Review of literature

The important investigations done so far on the related aspects of the present study have been reviewed and represent underneath.

Effect of bio fertilizers on growth, yield and quality of turmeric rhizomes

Datta *et al.* (2017) ^[6] studied effect of organic sources of nutrients and bio-fertilizers on growth, yield and quality of Turmeric (*Curcuma longa* L.) at U.B.K.V., Cooch Behar, West Bengal. The result revealed that application of green leaf manure (from *Glyricidia maculate*) @ 12 tonnes ha⁻¹ along with rock phosphate @ 0.2 tonnes ha⁻¹, wood ash @ 1 tonnes ha⁻¹, *Azospirillum* @ 5 kg ha⁻¹ + PSB @ 5 kg ha⁻¹ gave the significantly highest fresh (29.2 tonnes ha⁻¹) and dry yield (7.81 tonnes ha⁻¹) followed by vermicompost 5 tonnes ha⁻¹ along with *Azospirillum* @ 5 kg ha⁻¹ + PSB @ 5 kg ha⁻¹ which was statistically at par with sole application of 30 t ha⁻¹ farm yard manure. Maximum dry recovery (27.22%) and curcumin content (5.24 %) was recorded in the treatment of sole application of FYM @ 15 tonnes ha⁻¹.

Kanaujia *et al.* (2018) ^[10] conducted a field experiment to evaluate the effect of integrated nutrient management on growth, yield and quality of turmeric under Nagaland conditions. The maximum plant height (83.22 cm), number of leaves plant⁻¹ (10.45), leaf area (905.73 cm²), number of tillers clump⁻¹ (3.22), chlorophyll content (0.97 mg g⁻¹ fresh weight), number of primary fingers clump⁻¹ (8.50), number of secondary fingers clump⁻¹ (19.50), fresh rhizome yield (48.06 t ha⁻¹), cured rhizomes yield (8.22 t ha⁻¹) and curcumin content (6.68%) were recorded in the integrated application of 50% NPK + 50% poultry manure + *Azospirillum*.

Amala *et al.* (2019) ^[2] carried out a field experiment on turmeric *var.* IISR Pragathi with varied combinations of organic, inorganic and bio fertilizers with 7 treatments replicated thrice and in complete RBD at PG Students Research Farm, College of Horticulture, SKLTSHU, during kharif 2018-19. Among the seven treatments combinations application of 75% NPK (Recommended Dose Fertilizer) + Farm yard manure (25 t ha⁻¹) + Vermicompost (5 t ha⁻¹) + Neem cake (500 kg ha⁻¹) + *Azotobacter* (2 kg ha⁻¹) + Phosphorous solubilizing bacteria (2 kg ha⁻¹) (T₆) enhanced the fresh rhizome yield (29.69 t ha⁻¹), curcumin content (4.74%) whereas curing percentage (24%) and benefit cost ratio (4.76) was highest in (T₄): Farm yard manure (25 t ha⁻¹) + Vermicompost (5 t ha⁻¹) + Neem cake (500 kg ha⁻¹) + *Azotobacter* (2 kg ha⁻¹) + Phosphorous solubilizing bacteria (2 kg ha⁻¹).

Ronya *et al.* (2020) ^[18] evaluated an experiment was carried out during 2016-17 to study the effect of organics on growth, yield and quality attributes of turmeric with 7

different organic treatments laid out in RBD. The treatments were T₁: recommended dose of fertilizer, T₂: In-situ incorporation of Dhaincha (*Sesbania aculeata*), T₃: FYM @ 10t ha⁻¹, T₄: Enriched compost ≈ FYM @ 10 t ha⁻¹ in the furrow at planting, T₅: Vermicompost ≈ FYM @ 10t ha⁻¹ + Microbial consortia as slurry for treatment of rhizome at planting, T₆: Microbial consortia as slurry for treatment of rhizome with vermiwash (1:7) + Vermiwash spray (1:7) every month upto seven months of planting, T₇: FYM@ 10 t ha⁻¹ + Microbial consortia as slurry for treatment of rhizome at planting. The experimental results revealed that maximum plant height (167.23 cm), number of leaves per plant (23.46) number of tillers per plant (3.90), leaf area of a single leaf (648.33 cm²), leaf area per plant (15209.82 cm²), leaf area index (12.42) were observed in T₁, they were followed by treatment T₇ and T₄ and the minimum was recorded in T₆. Among the treatments T₇ exhibited best performance in terms of curing percentage (18.09 %) and curcumin content (3.62 %).

Effect of bio stimulants on growth, yield and quality of turmeric rhizomes

Sathiyarayanan and Sathiyabama (2016) ^[19] conducted field experiments in Erode, Tamil Nadu to investigate the effect of foliar application of chitosan (a growth promoter) on growth, yield attributes and curcumin content of turmeric (Erode local). The chitosan (0.1%, w/v) was sprayed at a regular interval of 30 days up to 210 days. Results revealed that the growth parameters (shoot height, leaf number/plant, and plant fresh weight) were increased with application of chitosan. Chitosan treatment to turmeric plants results in high yield and curcumin content.

Manoj (2017) ^[12] carried out a study at the College of Horticulture, Venkataramannagudem, West Godavari district, Andhra Pradesh, during 2016-17. The experiment involved five elicitors-methyl jasmonic acid, salicylic acid, ethephon, chitosan, potassium silicate, and potassium phosphate-applied at different concentrations. These elicitors were sprayed three times, at 120, 150, and 180 days after planting (DAP). The results showed that salicylic acid at 100 ppm produced the highest plant height, number of leaves per plant, leaf length, leaf width, and biomass, followed closely by chitosan at 100 ppm. The maximum curcumin content, however, was recorded with chitosan at 100 ppm.

An experiment was carried out by Thengumpally (2019) ^[22] at College of Agriculture, Vellayani during 2017-2019, to study the effect of chitosan on plant growth, yield and development of *Curcuma aromatic*. The experiment was laid out in CRD with nine treatments and three replications. The treatments consisted of foliar spray of chitosan (0.5 g, 1.0 g, 1.5 g, 2 g, 2.5 g and 3.0 g l⁻¹), acetic acid (0.25 %), water spray and control. The plant growth parameters viz., plant height, number of tillers, number of leaves, leaf area, rhizome thickness, number of fingers, root length etc. Were recorded at 4 and 6 Month after Planting (MAP) and at harvest. The observations on plant metabolites viz., chlorophyll content, total proteins were recorded at 4 and 6 MAP. The chitosan concentration of 2.5 g l⁻¹ gave minimum enhancement in growth, yield and quality parameters followed by chitosan (3 g l⁻¹).

In their experiment, Chitra *et al.* (2020) ^[3] used different organic substances viz., humic acid, panchagavya, vermiwash and neem cake extracts. The study envisaged

that spraying of 3% Panchakavya resulted in higher plant height, number of leaves, number of tillers, leaf length and leaf breadth. The estimated fresh rhizome yield of 21.83 t

ha⁻¹ was recorded from the treatment of 3% Panchagavya and was significantly differed from other treatments.

Materials and Methods

Experiment details

Particulars	Details
Variety	IISR-Pragati
Design of the experiment	Randomised Block Design (RBD)
Number of replications	3
Number of plots	54
Plant population	40 plants
Seed rhizome size	30 g (approximately)
Plot size	3 m ² (3.0 m × 1.0 m)
Season of planting	Kharif
Date of planting	13 April 2021 and 13 April 2022
Spacing	30 cm × 25 cm
Number of treatments	18
Date of harvesting	13 January 2021 and 15 January 2022

Treatment details

S₁ - 100% RDF, S₂ - 75% RDF + *Azotobacter* + PSB + KMB + Humic acid, S₃ - 75% RDF + *Azotobacter* + Humic acid, S₄ - 75% RDF + PSB + Humic acid, S₅ - 75% RDF + KMB + Humic acid, S₆ - 75% RDF + *Azotobacter* + PSB + KMB + Chitosan, S₇ - 75% RDF + *Azotobacter* + Chitosan, S₈ - 75% RDF + PSB + Chitosan, S₉ - 75% RDF + KMB + Chitosan, S₁₀ - 50% RDF + *Azotobacter* + PSB + KMB + Humic acid, S₁₁ - 50% RDF + *Azotobacter* + Humic acid, S₁₂ - 50% RDF + PSB + Humic acid, S₁₃ - 50% RDF + KMB + Humic acid, S₁₄ - 50% RDF + *Azotobacter* + PSB + KMB + Chitosan, S₁₅ - 50% RDF + *Azotobacter* + Chitosan, S₁₆ - 50% RDF + PSB + Chitosan, S₁₇ - 50% RDF + KMB + Chitosan and S₁₈ - Absolute control (without any RDF, Bio-fertilizers and Bio-stimulants) [Note: Recommended Dose of Fertilizer (RDF) @ 120: 60: 100 kg NPK ha⁻¹ (Tripathi *et al.*, 2019) ^[23] and Uniform quantity of FYM @ 10t /ha was applied in all the treatments.]

Bio-fertilizers

1. Nitrogen fixing Bacteria (*Azotobacter* sp.) @ 4 kg/ha

- **Date of manufacturing:** Jan. 2021
- **Date of expiry:** Best before 6 months from the date of manufacturing
- **Source:** AICRP-MSNPEP, *Ad-hoc* Cooperating Centre BCKV, West Bengal.

2. Phosphorus solubilizing bacteria [PSB] (*Pseudomonas putida*) @ 4 kg/ha

- **Date of manufacturing:** Jan. 2021
- **Date of expiry:** Best before 6 month from the date of manufacturing
- **Source:** AICRP-MSNPEP, *Ad-hoc* Cooperating Centre BCKV, West Bengal

3. Potash Mobilizing Bacteria [KMB] (*Frateuria aurantia*) @ 4 kg/ha

- **Date of manufacturing:** Jan. 2021
- **Date of expiry:** Jan 2022
- **Source:** Biosar, Agrocure Pvt. Ltd.

Bio-stimulants

(Applied as foliar spray 60, 90, and 120 DAP)

1. Humic acid @ 0.1% (foliar Spray)

- **Chemical name:** C9H9NO6

- **Date of manufacturing:** March, 2021
- **Date of expiry:** March, 2026
- **Source:** Grow tech Agri. Science Pvt. Ltd.

2. Chitosan @ 0.1% (foliar Spray)

- **Chemical name:** C11H17O7N2
- **Date of manufacturing:** March, 2021
- **Date of expiry:** March, 2026
- **Source:** Sisco Research Laboratories Pvt. Ltd.

Time of application of biostimulants	1st spray at 60 days after planting 2nd spray at 90 days after planting 3rd spray at 120 days after planting
Method of application of biostimulants	Spray

Time of application of biofertilizers	1 st - At the time of planting 2 nd - 60 days after planting
Method of application of biofertilizers	Soil Application

Results and discussion

Title: Effect of bio-fertilizers and bio-stimulants on growth, yield and quality of Turmeric (*Curcuma longa* L.) var. IISR-Pragati.

The results were discussed based on year wise data and pooled analysis.

Growth parameters

Plant growth parameters are various measurable characteristics used to quantify and assess a plant's development and health.

Height of the plant (cm): It was evident from the data presented in Table-1 revealed that, at 90 Days after Planting (DAP), among eighteen treatments the maximum plant height was recorded in plants at treatment S₆ was 102.59 cm followed by S₂ was 101.82 cm plant height recorded in the year 2021-22. The minimum plant height observed in S₁₇ was 66.05 cm (2021-22) followed by S₁₈ was 61.53 cm. In next year (2022-23), the minimum plant height recorded was 66.6 cm. Nair, 1964 ^[14]; Marchner, 1983 ^[13]; Rao and Swami, 1984 ^[17] also reported the favourable effect of N, P, and K in promoting the growth of turmeric plants. The

pooled data at 90 days after planting, among eighteen treatments was varies from 64.07 to 98.95 cm.

At 120 days after planting (DAP), among eighteen treatments the maximum plant height was recorded in treatment S₂ where it was given 127.63 cm followed by S₆ was 125.38 cm and S₃ was 123.92 cm. As per pooled data of plant height was increasing trend from 94.63.68 to 128.46. Among all treatments, the minimum plant height was observed in S₁₈ (93.1 cm) followed by S₁₇ was 102.06 cm and S₁₆ was 104.05 cm. The findings of the present experiment are in conformity with the results of Hrideek *et al.* (2006) [8]. The pooled data at 120 days after planting, among eighteen treatments was varies from 94.63 to 128.46 cm.

At 150 Days after Planting (DAP), in respect among eighteen treatments the maximum plant height was recorded in S₂ (155.43 cm) for 1st year of planting and treatment combination of S₂. In 2nd year, the height of plant was recorded 157.05 cm. The second highest plant height was recorded in S₁ was 149.82 cm (2021-22) followed by S₃ was recorded 146.03 cm in 2021-22. The minimum plant height was recorded in S₁₈ (115.05 cm) in 1st year of planting and in second year plant height recorded was 118.33 cm. Variations in leaf length among different cultivars in turmeric also reported by Hrideek *et al.* (2006) [8]. In an experiment Deshmukh *et al.* (2005) [7] also reported that maximum leaf length was found in waigon and it was 61.05 cm. The findings of the present experiment are in conformity with the results of Singh *et al.* (2013) [21]. The pooled data at 150 days after planting, among eighteen treatments was varies from 116.69 to 156.24 cm.

Yield parameter

Yield parameters are quantitative measures of plant growth and development that influence the amount of harvestable material produced per unit area. Different yield parameters were recorded at harvest, showed variations with different treatment combination.

Length of clump (cm)

Persual of the data from Table-2, the length of clump of pooled data was increased from 13.99 cm to 18.55 cm. The increasing trend in length of clump highest for the treatment S₂ was 18.95 cm (2021-22) and 18.15 cm (2022-23) followed by S₆ and S₃. The increasing trend in length of clump for treatment S₆ was 18.43 cm (2021-22) and 18.25 cm (2022-23). The increasing trend in length of clump for treatment S₃ was 17.58 cm (2021-22) and 17.24 cm (2022-23). The decreasing trend in length of clump for the treatment S₁₈ was 14.65 cm (2021-22) and 13.32 cm (2022-23). The experimental results are in good agreement with findings of Indiresk *et al.* (1990) [9].

Breadth of clump (cm)

The increasing trend for breadth of clump for treatment S₆ was 16.65 cm (2021-22) and 16.72 cm (2022-23). The increasing trend for breadth of clump for treatment S₂ was 16.65 cm (2021-22) and 16.26 cm (2022-23). The increasing trend for breadth of clump for treatment S₇ was 15.46 cm (2021-22) and 15.29 cm (2022-23). The decreasing trend in breadth of clump for the treatment S₁₈ was 12.05 cm (2021-22) and 12.2 cm (2022-23). The decreasing trend in breadth of clump for the treatment S₁₇ was 13.72 cm (2021-22) and 13.56 cm (2022-23). The decreasing trend in breadth of

clump for the treatment S₁ was 12.1 cm (2021-22) and 12.27 cm (2022-23). The pooled data at 90 days after planting, among eighteen treatments was varies from 12.12 cm to 16.45 cm.

Weight of clump (g)

It was evident from Table-2, the increasing trend in weight of clump for the treatment S₂ was 352.15 g (2021-22) and 299.74 g (2022-23). The increasing trend in weight of clump for the treatment S₆ was 331.16 g (2021-22) and 302.74 g (2022-23). The decreasing trend in weight of clump for the treatment S₁₇ was 262.08 g (2021-22) and 232.53 g (2022-23). The decreasing trend in weight of clump for the treatment S₁₈ was 256.3 g (2021-22) and 240.56 g (2022-23).

Weight of primary fingers (g)

According to the two years pooled data presented in Table - 3, the number of primary fingers of pooled data was increased from 122.30 g to 166.29 g. The increasing trend in weight of primary fingers for the treatment S₂ was 183.75 g (2021-22) and 148.83 g (2022-23). The increasing trend in weight of primary fingers for the treatment S₆ was 178.8 g (2021-22) and 144.76 g (2022-23). The decreasing trend in weight of primary fingers for the treatment S₁₇ was 125.32 g (2021-22) and 119.29 g (2022-23). The decreasing trend in weight of primary fingers for the treatment S₁₈ was 125.62 g (2021-22) and 123.08 g (2022-23).

Breadth of primary fingers (cm)

It was evident from the data presented in Table-3, the breadth of primary fingers of pooled data was increased from 1.68 cm to 2.39 cm. Among interaction, increasing trend in breadth of Primary fingers for the treatment S₂ was 2.46 cm (2021-22) and 2.32cm (2022-23). The increasing trend in breadth of Primary fingers for the treatment S₆ was 2.3 cm (2021-22) and 2.36 cm (2022-23). The increasing trend in breadth of Primary fingers for the treatment S₁₀ was 2.28 cm (2021-22) and 2.14 cm (2022-23). Similarly, the decreasing trend in breadth of Primary fingers for the treatment S₁₇ was 1.79 cm (2021-22) and 1.58 cm (2022-23). The decreasing trend in breadth of Primary fingers for the treatment S₁₂ was 1.74 cm (2021-22) and 1.63 cm (2022-23).

Number of secondary fingers

Among most other treatment wise, in case of number of secondary fingers of pooled data showed significant variation in both the years increased from 8.41 to 14.12. Similarly, among all treatments increasing trend in number of secondary fingers for treatment S₂ was 14.61 (2021-22) and 13.64 (2022-23). The increasing trend in number of secondary fingers for the treatment S₁₀ was 13.64 (2021-22) and 13.27 (2022-23). The increasing trend in number of secondary fingers for the treatment S₁₄ was 13.51 (2021-22) and 13.2 (2022-23). Now, if we consider year wise among all treatments decreasing trend in number of secondary fingers for the treatment S₁₈ was 9.46 (2021-22) and 7.36 (2022-23). Again, from Table 4, if we consider the decreasing trend followed in S₁₆ was 11.49 (2021-22) and 10.46 (2022-23). The decreasing trend in S₁₇ was 10.66 (2021-22) and 10.59 (2022-23). It shows better growth in 2021-22 as compared with 2022-23 irrespective of any

treatments. Even data wise the pooled data of both the years showed better and significant result.

Weight of secondary fingers (g)

It was evident from the above data presented in Table 4, in case weight of secondary fingers of pooled data had significant variation in both individual years from 77.37 g to 143.44 g. Similarly, among all treatments increasing trends in weight of secondary fingers for treatment S₂ was 149.51 g (2021-22) and 137.38 g (2022-23). The increasing trend in weight of secondary fingers for the treatment S₆ was 146.92 g (2021-22) and 138.4 g (2022-23). The increasing trend in weight of secondary fingers for the treatment S₁₀ was 136.5 g (2021-22) and 131.39 g (2022-23). Similarly, among all treatments decreasing trend in S₁₈ was 86.79 g (2021-22) and 67.95g (2022-23). The decreasing trend in S₁₇ was 91.38 g (2021-22) and 93.64 g (2022-23). The decreasing trend in S₁₃ was 105.56 g (2021-22) and 94.72 g (2022-23).

Length of secondary fingers (cm)

Among most of the treatment wise from Table 4, in case weight of secondary fingers of pooled data had significant variation from 3.37 cm to 5.15 cm. Similarly, among all treatments increasing trends in weight of secondary fingers for treatment S₂ was 5.36 cm (2021-22) and 4.95 cm (2022-23). The increasing trend in length of secondary fingers for the treatment S₆ was 5.13 cm (2021-22) and 4.73 cm (2022-23). The increasing trend in length of secondary fingers for the treatment S₃ was 3.86 cm (2021-22) and 5.34 cm (2022-23). Similarly, among all treatment decreasing trend in S₁₃ was 3.15 cm (2021-22) and 3.59 cm (2022-23). The decreasing trend in length of secondary fingers for the treatment S₁₂ was 3.27 cm (2021-22) and 3.65 cm (2022-23). The decreasing trend in length of secondary fingers for the treatment S₁ was 3.56 cm (2021-22) and 3.73 cm (2022-23).

Breadth of secondary fingers (cm)

It was depicted from the above data presented in Table -4, in respect of breadth of secondary fingers of pooled data had significant variation in both the individual years from 1.39 cm to 1.76 cm. Similarly, among all treatment increasing trends in breadth of secondary fingers for treatment S₂ was 1.85 cm (2021-22) and 1.67cm (2022-23). The increasing trend in length of secondary fingers for treatment S₃ was 1.65 cm (2021-22) and 1.57 cm (2022-23). Similarly, among all treatment decreasing trend in breadth of secondary fingers for the treatment S₁₈ was 1.46cm (2021-22) and 1.32 cm (2022-23). The decreasing trend in breadth of secondary fingers for the treatment S₁₇ was 1.42 cm (2021-22) and 1.38 cm (2022-23).

Rhizome yield per plot (kg/3m²)

Among above data presented in Table -5, in case rhizome yield per plot (kg/3m²) of pooled data had significant variation in both the individual years from 9.93 kg/3m² to 12.38kg/3m². Similarly, among all treatments in year wise data increasing trends in rhizome yield for treatment S₂ was 13.38kg/3m² (2021-22) and 11.39 kg/3m² (2022-23). The increasing trends in rhizome yield for treatment S₆ was 12.58 kg/3m² (2021-22) and 11.47 kg/3m²(2022-23). The increasing trend in rhizome yield for treatment S₁₀ was 11.97kg/3m²(2021-22) and 11.05 kg/3m²(2022-23).

Similarly, in case of decreasing trend in rhizome yield for treatment S₁₈ was 10.25 kg/3m²(2021-22) and 9.62 kg/3m²(2022-23). The decreasing trend in rhizome yield for treatment S₁₇ was 11.03 (2021-22) and 9.1 (2022-23). The decreasing trend in rhizome yield for treatment S₁₆ was 11.2 kg/3m²(2021-22) and 9.92 kg/3m²(2022-23).

Projected rhizome yield per hectare (t ha⁻¹)

Among most of the treatment wise from Table -5, in case projected rhizome yield per hectare (t ha⁻¹) of pooled data had significant variation from 24.88 to 30.96. Similarly, among all treatments in year wise data increasing trend in projected rhizome yield per hectare for treatment S₂ was 33.45 t ha⁻¹(2021-22) and 28.48 t ha⁻¹ (2022-23). The increasing trend in projected rhizome yield per hectare for treatment S₆ was 31.45 t ha⁻¹(2021-22) and 26.83 t ha⁻¹(2022-23). The increasing trend in projected rhizome yield per hectare for treatment S₃ was 30.68 t ha⁻¹(2021-22) and 26.82 t ha⁻¹(2022-23). The decreasing trend in projected rhizome yield per hectare for treatment S₁₈ was 25.63 t ha⁻¹(2021-22) and 24.13 t ha⁻¹(2022-23). The decreasing trend in projected rhizome yield per hectare for the treatment S₁₇ was 26.95 t ha⁻¹(2021-22) and 23.65 t ha⁻¹(2022-23).

Biochemical and quality parameters (post-harvest stage)

Biochemical and quality parameters refer to characteristics that determine the suitability or desirability of the product.

Curcumin content (%)

Among most of the treatment wise from Table -6, in case of curcumin content of pooled data had significant variation in both the individual years from 3.5 %to 6.07%. Similarly, among all treatments in year wise data increasing trend in curcumin content for the treatment S₆ was 6.24% (2021-22) and 5.90 % (2022-23). The increasing trend in curcumin content for treatment S₂ was 6.20% (2021-22) and 6.13% (2022-23). The increasing trend in curcumin content for the treatment S₃ was 5.7% (2021-22) and 5.53 % (2022-23). Similarly, the decreasing trend in curcumin content for treatment S₁₈ was 3.63 % (2021-22) and 3.37 % (2022-23). The decreasing trend in curcumin content percentage for the treatment S₁ (100% RDF) was 5.03 % (2021-22) and 4.54 % (2022-23).

Essential oil (%)

Among most of treatment wise from Table -6, in case of essential oil percentage had significant variation in both the individual years from 5.11% to 6.45%. Similarly, increasing trend in essential oil content in turmeric *var.* IISR Pragati for the treatment S₂ was 6.7% (2021-22) and 6.2 % (2022-23). The increasing trend in essential oil content for the treatment S₆ was 6.5 % (2021-22) and 6.3 % (2022-23). The decreasing trend in essential oil content for the treatment S₁₈ was 4.86 % (2021-22) and 5.36 % (2022-23). The decreasing trend in essential oil content for the treatment S₁₇ was 5.43 % (2021-22) and 5.6 % (2022-23). Fruit yield of 776.7 kg ha⁻¹ and 611.3 kg ha⁻¹ were observed with salicylic acid 0.1mM and methyl jasmonate 1.0 mM as compared to 439.0 kg ha⁻¹ under control. Important role in plant development and physiological processes, induces or increases the biosynthesis of many secondary metabolites that play important role. (Choi *et al.*, 2005 and Kim *et al.*, 2005)^[4, 11].

Table 1: Effect of bio-fertilizers and bio-stimulants on plant height (cm) of turmeric *var.* IISR-pragati

Treatments	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
	90	days after planting		120 days after planting			150 days after planting		
S1	97.60	85.30	91.45	130.92	123.05	126.97	149.82	141.91	145.86
S2	101.82	96.17	98.95	127.63	129.30	128.47	155.43	157.05	156.24
S3	95.03	88.08	88.08	119.12	117.01	118.07	146.03	139.21	142.62
S4	94.02	86.05	90.03	117.23	114.23	115.73	144.72	138.82	141.77
S5	92.06	85.57	88.82	111.54	109.73	110.64	136.52	131.07	133.80
S6	102.59	85.80	94.20	125.38	126.70	126.04	151.03	145.91	148.47
S7	96.45	75.30	85.88	115.81	116.08	115.95	142.82	139.11	140.96
S8	92.18	69.05	80.62	113.72	115.21	114.46	139.05	135.22	137.14
S9	91.63	67.05	79.34	108.98	114.67	111.82	133.69	133.06	133.38
S10	85.80	82.33	84.07	114.67	120.35	117.51	142.59	143.14	142.87
S11	78.08	79.74	78.91	110.04	113.51	111.77	138.62	137.1	137.86
S12	72.70	78.93	75.82	107.75	112.36	110.05	135.04	134.22	134.63
S13	66.60	77.53	72.07	103.05	110.50	106.77	131.06	132.05	131.56
S14	83.21	82.03	82.62	113.25	119.56	116.41	141.32	142.23	141.78
S15	74.02	78.08	76.05	108.12	113.06	110.59	133.06	136.91	134.99
S16	69.05	76.06	72.56	104.05	112.35	108.20	132.07	133.06	132.57
S17	66.05	74.10	70.07	102.06	106.55	104.31	131.09	128.98	130.04
S18	61.53	66.60	64.07	93.10	96.17	94.635	115.05	118.33	116.69
S.Em. (±)	0.283	0.185	1.694	0.248	0.208	2.991	0.290	0.239	1.988
C.D. (P=0.05)	0.817	0.535	4.974	0.715	0.602	8.783	0.838	0.690	5.838

[N. B : S1 - 100% RDF, S2 - 75% RDF + *Azotobacter* + PSB + KMB+ Humic acid, S3 - 75% RDF + *Azotobacter* + Humic acid, S4 - 75% RDF + PSB+ Humic acid, S5 - 75% RDF + KMB + Humic acid, S6 -75% RDF + *Azotobacter* + PSB + KMB + Chitosan, S7 -75% RDF + *Azotobacter* + Chitosan, S8- 75% RDF + PSB + Chitosan, S9 - 75% RDF + KMB + Chitosan, S10 - 50% RDF + *Azotobacter* + PSB + KMB + Humic acid, S11 - 50% RDF + *Azotobacter* + Humic acid, S12 - 50% RDF + PSB + Humic acid, S13 - 50% RDF + KMB + Humic acid, S14 - 50% RDF + *Azotobacter* + PSB + KMB + Chitosan, S15 -50% RDF + *Azotobacter* + Chitosan, S16 -50% RDF + PSB + Chitosan, S17 -50% RDF + KMB + Chitosan and S18 - Absolute control (without any RDF, Bio-fertilizers and Bio-stimulants)]

Table2: Effect of bio-fertilizers and bio-stimulants on clump characters of turmeric *var.* IISR-pragati

Treatments	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
	Length of clump (cm)			Breadth of clump (cm)			Weight of clump (g)		
S1	15.96	15.36	15.66	12.10	12.27	12.18	384.20	362.56	379.38
S2	18.95	18.15	18.55	16.65	16.67	16.45	458.15	399.75	428.95
S3	17.58	17.24	17.41	15.23	15.45	15.34	398.28	344.64	371.46
S4	17.62	16.92	17.27	15.06	15.12	15.09	373.49	333.51	353.50
S5	16.21	15.57	15.89	14.37	15.29	14.83	330.23	287.62	308.92
S6	18.43	18.25	18.34	16.65	16.72	16.68	430.16	401.74	415.95
S7	17.25	15.83	16.54	15.46	15.29	15.37	415.19	312.39	363.79
S8	16.60	15.68	16.14	14.90	13.56	14.23	355.35	331.22	343.28
S9	15.82	15.92	15.87	13.76	13.94	13.85	324.86	301.17	313.01
S10	17.56	17.08	17.32	15.37	15.13	15.25	396.17	351.55	373.86
S11	16.42	15.69	16.05	14.92	14.06	14.49	356.86	315.17	336.01
S12	15.92	15.32	15.62	14.10	14.58	14.34	335.82	292.34	314.08
S13	14.92	14.86	14.89	14.60	14.72	14.66	297.76	280.38	289.07
S14	15.67	15.47	15.57	15.09	15.28	15.18	392.47	332.92	362.69
S15	15.36	15.92	15.64	13.76	13.94	13.85	345.68	305.32	325.54
S16	14.77	14.58	14.67	13.90	13.83	13.86	327.72	287.39	307.55
S17	14.56	14.97	14.76	13.72	13.56	13.64	312.08	271.26	291.67
S18	17.65	13.32	13.99	12.05	12.20	12.12	295.29	246.55	270.92
S.Em. (±)	0.147	0.148	0.236	0.354	0.144	0.283	0.432	0.312	5.762
C.D. (P=0.05)	0.423	0.428	0.665	0.123	0.415	0.821	1.247	0.901	16.675

[N. B. : S1 - 100% RDF, S2 - 75% RDF + *Azotobacter* + PSB + KMB+ Humic acid, S3 - 75% RDF + *Azotobacter* + Humic acid, S4 - 75% RDF + PSB+ Humic acid, S5 - 75% RDF + KMB + Humic acid, S6 -75% RDF + *Azotobacter* + PSB + KMB + Chitosan, S7 -75% RDF + *Azotobacter* + Chitosan, S8- 75% RDF + PSB + Chitosan, S9 - 75% RDF + KMB + Chitosan, S10 - 50% RDF + *Azotobacter* + PSB + KMB + Humic acid, S11 - 50% RDF + *Azotobacter* + Humic acid, S12 - 50% RDF + PSB + Humic acid, S13 - 50% RDF + KMB + Humic acid, S14 - 50% RDF + *Azotobacter* + PSB + KMB + Chitosan, S15 -50% RDF + *Azotobacter* + Chitosan, S16 -50% RDF + PSB + Chitosan, S17 -50% RDF + KMB + Chitosan and S18 - Absolute control (without any RDF, Bio-fertilizers and Bio-stimulants)]

Table 3: Effect of bio-fertilizers and bio-stimulants on different characters in primary finger of turmeric *var.* IISR-pragati

Treatments	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
	Number			Weight (g)			Length (cm)			Breadth (cm)		
S1	8.67	7.86	8.26	162.60	154.7	158.6	8.62	7.80	8.21	2.11	1.89	2.00
S2	10.45	8.76	9.60	224.75	192.83	208.29	10.42	9.55	9.98	2.46	2.32	2.39
S3	9.86	9.08	9.47	160.41	156.67	158.54	8.94	8.74	8.84	2.20	1.83	2.02
S4	9.61	9.08	9.34	152.07	136.58	144.32	8.60	8.40	8.50	1.86	1.73	1.79
S5	9.20	9.16	9.18	148.57	134.73	141.65	8.06	8.56	8.31	1.62	1.91	1.76
S6	9.17	9.65	9.41	220.80	184.76	202.77	9.71	9.54	9.62	2.30	2.36	2.33
S7	9.08	9.16	9.12	158.26	155.31	156.78	8.46	8.96	8.71	1.86	1.80	1.83
S8	8.26	7.45	7.85	143.56	126.71	135.13	8.42	9.21	8.81	1.90	1.72	1.81
S9	8.10	7.50	7.80	140.41	132.24	136.32	8.24	8.74	8.49	1.65	1.73	1.69
S10	9.57	9.08	9.32	177.23	161.92	169.57	9.48	8.99	9.23	2.28	2.14	2.21
S11	8.47	7.70	8.08	147.52	138.29	142.90	7.56	7.32	7.44	1.68	1.78	1.73
S12	8.33	7.86	8.09	144.33	132.72	138.52	7.61	7.09	7.35	1.74	1.63	1.68
S13	8.21	7.44	7.82	131.03	119.23	125.13	7.47	7.78	7.62	1.86	1.53	1.69
S14	9.16	8.86	9.01	172.67	159.30	165.98	9.13	8.84	8.98	2.11	2.15	2.13
S15	8.61	8.09	8.35	136.78	135.14	135.96	7.70	8.06	7.88	1.88	1.65	1.76
S16	8.50	8.06	8.28	132.72	126.71	129.71	7.65	7.80	7.72	1.84	1.60	1.72
S17	8.32	8.08	8.20	125.32	119.29	122.30	7.52	7.64	7.58	1.79	1.58	1.68
S18	7.93	7.44	7.68	125.62	123.08	124.35	7.52	6.76	7.14	1.74	1.98	1.86
S.E.m. (±)	0.051	0.036	0.336	0.268	0.268	3.350	0.385	0.330	0.285	0.052	0.047	0.038
C.D. (P=0.05)	0.148	0.104	0.955	0.774	0.850	9.838	1.131	0.969	0.836	0.151	0.138	0.111

[N. B. : S1 - 100% RDF, S2 - 75% RDF + Azotobacter + PSB + KMB+ Humic acid, S3 - 75% RDF + Azotobacter + Humic acid, S4 - 75% RDF + PSB+ Humic acid, S5 - 75% RDF + KMB + Humic acid, S6 -75% RDF + Azotobacter + PSB + KMB + Chitosan, S7 -75% RDF + Azotobacter + Chitosan, S8- 75% RDF + PSB + Chitosan, S9 - 75% RDF + KMB + Chitosan, S10 - 50% RDF + Azotobacter + PSB + KMB + Humic acid, S11 - 50% RDF + Azotobacter + Humic acid, S12 - 50% RDF + PSB + Humic acid, S13 - 50% RDF + KMB + Humic acid, S14 - 50% RDF + Azotobacter + PSB + KMB + Chitosan, S15 -50% RDF + Azotobacter + Chitosan, S16 -50% RDF + PSB + Chitosan, S17 -50% RDF + KMB + Chitosan and S18 - Absolute control (without any RDF, Bio-fertilizers and Bio-stimulants)]

Table 4: Effect of bio-fertilizers and bio-stimulants on different characters of secondary finger of turmeric *var.* IISR-pragati

Treatments	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
	Number			Weight (g)			Length (cm)			Breadth (cm)		
S1	11.94	10.68	11.31	129.32	122.19	123.75	3.56	3.73	3.64	1.50	1.38	1.44
S2	14.61	13.64	14.12	149.51	137.38	143.44	5.36	4.95	5.15	1.85	1.67	1.76
S3	13.41	12.75	13.08	142.92	123.67	133.29	3.86	5.34	4.60	1.65	1.57	1.61
S4	13.23	12.88	13.05	140.36	122.37	131.36	3.96	4.32	4.14	1.61	1.49	1.55
S5	13.07	12.38	32.72	138.21	118.35	128.28	3.85	4.62	4.23	1.60	1.48	1.54
S6	14.53	13.47	14.00	146.92	138.40	142.66	5.13	4.73	4.93	1.72	1.48	1.60
S7	13.54	12.56	13.05	141.07	123.67	132.37	3.84	4.53	4.18	1.67	1.46	1.56
S8	12.85	12.95	12.9	139.23	121.29	130.26	3.93	4.29	4.11	1.62	1.24	1.43
S9	12.59	12.73	12.66	137.67	119.93	128.80	3.48	4.53	4.00	1.58	1.30	1.44
S10	13.64	13.27	13.45	136.50	131.39	133.94	3.78	4.92	4.35	1.66	1.56	1.61
S11	12.44	12.85	12.64	124.30	119.30	121.70	3.51	3.82	3.66	1.56	1.40	1.48
S12	12.69	11.58	12.13	115.93	99.70	107.81	3.27	3.65	3.46	1.48	1.40	1.44
S13	13.00	10.92	11.96	105.56	94.72	100.14	3.15	3.59	3.37	1.52	1.32	1.42
S14	13.51	13.20	13.35	135.30	122.34	128.82	4.28	3.96	4.12	1.61	1.48	1.54
S15	12.34	11.25	11.79	124.34	112.63	118.48	3.86	3.78	3.82	1.58	1.42	1.50
S16	11.49	10.46	10.97	112.62	94.58	103.67	3.82	3.77	3.79	1.55	1.35	1.45
S17	10.66	10.59	10.63	91.38	93.64	92.51	3.57	3.97	3.77	1.42	1.38	1.40
S18	9.46	7.36	8.41	86.79	77.95	82.37	3.62	3.91	3.76	1.46	1.32	1.39
S.E.m. (±)	0.071	0.058	0.313	0.247	0.547	2.802	0.025	0.035	0.215	0.023	0.022	0.028
C.D. (P=0.05)	0.206	0.368	1.030	0.712	0.181	8.210	0.073	0.301	0.632	0.068	0.063	NS

[N. B. : S1 - 100% RDF, S2 - 75% RDF + Azotobacter + PSB + KMB+ Humic acid, S3 - 75% RDF + Azotobacter + Humic acid, S4 - 75% RDF + PSB+ Humic acid, S5 - 75% RDF + KMB + Humic acid, S6 -75% RDF + Azotobacter + PSB + KMB + Chitosan, S7 -75% RDF + Azotobacter + Chitosan, S8- 75% RDF + PSB + Chitosan, S9 - 75% RDF + KMB + Chitosan, S10 - 50% RDF + Azotobacter + PSB + Humic acid, S11 - 50% RDF + Azotobacter + Humic acid, S12 - 50% RDF + PSB + Humic acid, S13 - 50% RDF + KMB + Humic acid, S14 - 50% RDF + Azotobacter + PSB + KMB + Chitosan, S15 -50% RDF + Azotobacter + Chitosan, S16 -50% RDF + PSB + Chitosan, S17 -50% RDF + KMB + Chitosan and S18 - Absolute control (without any RDF, Bio-fertilizers and Bio-stimulants)]

Table 5: Effect of bio-fertilizers and bio-stimulants on yield of turmeric var. IISR-pragati

Treatments	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
	Rhizome yield per plot (kg/3m ²)			Projected rhizome yield per hectare (t ha ⁻¹)		
S1	11.32	11.03	11.175	28.23	23.63	25.93
S2	13.38	11.39	12.38	33.45	28.48	30.96
S3	12.44	10.13	11.28	30.68	26.82	28.75
S4	12.27	10.47	11.37	29.95	25.33	27.64
S5	12.10	10.52	11.31	28.10	24.95	26.525
S6	12.58	11.47	12.02	31.45	26.83	29.14
S7	11.98	10.79	11.38	31.10	26.18	28.64
S8	11.75	10.55	11.15	29.55	24.95	27.25
S9	11.56	10.50	11.03	28.93	23.63	26.28
S10	11.97	11.05	11.51	30.68	26.83	28.75
S11	11.52	10.73	11.12	28.30	25.90	27.10
S12	11.20	10.60	10.90	27.63	24.85	26.24
S13	11.02	10.92	10.97	27.58	23.65	25.61
S14	11.57	10.76	11.16	30.98	25.50	28.24
S15	11.34	10.71	11.02	27.85	26.96	27.40
S16	11.20	9.92	10.56	27.21	26.03	26.62
S17	11.03	9.50	10.26	26.95	23.65	25.30
S18	10.25	9.62	9.93	25.63	24.13	24.88
S.E.m. (±)	0.205	0.185	0.238	0.412	0.123	0.715
C.D. (P=0.05)	0.592	0.536	0.662	1.182	0.355	2.107

[N. B. : S1 - 100% RDF, S2 - 75% RDF + *Azotobacter* + PSB + KMB+ Humic acid, S3 - 75% RDF + *Azotobacter* + Humic acid, S4 - 75% RDF + PSB+ Humic acid, S5 - 75% RDF + KMB + Humic acid, S6 -75% RDF + *Azotobacter* + PSB + KMB + Chitosan, S7 -75% RDF + *Azotobacter* + Chitosan, S8- 75% RDF + PSB + Chitosan, S9 - 75% RDF + KMB + Chitosan, S10 - 50% RDF + *Azotobacter* + PSB + KMB + Humic acid, S11 - 50% RDF + *Azotobacter* + Humic acid, S12 - 50% RDF + PSB + Humic acid, S13 - 50% RDF + KMB + Humic acid, S14 - 50% RDF + *Azotobacter* + PSB + KMB + Chitosan, S15 -50% RDF + *Azotobacter* + Chitosan, S16 -50% RDF + PSB + Chitosan, S17 -50% RDF + KMB + Chitosan and S18 - Absolute control (without any RDF, Bio-fertilizers and Bio-stimulants)]

Table 6: Effect of bio-fertilizers and bio-stimulants on quality parameters (dry recovery % and curcumin %) of turmeric var. IISR-pragati

Treatments	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
	Essential Oil (%)			Curcumin (%)		
S1	6.30	6.00	6.15	5.22	5.03	5.12
S2	6.70	6.20	6.45	6.20	6.13	6.16
S3	6.20	5.80	6.00	5.70	5.53	5.61
S4	5.90	6.16	6.03	5.35	5.39	5.37
S5	5.63	6.30	5.96	5.32	5.15	5.23
S6	6.50	6.30	6.40	6.24	5.90	6.07
S7	6.30	6.03	6.16	5.54	5.69	5.61
S8	6.46	5.80	6.13	5.22	5.08	5.15
S9	5.86	5.70	5.78	5.14	5.03	5.08
S10	6.46	5.80	6.13	5.51	5.42	5.46
S11	6.26	5.76	6.01	5.16	5.03	5.09
S12	5.86	5.46	5.66	5.12	4.89	5.00
S13	5.36	5.53	5.44	5.05	4.91	4.98
S14	6.40	5.76	6.08	5.39	5.25	5.32
S15	6.26	5.76	6.01	5.42	5.12	5.27
S16	5.46	5.80	5.63	5.32	5.00	5.16
S17	5.43	5.60	5.51	5.16	4.77	4.96
S18	4.86	5.36	5.11	4.83	4.33	4.58
S.E.m.(±)	0.065	0.048	0.125	0.059	0.052	0.106
C.D. (P=0.05)	0.629	0.14	0.309	0.162	0.139	0.408

[N. B. :S1 - 100% RDF, S2 - 75% RDF + *Azotobacter* + PSB + KMB+ Humic acid, S3 - 75% RDF + *Azotobacter* + Humic acid, S4 - 75% RDF + PSB+ Humic acid, S5 - 75% RDF + KMB + Humic acid, S6 -75% RDF + *Azotobacter* + PSB + KMB + Chitosan, S7 -75% RDF + *Azotobacter* + Chitosan, S8- 75% RDF + PSB + Chitosan, S9 - 75% RDF + KMB + Chitosan, S10 - 50% RDF + *Azotobacter* + PSB + KMB + Humic acid, S11 - 50% RDF + *Azotobacter* + Humic acid, S12 - 50% RDF + PSB + Humic acid, S13 - 50% RDF + KMB + Humic acid, S14 - 50% RDF + *Azotobacter* + PSB + KMB + Chitosan, S15 -50% RDF + *Azotobacter* + Chitosan, S16 -50% RDF + PSB + Chitosan, S17 -50% RDF + KMB + Chitosan and S18 - Absolute control (without any RDF, Bio-fertilizers and Bio-stimulants)]

Conclusion

On the basis of the data pooled over 2 years i.e., 2021-22 and 2022-23 results showed that after 90 days of planting, the maximum plant height (98.95 cm) was recorded in the treatment S2. The same trend was also observed at 120

and 150 days after planting with the highest data of 128.47cm and 156.24 cm respectively. The maximum number of leaves per clump (25.89) and highest number of tillers per clump (4.80) were also recorded in S2 at 150 days after planting. The maximum length of clump (18.55 cm),

breadth of clump (16.45 cm) and weight of clump (428.95 g) were recorded in the same treatment i.e., S₂. Among all treatments, the pooled, data showed that projected rhizome yield per hectare were found the highest (30.96 ton) in the treatment S₂.

The maximum length of clump was recorded in the treatment S₂ with value of 18.95 cm (2021-22) and 18.15 cm (2022-23). Whereas minimum length of clump was recorded in the treatment S₁₈ i. e., 14.65 (2021-22) and 13.32 (2022-23). Regarding breadth of clump the maximum breadth was recorded in the treatment S₆ with value of 16.65 cm (2021-22) and 16.72 cm (2022-23). The lowest breadth of clump was found in S₁₈ i.e., 12.05 (2021-22) and 12.2 (2022-23). The same trend was recorded in case of weight of clump. S₂ recorded the maximum weight with a value of 352.15 (2021-22) and 299.74 (2022-23). The lowest breadth of clump was found for the treatment S₁₈ i. e., 256.3 (2021-22) and 240.56 (2022-23). The data pooled over 2 years showed the same trend in result.

The maximum number of primary fingers was observed in S₂ i. e., 10.45 (2021-22) and 8.76 (2022-23). The lowest number of primary fingers was found in for S₁ with value of 8.67 (2021-22) and 7.86 (2022-23). The highest weight of primary finger was found in the treatment i.e., 183.75 (2021-22) and 148.83 (2022-23). The lowest weight of primary finger was recorded in the treatment S₁₈. Among the treatments the maximum length of primary finger was noticed in treatment S₂ with value of 10.42 (2021-22) and 9.55 (2022-23). The lowest length of primary finger was noticed in the treatment S₁₈ i.e., 7.52 (2021-22) and 6.67 (2022-23).

The same trend was noticed in case of breadth of Primary finger. Maximum breadth was observed in S₂ with value of 2.46 cm (2021-22) and 2.32cm (2022-23). Whereas, minimum breadth of Primary finger was recorded in S₁₃ was 1.86 cm (2021-22) and 1.53cm (2022-23).

Similarly, among all treatments minimum number of secondary finger was observed in the treatment S₁₈ with value of 9.46 (2021-22) and 7.36 (2022-23).Maximum weight of secondary finger was recorded in the treatment S₂ with a value of 149.51 g (2021-22) and 137.38 (2022-23).The lowest was found in S₁₃ i.e., 105.56 (2021-22) and 94.72 (2022-23).Similarly, among all treatments maximum length of secondary finger was found in the treatment S₂ was 5.36 cm (2021-22) and 4.95cm (2022-23).The minimum length of secondary finger was found in the treatment S₁₂ i.e., 3.27 (2021-22) and 3.65 (2022-23).The highest breadth of secondary finger was recorded in treatment S₂ with a value of 1.85 cm (2021-22) and 1.67 cm (2022-23).The lowest breadth of secondary finger was recorded for the treatment S₁₇ with a value of 1.42 (2021-22) and 1.38 (2022-23).

Among all treatments year wise data showed the highest rhizome yield per plot in the treatment S₂ with a value of 13.38kg (2021-22) and 11.39kg (2022-23). The lowest yield of 11.03kg (2021-22) and 9.1kg (2022-23) was recorded in S₁₇. Similarly, among all treatments highest projected rhizome yield per hectare of 33.45ton (2021-22) and 28.48ton (2022-23) was recorded for treatment S₂. The minimum projected rhizome yield per hectare was recorded in treatment S₁₈with a value of 25.63 (2021-22) and 24.13 (2022-23).Regarding quality parameters, the maximum curcumin content (6.16%) was found in the treatment S₂, whereas oleoresin content in the rhizome was recorded

highest (14.33%) in the treatment S₆.On the basis of growth and yield attributing characters, the cultivar IISR- Pragati was found most promising with the combination treatment of S₂ in the Gangetic plains of West Bengal.

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