EFFECT OF HUMIC ACID BASED BIO-STIMULANT ON GROWTH, YIELD AND QUALITY OF *KHARIF* RICE (*Oryza sativa* L.) UNDER LATERITIC SOILS OF KONKAN

THESIS

Submitted in partial fulfilment of the requirements
for the Degree of

MASTER OF SCIENCE
IN
AGRICULTURE
(AGRONOMY)

By
KARENNAVAR SACHIN SURESH
(ADPM/20/2726)

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE, DAPOLI

DR. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI, RATNAGIRI (M.S.) 415712

AUGUST, 2022

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Under the Guidance of
Dr. V. G. CHAVAN
Assistant Professor,
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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled **"EFFECT OF HUMIC ACID BASED BIO-STIMULANT ON GROWTH, YIELD AND QUALITY OF *KHARIF* RICE (*Oryza sativa* L.) UNDER LATERITIC SOILS OF KONKAN"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis/publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged and that no part of the thesis has been submitted for any other degree or diploma.

Place: Dapoli

Date : 28/11 /2022

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CERTIFICATE

This is to certify that the thesis entitled, **"Effect of Humic Acid Based Bio-Stimulant on Growth, Yield and Quality of *Kharif* Rice (*Oryza Sativa* L.) Under Lateritic Soils of Konkan"** submitted for the degree of M. Sc. (Agri.) in Agronomy of the College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, is a bonafide research work carried out by **Mr. Karennavar Sachin Suresh (ADPM/20/2726)** under my supervision and that no part of this thesis has been submitted for any other degree. The student had completed all the Course and Research requirement as per the norms in regular mode and has submitted One research paper from his M.Sc. work.

The assistance and help received during the course of investigation have been fully acknowledged.

Place: Dapoli
Date: 28 / 11 /2022

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Head
Department of Agronomy

THESIS APPROVAL BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER

This is to certify that the thesis entitled, **"Effect Of Humic Acid Based Bio-Stimulant on Growth, Yield And Quality of *Kharif* Rice (*Oryza Sativa* L.) Under Lateritic Soils of Konkan"** submitted by **Mr. Karennavar Sachin Suresh (ADPM/20/2726)** to the College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, in partial fulfillment of the requirements for the degree of M.Sc. (Agronomy) in the subject having Soil Physics as Minor subjects of Department Agril. Chemistry and Soil Science and Department of Agricultural Botany respectively has been approved by Student's Advisory Committee, Board of Studies of the Department and Evaluated by One External Examiner after an open Viva Voce examination in the presence of External Examiner on the same held on dated: **18/11/ 2022**.

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Place: Dapoli

Date: / / 2022 **(Karennavar Sachin Suresh)**

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List of Abbreviations

%	:	per cent
@	:	at the rate of
&	:	and
°C	:	Degree centigrade
₹	:	Rupees
CD (P=0.05)	:	Critical Difference at 5 per cent level
cm	:	Centimeter
DAT	:	Days after transplanting
day^{-1}	:	Per day
$dS\ m^{-1}$	:	Deci siemen per meter
EC	:	Electrical conductivity
et al.	:	and others
Fig.	:	Figure
FYM	:	Farm Yard Manure
g	:	grams
ha^{-1}	:	Per hectare
$hill^{-1}$	:	Per hill
i.e.	:	That is
ICAR	:	Indian Council of Agricultural Research
K	:	Potassium
K_2O	:	Potassium oxide
kg	:	Kilogram
$kg\ ha^{-1}$	:	kg per hectare
L	:	Litre
$l\ ha^{-1}$	:	Litre per hectare
ppm	:	parts per million
m^2	:	Metre square
m^{-2}	:	Per square metre
mm	:	milli metre
M.S.	:	Maharashtra
N	:	Nitrogen
No.	:	Number
P	:	Phosphorous
P_2O_5	:	Phosphorous pentoxide
RH-I	:	Morning relative humidity

RH-II	:	Afternoon relative humidity
S. Em. ±	:	Standard error mean
t ha^{-1}	:	Tonnes per hectare
Tmax.	:	Maximum temperature
Tmean	:	Mean temperature
Tmin.	:	Minimum temperature
viz.,	:	Namely

Glossary

Bio-stimulant: Bio-stimulants are natural or synthetic substances that can be applied to seeds, plants, and soil which cause changes in vital and structural processes in order to influence plant growth through improved tolerance to abiotic stresses and increase seed and/or grain yield and quality.

Cost of cultivation: Cost of cultivation refers to the total expenses incurred in cultivating on one hectare of land.

Humic acid or humic substance (HS): Humic substances (HS) are organic compounds that are important components of humus, the major organic fraction of soil, peat, and coal (and also a constituent of many upland streams, dystrophic lakes, and ocean water).

Konkan: Konkan is the 700 km long rugged section of the western coastline of Arabian Sea which extends from Damon in the North to western side land of Maharashtra and Goa.

Lateritic soils: Soil layer that is rich in iron oxide and derived from a wide variety of rocks weathering under strongly oxidizing and leaching conditions.

Seaweed extracts: Seaweed extracts isolated from seaweed, which contain a wide range of macronutrient and microelement nutrients and organic components such as growth hormones, amino acids, vitamins, betaines, cytokinins, and sterols, have played an important role in the development of the environment-friendly crops planting system. In general, seaweed extracts can induce changes in the physiological/biochemical process in agriculture associated with nutrient uptake and growth of plants. For example, seaweed extracts promoted early seed germination and establishment, boosted root growth, increased leaf chlorophyll, improved crop performance and yield of tomato, and elevated resistance to biotic/abiotic stress.

Tricontanol: Triacontanol is a natural plant growth regulator. It has been widely used to enhance the yield of various crops around the world. Tricontanol has been reported to increase the growth of plants by enhancing the rates of photosynthesis, protein biosynthesis, the transport of nutrients in a plant and enzyme activity, reducing complex carbohydrates among many other purposes.

INTRODUCTION

CHAPTER I

INTRODUCTION

1.1 Background information

Rice (*Oryza sativa* L.) is the world's single most important crop, a primary food source for half of the world's population. A total of 49 per cent calories consumed by the world human population come from rice, wheat, and maize, where 23 per cent are provided by rice, 17 per cent by wheat and 9 per cent by maize. Thus almost 25 per cent of the calories consumed by the entire world human population come from rice. Besides that, rice also plays an important role both in economically and in terms of food security. Rice is cooked by boiling or it can be finely ground into flour. It is eaten alone or else in a great variety of soups, side dishes, and main dishes in Asian, Middle Eastern, and many other countries. The products in which rice is used are breakfast cereals, noodles, and such alcoholic beverages as Japanese sake. The cultivated rice plant is an annual grass can grow to about 1.2 meters (4 feet) in height depending on the type of varieties. The leaves are long and flattened and are borne on hollow stems. The fibrous root system is often broad and spreading. The panicle or inflorescence (flower cluster) is made up of spikelets bearing flowers that produce the fruit, or grain. Varieties differ greatly in the length, shape, and weight of the panicle and the overall productivity of a given plant.

Rice cultivation needs urgent emphasis regarding its revamp in productivity. The concernment of uplifting rice productivity is more prominent under the scenarios of increasing food demand in response to consistent population growth as well as agricultural land shrinkage. Moreover, in the present context of changing climate, unsatisfactory performance of rice crop is a major challenge which needs to be addressed with competent agro-technological interventions. India is the largest producer of rice in terms of area (43.79 million hectare) in the world with production.

India has the largest area of land under rice cultivation in the world. In India the area occupied under rice cultivation is 44 million hectares with production of 102.32 million tonnes and an average productivity of 2550 kg ha^{-1} (Anonymous, 2020[a]).

In Maharashtra area under rice is 1.53 million hectares with production of 3.51 million tonnes with average productivity of 1873 kg ha^{-1}during 2019-2020. The average productivity of the Maharashtra state is low as compared to other rice growing states *viz*., West Bengal, Uttar Pradesh, Punjab, Odisha, Tamil Nadu, Haryana, Andhra Pradesh etc. West Bengal is highest rice producing state in India (Anonymous, 2020[b]).

In Konkan rice is cultivated over an area of 0.39 million hectares with an annual production of about 1.52 million tonnes with average productivity around 2930 kg ha^{-1}. The area, production and average productivity of the Konkan region is more as compared to Western Maharashtra, Marathwada and Vidarbha. The Konkan region comprises five districts *viz*., Palghar, Raigad, Thane, Ratnagiri and Sindhudurg. The area under rice in Raigad districts is 0.11 million hectares with a production of 0.31 million, which is the highest in Konkan region. Sindhudurg has the highest productivity in Konkan region with 3500 kg ha^{-1}. Thane is supposed to be the lowest in area (0.055 million hectare) with production 0.11 million tonnes and productivity 1667 kg ha^{-1} (Anonymous, 2020[b]).

However, in order to cope up with the rapid population growth, the requirement of rice production by 2030 is estimated to be 160 million tonnes (Mishra *et al*., 2013) which is not achievable through relying solely on green revolution based farming methods as it is gradually losing its hope due to excessive and unscientific exploitation of its broods (chemical fertilizers, pesticides, irrigation etc). Yield stagnation, sharp rise of input price, soil health deterioration and environmental footprints (Biswas *et al*., 2019) are some pertinent issues associated with the use of chemical fertilizers and therefore, there is an urgent need for its partial replacement or complete paradigm shift towards modern biotechnological advances.

1.2 Importance and need of the study

Due to growing demand for better yield and quality and quantity of food and crops, seeking eco-friendly and sustainable ways to produce fertilization inputs of natural origins has become a main objective in agriculture (Xu *et al*., 2018). There is a growing interest in using cultivation methods such as natural bio-stimulants because their application activates several physiological processes that enhance nutrient use efficiency, stimulating plant development and allowing the reduction of fertilizers consumption (Bulgari *et al*., 2014) which improves yield without any negative effects on plant quality (Kocira *et al*., 2018). Agricultural bio-stimulants are biological or biologically derived fertilizer additives and similar products that are used in crop production to enhance plant growth, health and productivity (Nori. *et al*., 2016). Bio-stimulants are distinguished from agrochemicals because they only influence the vigour of plants and have neither direct action against pests nor diseases. Bio-stimulants cannot be defined as fertilizers because they do not provide nutrients directly to plants (Drobek *et al*., 2019). Rather, they uniquely facilitate the uptake of existing and applied nutrients, resistance to abiotic stress such as salinity or drought and contribute to sustainable, high-output low-input crop productions. They do not directly control crop pests such as insects, disease or weed competition.

Moreover, they might achieve this by helping to improve nutrient-use efficiency, helping plants tolerate abiotic stresses like heat, cold, drought and too much water, helping to improve quality attributes like nutritional content, appearance, and shelf-life. Natural stimulants often included under the term bio-stimulants encompass a diverse group of product technologies and may include bacterial or microbial inoculants, biochemical materials, amino acids, humic acids, fulvic acids, seaweed extracts, protein hydrolysates and more(Du Jardin., 2015). A final category of bio-stimulants includes those derived from extracts of food waste or industrial waste streams, composts, vermicompost, aquaculture residues and waste streams, and sewage treatments among others (Rehman *et al*., 2018). Bio-stimulant can be used to supplement and enhance existing agricultural practices and crop inputs. They enhance the uptake of nutrients, develop tolerance to abiotic stresses and increase the vigor and yield of crops such as wheat, rice, and barley. This is because these organic compounds are easily assimilated by crops and therefore improve crop nutrition, increasing both the productivity and the quality of the grain or fruit harvested (Tejada *et al*., 2016). These plant bio-stimulants are rich sources of minerals, plant growth hormones, antioxidants and secondary metabolites to affect physiological and biochemical processes, induce stress tolerance, enhance plant growth and optimize productivity.

Bio-stimulants have increasingly been considered as valuable advanced farming techniques used in worldwide agricultural production. They enhance crop health, quality and grower profitability and can effectively contribute to overcome the challenges posed by the increasing demand for food by the world's population in continuous growth. The cost and time required for the development of new formulations may be even less than that required for the development of new bio-stimulants. Current resources are directed toward the development of safer bio-stimulants, for the worker and for the environment, as well as toward more efficient application and formulation technologies.

Recently, bio-stimulant market globally has grown rapidly and, to fulfill crop requirements and to increase productivity, industries and research institutes have effectively incorporated various innovative products and ingredients. Further, demand from farmers and consumers for organic products that provides alternatives to synthetic inputs are also boosting the growth of the market. Increasing agronomic production demands is also expected to boost demand for bio-stimulants across the globe. The global bio-stimulants market is projected to reach $4.14-4.9 billion by 2025 (Anonymous., 2019).

One of the major impacts of Humic Substances (HS) on plant growth is the reinforcement in nutrient uptake and the elongation of the lateral root growth, often recognized as "auxin-like effect," which is a result of the induction of ATPase activity in the plasma membrane (Zandonadi *et al*., 2019).

1.3 Objectives of the study

Keeping these points in the view, the proposed research entitled "Effect of humic acid based bio-stimulant on growth, yield and quality of *kharif*, rice (*Oryza sativa* L.) under lateritic soils of Konkan" is planned at Instructional Farm, Department of Agronomy, College of Agriculture Dapoli, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli during *kharif*, season of 2021 with the following objectives-

1. To study the effect of bio-stimulant on growth, yield and quality of *kharif* rice

2. To study the nutrient uptake by crop and nutrient availability in soil

3. To study the economics of treatments

1.4 Hypothesis or assumptions

The research is conducted on rice crop (*Oryza sativa* L.) of variety Ratnagiri-1. The research was conducted with the assumption i.e. with the optimum use of inputs i.e. application of humic acid based bio-stimulant will have relatively higher crop growth (*viz*., plant height, number of tillers, number of leaves, dry weight) and crop yield (*viz*., grain yield and straw yield) by effective uptake of nutrients by the rice crop. Similarly optimum level of humic acid based bio-stimulant will give better gross returns, net returns and benefit cost ratio.

1.5 Scope and Limitations

Use of bio-stimulants in agriculture has wide scope in India and in any other country as well. Its use in crop production not only improved quality of the produce but also final quantity of the crop.

Major limitations on their use are the technical difficulties to propagate them on a large scale and more fundamentally, the lack of understanding of the determinants of host specificities and population dynamics of mycorrhizal communities and agro-ecosystems (Dalpe *et al*., 2004). Technical challenges include the formulation and blending of bio-stimulants with other fertilizing materials or plant protection materials.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

A brief review of relevant and research work related to the research topic entitled entitled "Effect of humic acid based bio-stimulant on growth, yield and quality of *kharif* rice (*Oryza sativa* L.) under lateritic soils of Konkan" has been done and presented in this chapter. The available literature pertaining to the aspect under the investigation is reviewed under the following headings.

2.1 Effect of bio-stimulant on growth, yield and yield attributing characters and quality of *kharif* rice.

2.2 Effect of bio-stimulant on the nutrient uptake by crop and nutrient availability in soil.

2.3 Effect of bio-stimulant on economics of treatments**.**

2.1 Effect of bio-stimulant on growth, yield and quality of *kharif* rice

2.1.1 Effect of bio-stimulant on growth parameters of *kharif* rice

Kavita *et al*. (2008) carried out field experiment at Central Farm, Agricultural College and Research Institute, Madurai during *rabi* season of 2006-2007 to evaluate effect of foliar spraying of sea weed extract on growth and yield of rice *(Oryza sativa* L.). The experiment consisted of eight treatments *viz*., foliar spraying of 0.3 per cent phytozyme at pre flowering stage (T_1), foliar spraying of 0.3 per cent phytozyme at 50 per cent flowering stage (T_2), foliar spraying of 0.3 per cent phytozyme at milk stage (T_3), foliar spraying of 0.3 per cent phytozyme at dough stage (T_4), foliar spraying of 0.3 per cent phytozyme at 50 per cent flowering stage + milky stage (T_5), foliar spraying of 0.3 per cent phytozyme at 50 per cent flowering stage + dough stage (T_6), water spray (T_7) and Control (no spray) (T_8). They reported that, application of foliar spraying of 0.3 per cent phytozyme at 50 per cent flowering stage + milky stage shown significantly higher number of productive tillers m^{-2} over other treatments.

Shrotri (2013) conducted a field experiment during 2013 at Agricultural University, Gwalior to evaluate the effect of shilajeet and moringa leaf extract as a bio-stimulant on pearl millet (*Pennisetum typhoides* L.) seed germination. The experiment consisted of 4 treatments *viz.*, water spray or control (T_1), shilajeet @ 100 ppm (T_2), moringa leaf juice @ 0.1 per cent (T_3), shilajeet @ 100 ppm + moringa leaf juice @ 0.1 per cent (T_4). He reported that, application of shilajeet @ 100 ppm + moringa leaf juice @ 0.1 per cent has significantly increased seed germination, shoot length and root length followed by application of shilajeet @100 ppm.

Rajpar *et al*. (2011) conducted a field experiment during 2010 at Agricultural Research Institute, Tandojam, Sindh to study effect of humic acid on growth, yield and oil content of *Brassica compestris* L. The field experiment was laid out in a four replicated randomized complete block design and the humic acid was applied before sowing. In total, four humic acid application rates were tested in this experiment, i.e. 0 (control) (T_1), 3.17 kg acre^{-1} (T_2), 6.35 kg acre^{-1} (T_3) and 9.53 kg acre^{-1} (T_4). They reported that, application of humic acid 9.53 kg acre^{-1} (T_4) significantly increased the number of branches per plant over other treatments. They also reported that, application of the same significantly increased the yield of the crop over other treatments.

Augustin *et al*. (2018) conducted a green house research during May to October of 2016 at IRIBB, Indonasia to evaluate the effect of bio-stimulant in root and population of phosphate solubilizing bacteria: a study case in upland rice. The experiment consisted of 18 treatments with 5 replications. The treatments were as follows- Control (T_0), Soil + ERL 0 ppm 2x (T_1), Soil + seaweed extract (ERL) 10 ppm 2x (T_2), Soil + ERL 10 ppm 3x (T_3), Ground + (ERL) 0 ppm 2x (T_4), Soil + ERL 40 ppm 3x (T_5), Soil + organic material + ERL 0 ppm 2x (T_6), Soil + organic material + ERL 0 ppm 3x (T_7), Soil + organic material + ERL 10 ppm 2x (T_8), Ground + organic material + ERL 10 ppm 3x (T_9), Soil + organic material + ERL 40 ppm 2x (T_{10}), Soil + organic material + ERL 40 ppm 3x (T_{11}), Soil + Humic Acid 0 ppm 2x (T_{12}), Soil + Humic Acid + ERL 0 ppm 3x (T_{13}), Soil + Humic Acid + ERL 10 ppm 2x (T_{14}), Soil + Humic Acid + ERL 10 ppm 3x (T_{15}), Soil + Humic Acid + ERL 40 ppm 2x (T_{16}), Soil + Humic acid + ERL 40 ppm 3x (T_{17}). They reported that, significantly higher root weight, longer roots and plant growth parameters were observed in humic acid treated treatments followed by organic applied treatments.

Lima *et al.* (2019) conducted a field experiment during 2012-2013 at Chapadao do Sul to evaluate development and production of sweet corn applied with *bio-stimulant* as seed treatment. The experiment consisted of 32 plots. Treatments were composed of eight commercial bio-stimulant doses (0.0, 4.0, 8.0, 12.0, 16.0, 20.0, 24.0 and 28.0 mL kg^{-1} seeds) and composed of three plant regulators in the formulations *viz.*, 0.009 per cent kinetin (cytokinin), 0.005 per cent gibberellic acid (gibberiline) and 0.005 per cent indole-butyric acid (auxin) were bio-stimulants. They reported that, application of bio-stimulants @ 20 ml kg^{-1} significantly increased the crop height compared to control. They also reported that, significantly the highest productivity of the crop per hectare with the application of same dose of bio-stimulant over other treatments.

Deepana *et al*. (2021) conducted experimental study at the Tamil Nadu Rice Research Institute, Aduthurai, Thanjavur district, representing the Cauvery Delta Zone of Tamil Nadu during summer season of 2021 to evaluate effect of seaweed extract on rice (*Oryza sativa* var. ADT53) productivity and soil fertility in Cauvery delta zone of Tamil Nadu. The experiment consisted of twelve treatments *viz.*, sea weed extract (SWE) gel soil application 12.5 kg ha^{-1} (T_1), SWE gel soil application 25 kg ha^{-1} (T_2), SWE gel soil application 37.5 kg ha^{-1} (T_3), Foliar spraying of SWE gel 0.5 per cent (v/v) at tillering + panicle initiation stage (T_4), foliar spraying of SWE liquid 0.5 per cent (v/v) at tillering + Panicle initiation stage (T_5), SWE gel soil application 12.5 kg ha^{-1} + foliar spraying of SWE gel 0.5 per cent (v/v) at tillering + panicle initiation stage (T_6), SWE gel soil application 25 kg ha^{-1} + Foliar spraying of SWE gel 0.5 per cent (v/v) at tillering + panicle initiation stage (T_7), SWE gel soil application 37.5 kg ha^{-1} + Foliar spraying of SWE gel 0.5 per cent (v/v) at tillering + panicle initiation stage (T_8), SWE gel soil application 12.5 kg ha^{-1} + Foliar spraying of SWE liquid 0.5 per cent (v/v) at tillering + Panicle initiation stage (T_9), SWE gel soil application 25 kg ha^{-1} + Foliar spraying of SWE liquid 0.5 per cent (v/v) at tillering + Panicle initiation stage (T_{10}), SWE gel soil application 37.5 kg ha^{-1} + foliar spraying of SWE liquid 0.5 per cent (v/v) at tillering + panicle initiation stage (T_{11}), Control (fertilizer alone) (T_{12}). They revealed that, the soil application of SWE gel soil application 12.5 kg ha^{-1} + Foliar spraying of SWE liquid 0.5 per cent (v/v) at tillering + Panicle initiation stage (T_9) recorded significantly higher plant height, number of productive tillers per m^2 and dry matter production over other treatments. They also reported that, significantly higher number of grains per panicle, panicle length, thousand grain weight, grain yield and straw yield with the application of SWE gel soil application 12.5 kg ha^{-1} + Foliar spraying of SWE liquid 0.5 per cent (v/v) at tillering + Panicle initiation stage (T_9) over other treatments.

Pascual *et al*. (2021) conducted an experiment inside a greenhouse of Cebu Technological University, Barili Campus, Cebu, Philippines during 2020 on rice bean to evaluate effect of seaweed bio-stimulant on growth and yield of rice bean (*Vigna umbellate*). The experiment consisted of five treatments *viz*., commercial natural liquid fertilizer (T_1), fermented sea weed @ 10 ml L^{-1} (T_2), fermented bamboo shoot @ 10 ml L^{-1} (T_3) and Japanese snail @ 10 ml L^{-1} (T_4) and control treatment (T_5). They reported that, application of fermented sea weed @ 10 ml L^{-1} significantly produced taller plants over control treatment.

2.1.2 Effect of bio-stimulant on yield and yield attributing characters of *kharif* rice

Mujathoub (2004) conducted a field experiment during 2003 at Saudi Arabia to evaluate effect of bio-stimulants on production of wheat (*Triticum aestivum* L.). The experiment consisted of 5 treatments in which different kinds of bio-stimulants used to assess the productivity of wheat. The treatments consisted of control or water spray (T_1), Vigro @ 1 L ha^{-1} (T_2), Biomin @ 2 L ha^{-1} (T_3), Humiplus @ 2 L ha^{-1} (T_4), Humacare @ 2 L ha^{-1} (T_5). He reported that, foliar application of Vigro @ 1 L ha^{-1} significantly increased the number of tillers per hill, number of grains per ear, 1000 seed weight and yield followed by application of Biomin @ 2 L ha^{-1}. Similar trend was reported on water uptake and nutrient uptake.

Paradikovi *et al*. (2011) the study was carried out during 2009 at the Agricultural Company located in Eastern Croatia to evaluate effect of natural bio-stimulants on yield and nutritional quality of sweet yellowpepper (*Capsicum annuum* L.) plants. The experiment consisted of four different variants, namely treated Blondy F1 (BlT) (A_1), non-treated or control Blondy F1 (BlC) (A_2), treated Century F1 (CenT) (A_3) and non-treated or control CenturyF1 (CenC) (A_4) pepper plant and the treatments consisted of four commercial bio-stimulants *viz*., Radifarm (B_1), Megafol (B_2), Viva (B_3) and Benefit (B_4). They reported that, bio-stimulant application agreed well with the significantly higher total and commercial yields of treated pepper cultivars compared with their controls. Also application of bio-stimulant produced significantly higher yield and yield attributing characters than the control treatment.

Saha *et al.* (2013) conducted a field experiment during 2010 at Bangladesh Agricultural University to study influence of *Humic* acid and Poultry manure on growth and yield of rice (*Oryza sativa* L). The experiment consisted of 9 treatments of which three rates of *humic* acid (0, 3 and 6 l ha^{-1}) and three rates of poultry manure (0, 3 and 6 t ha^{-1}) were permuted. The treatments consisted of no humic acid + no poultry manure (T-0), no humic acid + poultry manure @ 3 t ha^{-1} (T_1), No humic acid + poultry manure @ 6 t ha^{-1} (T_2), humic acid @ 3 L ha^{-1} + no poultry manure (T_3), humic acid @ 3 L ha^{-1} + poultry manure @ 3 t ha^{-1} (T_4), humic acid @ 3 L ha^{-1} + poultry manure @ 6 t ha^{-1} (T_5), humic acid @ 6 L ha^{-1} + no poultry manure (T_6), humic acid @ 6 L ha^{-1} + poultry manure @ 3 t ha^{-1} (T_7) and humic acid @ 6 L ha^{-1} + poultry manure @ 6 t ha^{-1} (T_8). They reported that, *humic* acid applied @ 3 L ha^{-1} treatment recorded significantly taller plants, higher effective tillers/hill compared to control treatment. They also reported that the significantly longer panicle length, 1000 grain weight and number of grains per panicle were obtained when *humic* acid applied at 6 L ha^{-1} over the control treatment.

Aziz *et al.* (2014) conducted two field trials during 2012 and 2013 at Sakha Agricultural Research Farm to study the effect of cyanobacteria, humic substances and mineral nitrogen fertilizer on rice yield and its components. The field trial consisted of 8 treatments *viz.*, control (T_1), algalization with 500 g cyanobacteria/fed i.e. recommended (T_2), the recommended dose of *humic* substances i.e. HS @ 2L/fed (T_3), the recommended dose of N i.e. @ 150 kg N/fed (T_4), 50 per cent the recommended dose of cyanobacteria and 50 per cent HS (T_5), 50 per cent the recommended dose of cyanobacteria and 50 per cent N (T_6), 50 per cent the recommended dose of HS and 50 per cent N (T_7), 50 per cent the recommended dose of cyanobacteria 50 per cent HS and 50 per cent of N (T_8). They reported that, application of 50 per cent the recommended dose of cyanobacteria, 50 per cent HS and 50 per cent of N gave significantly higher grain yield than other treatments. They also reported that, similar trend was observed in case of straw yield and harvest index.

Pramanick *et al.* (2013) conducted a field experiment during *rabi* season of 2011 at Bankapasi village, Bardaman to study the effect of sea weed saps on growth and yield improvement of transplanted rice in old alluvial soils of West-Bengal. The experiment comprised of ten treatments, *viz.*, 2.5 per cent Kappaphycus-sap + RDF (T_1), 5 per cent Kappaphycus-sap + RDF (T_2), 10 per cent Kappaphycus-sap + RDF (T_3), 15 per cent Kappaphycus-sap + RDF (T_4), 2.5 per cent Gracilaria-sap + RDF (T_5), 5 per cent Gracilaria-sap + RDF (T_6), 10 per cent Gracilaria-sap + RDF (T_7), 15 per cent Gracilaria-sap + RDF (T_8), RDF + Water spray (T_9) and 7.5 per cent Kappaphycus-sap + 50 per cent RDF (T_{10}). They reported that, significantly higher number of panicles m^{-2}, length of panicle, number of filled grains per panicle, test weight, grain yield, straw yield and harvest index observed for application of 15 per cent Gracilaria-sap + RDF (T_8) over control treatment. Similar trends were observed with respect to nutrients uptake (N-P-K) by grain and straw of rice.

Devi *et al*. (2015) conducted a field experiment during 2013 at Sugarcane Research Station, Cuddalore, Tamil Nadu to study the potential of sea weed saps (*Kappaphycus alvarezi* and *Gracilaria* spp) on growth, yield and quality of rice. The experiment consisted of 12 treatments. The treatments consisted of 100 per cent RDF (T_1), 100 per cent RDF + Water spray (T-2), 50 per cent RDF + 7.5 per cent K-sap (T_3), 100 per cent RDF +2.5 per cent K-sap (T_4), 100 per cent RDF + 5 per cent K-sap (T_5), 100 per cent RDF +10 per cent K-sap (T_6), 100 per cent RDF + 15 per cent K-sap (T_7), 2.5 per cent G-sap (T_8), 100 per cent RDF +5 per cent G-sap (T_9), 100 per cent RDF +10 per cent G-sap (T_{10}), 100 per cent RDF + 15 per cent K-sap (T_{11}) and 50 per cent RDF + 7.5 per cent G-sap (T_{12}). They reported that, application of 100 per cent RDF + 15 per cent K-sap significantly increased the plant growth attributes *viz*., height, LAI, Dry matter production over the other treatments at 30, 60, 90 days after planting (DAP). The similar trend was observed for yield attributes like number of productive tillers per m^2, number of productive tillers per hill, panicle length, 1000 grain weight, grain and straw yield for application of 100 per cent RDF + 15 per cent K-sap over other applications.

Jayanta *et al*. (2017) conducted the field experiment during 2012-13 at ICAR Research Complex for NEH region, Umiam, Meghalaya to study seaweed extract as organic bio-stimulant improves productivity and quality of rice in eastern Himalayas. The experiment consisted of nine treatments. The treatments consisted of spray of water (T_1), 2.5 per cent K sap (T_2), 5 per cent. K sap (T_3), 10 per cent K sap (T_4), 15 per cent K sap (T_5), 2.5 per cent G sap (T_6), 5 per cent G sap (T_7), 10 per cent G sap (T_8), 15 per cent G sap (T_9) and all the treatments were given 100 per cent of recommended dose of fertilizer. They reported that, the significantly taller plants were observed with foliar application of 15 per cent G sap followed by 15 per cent K sap, similar trend was observed with respect to dry matter production per plant. Further, they also reported that, the yield attributes *viz*., number of panicles per hill and number of effective grains per panicle were significantly higher for the application of 15 per cent K sap followed by 15 per cent G sap were at par with 10 per cent and 5 per cent K sap. The application of 15 per cent K sap or G sap shown significantly higher nitrogen content in grains over control treatment.

Mahmood *et al*. (2017) conducted a field experiment for two consecutive years 2012 and 2013 at Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan; to study effect of bio-stimulants on growth, yield and quality of bell pepper cv. Yolo wonder. The experiment consisted of ten treatmants i.e. different concentrations of chitosan (0.3, 0.4 and 0.5 per cent), putrescine (1 mM, 2 mM and 3 mM) and salicylic acid (1 mM, 2 mM and 3 mM) as foliar sprays were applied to bell pepper cv. “Yolo Wonder”. They reported that, significantly higher plant height was recorded with the application of salicylic acid (SA) 3mM treatment followed by putrescine (3 mM and 2mM). They also reported similar results with respect to days required for fruit maturity, fruit weight, total crop yield etc.

Silva *et al.* (2017) conducted a field experiment during 2013 at Commercial Farm of Sugarcane Production, Campos dos Goytacazes, Rio de Janeiro, Brazil to evaluate effectiveness in increasing sugarcane yield by the application of bio-stimulant manufactured using diazotrophic endophytic bacteria and humates. The experiment consisted of comparing the two delivering methods by the application of bio-stimulant in the furrow against foliar spray and in the split plot i.e., the foliar application at three different times (60, 90, and 60 + 90 days after the emergence), application of the bio-stimulant at a rate of 400 L ha^{-1} was done using a tractor at constant pressure and velocity in an alternate strip using five replicates. They reported that, application of bio-stimulant at 60 days after the emergence of sugarcane significantly increased the crop yield.

Shah *et al.* (2017) conducted a field experiment during 2014 to 2016 at Agri Technology Centre, Swindon to study the effect of bio-stimulants on crop vigor, disease incidence and grain yield of winter wheat and winter oilseed rape. The experiment consisted of 7 treatments *viz.*, Control (T_1), MG (proline and tryptophan based bio-stimulant) @ 2.5 L ha^{-1} (T_2), KD (an oligosaccharide based bio-stimulant) @ 1 L ha^{-1} (T_3), NTM (amino acid and nitrogen based bio-stimulant) @ 200 L ha^{-1} (T_4), NTM (500 g) 2 times (T_5), NTM (300 g) 2 times (T_6), NTM (500 g) 2 times later period (T_7). They reported that, application of NTM (500 g) 2 times in later period significantly increased the grain yield of winter rape over other treatments of the bio-stimulants. Similar results were observed when winter wheat was grown.

El-Helaly (2018) an investigation was conducted during 2015-16 and 2016-17 at the Experiment Station of the Faculty of Agriculture, Cairo University, Egypt to study the effect of growth stimulants (humic acid and fulvic acid) as foliar spray on some carrot cultivars. The experiment consisted of 12 treatments which were the combination of control or without spray (H_1), humic acid @ 1 g/L and fulvic acid @ 0.5 g/L (without spray) (H_2), humic acid @ 1 g/L and fulvic acid @ 0.5 g/L as foliar spray (H_3) and four cultivars *viz*., Corall (S_1), Terracotta (Takii seeds) (S_2), Siroco(S_3) and Exelso (Semences seeds) (S_4). They reported that, application of humic acid @ 1g/L treatment increased significantly higher root weight, yield/plot, economic yield and harvest index over control treatment. While, fulvic acid @ 0.5 g/L treatment improved significantly leaves and roots dry matter over other treatments.

Layek *et al.* (2018) conducted a field experiment during 2015-16 *kharif* season at ICAR Research Complex for NEH region, Meghalaya for evaluation of sea weed saps on performance of tomato under organic production system. The experiment consisted of nine treatments *viz*., control or water spray (T_1), K-sap @ 5 per cent (T_2), K-sap @ 10 per cent (T_3), G-sap @ 5 per cent (T_4), G-sap @ 10 per cent (T_5), GA_3 free sap @ 5 per cent (T_6), GA_3 free sap @ 10 per cent (T_7), vermiwash @ 5 per cent (T_8), vermiwash @ 10 per cent (T_9). They reported that, the significantly taller plants were observed with the application of GA_3 free sap @ 10 per cent followed by application of G-sap @ 10 per cent over control treatment. Similar trends were observed in respect of crop yield.

Arun *et al*. (2019) conducted a field experiment during 2016 at ICAR Indian Institute of Rice Research - Hyderabad, Telangana to study the effect sea weed extract (SWE) as bio-stimulant on growth and yield of rice (*Oryza sativa* L.) under transplanted condition. The experiment consisted of seven treatments *viz.*, LBS6 @ 1 ml L^{-1} (T_1), LBS6 @ 1 ml L^{-1} + 20per cent less NPK (T_2), LBS6-S @ 1 ml L^{-1} (T_3), LBS8 @ 1 ml L^{-1} (T_4), LBS9 @ 1 ml L^{-1} (T_5), LBS10 @ 1 ml L^{-1} (T_6) and recommended doses of NPK (T_7) where LBS6, LBS6-S, LBS8, LBS9, LBS10 are liquid bio-stimulants extracted from sea weed extracted. They reported that, all growth parameters *viz.*, plant height, number of leaves per hill, number of tillers per m^2 *etc*. were shown significantly higher responses towards application of sea weed extract bio-stimulant over RDF. They also found that, significantly higher plant height, number of leaves per hill, tillers per m^2 to LBS6-S (T_3) over control at 30, 60, 90 DAT and at harvest.

Gawade *et al*. (2019) field experiment was carried out twice during October 2017 to February 2019 at the Jamuvadi Farm, Department of Horticulture, Junagadh Agricultural University, Junagadh (Gujarat) to evaluate response of bio-stimulants and bio-fertilizers on yield and quality of chrysanthemum cv. Ratlam selection. The treatment comprised of five treatments of bio-stimulants *viz*., Without spray of bio-stimulants(B_0), Banana pseudo-stem Sap @ 1 per cent (B_1), Seaweed extract @ 0.5 per cent (B_2), Panchgavya @ 4 per cent (B_3), Humic acid @ 0.2 per cent (B_4) and three treatments of bio-fertilizers i.e. Without bio-fertilizers (F_0), Azotobacter @ 2 l/ha + PSB @ 2 l/ha + KSB @ 2 l/ha (F_1) and Azotobacter @ 3 l/ha + PSB @ 3 l/ha + KSB @ 3 l/ha (F_2). The plants from each treatment plot were randomly selected, labeled and used for recording observations. They reported that, significantly maximum yield was observed with the application of humic acid @ 0.2 per cent with Azotobacter @ 3 l ha^{-1} + PSB @ 3 l ha^{-1} + KSB @ 3 l ha^{-1} over other treatments.

Talha *et al*. (2020) conducted a field experiment at Sakha Agricultural Research Station, Egypt during 2019-20 to study enhancement of the productivity of rice varieties by using some growth promoting supplements. The experiment was laid out in a split plot design where nine rice varieties *viz*., GZ 1010 (V_1), GZ 10154 (V_2), GZ 10365 (V_3), MJ 5460 (V_4), Giza 178 (V_5), Giza 179 (V_6), Sakha 104 (V_7), SK 2034H (V_8), SK 2003H (V_9) were evaluated under three growth promoter supplements or bio-stimulants *viz*., viusid agro (G_1), alfarid 1 (G_2), humic plus (G_3) and control (G_4) . They reported that, application of viusid agro was significantly increased the grain yield over control accompanied by significant increase in number of panicles per plant, 1000 grain weight, compared with control treatment.

Xiao *et al*. (2021) conducted a laboratory experiment at Spain to study influence on grain development by the application of Selenium and a bio-stimulant of different wheat growth stages. The experiment consisted of eight treatments *viz*., control or water spray (T_1), no bio-stimulant + Selenite (T_2), no bio-stimulant + Selenate (T_3), no bio-stimulant+ mixture 1:1 *v/v* selenite and selenate (T_4), only bostimulant spray (T_5), bio-stimulant + Selenite (T_6), bio-stimulant + Selenate (T_7), bio-stimulant+ mixture 1:1 *v/v* selenite and selenate (T_8). They reported that, application of bio-stimulant with selenium mix 1:1 *v/v* at heading stage significantly increased the number of grains produced per spike over other treatments.

2.1.3 Effect of bio-stimulant on quality (i.e. protein content) of *kharif* rice.

Mona (2013) conducted a field experiment during 2012 at Agricultural Research Center, Giza, Egypt to evaluate the potential of *Moringa oleifera* extract as a bio-stimulant in enhancing the growth, biochemical and hormonal contents in rocket (*Eruca vesicaria subsp. sativa*) plants. The experiment consisted of seven treatments *viz*., control (T_1), *Moringa oleifera* leaf extract @ 1 per cent (T_2), *Moringa oleifera* leaf extract @ 2 per cent (T_3), *Moringa oleifera* leaf extract @ 3 per cent (T_4), *Moringa oleifera* twig extract @ 1 per cent (T_5), *Moringa oleifera* twig extract @ 2 per cent (T_6), *Moringa oleifera* twig extract @ 3 per cent (T_7). He reported that, application of *Moringa oleifera* leaf extract @ 2 per cent gave significantly higher protein content of rocket crop (*Eruca vesicaria subsp. sativa*) over other treatments.

Hidangmayum and Sharma (2017) conducted a field experiment during rabi season of 2015-16 at, Sam Higginbottom Institute of Agriculture Technology and Sciences Allahabad (U.P) to study effect of different concentrations of commercial seaweed liquid extract of *Ascophyllum nodosum* as a plant bio-stimulant on growth, yield and biochemical constituents of onion (*Allium cepa* L.). The experiment consisted of six treatments *viz*., control (T_1), seaweed liquid extract of *Ascophyllum nodosum* @ 0.35 per cent (T_2), seaweed liquid extract of *Ascophyllum nodosum* @ 0.45 per cent (T_3), seaweed liquid extract of *Ascophyllum nodosum* @ 0.55 per cent (T_4), seaweed liquid extract of *Ascophyllum nodosum* @ 0.65 per cent (T_5) and seaweed liquid extract of *Ascophyllum nodosum* @ 0.75 per cent (T_6). They reported that, application of seaweed liquid extract of *Ascophyllum nodosum* @ 0.55 per cent significantly increased the bulb protein as well as leaf protein over other treatments.

Ivana *et al*. (2017) conducted research during 2016 at the Faculty of Agriculture, University of Banja Luka to evaluate prevention of yield loss by the bio-stimulants and reduction of oxidative damage in tomato plants grown under reduced N-P-K condition. The experiment consisted of five treatments *viz*., control (T_1), standard nutrition (100 per cent N-P-K) (T_2), reduced nutrition (40 per cent N-P-K) (T_3), standard nutrition (100 per cent N-P-K) with bio-stimulant (T_4), reduced nutrition (40 per cent N-P-K) with bio-stimulant (T_5). They reported that, application of reduced nutrition (40per cent N-P-K) significantly increased the total soluble protein content in the tomato leaves followed by application of reduced nutrition (40 per cent N-P-K) with bio-stimulant over other treatments.

Popko *et al.* (2018) conducted field and laboratory experiments during 2012-13 at Agreco Co. Poland to evaluate effect of the new plant growth bio-stimulants based on amino acids on yield and grain quality of winter wheat. The experiment consisted of five treatments *viz.*, control (T_1), AminoPrim @ 1 L ha^{-1} in 2 doses (T_2), AminoHort @ 1 L ha^{-1} in 2 doses (T_3), AminoHort @ 1.25 L ha^{-1} in 2 doses (T_4), Asahi SL @ 0.6 L ha^{-1} in 2 doses (T_5); where AminoPrim, AminoHort and Asahi SL are amino acid based bio- stimulants. They reported that, significantly taller plants were observed with application of Asahi SL @ 0.6 L ha^{-1} in 2 doses followed by T_3. Similar trend was observed for average number of ears per m^2, grain yield. They also reported that, significantly higher protein content in the winter wheat for application of Asahi SL @ 0.6 L ha^{-1} in 2 doses over other treatments.

Tajeda *et al.* (2018) study was carried out during two consecutive experimental seasons i.e. from April to October in 2014 and 2015 at Trujillanos, Extremadura, Spain to study effect of foliar fertilization of a bio-stimulant obtained from chicken feathers on maize yield. The experiment consisted of four treatments *viz.*, plots fertilized with 300 kg N ha^{-1} + 80 kg P ha^{-1} + 41.7 kg N ha^{-1} [as $(NH_4)H_2PO_4$] + 120 kg K ha^{-1} (T_1), 300 kg N ha^{-1} + 80 kg P ha^{-1} + 41.7 kg N ha^{-1} [as $(NH_4)H_2PO_4$] + 120 kg K ha^{-1} + bio-stimulant @ 3.6 L ha^{-1} (T_2), 300 kg N ha^{-1} + 80 kg P ha^{-1} + 41.7 kg N ha^{-1} [as $(NH_4)H_2PO_4$] + 120 kg K ha^{-1} + bio-stimulant @ 7.2 L ha^{-1} (T_3) and control (T_4). They reported that, application of 300 kg N ha^{-1} + 80 kg P ha^{-1} + 41.7 kg N ha^{-1} [as $(NH_4)H_2PO_4$] + 120 kg K ha^{-1} + bio-stimulant @ 7.2 L ha^{-1} was found to be significantly higher the protein content of maize grains over other treatments.

2.2 Effect of bio-stimulant on nutrient uptake by crop and nutrient availability in soil.

Nikbakht *et al.* (2008) conducted a green house experiment during 2008 at Zhejiang University, China to evaluate effect of humic acid on plant growth, nutrient uptake, and postharvest life of gerbera. The experiment consisted of different levels of humic acid were applied to nutrient solution *viz.*, control or no humic acid @ 0 mg L^{-1} (T_1), humic acid @ 100 mg L^{-1} (T_2), humic acid @ 500 mg L^{-1} (T_3) and humic acid @ 1000 mg L^{-1}(T_4). They reported that, application of humic acid @1000mg L^{-1} has significantly increased the accumulation of macro-nutrients like nitrogen (N), phosphorous (P) and potassium (K) over other treatments.

Zodape *et al.* (2011) carried out a farm experiment during 2006-07 *kharif* season at Horticulture Farm, College of Agriculture Udaipur, Rajasthan to evaluate effect of foliar application of sea weed sap as a bio-stimulant for enhancement of yield and quality of tomato*(Lycopersicon esculentum* Mill.). The experiment consisted of five treatments where varied levels of *Kappaphycus alvarezi* (K-sap) a sea weed sap as a bio-stimulant applied *viz*., control or water spray (T_1), K-sap @ 2.5 per cent (T_2), K-sap @ 5 per cent (T_3), K-sap @ 7.5 per cent (T_4), K-sap @ 10 per cent (T_5). They reported that, application of K-sap @ 5 per cent significantly increased the height of the plant over the control treatment. Further they noticed that application of K-sap @ 5 per cent (T_3) had significantly increased the yield over control treatment. They also reported that, application of the same has significantly increased the uptake of nitrogen (N) and phosphorous (P) and significantly higher potassium uptake was found with the application of K-sap @ 7.5 per cent (T-4) over remaining treatments.

Chang *et al.* (2012) conducted a pot culture experiment during 2008 at Zhejiang University, Hangzhou, China to evaluate effects of calcium and humic acid treatment on the growth and nutrient uptake of Oriental lily. The experiment consisted of 5 treatments *viz*., no Ca and no humic acid (T_1), 3.5 meq/L Ca + 500 mg/L humic acid (T_2), 3.5 meq/L Ca (T_3), 7.0 meq/L Ca + 500 mg/L humic acid (T_4), 7.0 meq/L Ca (T_5). They reported that application of 7.0 meq/L Ca + 500 mg/L humic acid significantly increased the uptake of nutrients *viz*., nitrogen, phosphorous and potassium (N, P, K) content by plant over all the treatments.

Zeljkovic *et al*. (2013) investigation was conducted during the 2009, 2010 and 2011 year in greenhouses of Banja Luka, Bosnia to evaluate nutrient status, growth and proline concentration of french marigold (*Tagetes patula* L.) as affected by bio-stimulant treatment. Trial was set out in a split-plot design containing treated and untreated plants during three years of investigation. Treated plants were watered with bio-stimulant Radifarm® in concentration of 0.25 per cent whilst untreated plants were watered only with water. The duration of trial was two months, where treatments with bio-stimulants were performed every seven days each year of investigation. At the end of the trial roots and above-ground part *viz*., weight of the plant, number of leaves, flowers and buds and plant height were recorded. They reported that, significantly higher number of leaves, flowers and buds was recorded in treated plants comparing to control plants. Furthermore, higher concentrations of N, P and K, especially in plant above-ground part, were significantly higher in treated than in non-treated plants.

Perumal *et al.* (2015) conducted a pot culture experiment during 2015 at Malaysia to study lowland rice (*Oryza sativa* L. cv. MR219) plant growth variables, nutrients uptake, and nutrients recovery using crude humic substances. The experiment consisted of 5 treatments *viz*., only soil (T_1), soil + RDF (T_2), 20 g humic substance (CHS1) pot^{-1} (T_3), 40 g humic substance (CHS2) pot^{-1} (T_4), 60 g humic substance (CHS3) pot^{-1} (T_5). They reported that, treatments with application of crude humic substances @ 40 g showed significantly higher nutrients uptake (K, P) and recovery (P, K) compared with normal fertilizer application. The results also depicted that, application of CHS1, CHS2, and CHS3 increased soil organic matter (OM), total organic carbon (TOC) and total carbon (TC) compared with soil alone and normal fertilization.

Selladurai and Purakayastha (2015) field experiment was conducted during 2009-10 at IARI New Dehli to study the effect of humic acid multinutrient fertilizers *viz*., Grow Flow 45H and HA-NPK complex on crop yield, nutrient content and uptake, and nutrient use efficiency of potato. The experiment consisted of ten treatments. They were 100 per cent (T_1 and T_4), 75 per cent (T_2 and T_5) and 50 per cent (T_3 and T_6) of recommended dose (RDF) of fertilizers (180 kg N, 90 kg P_2O_5) and 100 kg K_2O per hectare) were supplied through GF 45H and HA-NPK, respectively. Chemical fertilizer (100 per cent RDF) (T_7) and absolute control (without fertilizers) (T_{10}) were also included as treatments for comparison. Humic acid (SH 26) alone (T_8) and humic acid with chemical fertilizers (T_9) were treatments. They reported that, the application of humic acid multinutrient fertilizer particularly Grow Flow 45H showed the significantly higher economic yield of potato over fertilizer applied treatments. Also application of GF 45H at 75 per cent RDF and HA-NPK (100 per cent RDF) showed significantly higher N content as compared to chemical fertilizers (100 per cent RDF). Furthur they reported that, the uptake of N, P, K was significantly higher in GF 45H at 100 per cent RDF treated potato which differed from other treatments.

Eshwar *et al*. (2016) conducted a pot culture experiment in greenhouse during 2016 at College of Agriculture Hyderabad. The experiment consisted of eleven treatments *viz*., Control (T_1), Fulvic acid (T_2), Humic acid (T_3), Soil application of Fe-chelate @ 2.5 mg Fe kg^{-1} soil (T_4), Soil application of Fefulvate @ 2.5 mg Fe kg^{-1} soil (T_5), Soil application of Fe-humate @ 2.5 mg Fe /kg soil (T_6), Soil application of $FeSO_4$ @ 2.5 mg Fe /kg soil (T_7), Foliar application of Fe-chelate @ 0.25 per cent at vegetative stage and panicle initiation stage (T_8), Foliar application of Fe-fulvate @ 0.25 per cent at vegetative stage and panicle initiation stage (T_9), Foliar application of Fe-humate @ 0.25 per cent at vegetative stage and panicle initiation stage (T_{10}), Foliar application of $FeSO_4$ @ 0.25 per cent at vegetative stage and panicle initiation stage (T_{11}). They reported that, significantly higher nitrogen uptake with the Foliar application of $FeSO_4$ @ 0.25 per cent at vegetative stage and panicle initiation stage(T_{11}) treatment followed by Soil application of $FeSO_4$ @ 2.5 mg Fe /kg soil (T_7) over control (only RDF application). They also reported similar trend with respect to uptake of phosphorous and potassium.

Szczepanek *et al*. (2018) studied field experiments located in Poland conducted during 2010-2012 to assess the response of grain yield, yield components as well as the content and uptake of N, P and K in grain for wheat to various methods of seaweed bio-stimulant application. In the experiment the marine macroalga bio-stimulant Kelpak was used in three growing seasons. Kelpak was applied in different doses and developmental stages of wheat: as a single dose of 2 l/ha at BBCH 22 (early treatment) (T_1) and in a dose of 2 l/ha BBCH 31 (late treatment) (T_2), as well as two-times, 1.5 l/ha each, in both mentioned stages (sequential treatment) (T_3) and control treatment (T_4). They reported that, significant increase in P and K content and uptake in the wheat grain after the sequential application of T_3 in comparison with the control treatment.

Szczepanek and Ziomek (2019) conducted a field experiment during 2011-12 at Kuyavian-Pomeranian region, Poland to study P and K accumulation by rapeseed as affected by bio-stimulant under different N-P-K and S fertilization doses to rape seed. The field experiment was consisted of two levels of NPK fertilization (high i.e. 180 N, 70 P_2O_5, 132 K_2O kg ha^{-1} or low i.e. 144 N, 35 P_2O_5, 66 K_2O kg ha^{-1}); elementary S fertilization (36 or 0 kg ha^{-1}) and application of seaweed bio-stimulant or without that treatment to rapeseed crop. They reported that, application of the seaweed bio-stimulant, on average for the other experimental treatments, significantly increased P accumulation in shoots at each developmental stage over the control treatment. They also reported that, application of the bio-stimulant, the use of the higher N-P-K fertilization level or fertilization with S caused a significant increase in K accumulation in shoots at each analyzed stage of generative development over the control treatment.

Cardarelli *et al*. (2020) conducted a glass-glazed greenhouse experiment during 2017 at Department of Horticulture and Landscape Architecture, Purdue University, West Lafayette to evaluate growth and nitrogen uptake using micro-granular based bio-stimulant in for tomato production. The experiment consisted of randomized complete block design with five replicates to evaluate the bio-stimulant action of a micro-granular based PH containing *Trichoderma atroviride* (MUCL45632) mixed into the substrate prior to sowing at the following rates *viz*., 0 g L^{-1} (T_1), 1 g L^{-1} (T_2), 2 g L^{-1} (T_3) and 4 g L^{-1} (T_4). They reported that application of bio-stimulant @4 g L^{-1} (T-4) significantly increased the shoot dry weight in tomato plants against other treatments. They also reported that, application of the bio-stimulant @ 4 g L^{-1} significantly increased the nitrogen (N) content in the tomato leaves over other treatments.

Suseendran *et al*. (2020) conducted a field experiment during Jan-May of 2018 at Annamalai University, Tamil Nadu to study the performance of rice to the foliar application of plant growth regulators on growth and yield of rice. The experiment consisted of 6 treatments *viz*., Sodium Para-Nitrophenolate 0.3 per cent SL @ 5 ml/L (T_1), Sodium Para-Nitrophenolate 0.3 per cent SL @ 10 ml/L (T_2), Sodium Para-Nitrophenolate 0.3 per cent SL @ 20 ml/L (T_3), Triacontanol 0.1 per cent EW @0.5 ml/L (T_4), Gibberellic acid 0.001 per cent L @0.36 ml/L (T_5), Control (T_6) where Sodium Para-Nitrophenolate is used as a bio-stimulant cum growth regulator. They reported that, significantly higher nutrient uptake (N, P, K) observed with the application of Sodium Para-Nitrophenolate 0.3 per cent SL @ 5 ml/L (T_1) over the other treatments. They also reported that, foliar application of Sodium Para-Nitrophenolate 0.3 per cent SL @ 5 ml/L (T_1) at 20-25, 45-50 and 65-70 days after transplanting recorded significantly the highest yield attributes *viz*., number of panicles m^{-2}, number of grains $panicle^{-1}$ and test weight, yield (grain and straw) over other treatments.

Vijaykumar *et al*. (2021) conducted a field experiment during 2019 *kharif* at ICAR-Perunthalaivar Kamaraj Krishi Vigyan Kendra, Puducherry to evaluate the soil fertility and nutrient uptake of rice influenced by plant growth promoting microbes, seaweed extract and humic acid fortified *in-situ* rice residue compost. The experiment consisted of ten treatments *viz*., 100 per cent recommended dose of NPK (T_1), 100 per cent NPK + in-situ rice residue (straw & stubble) compost (IRRC) (T_2), 100 per cent NPK + Plant Growth Promoting Microbial (PGPM) consortia and Humic acid (HA) and Seaweed extract (SWE) fortified FYM (FFYM) 5 t ha^{-1} (T_3), 100 per cent NPK + *in-situ* rice residue compost fortified with PGPM, HA and SWE (FIRRC) (T_4), 75 per cent NPK + IRRC (T_5), 75 per cent NPK + FFYM 5t ha^{-1} (T_6), 75 per cent NPK + FIRRC (T_7), 50 per cent NPK + IRRC (T_8), 50 per cent NPK + FFYM 5t ha^{-1} (T_9), and 50 per cent NPK + FIRRC (T_{10}). They reported that, application of FIRRC + 75 per cent NPK (T_7) was found to be significantly higher nutrient uptake of NPK by rice over all other treatments.

2.3 Effect of bio-stimulant on economics of treatments.

Arafa *et al*. (2012) two field experiments were conducted during the two successive winter seasons of 2007-08 and 2008-09 at the EL-Maniel, Dakahlia to study the influence of effective microorganisms(EM), bio-stimulants, and potassium levels as well as their combinations on the potato yield quantity and quality and its economic consideration. The experiment comprised of 18 treatments including three different rates of potassium fertilizers used individually or in combinations with EM and bio-stimulants (Humic acid @ 150 mg/l or seaweed extract @ 500 mg/l). They reported that, application of either seaweed extract or humic acid increased the total income, net income and investment rate as compared to untreated plants or control treatment.

Kumar *et al*. (2016) carried out an investigation during *kharif* season of 2014 at S. K. Rajasthan Agricultural University Bikaner, Rajasthan to evaluate role of humic acid and salicilyc acid on yield attributes yield and economics of tomato under saline stress condition. The experiment was carried out using 18 treatment combinations comprising three levels of saline water i.e. control (0.25 dS m^{-1}), 4 dS m^{-1} and 8 dS m^{-1}; three levels of humic acid i.e. control, 750 and 1500 ppm and two levels of salicilyc acid i.e. control and 1.5 mM were tested. They reported that, application of humic acid at 1500ppm was increased the net returns and B:C ratio over the control treatment.

Rachelle (2018) conducted a survey during 2018 at Philippines to analyse profitability of irradiated carrageenan as a bio-stimulant in small-scale rice farming in selected provinces in the Philippines. The survey consisted of collection of data from 117 farmers of both using bio stimulant and without using bio stimulant. He collected data from 117 farmers who were using irradiated carrageenan. He reported that, significantly higher gross margin of Php 17000 due to the increase in yield of 900 kg per ha over farmers without using bio-stimulant. He also found that B:C ratio of 3.04 by use of bio stimulant over the farmers not using bio-stimulants.

Baradhan *et al*. (2019) conducted field experiment during 2017 at Tamilnadu to study influence of modulin (*bio-stimulant*) on growth, yield and gene expression of calmodulin in rice under lowered NPK fertilizers. The experiment consisted of five treatments *viz.*, control or 100 per cent RDF only (T_1), 75 per cent RDF +Modulin @ 1 kg ha^{-1} (T_2), 75 per cent RDF +Modulin @ 2 kg ha^{-1} (T_3), 100 per cent RDF + Modulin @ 1 kg ha^{-1} (T_4), 100 per cent RDF + Modulin@ 2 kg ha^{-1}(T_5). They reported that significantly higher gross return (Rs. 104,200 ha^{-1}), net return (Rs. 59,600 ha^{-1}) by application of 100 per cent RDF + Modulin @ 2 kg ha^{-1} followed by 75 per cent RDF +Modulin @ 1 kg ha^{-1} over control and rest of the treatments. Significantly higher B:C ratio was observed with application of 100 per cent RDF + Modulin @ 2 kg ha^{-1} when compared to control treatment.

Khan *et al*. (2019) a field experiment was carried out during the year 2017 and 2018 in the village of Kanelwan of district Anantnag, Jammu and Kashmir to evaluate effect of N, P and K nano-fertilizers in comparison to humic and fulvic acid on yield and economics of red delicious (*Malus x domestica* Borukh.). The experiment where inorganic/conventional orchard was treated with nano-nitrogen (100 ppm, 200 ppm and 300 ppm), nano-phosphorous (30 ppm, 40 ppm and 50 ppm) and nano-potassium (100 ppm, 150 ppm and 200 ppm) all the nano-fertilizers replicated thrice and the control of inorganic was fully treated as per recommendations of SKUAST-K. The organic apple orchard was treated with humic acid (0.05 per cent, 0.10 per cent and 0.15 per cent) and fulvic acid (1.5 per cent, 2.5 per cent and 3.5 per cent) replicated thrice, while the organic control was given an initial vermicompost dose of 20 kg/tree. They reported that application of humic acid @ 0.15 per cent recorded higher B:C ratio (5.51) over all the treatments. They also reported that, under organic apple cultivation application of humic acid @ 0.15 per cent recorded significantly higher yield over all the treatments.

Szparaga *et al*. (2019) conducted field experiment during the years 2016–2018 in Perespa, Poland with common bean (*Phaseolus vulgaris* L.) of Mexican black cultivar to evaluate agronomic and economic effects of bio-stimulant use in common bean cultivation. The experiment consisted of application of two bio-stimulants at different rates *viz*., Atonik bio-stimulant i.e. single spraying: BBCH 13–15 (LSS) 0.1 per cent (T_1), single spraying: BBCH 13–15 (HSS) 0.2 per cent (T_2), double spraying: BBCH 13–15 + BBCH 61 (LDS) 0.1 per cent (T_3), double spraying: BBCH13–15 + BBCH61 (HDS) 0.2 per cent (T_4). And other bio-stimulant-Tytanit Single spraying: BBCH 13–15 (LSS) 0.07 per cent (T_5), single spraying: BBCH 13–15 (HSS) 0.13 per cent (T_6), double spraying: BBCH 13–15 + BBCH 61 (LDS) 0.07 per cent (T_7) double spraying: BBCH 13–15 + BBCH61 (HDS) 0.13 per cent (T_8). They reported that higher profitability of bio-stimulant use was demonstrated after single plant spraying with Tytanit in both concentrations. For Atonik significantly greatest economic profits were noted after double plant treatment with its higher concentration over the control treatment.

Nayak *et al.* (2020) conducted a field experiment during 2018 at Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal to study the effect of seaweed extracts on growth, yield and economics of *kharif* rice *(Oryza sativa* L.*)*. The experiment consisted of seven treatments *viz*., control or only 100 per cent RDF (T_1), 100 per cent RDF + Biozyme granule @ 15 kg ha^{-1} (T_2), 100 per cent RDF + Amaze-x granule @ 10 kg ha^{-1} (T_3), 75 per cent RDF + Biozyme granule @ 15 kg ha^{-1} (T_4), 75 per cent RDF + Amaze-x granule @ 10 kg ha^{-1}(T_5), 75 per cent RDF + Biozyme granule @ 15 kg ha^{-1} + Proventus DS legacy spray @ 625 ml ha^{-1} (T_6), 75 per cent RDF + Amaze-x granule @10 kg ha^{-1} + Proventus DS legacy spray @ 625 ml ha^{-1}(T_7). They reported that, higher economic viability of gross return (Rs. 71,271 ha^{-1} and Rs. 71,814 ha^{-1}), net returns (Rs. 26,614 ha^{-1} and Rs. 26,607 ha^{-1}), B:C ratio (1.59 & 1.58), respectively for T_6 and T_7 over other treatments.

Zarzecka *et al*. (2020) study was carried out in the years 2012–2014 in the town of Wojnow, Mazowian Voivodeship to evaluate agricultural and economic effects of the use of bio-stimulants of herbicides in cultivation of the table potato cultivar Gavin. analysis comprised five research variants that differed in the use of mechanical measures, herbicides and herbicides with bio-stimulants *viz*., Control variant or mechanical weeding or without herbicides and bio-stimulants (T_1), Herbicide Harrier 295ZC @ 2.0 dm^3 ha^{-1} (T_2), Herbicide Harrier 295ZC @ 2.0 dm^3 ha^{-1} and bio-stimulant Kelpak SL @ 2.0 dm^3 ha^{-1} (T_3), herbicide Sencor 70 WG @ 1.0 kg ha^{-1} (T_4), Herbicide Sencor 70 WG @ 1.0 kg ha^{-1} and bio-stimulant Asahi SL @ 1.0 dm^3 ha^{-1} (T_5). They reported that, higher gross returns, despite the largest cost was obtained on T_5 from which the highest yields were harvested is obtained over all other treatments.

Arioli *et al*. (2021) a multi-year study was conducted during 2012-17 at Australian Viticulture Industry to evaluate effect of sea weed extract application on wine grape yield in Australia. The study where field trials were conducted in commercial vineyards on large areas (2–70 ha) across five geographically diverse locations and with different grape cultivars, the seaweed extract treatment was applied at 5 or 10 L ha^{-1}, with the number of applications ranging from three to eight, applied to the soil through irrigation water (at a concentration of approximately 1:400) at different phonological stages of the crop during the growing season. They reported that, an analysis of the field trials found the economic effect of using seaweed extract in wine grape production was positive and increased profitability varied for wine grape cultivars over control.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

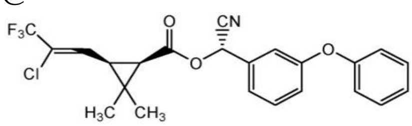
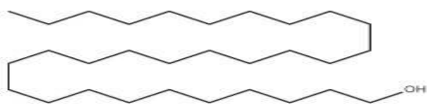
The present study entitled "Effect of humic acid based bio-stimulant on growth, yield and quality of *kharif* rice (*Oryza sativa* L.) under lateritic soils of Konkan" was conducted at Agronomy Farm, College of Agriculture, Dapoli, Dist. Ratnagiri (M.S.) during *Kharif*, 2021. The analytical work was done at research laboratory of Department of Agronomy. The materials used and methodology adopted during the investigation are explained in this chapter.

3.1 Materials Required

3.1.1 Inputs used

The details of inputs used for the experiment conducted during the *kharif* 2021 are given in the Tabe 3.1.

Table 3.1: Inputs used in the experimental plot.

<table>
<tr><td>1. Crop</td><td colspan="2">Rice (Oryza sativa L.)</td></tr>
<tr><td>2. Variety</td><td colspan="2">Ratnagiri-1</td></tr>
<tr><td>3. Seed rate (transplanted rice)</td><td colspan="2">40 kg ha^{-1}</td></tr>
<tr><td>4. Recommended dose of fertilizer</td><td colspan="2">100: 50: 50 (N: P: K) kg ha^{-1}</td></tr>
<tr><td colspan="3">5. Fertilizers applied</td></tr>
<tr><td>a) Urea</td><td colspan="2">217 kg ha^{-1}</td></tr>
<tr><td>b) Single super phosphate</td><td colspan="2">312 kg ha^{-1}</td></tr>
<tr><td>c) Muriate of potash</td><td colspan="2">83 kg ha^{-1}</td></tr>
<tr><td>6. FYM applied</td><td colspan="2">8.5 tonne ha^{-1}</td></tr>
<tr><td rowspan="2">7. Chemicals and bio-stimulants used</td><td colspan="2">A) Lambda-cyhalothrin 5% EC @ 1.5 l ha^{-1}
B) Bio-stimulants: i) Laatu
ii) Tricontanol 0.05% GR @ 25 kg ha^{-1}</td></tr>
<tr><td>Lambda-cyhalothrin 5% EC @ 1.5 l ha^{-1}

</td><td>Tricontanol 0.05% GR @ 25 kg ha^{-1}

</td></tr>
</table>

A) Varietal characteristics (Ratnagiri 1)

Morphological and physiological characteristics of the variety Ratnagiri 1 are given in Table 3.2.

Table 3.2: Morphological and Physiological characteristics of the variety Ratnagiri 1

Sr. No.	Characteristics	
1	Days to 50% flowering*	80-85
2	Maturity duration*	110-115
3	Plant height(cm)*	100-105
4	Grain type	LB
5	Test weight (g)*	29.30
6	Panicle length (cm)*	22.1
7	Panicle axis	Straight
8	Spikelets per panicle*	144
9	Plant habit	Compact
10	Seedling foliage colour*	Green
11	Basal leaf sheath colour*	Light purple
12	Leaf colour*	Green
13	Leaf pigmentation*	Absent
14	Leaf angle	Erect
15	Flag leaf angle	Erect
16	Leaf sheath colour*	Green
17	Collar colour*	Yellowish
18	Legulecolour*	Green
19	Legule shape	Two cleft
20	Auricle colour*	Colourless
21	Internode colour*	Green
22	Culm attitude	Erect
23	Stigma colour	White
24	Panicle type	Compact
25	Secondary branching*	Strong
26	Awning*	Awnless
27	Apiculus colour*	Straw
28	Lemma and Paleacolour*	Straw
29	Seed colour*	Straw
30	Seed length (mm)*	8.95
31	Seed width (mm)*	2.81
32	Decorticated grain length (mm)*	7.50
33	Decorticated grain width (mm)*	2.60
34	L : B ratio*	2.90
35	Decorticated grain colour	White
36	Decorticated grain aroma*	Absent
37	Mean grain yield (t/ha)*	4.7-5.0 t/ha
38	Potential yields (t/ha)*	10.0-10.5 t/ha
* Characters may be influenced by different environmental conditions		

The rice variety i.e. Ratnagiri-1 is cross between IR-8 and Ratnagiri-24 which was released during 1986. It is suitable to grow in konkan region of Maharashtra. The grain type is of long bold type and having yield potential of 4.7 to 5.0 t ha^{-1}. It is moderately resistant to leaf blast and bacterial leaf blight diseases.

B) Soil characteristics of experimental site

The techniques used in the determination of the various properties of the soil are given in Table 3.3.

Table 3.3: Initial physical and chemical properties of the soil from experimental plot.

Soil component analyzed	values	Methods used
A) Physical properties		
i) Particle size distribution		
➢ Sand (%)	57.0	Bouyoucos Hydrometer Method (Piper, 1956)
➢ Silt (%)	24.5	
➢ Clay (%)	18.5	
ii) Textural class	Sandy loam	Using textural triangle given by ISSS (Davis and Bennett, 1927)
B) Chemical properties		
➢ Soil pH (1:2.5)	6.28	Potentiometric method (Jackson, 1973)
➢ Ec (dS m^{-1})	0.10	Potentiometric method (Jackson, 1973)
➢ Organic carbon (g kg^{-1})	13.8	Walkely and Black oxidation method (Black,1965)
➢ Available N (kg ha^{-1})	242.3	Alkaline permanganate method (Subbaih and Asija, 1965)
➢ Available P_2O_5 (kg ha^{-1})	13.3	Bray's method (Bray's and Kurtz, 1945)
➢ Available K_2O (kg ha^{-1})	238.2	Flame photometer (Jackson, 1973)

The plot was well drained. The soil sample was collected from the top 0 to 30 cm layer with the help of screw auger and hole auger before the layout of an experiment. Soil thus collected was air dried and preserved properly in the aluminum boxes. The samples were then analyzed for the various physical and chemical properties. The soil analysis (Table 3.3) indicated that the experimental plot was sandy loam in texture, medium in available nitrogen (242.3 kg ha^{-1}) ,phosphorus (13.3 kg ha^{-1}) and potassium (238.2 kg ha^{-1}), very high in organic carbon (13.8 g kg^{-1}), acidic in reaction (pH 6.28) and 0.10 dS m^{-1} electrical conductivity.

3.1.2 Machines/ equipments/ instruments used

- Mould bold plough
- Rotovator
- Clod crusher
- Power tiller/ tractor
- Land leveller
- Vaibhav sickle
- Tractor and Trolley

3.2 Methods Adopted

The field experiment was conducted at Instructional Farm, Department of Agronomy, College of Agriculture Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during *kharif*, 2021. The experiment was laid out in plot No. 08. The site was selected on the basis of suitability of soil for growing early varieties of rice. Topography of the plot was fairly uniform with a slight gradient towards the west.

3.2.1 Research design details

a) Experimental design : Randomized block design (RBD)
b) No. of replications : Three
c) Number of treatments : Seven
d) Gross Plot size : 5.0 m ×3.00 m
e) Net plot size : 4.7 m ×2.6 m
f) Total plots : 21
g) Spacing : 20 × 15 cm
h) Season : *Kharif*, 2021
i) R.D.F : 100:50:50 N: P: K kg ha^{-1}

3.2.1.1 Treatments details along with the symbols used.

The details of the treatments along with the symbols which are regularly used in this research work are mentioned in the Table 3.4.

The experiment consists of seven treatments and replicated three times *viz*., T_1: Bio-stimulant @ 2.5 kg ha^{-1} (Laatu), T_2: Bio-stimulant @ 5.0 kg ha^{-1} (Laatu), T_3: Bio-stimulant @ 10.0 kg ha^{-1} (Laatu), T_4: Bio-stimulant @ 15.0 kg ha^{-1} (Laatu), T_5: Bio-stimulant @ 20.0 kg ha^{-1} (Laatu), T_6: Tricontanol bio-stimulant @ 0.05 per cent GR @ 25 kg ha^{-1} and T_7: Untreated control treatment.

Table 3.4: Treatment details along with their symbols

Symbols	Treatments
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)
T_6	Tricontanol bio-stimulant @ 0.05% GR @ 25 kg ha^{-1}
T_7	Untreated control.
Method of application: Broadcasting (Two applications) **1st Application** : 2-3 weeks after transplanting **2nd Application** : At panicle initiation stage.	
Note: Bio-stimulant made from humic acid, vitamins and fermented product.	

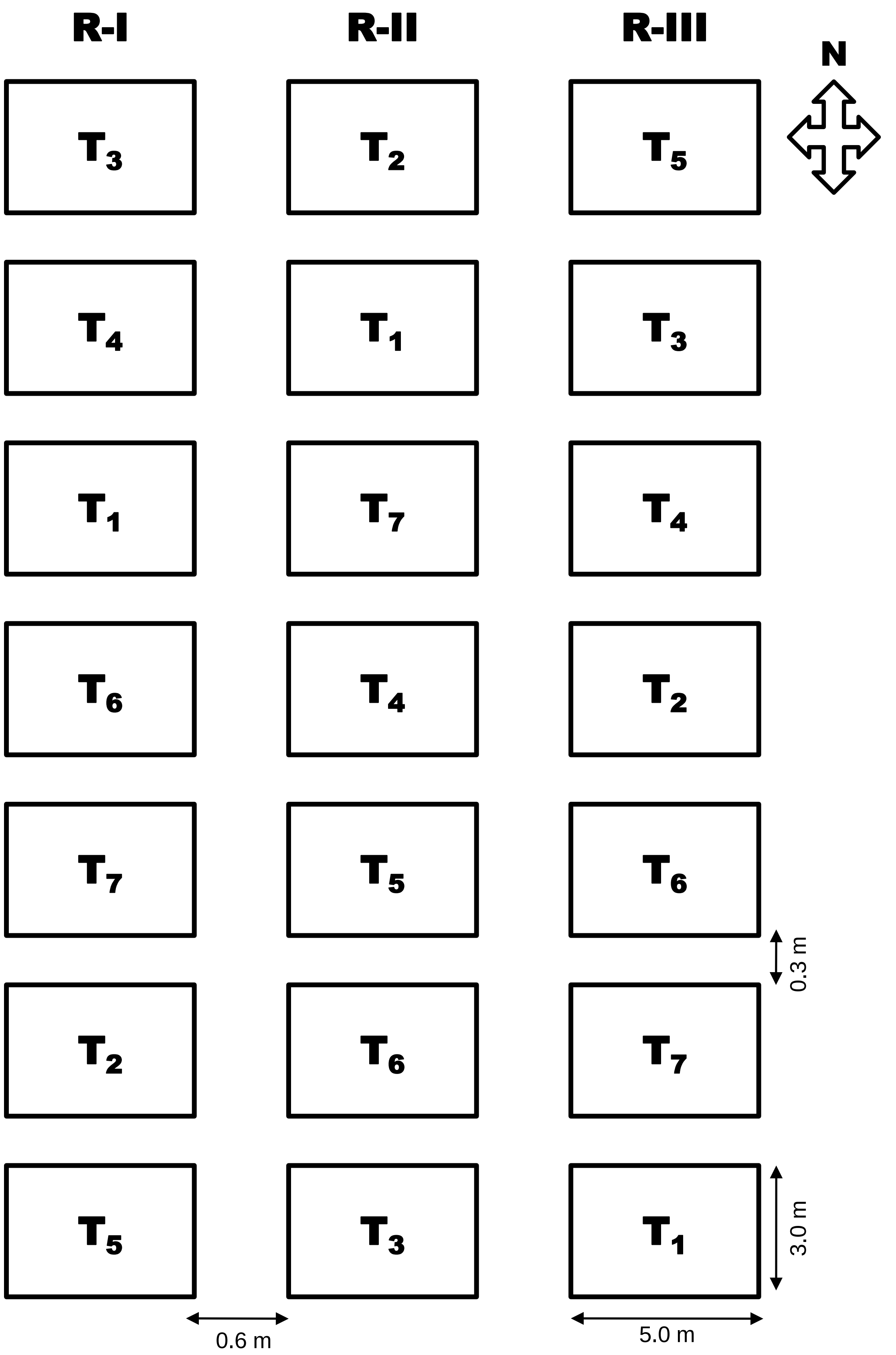


Fig. 3.1 Lay out of the experimental field

Plate No.1: General view of plot

3.2.2 Agro-climatic observations

The meteorological data recorded for the period from 12.06.2021 to 08.10.2021 is shown in the Table 3.5 and graphically represented in Figure 3.2.

Table 3.5: Meteorological observations during the crop growth period

MW	Period (12.06.2021 To 08.10.2021)	Temperature (°C)		Mean relative humidity (per cent)		Rainfall (mm)	RD	Sunshine (hrs/day)
		Tmax.	Tmin.	RH-I	RH-II			
24	11.06 - 17.06	28.3	22.3	96	88	581.6	7	1
25	18.06 - 24.06	29.7	22.6	93	86	332.6	7	2.2
26	25.06 - 01.07	29.1	22.6	96	86	197	7	1
27	02.07 - 08.07	30.9	24	92	81	57.4	3	5.7
28	09.07 - 15.07	27.6	22.5	98	96	695	7	0.1
29	16.07 - 22.07	27.1	22.4	98	97	970.2	7	0
30	23.07 - 29.07	28.4	23.4	93	89	164.8	7	1.8
31	30.07 - 05.08	28.3	23.2	94	86	89.8	7	0.9
32	06.08 - 12.08	29.5	22.8	96	82	73.3	5	3.4
33	13.08 - 19.08	28.4	21.7	95	86	178.8	7	1
34	20.08 - 26.08	29.1	21.8	96	79	109.8	3	4.2
35	27.08 - 02.09	28.8	21.9	96	83	74.2	6	3.7
36	03.09 - 09.09	28.5	22.1	98	89	598.2	7	1.6
37	10.09 - 16.09	28.5	23	96	86	238.4	6	3
38	17.09 - 23.09	28.8	22.3	96	88	224.9	6	4.8
39	24.09 - 30.09	29.1	22	96	83	120.6	6	3.2
40	01.10 - 07.10	31.7	22.4	94	74	14.4	2	6.6
41	08.10 - 14.10	31.6	22	93	76	13	2	7.3
Total / Average						**4734**	**102**	**2.86**

From the weather data (Table 3.5) it was observed that, the total rain fall received 4734 mm in 102 rainy days during the crop period of field trial and mean rainfall of the meteorological week was 263.0 mm. The intensity of rain fall varies from one meteorological week to other; higher intensity recorded in 28th, 29th, 36th to 24th MW. The relative humidity also played an important role in crop growth and development; it was ranged between 92 to 96per cent morning and evening during the cropping period. The main weather element which affected more in growth, development, yield attributes and final yield of paddy that is maximum and minimum temperature; the minimum temperature was varied from 21.7 °C to 23.4 °C while maximum temperature ranged between 27.1 °C to 31.7 °C. During the cropping season the bright sunshine hours was recorded in the range of 0 to 7.3 in the whole cropping period. The climate was generally optimum for better crop establishment and growth and the crop period was between 12.06.2021 to 08.10.2021

3.2.3 Details of field operations

Details of cultural operations which are carried out during the course of investigation are presented in the Table 3.6.

a) Raising seedlings on nursery bed

The experimental field was ploughed and subsequently brought under fine tilth with the help of tractor drawn rotavator and planker. The raised bed of 10 m length, 1 m breadth and 10 cm height were prepared for sowing of Ratnagiri-1 variety. Sowing is done on the beds with at most care.

b) Preparatory tillage

The experimental site was ploughed with tractor drawn plough. After showers of monsoon, a day before transplantation of each treatment, the field was puddled with a tractor and leveled by a plank simultaneously. A thin film of water was maintained continuously from date of puddling to transplantation and made ready for the layout.

c) Layout of field

Layout of experiment was done as per the randomized block design. The plot consisted of three replications each of which consisted of seven treatments. The gap between replications is 60 cm and the gap between treatments is 30 cm.

d) Transplanting of seedlings

21-day old healthy and well nurtured seedlings were pulled out from the nursery beds and transplanted on the same day by adopting 20 x 15 cm spacing with 2 to 3 seedlings $hill^{-1}$. Transplanting was done as per sowing treatment and skilled labours were used for the transplanting of rice crop. At most care was taken while transplanting so that, fixed spacing between plants and rows is maintained.

e) Fertilizer application

A common dose of 50 kg ha^{-1} of P_2O_5 and K_2O was applied through single super phosphate and muriate of potash fertilizers respectively, as a basal dose before transplanting of each planting. Besides, 100 kg $ha^{-1}$of N, in the form of urea was applied in three splits- 50 per cent at transplanting, 25 per cent at tillering stage and remaining 25 per cent at flowering stage of concerned variety.

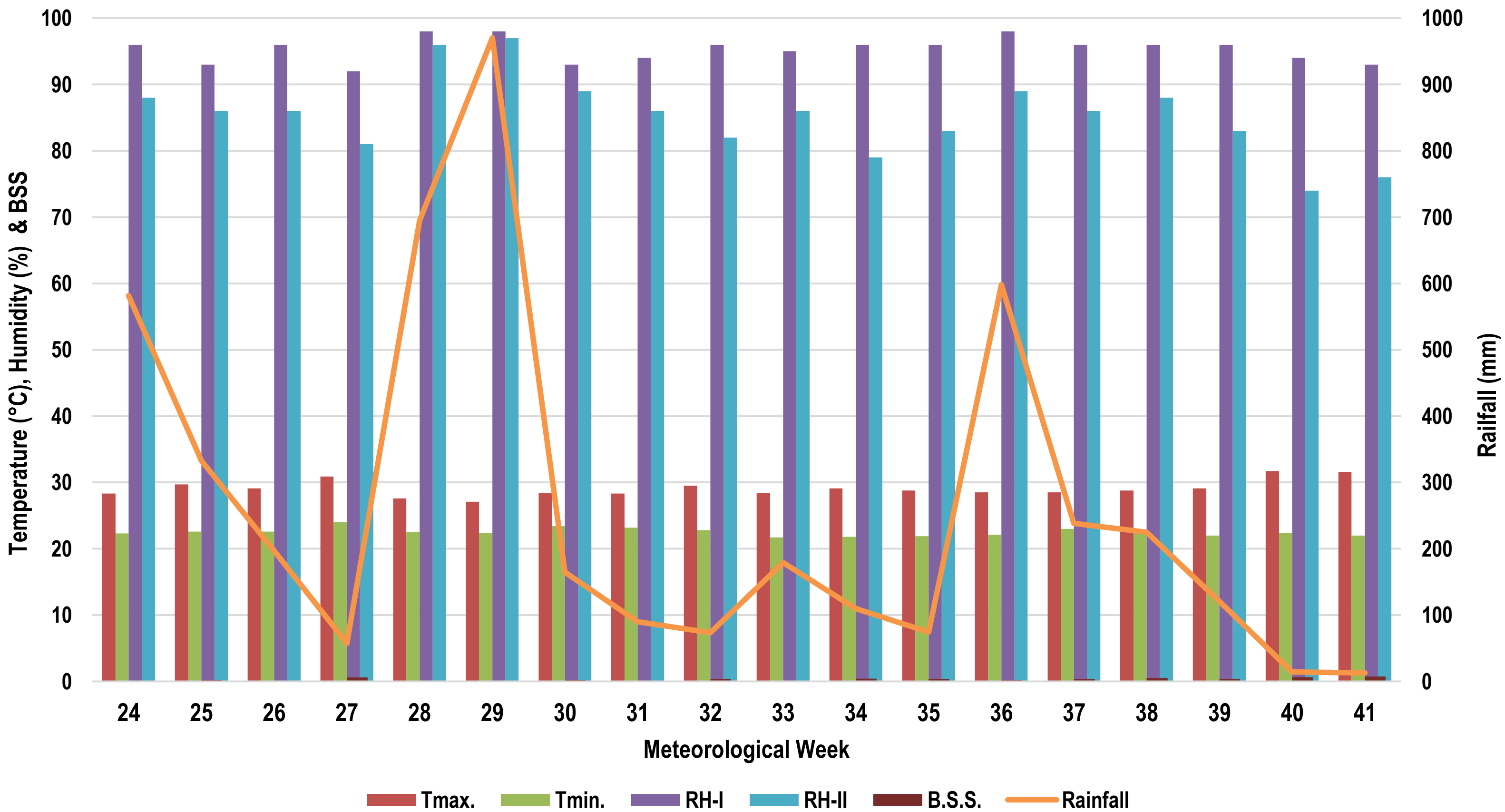


Fig. 3.2: Meteorological observations

Table 3.6: Schedule of cultural operations carried out in the experimental plot during *Kharif* season of 2021.

Sr. No	Field operations	Frequency	Date of operation.
A.	**Preparatory tillage (Preparation of nursery)**		
	a. Tractor ploughing.	1	25.05.2021
	b. Harrowing	1	27.05.2021
	c. Clod crushing by tractor drawn rotavator.	1	27.05.2021
	d. Stubble picking and preparation of nursery beds.	1	31.05.2021
	e. Preparation of nursery beds	1	03.06.2021
	f. Application of FYM	1	11.06.2021
	g. Application of fertilizers to nursery beds	1	12.06.2021
	h. Sowing of seeds in beds.	1	12.06.2021
B.	**Preparation of experimental field**		
	a. Tractor ploughing.	1	22.06.2021
	b. Harrowing	1	24.06.2021
	c. Clod crushing by tractor drawn rotavator.	1	30.06.2021
	d. Levelling.	1	01.07.2021
	e. Layout of experiment	1	02.07.2021
	f. Puddling and planking with tractor.	1	04.07.2021
C.	**Transplanting**		05.07.2021
D.	**Fertilizer application**		
	a) At the time of transplanting.		
	1) Full dose of phosphate and potash fertilizer	1	05.07.2021
	2) Basal dose of nitrogen (50% of RDF).	1	05.07.2021
	b) Second dose of nitrogen (25% of RDF) (30 DAT)	1	06.08.2021
	c) Third dose of nitrogen (25% of RDF) (60 DAT)	1	05.09.2021
E.	**Application of bio-stimulants**		
	i) 1st application	1	15.07.2021
	ii) 2nd application	1	18.08.2021
F.	**Gap filling**	1	25.07.2021
G.	**Plant protection measures**		
	a. Lambda-cyhalothrin 5% EC @ 1.5 l ha^{-1}	1	08.08.2021
H.	**Intercultural operations**		
	Hand weeding	3	
	a. 28th Met. Week sowing.	1	10.07.2021
	b. 30th Met. Week sowing.	1	25.07.2021
	c. 32th Met. Week sowing.	1	08.08.2021
I.	**Harvesting and Threshing**		
	a. Date of harvesting	1	08.10.2021
	b. Drying of grains and Drying of straw	1	09.10.2021 to 18.10.2021
	c. Threshing and winnowing	1	20.10.2021
	d. Weighing of grains and straw	1	20.10.2021

f) Application of bio-stimulant

The bio-stimulants which are mentioned in Table 3.4 are applied to the soil by broadcasting. The bio-stimulant (Laatu) and well dried sand which is collected from water stream are thoroughly mixed and accordingly broadcasted in treatments. The care is taken so that there is no wash away of applied bio-stimulant by excessive rainfall by constructing small V-shaped bunds.

During entire crop growth period, the bio-stimulant applied twice. First application at two to three weeks of transplanting whereas second at the stage of panicle initiation of rice crop.

g) Weed management

Experimental plots were kept weed free throughout the crop growth by hand weeding and by mechanical weeding implements.

h) Plant protection

Since the seeds were treated with Thiram @ 3 g kg^{-1} before sowing the crop was free from disease during the early growing period. Crab attack was observed at the early growth stage which was controlled very early by Poison bait of Phorate @ 10 kg ha^{-1} placed in crab holes and another sucking pest was observed at 30-35 days after sowing which was controlled by Lambda-cyhalothrin @ 0.6 ml $L^{-1}$of water.

i) Harvesting and threshing

The crop was harvested soon after attaining physiological maturity which has been decided upon having a constant watch over crop from few days before probable harvest time and testing whether the entire panicle attained the hard dough stage and the straw colour was turn to yellow.

Harvesting was done with the Vaibhav sickle. Initially border rows of plants were cut close to the ground and kept for sun drying. Later the samples hills (harvest samples) and net plot hills were harvested separately and bundled. The post-harvest observations were recorded from the sample hills. The hills from the net plot area were threshed with sickle and after winnowing fresh grain weight were recorded. After sun drying, the net plot grain yield was recorded treatment-wise and reported in kg ha^{-1}.

3.2.3.1 Cropping history of the experimental Plot

The cropping sequence followed on the experiment plot for previous four years of the experimentation up to completion of the experiment is presented in the Table 3.7.

Table 3.7: Cropping history of the experimental plot

Year	Season	
	Kharif	***Rabi***
2017-2018	Paddy	Green gram
2018-2019	Paddy	Cowpea
2019-2020	Paddy	Cowpea
2020-2021	Paddy	Cowpea
2021-2022	Experimental crop- Paddy	-

3.2.4 Variables under study

The experiment consisted of seven treatments and replicated thrice. In this experiment varied concentrations or doses of bio-stimulant was applied. A plant bio-stimulant is any substance or microorganism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrients content. In this experiment a *humic* acid based bio-stimulant was used (commercial name- Laatu). The application with their symbols is given in the Table 3.4 of this section.

3.2.5 Observations recorded

3.2.5.1 Growth studies of rice crop

a. Plant population

Plant population count was recorded from respective plots at 20 DAT and at harvest stage of rice crop for each treatment from net plot.

b. Height of plant

Plant height was measured using one meter scale from the base of the plant i.e. from ground level up to the tip of the last fully opened leaf from the tagged plants at 30, 60, 90 DAT and at harvest.

c. Number of functional leaves hill^{-1}

The number of functional leaves produced hill^{-1} was recorded periodically from each net plot from five tagged observational plants and the average was worked out at 30, 60, 90 DAT and at harvest

d. Number of tillers hill^{-1}

The total number of tillers produced hill^{-1} was recorded periodically from each net plot from the five hills and average of five hills was worked out at 30, 60, 90 DAT and at harvest.

e. Dry matter per hill.

Dry matter produced was weighed after oven drying the samples taken from respective plots from guard rows of the plot which were grown outside net plot but inside gross plot at 30, 60, 90 DAT and at harvest.

f. Days to 50% flowering

Number of days taken by each treatment for at least 50 per cent of the plants to flower was recorded

g. Days to maturity

Average number of days taken by plants of each treatment to reach physiological maturity was recorded.

3.2.5.2 Post harvest studies in rice.

a. Number of panicle hill^{-1}

From five selected observational plant hills, the number of panicle hill^{-1} were counted and average was worked out.

b. Number of grains panicle^{-1}

The number of filled grains was counted from all the panicles from the five observation hills and average number was worked out.

c. Length of panicle (cm)

Length of all panicles from the five tagged hills was measured from the base of whorl i.e. peduncle upto the tip of the panicle and the average was worked out.

d. 1000 grain weight or Test weight (g)

After the harvest of the rice crop 1000 grains were counted and weight was recorded as per the treatments from representative samples.

e. Grain yield (kg ha^{-1})

The grain yield obtained after threshing and drying the produce from each net plot and weight was converted into kg ha^{-1}.

f. Straw yield (kg ha^{-1})

The straw yield was obtained by weighing air dried straw which remained after threshing from each net plot. The yield was converted on hectare basis.

g. Harvest index (%)

Harvest index is calculated by dividing economic yield with the biological yield. Here rice grain yield is economic yield whereas both grain and straw yield constitutes biological yield. It is usually expressed in per cent.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.2.5.3 Soil and plant sample analysis

A) Soil analysis

Initial soil samples were collected from the field before preparatory tillage operation, similarly, after harvest of crop soil samples were collected from respective net plot. The samples were air dried and properly sieved. Soil analysis of initial and after harvest soil sample for chemical properties was undertaken by appropriate methods.

B) Plant analysis

The sampled plants from each net plot were harvested and used for chemical analysis of the grain and straw. The dried samples were ground to fine powder and kept in the properly labeled bags and used for estimation of total nitrogen by Micro-kjeldhal method (Tandon, 1993), total phosphorous was estimated by Ammonium molybdo-vanadate method (Tandon, 1993) and total potassium was determined by flame photometer method (Tandon, 1993).

a. Nitrogen content in grain and straw (per cent)

Nitrogen content in rice grain and straw was determined by modified Microkjeldahl's method (Piper, 1956) and it is expressed in per cent.

b. Nitrogen uptake in grain and straw (kg ha^{-1})

Nitrogen uptake in the grains and straw was calculated by multiplying the grain and straw per hectare at harvest from the respective percentage figure. It is given as below-

$$\text{Nitrogen uptake in grain (kg ha}^{-1}\text{)} = \frac{\text{Nitrogen content in grain (\%)}}{100} \times \text{Grain yield (kg ha}^{-1}\text{)}$$

$$\text{Nitrogen uptake in straw (kg ha}^{-1}\text{)} = \frac{\text{Nitrogen content in straw (\%)}}{100} \times \text{Straw yield (kg ha}^{-1}\text{)}$$

c. Total nitrogen uptake (kg ha^{-1})

This was calculated by addition of nitrogen accumulation in grain and straw recorded under the individual treatment.

$$\text{Total nitrogen uptake (kg ha}^{-1}\text{)} = \text{Nitrogen uptake in grain (kg ha}^{-1}\text{)} + \text{Nitrogen uptake in straw (kg ha}^{-1}\text{)}$$

d. Phosphorus content in grain and straw (per cent)

Phosphorus content in grain and straw was determined by Calorimetric method and it is expressed in per cent.

e. Phosphorus uptake in grain and straw (kg ha^{-1})

It was determined separately from grain and straw from their respective percentage figure with the help of grain and straw yield per hectare respectively and is given as given below.

$$\text{Phosphorus uptake in grain (kg ha}^{-1}\text{)} = \frac{\text{Phosphorus content in grain (\%)}}{100} \times \text{Grain yield (kg ha}^{-1}\text{)}$$

$$\text{Phosphorus uptake in straw (kg ha}^{-1}\text{)} = \frac{\text{Phosphorus content in straw (\%)}}{100} \times \text{Straw yield (kg ha}^{-1}\text{)}$$

f. Total phosphorus uptake (kg ha^{-1})

It was calculated by addition of phosphorus uptake in the grain and straw of respective treatments.

$$\text{Total phosphorous uptake (kg ha}^{-1}\text{)} = \text{Phosphorous uptake in grain (kg ha}^{-1}\text{)} + \text{Phosphorous uptake in straw (kg ha}^{-1}\text{)}$$

g. Potassium content in grain and straw (per cent)

Potassium content in grain and straw determined with the help of Flame photometer and it is expressed in per cent.

h. Potassium accumulation in grain and straw (kg ha^{-1})

It was calculated by multiplying grain and straw yield with respective percentage figure and is give as below.

$$\text{Potassium uptake in grain (kg ha}^{-1}) = \frac{\text{Potassium content in grain (\%)}}{100} \times \text{Grain yield (kg ha}^{-1})$$

$$\text{Potassium uptake in straw (kg ha}^{-1}) = \frac{\text{Potassium content in straw (\%)}}{100} \times \text{Straw yield (kg ha}^{-1})$$

i. Total potassium uptake (kg ha^{-1})

It was calculated by addition of potassium accumulation in grain and straw of respective treatments and it is as given below.

$$\text{Total potassium uptake (kg ha}^{-1}) = \text{Potassium uptake in grain (kg ha}^{-1}) + \text{Potassium uptake in straw (kg ha}^{-1})$$

j. Protein content estimation

Protein content can be estimated multiplying the nitrogen content in grain by conversion factor for rice i.e. 5.95 (Mariotti., *et al* 2019). and it is expressed in per cent (%). It is given by following formula.

Protein content (%) = N content of the grain (%) × 5.95

3.2.5.4 Economics of treatments

On the basis of the results obtained from the field experiments the economics of different treatments are worked out. The gross returns in rupees hectare^{-1} are worked out on the basis of grain and straw yield of rice from the respective treatment. For that the prevailing market prices of grain and straw were considered. Similarly, the cost of cultivation of the crop under the individual treatment was worked out by taking into account the cost of all inputs and the cost incurred for all the operations from field preparations to harvest of the rice crop. The net income was worked out by deducting the cost of cultivation from the gross returns. And the B:C ratio for each treatment was worked out by dividing gross returns by cost of cultivation. And B:C ratio calculated on input cost as well as total cost are presented (Table 4.18)

a. Gross returns (Rs. ha^{-1})

The gross returns ha^{-1} was worked out on the basis of grain and straw yield of rice obtained under different treatment. It was worked out considering the price prevailing in the market during the year 2021 i.e. MSP price. It is given as below.

Gross returns = (Grain yield × price of the grain) + (Straw yield × price of the grain)

Table 3.8: Observations recorded with number of frequencies.

Sr. No.	Particulars	Freq.	Days after transplanting (DAT)	Sample size
A.	**Pre- harvest studies**			
1.	Plant population	2	20 DAT and at harvest	All plants in each net plot
2.	Plant height (cm)	4	30, 60, 90 DAT and at harvest	5 plants
3.	No. of functional leaves hill^{-1}	4	30, 60, 90 DAT and at harvest	5 plants
4.	No. of tillers hill^{-1}	4	30, 60, 90 DAT and at harvest	5 plants
5.	Dry matter per hill^{-1} (g)	4	30, 60, 90 DAT and at harvest	5 plants
6.	Days of 50 % flowering	1	-	Whole plot
7.	Days to physiological maturity	1	-	Whole plot
B.	**Post harvest studies**			
1.	No. of panicles hill^{-1}	1	At harvest	5 plants
2.	No. of grains panicle^{-1}	1	At harvest	5 plants
3.	Panicle length (cm)	1	At harvest	5 plants
4.	1000 grain weight (g)	1	At harvest	5 plants
5.	Grain yield (kg ha^{-1})	1	At harvest	5 plants
6.	Straw yield (kg ha^{-1})	1	At harvest	5 plants
7.	Harvest index (%)	1	At harvest	5 plants
C.	**Chemical analysis**			
i)	**Soil analysis**			
1.	pH	2	Initial and at harvest	
2.	Electrical conductivity	2	Initial and at harvest	
3.	Organic carbon(g/kg)	2	Initial and at harvest	
4.	Available N, P and K in soil (kg ha^{-1})	2	Initial and at harvest	
ii)	**Plant analysis**			
1.	N, P and K content in grain and straw (%)	1	After harvest	
2.	N, P and K uptake in grain and straw (kg ha^{-1})	1	After harvest	
iii)	**Quality analysis**			
1.	Protein content in grain (%)	1	After harvest	
D.	**Economic studies**			
1.	Cost of cultivation (Rs. ha^{-1})			
2.	Gross return (Rs. ha^{-1})			
3.	Net return (Rs. ha^{-1})			
4.	Benefit cost ratio			

Tabe 3.9 Methods used for soil and plant analysis

Sr. No.	Properties	Method	Reference
A) Soil analysis			
1.	Texture and textural class	Bouycos hydrometer method	Piper (1966)
2.	Soil reaction (pH)	Potentiometric (1:2.5)	Jakson (1973)
3.	Electrical conductivity	Potentiometric (1:2.5)	Jakson (1973)
4.	Organic carbon	Walkley and Black wet oxidation method	Black (1965)
5.	Available nitrogen (kg ha^{-1})	Alkaline permanganate method	Subbaiah and Asija (1956)
6.	Available phosphorus (kg ha^{-1})	Bray's No. 1 method (0.03 N NH_4F + 0.025 N HCL)	Bray and Kurtz (1945)
7.	Available potassium (kg ha^{-1})	Neutral normal NH_4OAc-extractable by Flame photometry	Jackson (1973)
B) Plant and grain analysis			
1.	Nitrogen content and uptake	Micro- Kjeldahl method	Tandon (1993)
2.	Phosphorous content and uptake	Vanado-molybdate yellow colour method	Tandon (1993)
3.	Potassium content and uptake	Flame photo-metry	Tandon (1993)
C) Quality Analysis (Grain)			
1.	Protein content in rice grain	Micro- Kjeldahl method	Tandon (1993)

b. Cost of cultivation (Rs. ha^{-1})

The cost of cultivation of per hectare was calculated for every treatment considering the current charges of agricultural operations including Labor charges, market price of inputs involved, rental value of the land, depreciation cost, machinery charges and plant protection costs, interest on working capital etc.

c. Net returns (Rs. ha^{-1})

The net returns ha^{-1}were worked out for individual treatment by deducting the total cost of cultivation of each treatment from gross returns of the respective treatment. It is given by the following formula

Net returns = Gross returns – Total cost of cultivation

d. Benefit cost ratio (B:C ratio)

The benefit cost ratio of single treatment was worked out by dividing the gross returns by the cost of cultivation of each treatment and B: C ratio is a unit-less quantity.

$$\text{Benefit cost ratio} = \frac{\text{Gross returns}}{\text{Cost of cultivation}}$$

3.3 Sampling techniques

Five representative plants were selected from the net plot area for recording periodic biometric observations and no plants were selected from the border rows. The growth observations *viz.,* plant height, number of functional leaves per hill, number of tillers per hill, dry matter production per hill were recorded from these five selected plants at 30, 60, 90 DAT and at harvest. For recording the dry matter representative plant samples were randomly selected from the net plot. Further yield attributing characteristics *viz.*, number of panicles per hill, number of grains per panicle, panicle length, 1000 grain weight, grain yield (kg ha^{-1}), straw yield (Kg ha^{-1}) and harvest index were selected from the same five observational plants after crop harvest.

3.4 Statistical analysis or methods

Experimental data were analyzed statistically by applying technique of analysis of variance as applicable in randomized block design. The significance of the treatment difference was tested by table value of 'F' at 5 % level of significance was worked out for comparison and statistical interpretation of significance between treatments mean (Panse and Sukhatme 1967). The results are given in tables and depicted by graphs and figures whenever necessary.

3.5 Place / duration / seasons of experiment

The experiment "Effect of humic acid based bio-stimulant on growth, yield and quality of *kharif,* rice (*Oryza sativa* L.) under lateritic soils of Konkan" was conducted at Agronomy Farm, College of Agriculture, Dapoli, Dist. Ratnagiri (M.S.) during *Kharif,* 2021. The experiment was carried out between May to December i.e. from field preparations in the plot to chemical analysis in the laboratory.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation entitled "Effect of humic-acid based bio-stimulant on growth, yield and quality of *kharif,* rice (*Oryza sativa* L.) under lateritic soils of Konkan" was conducted at Instructional Farm, Department of Agronomy, College of Agriculture Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during *kharif* 2021. The data collected for different parameters and the results obtained for each parameter has been described and discussed separately in following manner.

4.1 Plant population studies

4.2 Crop growth and development studies

4.3 Yield attributing characters

4.4 Yield studies

4.5 Nutrient content and uptake studies

4.6 Available nutrients status of soil (after harvest)

4.7 Soil chemical properties (pH, soil organic carbon and EC)

4.8 Protein content of the rice.

4.9 Economics of rice cultivation.

4.1 Plant population studies

The data pertaining to the effect of different treatments at 20 DAT and at harvest on plant population per net plot of rice are presented in Table 4.1.

During the investigation it was found that, no any significant difference between treatments for plant population of the rice both at 20 DAT and at harvest stage of the rice crop and was unchanged with the application of different levels of bio-stimulant. The general mean population per net plot was found to be 412.48 and 409.43 at 20 DAT and at harvest stage, respectively. The considerable decrease in plant population from 20 DAT to harvest stage of rice may be due to natural and/or man-made damages during intercultural operation *viz*., fertilizer application, bio-stimulant application, weeding etc.

Table 4.1: Plant population per net plot of rice as influenced by different treatments.

Treatments		20 DAT		At harvest	
		Plant population net plot^{-1}	Per cent	Plant population net plot^{-1}	Per cent
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	413.33	97.95	410.00	97.16
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	412.00	97.63	408.33	96.76
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	411.33	97.47	406.33	96.29
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	409.33	97.00	406.33	96.29
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	416.00	98.58	414.33	98.18
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	414.00	98.10	412.00	97.63
T_7	Untreated control.	411.33	97.47	408.67	96.84
S. Em. ±		5.39	-	5.09	-
C. D. at 5 %		N.S.	-	N.S.	-
General mean		412.48	97.74	409.43	97.02

4.2 Crop growth and development studies

The results obtained from different treatments on growth and development parameters *viz*., plant height (cm), number of functional leaves hill^{-1}, number of tillers hill^{-1}, dry matter hill^{-1} (g), days for 50 per cent flowering, days to maturity of rice at various growth stages are presented here.

4.2.1 Plant height (cm)

Data pertaining to the plant height (cm) of rice as influenced by different treatments at various crop growth stages are presented in Table 4.2 and graphically depicted in Figure 4.1.

From the investigation it was found that, at 30 DAT there was no any significant difference among the treatments for plant height. But from 60 DAT, 90 DAT and at harvest the crop has shown significant difference in plant height. At 60 DAT plant height was significantly higher for the application of bio-stimulant @ 20 kg ha^{-1} (78.53 cm) over T_1 and T_7 treatments and significantly shorter plant height observed for untreated or control treatment (T_7) whereas T_2, T_3, T_4 and T_6 treatments were found at par with T_5 treatment.

From the data it was revealed that, at 90 DAT there was significantly higher plant height was observed for the application of bio-stimulant @ 20 kg ha^{-1} (87.92 cm) over T_1, T_2, T_6 and T_7 treatments whereas T_3 and T_4 treatments were found at par with T_5 treatment. Similar trend was observed with respect to harvest stage of rice crop observations. The mean plant height recorded at 30 DAT, 60 DAT, 90 DAT and at harvest stage of the rice crop was 28.64 cm, 72.76 cm, 80.56 cm and 82.21 cm, respectively.

Table 4.2: Plant height (cm) of rice as influenced by different treatments.

Treatments		**Plant height (cm)**			
		30 DAT	**60 DAT**	**90 DAT**	**At harvest**
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	28.22	70.19	75.98	76.48
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	29.31	71.45	77.39	79.34
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	28.34	74.32	84.50	85.70
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	28.6	76.71	86.10	88.01
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	28.86	78.53	87.92	90.20
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	28.73	72.81	79.28	81.41
T_7	Untreated control.	28.44	65.31	72.73	74.10
S. Em. ±		0.98	2.53	2.68	2.83
C. D. at 5 %		N.S.	7.79	8.25	8.72
General mean		28.64	72.76	80.56	82.21

The plant height increased with the increase in the age of the crop and it was found maximum at the time of harvest stage of the rice crop. The rate of enhancement of plant height was found to be slow during early vegetative crop growth period i.e. up to 30 DAT but it later accelerated in height from the 30 DAT to 60 DAT and thereafter rate was slow until harvest of crop irrespective of treatments.

4.2.2. Number of functional leaves $hill^{-1}$

Data pertaining to the number of functional leaves $hill^{-1}$ of rice as influenced by different treatments at various crop growth stages are presented in Table 4.3 and depicted in Figure 4.2.

The number of functional leaves $hill^{-1}$ increased till mid age of the crop and later it showed decreasing trend and it was found maximum at 60 DAT. The rate of enhancement of number of functional leaves $hill^{-1}$ was found to be fast during early vegetative crop growth period i.e. up to 30 DAT and it was accelerated from the 30 DAT to 60 DAT and thereafter number of functional leaves $hill^{-1}$ started showing declining trend at the time of maturity of crop.

The mean number of functional leaves hill^{-1} recorded at 30 DAT, 60 DAT and 90 DAT and at harvest stage by the rice crop was 29.45, 44.36, 43.04 and 30.81, respectively.

Table 4.3: Number of functional leaves hill^{-1} of rice as influenced periodically by different treatments.

Treatments		Functional leaves hill^{-1}			
		30 DAT	**60 DAT**	**90 DAT**	**At harvest**
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	29.25	41.21	40.40	28.74
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	29.69	43.17	41.75	29.49
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	29.01	45.71	45.23	32.70
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	29.45	47.70	46.34	34.50
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	30.00	49.90	48.71	35.60
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	29.77	44.65	42.85	31.30
T_7	Untreated control.	28.99	38.22	36.00	23.30
S. Em. ±		1.02	1.53	1.50	1.06
C. D. at 5 %		N.S.	4.71	4.62	3.28
General mean		29.45	44.36	43.04	30.81

From the present investigation it was found that, at 30 DAT there was no any significant difference among the treatments for functional leaves per hill but from 60 DAT, 90 DAT and at harvest stage the rice crop showed significant difference for number of functional leaves hill^{-1}. At 60 DAT number of functional leaves hill^{-1} were significantly higher for the application of bio-stimulant @ 20 kg ha^{-1} (49.90) treatment over T_1, T_2, T_6 and T_7 treatment and lesser number of functional leaves hill^{-1} for untreated treatment. Whereas application of bio-stimulant @10 kg ha^{-1} and application of bio-stimulant @ 15 kg ha^{-1} were found at par with bio-stimulant @ 20 kg ha^{-1} for number of functional leaves per hill. Similar trend was observed at 90 DAT and at harvest stage of rice crop.

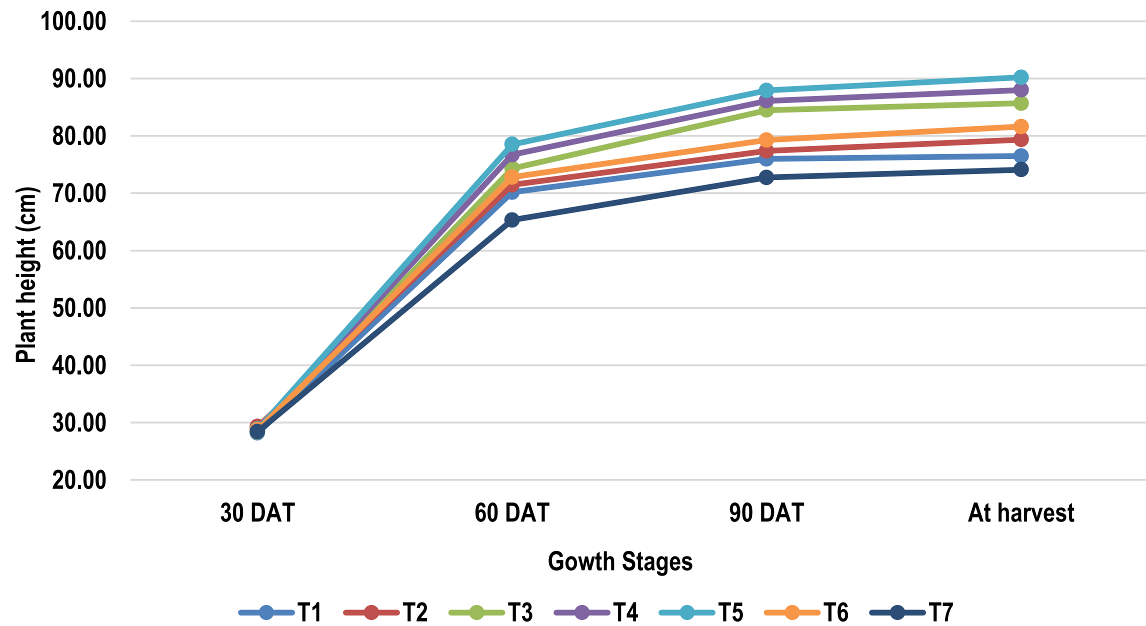


Fig. 4.1: Plant height (cm)

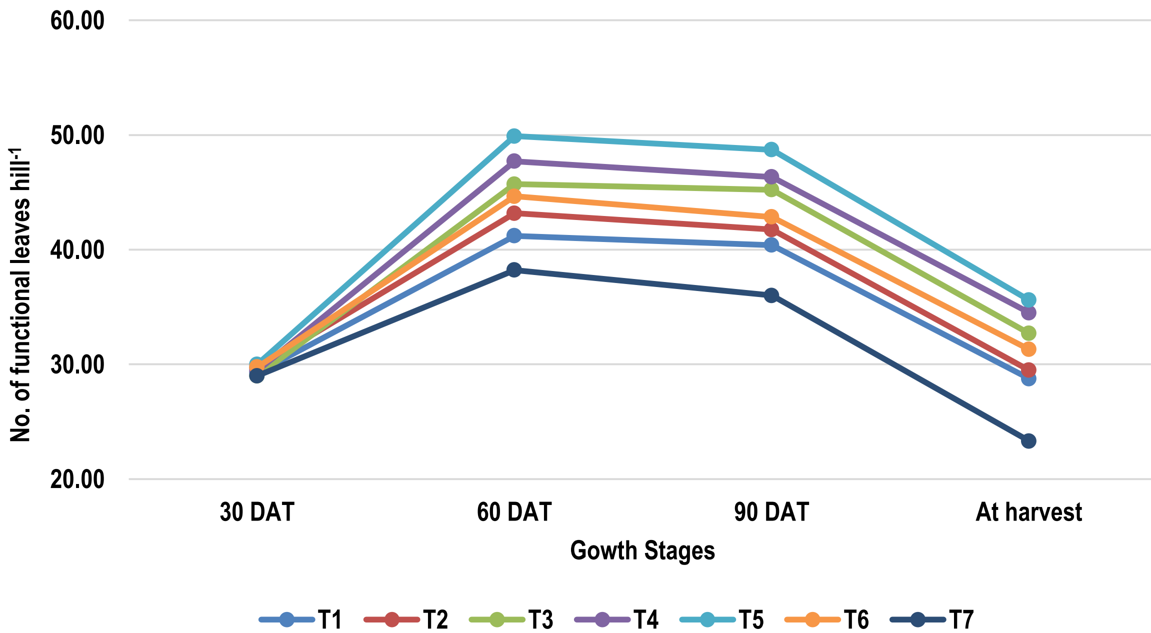


Fig. 4.2: No. of functional leaves hill^{-1}

4.2.3. Number of tillers hill^{-1}

Data pertaining to the number of tillers hill^{-1} of rice as influenced by different treatments at various crop growth stages are presented in Table 4.4 and graphically depicted in Figure 4.3.

Table 4.4: Number of tillers hill^{-1} of rice as influenced periodically by different treatments

Treatments		Number of tillers hill^{-1}			
		30 DAT	**60 DAT**	**90 DAT**	**At harvest**
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	8.75	13.17	14.5	12.12
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	8.82	13.45	14.81	12.21
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	8.85	14.2	15.63	12.95
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	8.63	14.6	16.07	13.12
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	8.43	15.1	16.63	13.45
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	8.59	13.5	14.87	12.33
T_7	Untreated control.	8.5	11.98	13.19	11.24
S. Em. ±		0.26	0.45	0.49	0.35
C. D. at 5 %		N.S.	1.39	1.53	1.08
General mean		8.65	13.71	15.1	12.49

The number of tillers hill^{-1} increased till 90 DAT and later it showed decreasing trend and it was found maximum at 90 DAT. The rate of enhancement of number of tillers hill^{-1} was found to be fast during 30 to 60 DAT and it increased up to 90 DAT started showing declining trend till the time of harvest stage. The mean number of tillers hill^{-1} recorded at 30 DAT, 60 DAT and 90 DAT and at harvest stage of the rice crop was 8.65, 13.71, 15.10 and 12.49 respectively.

From the investigation it was found that, at 30 DAT there was no significant difference among the treatments for number of tillers hill^{-1}. But from 60 DAT, 90 DAT and at harvest the crop has shown significant difference for number of tillers hill^{-1}. At 60 DAT number of tillers hill^{-1} was significantly higher with the application of bio-stimulant @ 20 kg ha^{-1} (T_5) treatment over T_1, T_2, T_6 and T_7 and lower number of tillers hill^{-1} for untreated control treatment (T_7). Whereas application of bio-stimulant @ 10 kg ha^{-1} (T_3) and application of bio-stimulant @ 15 kg ha^{-1} (T_4) were found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Similar trend was observed at 90 DAT and at harvest.

4.2.4. Dry weight hill^{-1} (g)

Data pertaining to the dry matter produced hill^{-1} of rice as influenced by different treatments at various crop growth stages are presented in Table 4.5 and depicted in Figure 4.4.

Table 4.5: Dry matter hill^{-1} (g) of rice as influenced periodically by different treatments

Treatments		Dry matter hill^{-1} (g)			
		30 DAT	60 DAT	90 DAT	At harvest
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	7.59	18.49	33.23	40.63
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	7.81	19.15	34.49	42.14
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	7.62	20.01	36.12	44.09
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	8.04	20.80	37.62	45.89
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	7.91	21.93	39.77	48.48
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	7.82	19.67	35.46	43.31
T_7	Untreated control.	7.34	17.00	29.23	35.83
S. Em. ±		0.27	0.68	1.28	1.54
C. D. at 5 %		N.S.	2.09	3.94	4.73
General mean		7.73	19.58	35.13	42.91

From the investigation it was found that, at 30 DAT there was no significant difference among the treatments for dry matter produced hill^{-1}. But from 60 DAT, 90 DAT and at harvest the crop showed significant difference for dry matter produced hill^{-1}. At 60 DAT dry matter produced hill^{-1} was significantly higher with the application of bio-stimulant @ 20 kg ha^{-1} (21.93 g) treatment over T_1, T_2, T_6 and T_7 and lower dry matter produced hill^{-1} for untreated treatment (T_7). Whereas application of bio-stimulant @10 kgha^{-1} (T_3) and application of bio-stimulant @ 15 kg ha^{-1} (T_4) were found at par with T_5. Similar trend was observed at 90 DAT and at harvest stage of rice crop.

4.2.5. Days to 50 per cent flowering and days to maturity.

Data pertaining to days to 50 per cent flowering and days to maturity of rice as influenced by different treatments are presented in Table 4.6.

From the table it was revealed that, there is no significant difference between the treatments for days to 50 per cent flowering and days to maturity. Average number of days taken for 50 per cent flowering and days to maturity was found to be 78.19 days and 110.67 days respectively.

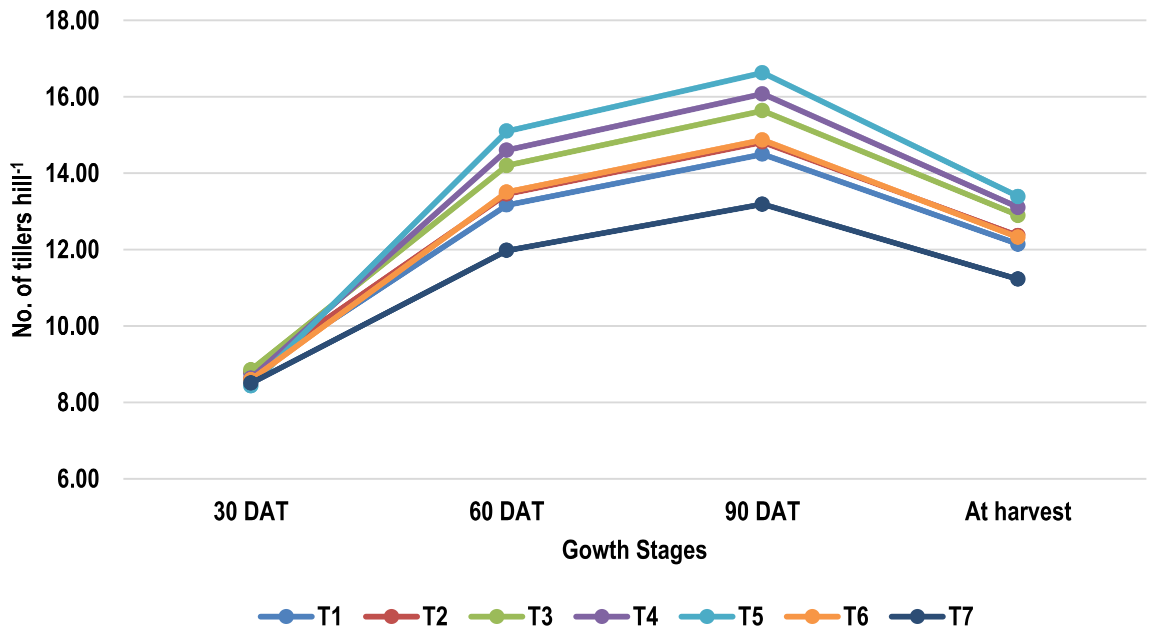


Fig. 4.3: No. of tillers hill^{-1}

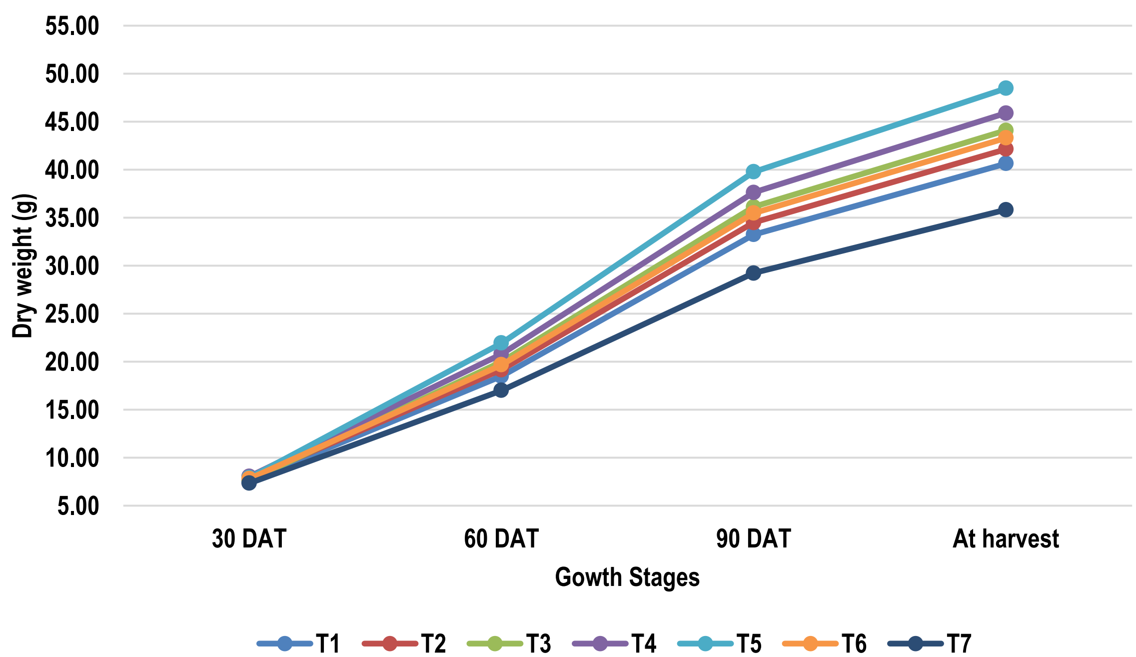


Fig. 4.4: Dry weight (g) hill^{-1}

Table 4.6: Days to 50 per cent flowering and days to physiological maturity of rice as influenced by different treatments

Treatments		Days to 50 per cent flowering	Days to physiological maturity
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	77.00	108.67
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	77.67	110.33
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	78.67	110.33
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	79.00	112.00
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	78.67	113.00
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	79.33	112.33
T_7	Untreated control.	77.00	108.00
S. Em. ±		1.86	2.78
C. D. at 5 %		N.S.	N.S.
General mean		78.19	110.67

4.3 Yield attributing characters

The results obtained during post harvest period from different treatments on yield attributing characters *viz*., number of panicles $hill^{-1}$, number of grains $panicle^{-1}$, panicle length (cm), 1000 grain weight (g) of rice are presented here.

4.3.1 Number of panicles $hill^{-1}$

The data regarding number of panicles $hill^{-1}$ of rice crop as influenced by different treatments are presented in Table 4.7.

The data presented in the table showed that, application of bio-stimulant significantly influenced the number of panicles $hill^{-1}$. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) produced significantly higher number of panicles $hill^{-1}$ (11.83 panicles $hill^{-1}$) over T_1, T_2, T_3, T_6 and T_7 treatments except application of bio-stimulant @ 15 kg ha^{-1} (T_4) which was found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). The average number of panicles per $hill^{-1}$ found to be 10.53.

4.3.2 Number of grains panicle^{-1}

The data in respect of number of grains panicle^{-1} of rice crop as influenced by different treatments are presented in Table 4.7.

The data presented in the table showed that, application of bio-stimulant significantly influenced the number of grains panicle^{-1}. Application of bio-stimulant @ 20 kg ha^{-1} (T_5) produced significantly higher number of grains panicle^{-1} (135.88) over T_1, T_2, T_6 and T_7 treatments whereas application of bio-stimulant @ 10 kg ha^{-1} (T_3) bio-stimulant @ 15 kg ha^{-1} (T_4) found at par with application bio-stimulant @ 20 kg ha^{-1} (T_5). It was noticed that, bio-stimulant induced positive effect on number of grains per panicle. The average number of grains panicle^{-1} found to be 121.72.

Table 4.7: Yield attributing characters *viz.*, number of panicles hill^{-1}, number of grains panicle^{-1}, panicle length (cm), 1000 grain weight (g) of rice crop as influenced by different treatments.

Treatments		No. of panicles hill^{-1}	No. of grains panicle^{-1}	Panicle length (cm)	1000 grain wt. (g)
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	10.09	112.69	21.40	27.9
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	10.19	119.31	21.43	27.9
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	10.52	124.96	22.27	28.8
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	11.05	130.03	23.60	28.6
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	11.83	135.88	24.13	28.8
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	10.31	121.87	21.73	28.2
T_7	Untreated control.	9.75	107.33	20.17	28.7
S. Em. ±		0.36	3.91	0.59	0.55
C. D. at 5 %		1.11	12.05	1.82	N.S.
General mean		10.53	121.72	22.10	28.4

4.3.3 Panicle length (cm)

The data in respect of panicle length of rice crop as influenced by different treatments are presented in Table 4.7.

The data presented in the table showed that, the application of bio-stimulant significantly influenced the length of rice panicle. Application of bio-stimulant @ 20 kg ha^{-1} (T_5) produced significantly higher panicle length (24.13 cm) than rest of the treatments however, it was at par with application of bio-stimulant @ 15 kg ha^{-1}. The average panicle length found to be 22.10 cm.

4.3.4 1000 grain weight (g)

The data regarding 1000 grain weight of rice crop as influenced by different treatments are presented in Table 4.7. The average of 1000 grain weight i.e. test weight found to be 28.4 g.

The data presented in the table revealed that, application of bio-stimulant showed no any significance to 1000 grain weight of the rice crop. Application of bio-stimulant @ 20 kg ha^{-1} (T_5) produced numerically higher 1000 grain weight (26.8 g).

4.4 Yield studies

Yield is the manifestation of yield attributing characteristics (Matsushima, 1976) higher grain yield was influenced mainly by yield attributing characters *viz*., number of panicles hill^{-1}, number of grains panicle^{-1}, panicle length etc. The results obtained during post harvest period from different treatments on yield studies *viz*., grain yield, straw yield and harvest index of rice crop are presented here.

4.4.1 Grain yield (kg ha^{-1})

Data pertaining to the grain yield (kg ha^{-1}) of rice as influenced by different treatments are presented in Table 4.8 and graphically depicted in Figure 4.5. The average grain yield of rice crop found to be 4268.02 kg ha^{-1}.

The data presented in the table showed that, application of bio-stimulant significantly influenced the grain yield. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) produced significantly higher grain yield (4753.33 kg ha^{-1}) over T_1, T_2, T_6 and T_7 treatments and lowest grain yield was found to be with control treatment (T_7) (3640 kg ha^{-1}). Application of bio-stimulant @ 10 kg ha^{-1} (T_3) and bio-stimulant @ 15 kg ha^{-1} (T_4) found at par with application of bio-stimulant @ 20 kg ha^{-1} (T_5).

4.4.2 Straw yield (kg ha^{-1})

Data pertaining to the straw yield (kg ha^{-1}) of rice as influenced by different treatments are presented in Table 4.8 and graphically depicted in Figure 4.5.

The data presented in the table revealed that, application of bio-stimulant significantly influenced the straw yield. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) produced significantly higher straw yield (6156.63 kg ha^{-1}) over T_1, T_2, T_6 and T_7 treatments and significantly lowest straw yield was found to be with control treatment (T_7). Application of bio-stimulant @ 10 kg ha^{-1} (T_3) and bio-stimulant @ 15 kg ha^{-1} (T_4) found at par with application of bio-stimulant @ 20 kg ha^{-1} (T_5) treatment. The average straw yield found to be 5548.00 kg ha^{-1}.

Table 4.8: Yield studies *viz.*, grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index (per cent) as influenced by different treatments.

Treatments		Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	4107.10	5248.41	9355.51	43.86
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	4174.93	5399.78	9574.71	43.59
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	4398.67	5716.49	10115.16	43.51
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	4581.44	5940.05	10521.50	43.54
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	4753.33	6156.63	10909.96	43.56
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	4220.69	5615.31	9836.00	42.94
T_7	Untreated control.	3640.00	4759.36	8399.36	43.37
S. Em. ±		148.10	146.13	201.83	--
C. D. at 5 %		456.33	450.29	621.90	--
General mean		4268.02	5548.00	9816.03	43.48

4.4.3 Harvest index (per cent)

Data pertaining to the harvest index of rice as influenced by different treatments at various crop growth stages are presented in Table 4.8 and graphically depicted in Figure 4.5.

The data presented in the table showed that, the numerically higher harvest index recorded on T_1 treatment i.e. application of bio-stimulant @ 2.5 kg ha^{-1}. The average harvest index of the rice crop was 43.48 per cent.

4.5 Nutrient (N, P_2O_5 and K_2O) content and uptake studies.

Nutrient content and uptake of major nutrients *viz.*, nitrogen (N), phosphorous (P_2O_5) and potassium (K_2O) were recorded in grain and straw of rice and total uptake by the crop at harvest are presented in Tables 4.9, 4.10 and 4.11.

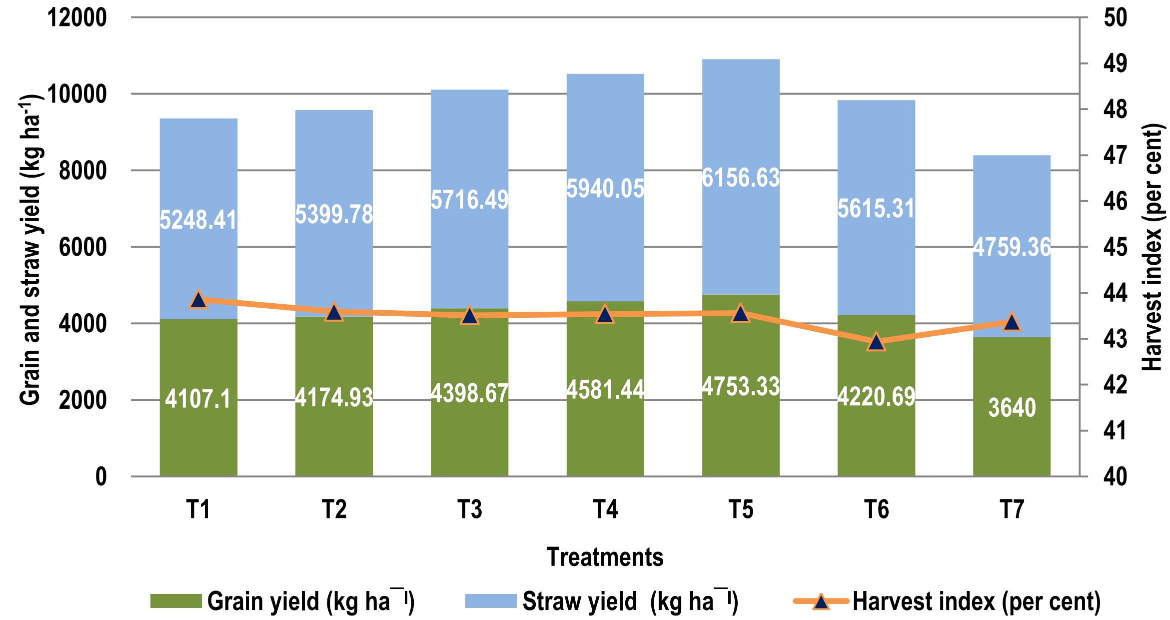


Fig. 4.5 Yield characters

4.5.1 Nitrogen content (per cent) and nitrogen uptake by grain and straw and total nitrogen uptake (kg ha^{-1}) by rice crop.

Nitrogen content in grain and straw (per cent), nitrogen uptake by grain and straw and total nitrogen uptake by the rice crop (kg ha^{-1}) as influenced by different treatments are given in the Table 4.9 and graphically depicted in Figures 4.6 and4.7.

4.5.1.1 Nitrogen content in grain and straw (per cent).

The data presented in the Table 4.9 revealed that, nitrogen content in the grain and the straw are significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) has shown significantly higher nitrogen content in grains over T_1, T_2 and T_7 treatments whereas application of bio-stimulant @ 10 kg ha^{-1} (T_3), bio-stimulant @ 15 kg ha^{-1} (T_4) and tricontanol 0.05 % GR @ 25 kg ha^{-1} (T_6) were found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average nitrogen content of the rice grain was found to be 1.29 per cent.

Table 4.9: Mean nitrogen content (per cent), nitrogen uptake (kg ha^{-1}) in grain and straw and total nitrogen uptake (kg ha^{-1}) by rice crop as influenced by different treatments.

Treatments		N content (per cent)		N uptake (kg ha^{-1})		Total N uptake (kg ha^{-1})
		Grain	Straw	Grain	Straw	
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	1.23	0.54	50.50	29.25	79.75
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	1.24	0.56	51.52	29.06	80.58
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	1.33	0.56	58.43	32.18	90.62
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	1.33	0.57	61.01	33.69	94.70
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	1.36	0.57	64.74	35.36	100.09
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	1.33	0.56	56.03	31.32	87.35
T_7	Untreated control.	1.22	0.53	44.30	25.03	69.32
S. Em. ±		0.03	0.01	2.67	0.91	3.21
C. D. at 5 %		0.09	0.03	8.22	2.79	9.90
General mean		1.29	0.55	55.22	30.84	86.06

Similarly nitrogen content in straw was significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) showed significantly higher nitrogen content in straw over T_1 and T_7 treatments whereas application of bio-stimulant @ 5 kg ha^{-1} (T_2), bio-stimulant @ 10 kg ha^{-1} (T_3), bio-stimulant @ 15 kg ha^{-1} (T_4) and tricontanol 0.05 % GR @ 25 kg ha^{-1} (T_6) were found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average nitrogen content of the rice straw was found to be 0.55 per cent.

4.5.1.2 Nitrogen uptake by grain and straw and total nitrogen uptake (kg ha^{-1}) by rice crop.

The data presented in the Table 4.9 revealed that, nitrogen uptake by the grain and the straw and total nitrogen uptake by crop was significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) has recorded significantly higher nitrogen uptake by the grain over T_1, T_2, T_6 and T_7 treatments whereas applications of bio-stimulant @ 10 kg ha^{-1} (T_3) and bio-stimulant @ 15 kg ha^{-1} (T_4) were found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average nitrogen uptake by of the rice grain was found to be 55.22 kg ha^{-1}.

Similarly nitrogen uptake in straw was significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) has shown significantly higher nitrogen uptake by straw over T_1, T_2, T_3, T_6 and T_7 treatments whereas applications of bio-stimulant @ 15 kg ha^{-1} (T_4) was seen at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average nitrogen uptake of the rice straw was found to be 30.84 kg ha^{-1}.

Total nitrogen uptake by rice crop is presented in Table 4.9. From the table it was revealed that, total nitrogen uptake by rice crop is significantly influenced by different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) showed significantly higher total nitrogen uptake in rice crop over T_1, T_2, T_6 and T_7 treatments whereas applications of bio-stimulant @ 10 kg ha^{-1} (T_3) and bio-stimulant @ 15 kg ha^{-1} (T_4) were found at par with bio-stimulant @ 20 kg ha^{-1}. Average total nitrogen uptake of the rice crop was found to be 86.06 kg ha^{-1}.

4.5.2 Phosphorous content (per cent) and phosphorous uptake by grain and straw and total phosphorous uptake (kg ha^{-1}) by rice crop.

Phosphorous content in grain and straw (per cent), phosphorous uptake by grain and straw and total phosphorous uptake by the rice crop (kg ha^{-1}) as influenced by different treatments is given in the Table 4.10 and graphically depicted in Figures 4.8 and 4.9.

4.5.2.1 Phosphorous content in grain and straw (per cent).

The data presented in the Table 4.10 revealed that, phosphorous content in the grain and straw are significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) has shown significantly higher phosphorous content in grains over T_1, T_2 and T_7 treatments whereas application of bio-stimulant @ 10 kg ha^{-1} (T_3), bio-stimulant @ 15 kg ha^{-1} (T_4) and tricontanol 0.05 % GR @ 25 kg ha^{-1} (T_6) were at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average phosphorous content of the rice grain was found to be 0.20 per cent.

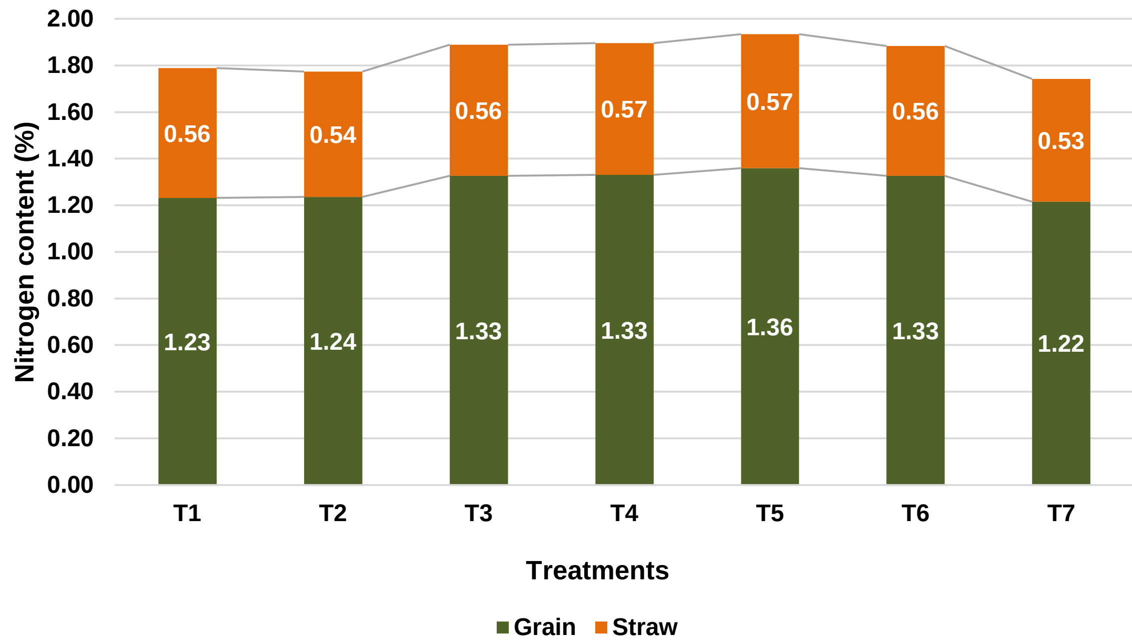


Fig. 4.6: N content in grain and straw

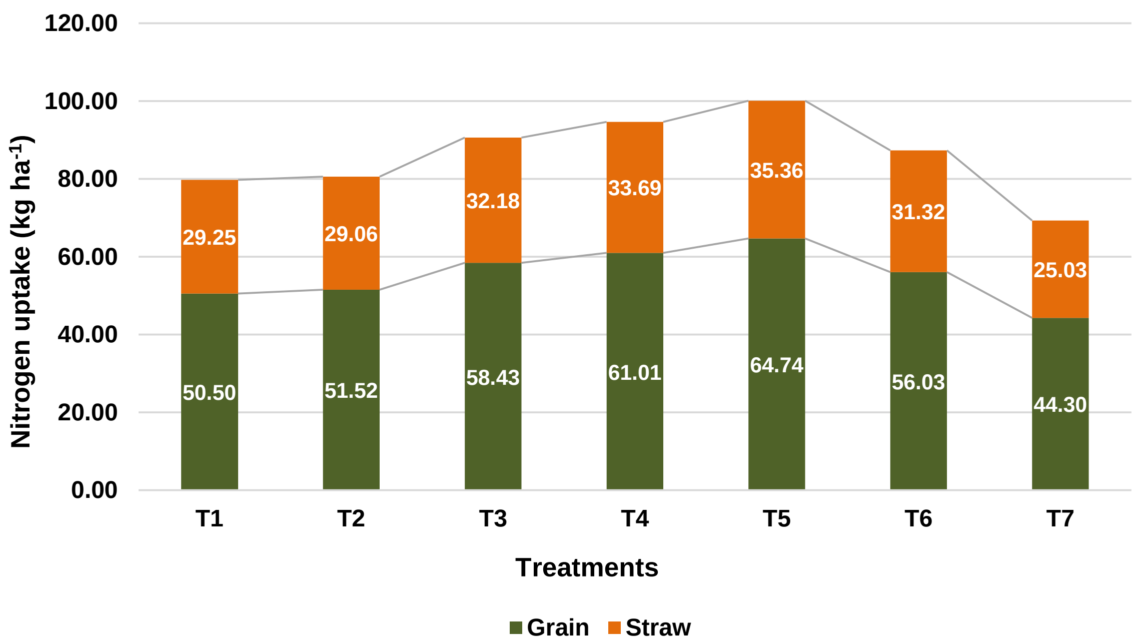


Fig. 4.7: N uptake in grain and straw

Similarly phosphorous content in straw was significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) has shown significantly higher phosphorous content by straw over T_1, T_2 and T_7 treatments whereas application of bio-stimulant @ 10 kg ha^{-1} (T_3), bio-stimulant @ 15 kg ha^{-1} (T_4) and tricontanol 0.05 % GR @ 25 kg ha^{-1} (T_6) were found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average phosphorous content of the rice straw was found to be 0.17 per cent.

Table 4.10: Mean phosphorous content (per cent), uptake in grain and straw and total phosphorous uptake (kg ha^{-1}) by rice crop as influenced by different treatments.

Treatments		P content (per cent)		P_2O_5 uptake (kg ha^{-1})		Total P_2O_5 uptake (kg ha^{-1})
		Grain	Straw	Grain	Straw	
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	0.18	0.14	7.19	7.48	14.67
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	0.19	0.16	7.89	8.40	16.29
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	0.21	0.18	9.21	10.01	19.22
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	0.21	0.19	9.63	11.06	20.70
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	0.22	0.19	10.47	11.61	22.08
T_6	Tricontanol 0.05% GR @ 25kg ha^{-1}	0.21	0.17	8.71	9.75	18.45
T_7	Untreated control.	0.17	0.14	6.16	6.42	12.58
S. Em. ±		0.01	0.01	0.41	0.33	0.63
C. D. at 5 %		0.02	0.02	1.25	1.02	1.94
General mean		0.20	0.17	8.46	9.25	17.71

4.5.2.2 Phosphorous uptake by grain and straw and total phosphorous uptake (kg ha^{-1}) by rice crop.

The data presented in the Table 4.10 revealed that, phosphorous uptake by the grain and the straw and total phosphorous uptake by crop are significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) showed significantly higher phosphorous uptake by the grain (i.e. 10.47 kg ha^{-1}) over T_1, T_2, T_3, T_6 and T_7 treatments whereas bio-stimulant @ 15 kg ha^{-1} (T_4) found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average phosphorous uptake by of the rice grain was found to be 8.46 kg ha^{-1}.

Similarly phosphorous uptake in straw was significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) has shown significantly higher phosphorous uptake in straw over T_1, T_2, T_3, T_6 and T_7 treatments whereas bio-stimulant @ 15 kg ha^{-1} (T_4) found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average phosphorous uptake of the rice straw was found to be 9.25 kg ha^{-1}.

Total phosphorous uptake by rice crop is presented in Table 4.10. From the table it is revealed that, total phosphorous uptake by rice crop is significantly influenced by different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) has shown significantly higher total phosphorous uptake (i.e. 22.08 kg ha^{-1}) in rice crop over T_1, T_2, T_3, T_6 and T_7 treatments whereas bio-stimulant @ 15 kg ha^{-1} (T_4) found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average total phosphorous uptake of the rice crop was found to be 17.71 kg ha^{-1}.

4.5.3 Potassium content (per cent) and Potassium uptake by grain and straw and total potassium uptake (kg ha^{-1}) by rice crop.

Potassium content (per cent), potassium uptake by grain and straw and total potassium uptake by the rice crop (kg ha^{-1}) as influenced by different treatments is given in the Table 4.11 and graphically depicted in Figure 4.10 and 4.11.

Table 4.11: Mean potassium content (per cent), uptake in grain and straw and total potassium uptake (kg ha^{-1}) by rice crop as influenced by different treatments.

Treatments		K content (per cent)		K_2O uptake (kg/ha)		Total K_2O uptake (kg/ha)
		Grain	Straw	Grain	Straw	
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	0.49	0.45	20.03	23.77	43.80
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	0.51	0.50	21.16	26.81	47.97
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	0.59	0.57	25.75	32.61	58.36
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	0.59	0.59	27.07	35.09	62.15
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	0.60	0.61	28.51	37.60	66.12
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	0.51	0.53	21.75	29.81	51.55
T_7	Untreated control.	0.42	0.44	15.31	20.91	36.22
S. Em. ±		0.02	0.02	1.52	1.12	2.39
C. D. at 5 %		0.06	0.05	4.70	3.46	7.35
General mean		0.53	0.52	22.79	29.51	52.31

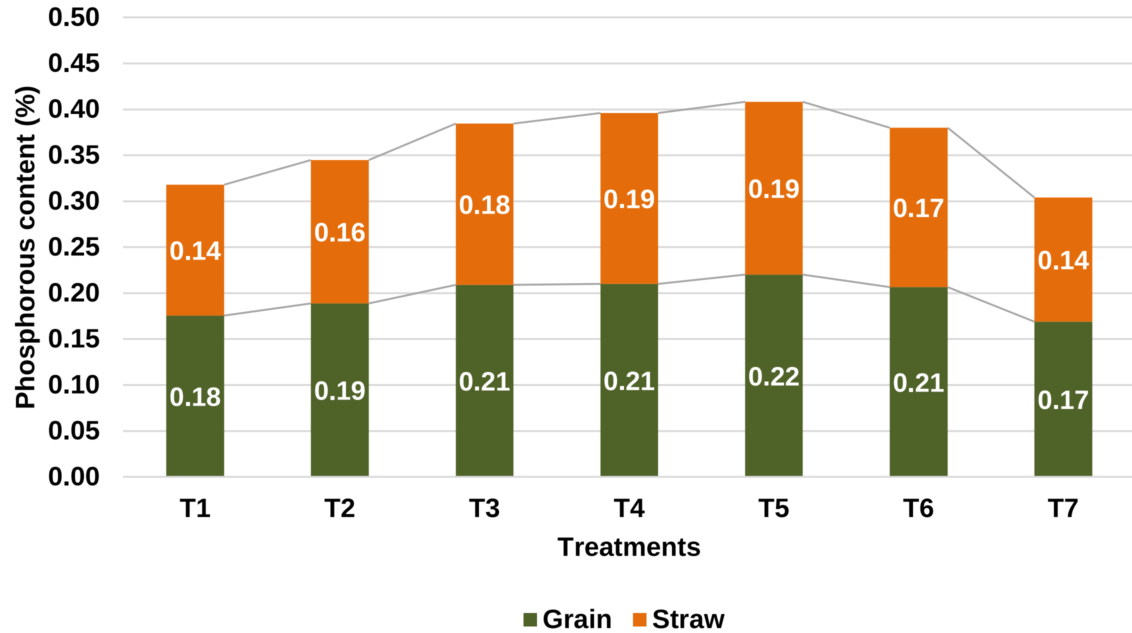


Fig. 4.8: P content in grain and straw

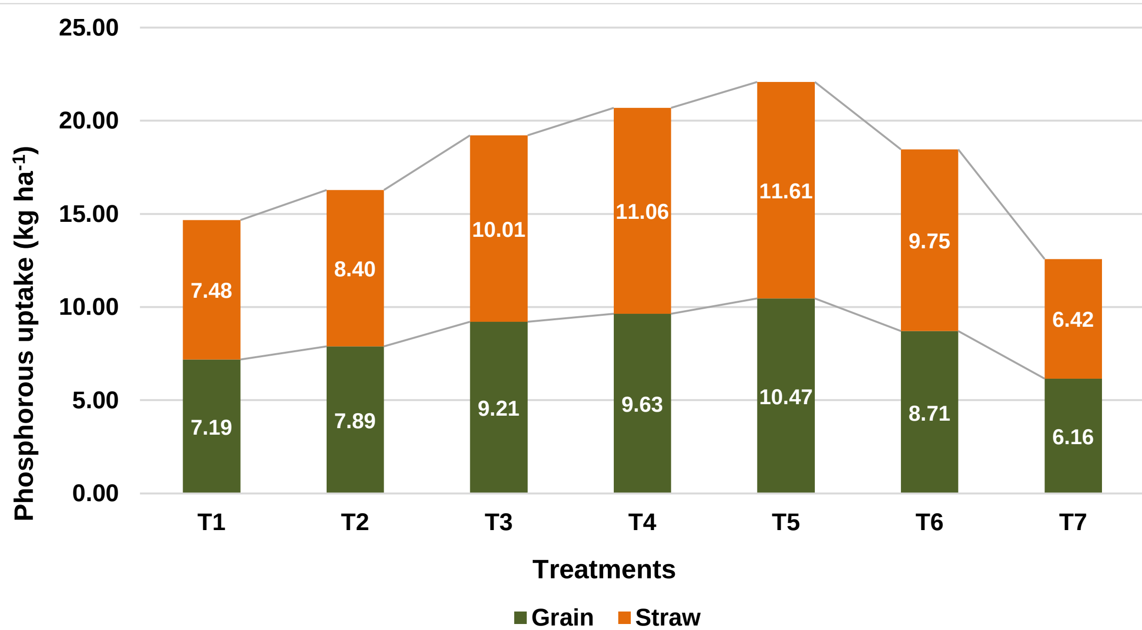


Fig. 4.9: P_2O_5 uptake in grain and straw

4.5.3.1 Potassium content in grain and straw (per cent).

The data presented in the Table 4.11 revealed that, potassium content in the grain and the straw significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) recorded showed significantly higher potassium content in grains over T_1, T_2, T_6 and T_7 treatments whereas bio-stimulant @ 10 kg ha^{-1} (T_3) and bio-stimulant @ 15 kg ha^{-1} (T_4) found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average potassium content of the rice grain was found to be 0.53 per cent.

Similarly potassium content in straw was significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) showed significantly higher potassium content in straw over T_1, T_2, T_6 and T_7 treatments whereas bio-stimulant @ 10 and 15 kg ha^{-1} (T_3 and T_4, respectively) found at par with bio-stimulant @ 20 kg ha^{-1}. Average potassium content of the rice straw was found to be 0.53 per cent.

4.5.3.2 Potassium uptake by grain and straw and total potassium uptake (kg ha^{-1}) by rice crop.

The data presented in the Table 4.11 revealed that, potassium uptake by the grain and the straw and total potassium uptake by crop are significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) showed significantly higher potassium uptake by the grain (i.e. 28.51 kg ha^{-1}) over T_1, T_2, T_6 and T_7 treatments whereas bio-stimulant @ 10 kg ha^{-1} (T_3) and bio-stimulant @ 15 kg ha^{-1} (T_4) found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average potassium uptake by of the rice grain was found to be 22.79 kg ha^{-1}.

Similarly potassium uptake in straw was significantly influenced by the different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) has shown significantly higher potassium uptake in straw over T_1, T_2, T_3, T_6 and T_7 treatments whereas bio-stimulant @ 15 kg ha^{-1} (T_4) found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average potassium uptake of the rice straw was found to be 29.51 kg ha^{-1}.

Total potassium uptake by rice crop is presented in Table 4.11. From the table it is revealed that, total potassium uptake by rice crop is significantly influenced by different treatments. The application of bio-stimulant @ 20 kg ha^{-1} (T_5) showed significantly higher total potassium uptake (i.e. 66.12 kg ha^{-1}) by rice crop over T_1, T_2, T_3, T_6 and T_7 treatments whereas bio-stimulant @ 15 kg ha^{-1} (T_4) found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average total potassium uptake of the rice crop was found to be 52.31 kg ha^{-1}.

4.6 Available nutrients status of soil (after harvest)

The data pertaining to available nitrogen, phosphorus and potassium (kg ha^{-1}) in soil after harvest of rice as influenced by different treatments are presented in Table 4.12 and graphically depicted in Figure 4.12. The mean soil available nitrogen, phosphorus and potassium status after harvest of experimental crop was 242.75, 12.96 and 238.49 kg ha^{-1}, respectively.

From the data presented in the table, it was revealed that, application of bio-stimulant significantly influenced the available nitrogen and phosphorous content of the soil after the harvest of rice crop.

The significantly higher available nitrogen and phosphorous content was observed with untreated control treatment (T_7). This may be due to lower nitrogen and phosphorous uptake by crop in the control treatment (T_7). Further it was revealed that, available potassium content in the soil after the harvest was non-significant.

Table 4.12: Available nitrogen, phosphorus and potassium after harvest of rice as influenced by different treatments

Treatments		Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	248.19	13.40	240.53
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	248.23	13.12	239.19
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	238.04	12.97	237.11
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	237.00	12.87	236.45
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	235.05	12.60	235.64
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	241.80	13.32	238.77
T_7	Untreated control.	249.52	13.57	241.74
S. Em. ±		3.15	0.18	4.25
C. D. at 5 %		9.72	0.56	N.S.
General mean		242.75	12.96	238.49
Initial soil		213.40	12.90	216.32

4.6.1 Nutrient balance sheet

Data pertaining to the balance sheets of N, P_2O_5 and K_2O are given in Tables 4.13, 4.14 and 4.15 respectively.

The positive values in the table after subtracting expected balance of nutrients in actual balance of the same indicate net gain in nutrients whereas negative values shows net loss in the nutrients. The highest net loss of N, P_2O_5 and K_2O (37.06, 53.76 and 30.87 kg ha^{-1} respectively) in the soil was observed in control treatment (T_7) whereas lower values of net losses (20.75,

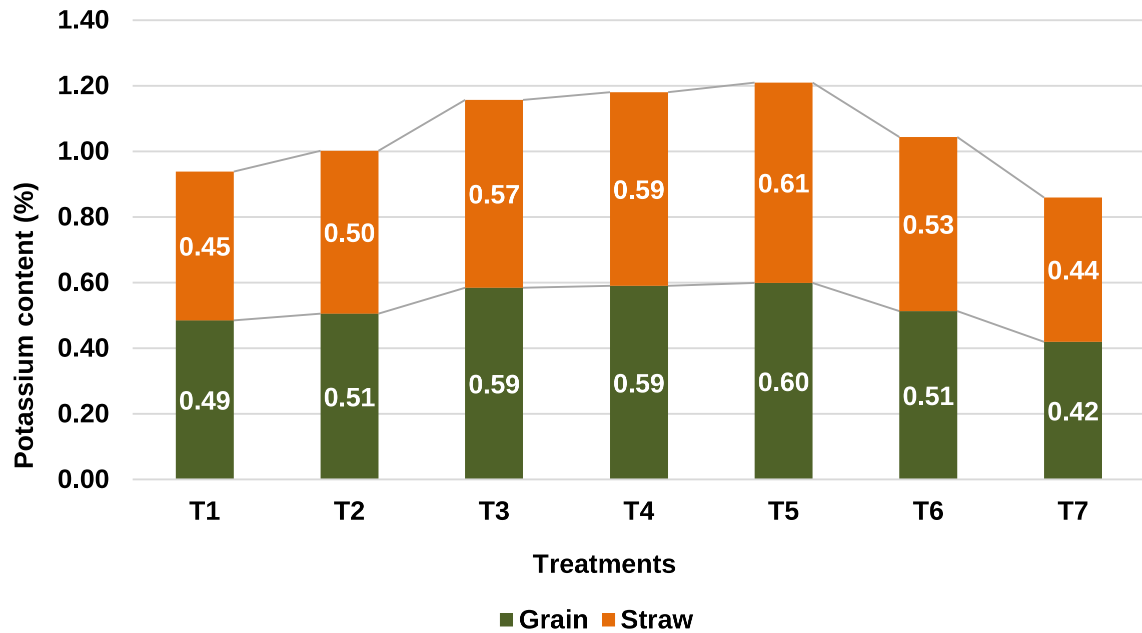


Fig. 4.10: K content in grain and straw

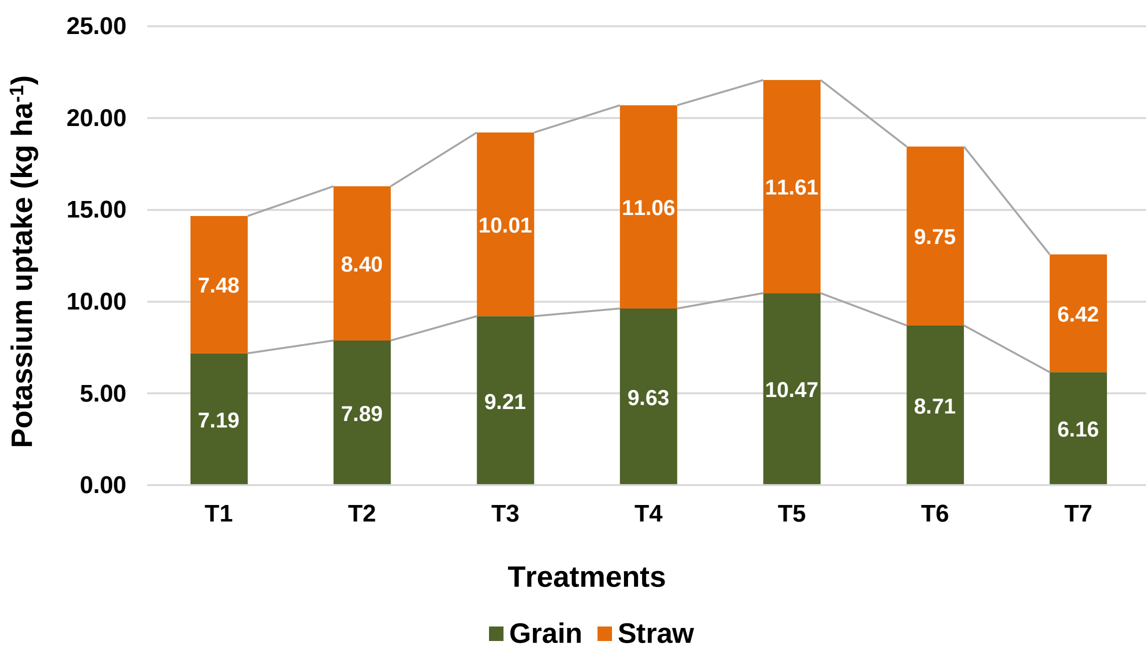


Fig. 4.11: K_2O uptake in grain and straw

Table 4.13: Balance sheet of available nitrogen (kg ha^{-1}) as influenced by different treatments after the harvest of rice crop.

Nitrogen								
Treatments	**Initial available soil N (kg ha^{-1})**	**Addition of N through fertilizer (kg ha^{-1})**	**Addition of N through FYM (kg ha^{-1})**	**Total available N (kg ha^{-1})**	**Total N uptake by the crop (kg ha^{-1})**	**Expected balance of N (kg ha^{-1})**	**Actual balance of available N (kg ha^{-1})**	**Net gain or loss (kg ha^{-1})**
T_1	213.4	100	42.5	355.9	79.75	276.15	248.59	-27.56
T_2	213.4	100	42.5	355.9	80.58	275.32	249.23	-26.09
T_3	213.4	100	42.5	355.9	90.62	265.28	238.04	-27.24
T_4	213.4	100	42.5	355.9	94.70	261.20	237.00	-24.20
T_5	213.4	100	42.5	355.9	100.09	255.81	235.05	-20.75
T_6	213.4	100	42.5	355.9	87.35	268.55	241.80	-26.75
T_7	213.4	100	42.5	355.9	69.32	286.58	249.52	-37.06

Table 4.14: Balance sheet of available phosphorous (kg ha^{-1}) as influenced by different treatments after the harvest of rice crop.

Phosphorous								
Treatments	**Initial available soil P_2O_5 (kg ha^{-1})**	**Addition of P_2O_5 through fertilizers (kg ha^{-1})**	**Addition of P_2O_5 through FYM (kg ha^{-1})**	**Total available P_2O_5 (kg ha^{-1})**	**Total P_2O_5 uptake by the crop (kg ha^{-1})**	**Expected balance of P_2O_5 (kg ha^{-1})**	**Actual balance of available P_2O_5 (kg ha^{-1})**	**Net gain or loss of P_2O_5 (kg ha^{-1})**
T_1	12.9	50	17	79.9	14.67	65.23	13.40	-51.83
T_2	12.9	50	17	79.9	16.29	63.61	12.42	-51.20
T_3	12.9	50	17	79.9	19.22	60.68	12.57	-48.11
T_4	12.9	50	17	79.9	20.70	59.20	12.87	-46.34
T_5	12.9	50	17	79.9	22.08	57.82	12.60	-45.22
T_6	12.9	50	17	79.9	18.45	61.45	13.32	-48.13
T_7	12.9	50	17	79.9	12.58	67.32	13.57	-53.76

Table 4.15: Balance sheet of available potassium (kg ha^{-1}) as influenced by different treatments after the harvest of rice crop.

Potassium								
Treatments	**Initial available soil K_2O (kg ha^{-1})**	**Addition of K_2O through fertilizers (kg ha^{-1})**	**Addition of K_2O through FYM (kg ha^{-1})**	**Total available K_2O (kg ha^{-1})**	**Total K_2O uptake by the crop (kg ha^{-1})**	**Expected balance of K_2O (kg ha^{-1})**	**Actual balance of available K_2O (kg ha^{-1})**	**Net gain or loss of K_2O (kg ha^{-1})**
T_1	216.32	50	42.5	308.82	43.80	265.02	240.53	-24.49
T_2	216.32	50	42.5	308.82	47.97	260.85	239.19	-21.66
T_3	216.32	50	42.5	308.82	58.36	250.46	237.11	-13.35
T_4	216.32	50	42.5	308.82	62.15	246.67	236.45	-10.22
T_5	216.32	50	42.5	308.82	66.12	242.70	235.64	-7.07
T_6	216.32	50	42.5	308.82	51.55	257.27	238.77	-18.50
T_7	216.32	50	42.5	308.82	36.22	272.60	241.74	-30.87

45.22 and 7.07 kg ha^{-1} respectively) were observed in treatment with application of bio-stimulant @ 20 kg ha^{-1} (T_5).

4.7 Soil chemical properties (pH, soil carbon and EC)

Various soil chemical properties *viz.*, organic carbon (g kg^{-1}), pH and electrical conductivity (dS m^{-1}) are shown in the Table 4.16.

From the table it was revealed that, various other soil properties *viz.*, organic carbon (g kg^{-1}), pH and electrical conductivity (dS m^{-1}) have shown no any significant difference over the application of different treatments. Initial organic carbon, pH and electrical conductivity found to be 13.8 g kg^{-1}, 6.29 and 0.10 dS m^{-1} respectively. Whereas mean organic carbon, pH and electrical conductivity after harvest of the rice crop were 14.2 g kg^{-1}, 6.25 and 0.12 dS m^{-1} respectively. Soil pH was found to be slightly acidic in nature and organic carbon was found to be very high in nature was analyzed.

Table 4.16: Soil chemical properties *viz.*, organic carbon (g kg^{-1}), pH and electrical conductivity (ds m^{-1})

Treatments		pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	6.26	14.2	14.15
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	6.24	14.3	14.27
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	6.25	14.3	14.27
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	6.25	14.0	14.04
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	6.24	14.4	14.38
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	6.25	13.9	13.92
T_7	Untreated control.	6.25	14.3	14.27
S. Em. ±		0.01	0.01	0.04
C. D. at 5 %		N.S.	N.S.	N.S.
General mean		6.25	0.12	14.2
Initial soil		6.29	0.10	13.8

4.8 Protein content of the rice.

Protein content of rice as influenced by different treatments is given in the Table 4.17 and graphically depicted in Figure 4.13. The protein content of the rice is calculated by the multiplying with the nitrogen content of rice grain by the factor 5.95 (Mariotti., *et al* 2019).

From the table it is revealed that, the protein content of the rice is significantly influenced by the application of different treatments. Application of bio-stimulant @ 20 kg ha^{-1} (T_5) recorded significantly higher protein content (8.09 per cent) over T_1, T_2 and T_7 treatments. Whereas application of bio-stimulant @ 10 kg ha^{-1} (T_3), bio-stimulant @ 15 kg ha^{-1} (T_4) and tricontanol 0.05% GR @ 25 kg ha^{-1} (T_6) were found at par with bio-stimulant @ 20 kg ha^{-1} (T_5). Average protein content found to be 7.67 per cent.

Table 4.17: Protein content of the rice as influenced by different treatments.

Treatments		Protein content (per cent)
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	7.33
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	7.35
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	7.89
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	7.91
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	8.09
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	7.89
T_7	Untreated control.	7.23
S. Em. ±		0.17
C. D. at 5 %		0.54
General mean		7.67

4.9 Economics of rice cultivation.

The evaluation of economics of the different treatments was assessed in terms of gross returns, input cost, net returns and benefit cost ratio (on input cost as well as total cost) during *kharif* season 2021 are presented in Table 4.18.

From the data it was revealed that, higher level of bio-stimulant has shown higher gross returns and application of bio-stimulant @ 20 kg ha^{-1} (T_5) gave higher gross returns (₹95292.98 ha^{-1})

whereas lowest gross returns was obtained for untreated control treatment (₹ 73081.50 ha^{-1}). An average gross return of all treatments was ₹85585.92 ha^{-1}.

Similarly higher level of application of bio-stimulant has shown higher net returns (on the bases of input cost) and application of bio-stimulant @ 20 kg ha^{-1} (T_5) gave higher net returns (₹ 30148.98 ha^{-1}) whereas lower net returns was obtained for application of tricontanol 0.05% GR @ 25 kg ha^{-1} (₹9797.02 ha^{-1}). An average net return of all treatments was ₹20637.50 ha^{-1}.

Table 4.18: Economics of rice crop as influenced by different treatments.

Treatments		Gross returns (₹ ha^{-1})	Cost of cultivation	Input cost (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio (on input cost)	B:C ratio (on total cost)
T_1	Bio-stimulant @ 2.5 kg ha^{-1} (Laatu)	82301.94	84977.41	62271.00	20030.94	1.32	0.97
T_2	Bio-stimulant @ 5 kg ha^{-1} (Laatu)	83693.60	85612.58	62646.00	21047.60	1.34	0.98
T_3	Bio-stimulant @ 10 kg ha^{-1} (Laatu)	88192.38	87430.18	63644.00	24548.38	1.39	1.01
T_4	Bio-stimulant @ 15 kg ha^{-1} (Laatu)	91850.05	88840.41	64394.00	27456.05	1.43	1.03
T_5	Bio-stimulant @ 20 kg ha^{-1} (Laatu)	95292.98	90216.28	65144.00	30148.98	1.46	1.06
T_6	Tricontanol 0.05% GR @ 25 kg ha^{-1}	84689.02	99242.44	74892.00	9797.02	1.13	0.85
T_7	Untreated control.	73081.50	82816.84	61648.00	11433.50	1.19	0.88
	General mean	85585.92	88448.02	64948.43	20637.50	1.32	0.97

B:C ratio calculated based on input cost had shown higher values for higher levels of bio-stimulant treatments. Application of bio-stimulant @ 20 kg ha^{-1} (T_5) gave higher B:C ratio (1.46) whereas lowest B:C ratio was observed for application of tricontanol 0.05% GR @ 25 kg ha^{-1} (1.13). An average B:C ratio of all treatments was 1.32 B:C ratio (benefit-cost ratio) is a unit-less quantity.

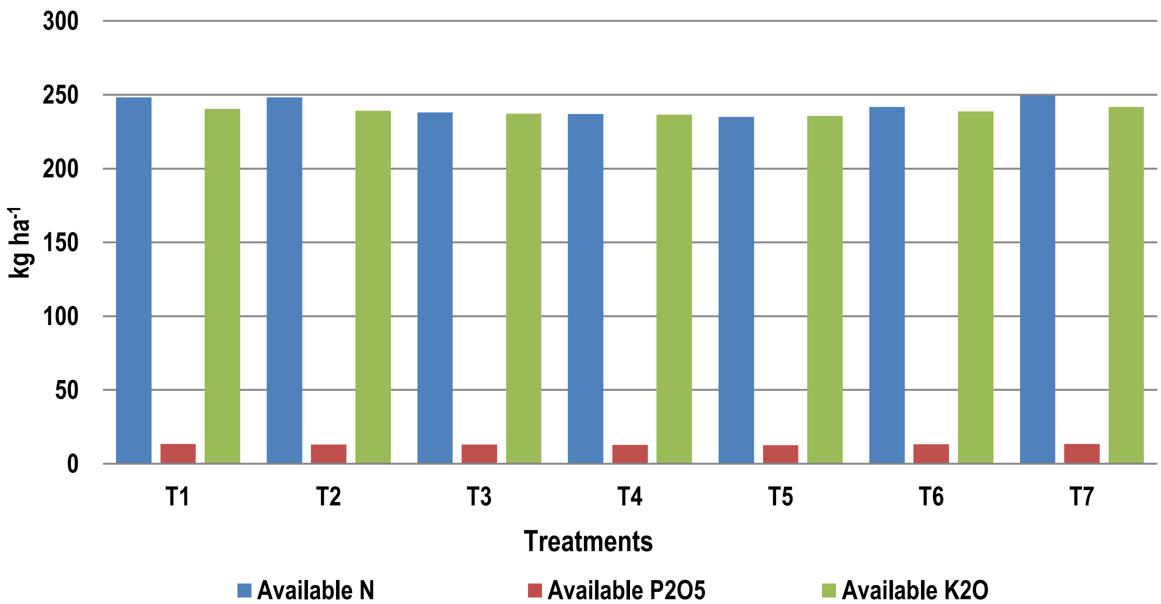


Fig. 4.12: Available N, P_2O_5 & K_2O

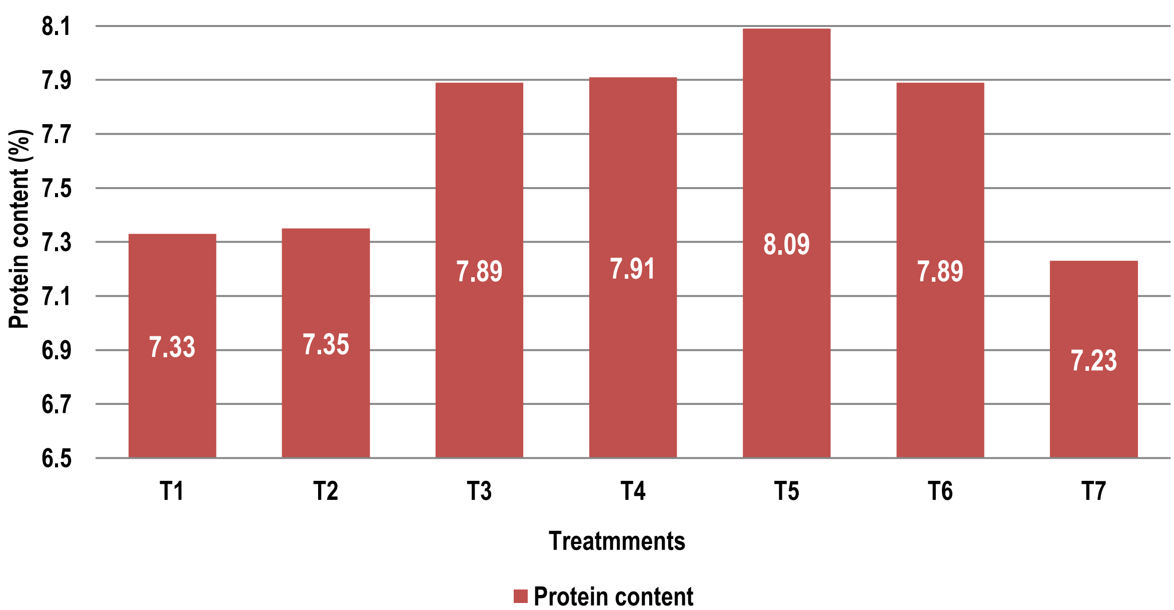


Fig. 4.13: Protein content (%) in rice grain

DISCUSSION

The experiment entitled, "Effect of humic acid based bio-stimulant on growth, yield and quality of *kharif* rice (*Oryza sativa* L.) under lateritic soils of Konkan" was conducted at Instructional Farm, Department of Agronomy, College of Agriculture Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during *kharif* 2021. Results of the experiment presented in the preceding part of this chapter have been discussed and elucidated into following sub-heads.

A) Soil and weather conditions during growth period.

B) Effect of bio-stimulant on crop growth and yield attributes

C) Effect of bio-stimulant on nutrient content and uptake and protein content.

D) Effect of bio-stimulant on available nutrient status of soil.

E) Economics of treatments

A) Soil and weather conditions during growth period.

Many biotic and abiotic stress environments prevented from expressing full genetic potential for better yield. It is must to focus on soil and weather condition under which crop is been grown. The analysis of the initial soil sample indicated that, the soil of the experimental plot was sandy loam in texture, acidic in pH and high in organic carbon content. It was low level in available nitrogen, available phosphorus and moderately high available potassium (Table 3.3). The soil was leveled, very well drained and uniform in depth.

The meteorological data presented in Table 3.5 showed that, the rainfall received during the crop growth period was 4734 mm, which received in 102 rainy days. Total rainy days during entire crop growth period were 102. The maximum and minimum temperatures were in the range of 21.7 °C to 23.2 °C and 27.1 °C to 31.7 °C respectively. The bright sunshine hours were between 0.0 to 7.3 hours day^{-1}. Average bright sunshine hours during the growth period was 2.86 hrs day^{-1}.

In general, the climate was favorable for normal growth and development of *kharif* rice without the incidence of any major pests or diseases during the crop growth period. Thus, the observed differences in growth were mainly because of treatment effects.

B) Effect of bio- stimulant on crop growth and yield attributes.

In order to study, "Effect of humic-acid based bio-stimulant on growth, yield and quality of *kharif* rice (*Oryza sativa* L.) under lateritic soils of Konkan", was considered worthwhile to scrutinize nature and growth of plant measured in terms of plant height (cm), number of functional leaves hill^{-1}, number of tillers hill^{-1}, dry matter hill^{-1} (g), days for 50 per cent flowering, days to physiological maturity at various stages of crop growth stages. The differences observed in the growth parameter, yield and yield attributing characters in respect of rice crop were due to the application of different levels of bio-stimulants.

It was evident from the plant population study that, initial and at harvest stage; plant population was not significantly influenced with different treatment applications. Optimum plant population was maintained by transplanting and gap filling. Hence there was no significant difference among treatments (Table 4.1).

There was significance difference between treatments for the plant height of rice crop at 60 DAT, 90 DAT and at the harvest stage of rice crop but was no significant at 30 DAT. At harvest stage of crop, the crop attained its maximum height of 90.20 cm (T_5) followed by T_4 treatment and minimum height of 74.14 cm (control treatment) (Table 4.2). This increase might be due to the existence of organic constituents of sea weed extract, humic acid, vitamins etc. which elicit strong physiological responses in lower doses (Pramanick *et al*., 2013). Plant height might be increased due to greater availability of nutrients which is stated by Sivakumar *et al*. (2007). Such results are in similar line with those obtained by Arun *et al*. (2019), Devi *et al*. (2015), Baradhan *et al*. (2019), Deepana *et al*. (2021), Pascual *et al*. (2021), Layek *et al*. (2017) and Saha *et al*. (2013).

There was significance difference between the treatments for the number of functional leaves hill^{-1} of rice crop at 60 DAT, 90 DAT and at the harvest stage of rice crop but was no significant at 30 DAT. The maximum number of functional leaves hill^{-1} 48.71 at 90 DAT (T_5) (Table 4.3). Arun *et al*. (2019) reported that, application of bio-stimulant (LBS6-S) along with RDF during time of transplanting and 30 DAT and 60 DAT produced significantly higher number of leaves per hill whereas least number of leaves per hill is produced in recommended dose of fertilizer (without bio-stimulant) treatment for rice crop.

There was significance difference between the treatments for the number of tillers hill^{-1} of rice crop at 60 DAT, 90 DAT and at the harvest stage of rice crop but was no significant at 30 DAT, maximum number of tillers hill^{-1} 16.63 at 90 DAT (Table 4.4) and control treatment produced significantly least number of tillers hill^{-1}. Saha *et al*. (2013) reported that, for rice crop application of humic acid @ 3 l ha^{-1} produced significantly the highest number of effective tillers hill^{-1} and the lowest was produced in the treatment with no application of humic acid. Also Arun *et al*. (2019) reported that, application of bio-stimulant i.e. LBS6-S has produced significantly more number of tillers m^{-2}.

There was significance difference between the treatments for the dry weight (g) at 60 DAT, 90 DAT and at the harvest stage of rice crop but was no significant at 30 DAT and maximum dry matter hill^{-1} 48.48g at harvest stage of rice crop (Table 4.5). Pramanick *et al*. (2013) reported that, in potato tubers, foliar application of bio-stimulant (K-sap) with the concentration of 7.5% along with 100% of RDF recorded higher dry matter production. Deepana *et al*. (2021) reported that, in rice crop higher values of dry matter production (kg ha^{-1}) with the application of sea weed extract gel soil application 12.5 kg ha^{-1} along with foliar spraying of sea weed extract liquid 0.5 per cent (*v/v*) at tillering and panicle initiation stage of rice crop.

From the data it is evident that, there was no any significant difference among the treatments for days to 50 per cent flowering and days to physiological maturity. Mean number of days to 50 per cent flowering and days to physiological maturity were 78.19 and 110.67 days respectively (Table 4.6).

Similarly, yield attributing characters *viz*., number of panicles hill^{-1}, number of grains panicle^{-1}, panicle length (cm) have shown significant difference between treatments and significantly higher values for T_5 treatment and lower values for control treatment (T_7). Values with respect of average number of panicles hill^{-1}, number of grains panicle^{-1}, panicle length (cm) were 10.53, 121.72, 22.10 cm, respectively and mean 1000 grain weight was 28.4 g (Table 4.7). Deepana *et al*. (2021) reported that, higher number of grains panicle^{-1} and panicle length of rice obtained with the soil application of sea weed extract @ 12.5 kg ha^{-1} along with foliar spraying of sea weed extract liquid @ 0.5 %. Jayanta *et al*. (2016) also reported that, application of bio-stimulant improved the yield attributing characters in rice crop.

All these character contributed positively towards the mean grain, straw yield biological yield and harvest index of 4268.02 kg ha^{-1}, 5548.00 kg ha^{-1}, 9816.03 kg ha^{-1} and 43.48 per cent respectively. Application of bio-stimulant @ 20 kg ha^{-1} (T_5) recorded highest grain yield, straw yield and biological yield of 4753.33 kg ha^{-1}, 6156.63 kg ha^{-1} and 10909.96 kg ha^{-1} respectively and lower values are recorded by control treatment (T_7) (Table 4.8). Pal *et al*. (2015) reported that, in maize, the foliar application of seaweed extract bio-stimulant @ 15% G sap along with RDF observed higher growth parameters and yield attributes *viz*., cob length, no of grain per row, green cob yield and fodder yield. The results are in similar line with Dwivedi *et al*. (2014) proved that, in black gram, the foliar application of bio-stimulant @ 15% K sap and RDF resulted in an increase by 49.2 per cent grain yield compared to RDF to control (water spray+ RDF). Arun *et al*. (2019) reported that, in rice under the transplanted condition, the application of liquid bio-stimulant LBS6-S obtained higher yield attributes due to effective utilization of native as well as applied nutrients. Deshmukh *et al*. (2013) also showed that, applying seaweed extract @ 1500 g ha^{-1} in sugarcane and RDF increased cane yield by 14 per cent and sugar yield by 23.1 per cent respectively..

C) Effect of bio-stimulant on nutrient content and uptake and protein content.

Nutrient content in grain and straw are significantly influenced by different levels of bio-stimulant application. pplication of bio-stimulant @ 20 kg ha^{-1} produced significantly higher values in N, P_2O_5 and K_2O content as well as uptake and lower values by control treatment (T_7). The mean nitrogen content in grain and straw were 1.29 and 0.55 per cent respectively; significantly higher N content in grain and straw (1.36 and 0.57 per cent respectively) in T_5 treatment. Mean nitrogen uptake in grain, straw and total uptake by rice was 55.22 kg ha^{-1}, 30.84 kg ha^{-1} and 86.06 kg ha^{-1} respectively and significantly higher N uptake in grain, straw and total uptake (64.74, 35.36 and 100.09 kg ha^{-1} respectively) (Table 4.9). Aziz *et al*. (2014) reported that, in rice crop with the application of 50 per cent humic substance along with 50 per cent cyanobacteria and 50 per cent N has increased the N content in rice grains. Pramanick *et al*. (2014) reported that, application of G sap 15 per cent along with RDF for rice crop showed higher N uptake in grain and straw (61.62 and 47.95 kg ha^{-1} respectively). Layek *et al*. (2018) in rice reported that, application of G sap 15 per cent showed higher N content in rice grain followed by K sap @ 15 per cent (1.50 and 1.49 per cent respectively) and also higher total N uptake in rice crop (127.4 and 129.3 kg ha^{-1} respectively).

The mean phosphorous content in grain and straw were 0.20 and 0.17 per cent respectively and significantly higher P_2O_5 content in rice grain and straw (0.22 and 0.19 per cent respectively) observed in T_5 treatment i.e. application of bio-stimulant @ 20 kg ha^{-1} but lower values were found in control treatment (0.17 and 0.14 per cent respectively). Mean P_2O_5 uptake by grain, straw and total uptake by rice crop was 8.46 kg ha^{-1}, 9.25 kg ha^{-1} and 17.71 kg ha^{-1} and significantly higher values of uptake in grain, straw and total uptake (10.47, 11.61 and 22.08 kg ha^{-1} respectively) were observed in T_5 treatment whereas lower values of uptake were observed in control treatment (Table 4.10). Pramanick *et al*. (2014) reported that, application of G sap 15 per cent along with RDF in rice crop showed higher phosphorous uptake in grain and straw (12.99 and 16.74 kg ha^{-1} respectively). Layek *et al*. (2016) in rice reported that, application of G sap @ 15 per cent showed higher phosphorous content in rice grain followed by 10 per cent K sap (0.28 per cent each) and also higher total N uptake in rice crop (22.4 and 21.5 kg ha^{-1} respectively).

The significantly higher K_2O content in grain and straw (0.60 and 0.61 per cent respectively) were found in T_5 treatment and lower values (0.42 and 0.44 per cent respectively) in control treatment. Mean potassium uptake in grain, straw and total potassium uptake by rice was 22.79 kg ha^{-1}, 29.51 kg ha^{-1} and 52.31 kg ha^{-1} respectively and significantly higher K_2O uptake in grain, straw and total uptake (28.51, 37.60 and 66.12 kg ha^{-1} respectively) were found in application of bio-stimulant @ 20 kg ha^{-1} whereas lower uptake in control treatment (T_7) (Table 4.11). Pramanick *et al*. (2014) reported that, application of G sap 15 per cent along with RDF in rice crop showed higher potassium uptake in grain and straw (63.29 and 202.13 kg ha^{-1} respectively). Layek *et al*. (2018) in rice reported that, application of G sap @ 10 per cent and G sap @ 15 per cent showed higher N content in rice grain (1.50 and 1.49 per cent respectively) and also higher total N uptake in rice crop (127.4 and 129.3 kg ha^{-1} respectively).

From the data (Table 4.17) it is evident that, there was significant difference among the treatments for protein content in rice grain. Application of bio-stimulant @ 20 kg ha^{-1} (T_5) gave significantly higher protein content (8.09 per cent) in the rice grains whereas the lowest protein content (7.23 per cent) was noticed in control treatment (T_7). The average protein content was about 7.67 per cent. Anantharaj *et al*. (2001) in *Vigna catajung* (cow pea species) crop reported that, application of sea weed extract bio-stimulant has increased the protein content. This might be because of promotive effects of root proliferation and higher uptake of nitrogen, phosphorous and sulphur needed for protein synthesis. Protein content in wheat grains was increased by 15.64 per cent with the application of K-sap @ 7.5 per cent (Shah *et al*. 2013).

D) Effect of bio-stimulant on available nutrient status of soil.

From the data (Table 4.12) it is evident that, there was significant difference among the treatments for available N and P_2O_5 of the soil. Control treatment (T_7) had significantly higher available N (249.52 kg ha^{-1}) whereas lowest available N content in the soil was observed with respect to T_5 treatment (235.05 kg ha^{-1}) i.e. application of bio-stimulant @ 20 kg ha^{-1}; the lowest value of available N in T_5 treatment is due to higher N uptake by the treatment. Similarly, Control treatment (T_7) had significantly higher available P_2O_5 (13.57 kg ha^{-1}) whereas lowest available N content in the soil was observed with respect to T_5 treatment (12.60 kg ha^{-1}); the lowest value of available P_2O_5 in T_5 treatment is due to higher P_2O_5 uptake by the treatment. Numerically higher K_2O content was observed in control treatment (241.74 kg ha^{-1}) and lowest by T_5 treatment (235.64 kg ha^{-1}).

E) Economics of treatments

On the basis of economic analysis, it was revealed that, application of bio-stimulant @ 20 kg ha^{-1} gave higher gross returns, net returns and B:C ratio of ₹ 95292.98 ha^{-1}, ₹ 30148.98 ha^{-1} and 1.46 respectively. Whereas the lowest gross returns (₹ 73081.50 ha^{-1}) were obtained with respect to control treatment (T_7). The lowest net returns (₹ 9797.02 ha^{-1}) and B:C ratio (1.13) was are obtained by the application of tricontanol 0.05 per cent GR @ 25 kg ha^{-1} (T_6) (Table 4.18). These lower values of the net returns and B:C ratio by T_6 treatment over control treatment is mainly due to high input cost of tricontanol. Baradhan *et al*. (2019) reported in rice crop that, foliar application of bio-stimulant (modulin) @ 2 kg ha^{-1} along with 100 per cent RDF has given higher gross returns (₹ 97,090 ha^{-1}), net returns (₹ 59,600 ha^{-1}) as well as B:C ratio (3.24).

SUMMARY AND CONCLUSION

Chapter V

SUMMARY AND CONCLUSIONS

5.1 SUMMARY

The field experiment was conducted on "Effect of humic acid based bio-stimulant on growth, yield and quality of *kharif* rice (*Oryza sativa* L.) under lateritic soils of Konkan" at Agronomy Farm, College of Agriculture, Dapoli, Dist. Ratnagiri (M.S.) during *kharif*, 2021 The experiment consisted of seven treatments which were replicated three times and laid out in a randomized block design *viz*., T_1: Bio-stimulant @ 2.5 kg ha^{-1} (Laatu), T_2: Bio-stimulant @ 5.0 kg ha^{-1} (Laatu), T_3: Bio-stimulant @ 10.0 kg ha^{-1} (Laatu), T_4: Bio-stimulant @ 15.0 kg ha^{-1} (Laatu), T_5: Bio-stimulant @ 20.0 kg ha^{-1} (Laatu), T_6: Tricontanol bio-stimulant @ 0.05 per cent GR @ 25 kg ha^{-1} and T_7: Untreated control treatment in which application of bio-stimulant is done through broadcasting.

The gross and net plot size were 3.00 m x 5.00 m and 2.60 m x 4.70 m, respectively. The spacing of 20 cm x 15 cm was adopted by transplanting rice. The recommended dose of fertilizer *i.e*. 100: 50: 50 kg N: P_2O_5: K_2O ha^{-1} was applied uniformly to all the treatments including control treatment. Nitrogen was supplied through urea in three split doses and phosphorus through single super phosphate and potassium through muriate of potash applied in single shot.

The observations were recorded on plant population net plot^{-1}, plant height (cm), number of functional leaves hill^{-1}, number of tillers hill^{-1}, dry matter (g) produced, days to 50 per cent flowering, days to physiological maturity, yield attributing characters *viz*., number of panicles hill^{-1}, number of grains panicle^{-1}, 1000 grain weight and panicle length (cm) and yield characters *viz*., grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) , biological yield (kg ha^{-1}) and harvest index (per cent), N, P_2O_5 and K_2O content in grains and straw and their uptake in rice grain, straw and total uptake, available N, P_2O_5 and K_2O, protein content in grains and economics of the treatments.

Initially the seeds were sown in the nursery, then after 21 days the seedlings were transplanted to main experimental plot. Transplanting was done with the help of skilled labours hence uniform plant population of rice crop was noticed in different treatment plots during investigation. Plant protection measures were undertaken to control the pest incidence.

During the growth period of rice crop excellent rainfall was received (4734 mm). Average sunshine hours day^{-1} was 2.86. The soil in which crop was grown was having 13.8 g kg^{-1} organic carbon, pH of 6.29 and electrical conductivity of 0.10 dS m^{-1}. The climate was favourable for growth and development of the rice crop (*Oryza sativa* L.). The important findings of field experiment are summarized as below.

5.1.1 Effect on growth attributes

Uniform plant stand was noticed when counted at 20 DAT and at harvest stage of the rice crop in the experimental plot. Hence there was no any significant difference among treatments.

Growth attributes *viz*., plant height (cm), number of functional leaves hill^{-1}, number of tillers hill^{-1}, dry matter (g) produced have showed significant difference between treatments at 60, 90 and at harvest stage of rice crop. Significantly higher values were found with the application of bio-stimulant @ 20 kg ha^{-1} (T_5) and it was followed by bio-stimulant @ 15 kg ha^{-1} (T_4) and bio-stimulant @ 10 kg ha^{-1} (T_3) which were at par with T_5 treatment. But there was no any significant difference between treatments at 30 DAT. Also there was no significant difference between treatments for days to 50 per cent flowering, days to physiological maturity.

5.1.2 Effect on yield and yield attributing characters.

All the yield attributing characters except 1000 grain weight *viz*., number of panicles hill^{-1}, number of grains panicle^{-1} and panicle length (cm) have shown significant difference between treatments. Significantly higher values were observed with the application of bio-stimulant @ 20 kg ha^{-1} (T_5) and it was followed by bio-stimulant @ 15 kg ha^{-1} (T_4). There was no any significant difference between treatments for 1000 grain weight.

Similarly, yield characters *viz*., grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and biological yield (kg ha^{-1}) have shown significant difference between treatments. Significantly higher values of yields were obtained by application of bio-stimulant @ 20 kg ha^{-1} (T_5) and it was followed by bio-stimulant @ 15 kg ha^{-1} (T_4) and bio-stimulant @ 10 kg ha^{-1} (T_3) which were found at par with T_5 treatment. No any significant difference was observed between treatments for harvest index of the rice crop.

5.1.3 Effect on nutrient content, uptake and protein content in grains of rice crop

There was significant difference between N, P_2O_5 and K_2O content (per cent) in rice grains and straw. Significantly higher N, P_2O_5 and K_2O content in grain and straw were observed with the application of bio-stimulant @ 20 kg ha^{-1} (T_5) and it was followed by bio-stimulant @ 15 kg ha^{-1} (T_4) and bio-stimulant @ 10 kg ha^{-1} (T_3).

There was significant difference between N, P_2O_5 and K_2O uptake (kg ha^{-1}) in rice grains and straw total uptake. Significantly higher values of uptake were observed with the application of bio-stimulant @ 20 kg ha^{-1} (T_5) and application of bio-stimulant @ 15 kg ha^{-1} (T_4) and bio-stimulant @ 10 kg ha^{-1} (T_3) were found at par with T_5 treatment.

There was significant difference between treatments protein content in the rice grains. Significantly higher protein content in the rice grain was observed with the application of bio-stimulant @ 20 kg ha^{-1} (T_5) and it was followed by bio-stimulant @ 15 kg ha^{-1} (T_4) and and bio-stimulant @ 10 kg ha^{-1} (T_3).

5.1.4 Economics of treatments

In respect of economics it was observed that treatment which was applied with bio-stimulant @ 20 kg ha^{-1} (T_5) had shown higher gross returns (₹ 95292.98 ha^{-1}) and higher net returns (₹ 30148.98 ha^{-1}) and B:C ratio of 1.46. It was followed by T_4 treatment.

5.2 Conclusions

On the basis of the objectives of present investigation, following broad conclusions can be drawn.

1) The application of recommended dose of fertilizer (RDF) along with humic-acid based bio-stimulant @ 20 kg ha^{-1}produced better crop growth and higher crop yield in the transplanted *kharif*, rice.
2) Higher nutrient content and uptake in the transplanted *kharif*, rice was observed with application of recommended dose of fertilizer (RDF) along with humic acid based bio-stimulant @ 20 kg ha^{-1}.
3) The higher gross returns, net returns and benefit-cost ratio (more than 1) was obtained in transplanted *kharif* rice with the application of recommended dose of fertilizer (RDF) along with humic acid based bio-stimulant @ 20 kg ha^{-1}.

LITERATURE CITED

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Anonymous. 2019. Biostimulants Market. https://bit.ly/2o3dbpz.

Anonymous. 2020[a]. Department of Agriculture Maharashtra State final estimate. krishi. maharashtra.gov.in 2019-20.

Anonymous. 2020[b]. Agricultural Statistics at a Glance 2020. Directorate of Economics and Statistics, Ministry of Agriculture & Farmers Welfare, Govt. of India.

Arafa, A. A., Hussien, S. F. M. and Mohamed, S. G. 2012. Response of tuber yield quantity of potato plants and its economic considerations to certain bioregulators or effective micro organisms under potassium fertilization. J. Plant Prod. 3(1):131 -150.

Arioli, T., Mattner, S. W., Hepworth, G., McClintock, D. and McClintock, R. 2021. Effect of sea weed extract application on wine grape yield in Australia. J. of App. Phycology. 33:1883–1891.

Arun, M. N., Mahender, K. R., Shailaja, N., Arati, S., Mangal, D. T., Shrinivas, D., Venkatesh, B., Surekha., Padmavath, C. and Prasad, M. S. 2019. Effect of seaweed extract as bio-stimulant on crop growth and yield in rice (*Oryza sativa* L.) under transplanted condition. J. of Rice Res. 12(2): 45-50.

Augustin, S. M., Praptana, R. H. and Santoso, D. 2018. The effect of bio-stimulant in root and population of phosphate solubilizing bacteria: a case study in upland rice. IOP Conf. Series. 183.

Aziz., Manal A., Faiza K., Abd, F. and Fatma A.S. 2014. Effect of cyanobacteria, humic substances and mineral nitrogen fertilizer on rice yield and its components. J. Agric. Chem. And Biotec. 5(11):253-264

Baradhan, G., Kumar, S. M. S., Murugan, S., Narayanan, G. S., Kumar, S. R., Latha, K. and Murugesan, N. V. 2019. Influence of modulin (bio-stimulant) on growth, yield and gene expression of calmodulin in rice under lowered NPK fertilizers. Plant Archieves. 19(2): 3283- 3289.

Biswas, S., Jana, K., Agrawal, R. K. and Puste, A. M. 2019. Effect of integrated nutrient management on growth attributing characters of crops under various oat-lathyrus intercropping system. The Pharma Inn. Jour. 8(9):368-373.

Black, C.A. 1965. Method of soil analysis part-I and part-II. Am. Soc. Agron. Inc. Madison, Wisconsin, U. S. A. 1040(41): 1374-1375.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available forms of phosphate in soil. Soil sci. 59:39.

Bulgari, R., Cocetta, G., Trivellini, A., Vernieri, P. and Ferrante, A. 2014. Biostimulants and crop responses. A review, Biol. Agric. Hortic. 31:1-17

Cardarelli, M., Rouphael, Y., Coppa, E., Hoagland, L. and Colla, G. 2020. Using microgranular based biostimulant in vegetable transplant production to enhance growth and nitrogen uptake. Agronomy. 10(842):1-12.

Chang, L., Yun, W., Xu, W., Nikbakht, A. and Xia, Y. P. 2012. Effects of calcium and humic acid treatment on the growth and nutrient uptake of Oriental lily. Afri. J. of Biotech. 11(9):2218-2222.

Dalpe, Y. and Monreal, M., 2004. Arbuscular mycorrhiza inoculum to supportsustainable cropping systems. Online symposium proceeding. Crop Management network, http://dx.doi.org/10.1094/CM-2004-0301-09-RV.

Davis, R. O. and Bennett, H. H. 1927. Grouping of soils on the basis if mechanical analysis. United States Dept. of Agriculture, Department circular 419. 1-15.

Deepana, P., Bama, K. S., Santhy, P. and Devi, T. S. 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. & Nat. Sci. 13(3): 1111-1120.

Deshmukh, P. S.and Phonde, D. B. 2013. Effect of seaweed extract on growth, yield and quality of sugarcane. Intl. J. of Agril. Scie. 9(2):750-753.

Devi, N. L. and Mani, S. 2015. Effect of sea weed saps *Kappaphycus alvarezii* and Gracilaria on growth, yield and quality of rice. Ind. J. of Sci. and Tech. 8(19): 1-6

Drobek, M., Frąc, M. and Cybulska, J. 2019. Plant biostimulants: importance of the quality and yield of horticultural crops and the improvement of plant tolerance to abiotic stress- A review. Agron. 9:335

Du Jardin, P. 2015. Plant biostimulants: Definition, concept, main categories and regulation. Sci. Hort. 196:3-14.

Dwivedi, S. K., Meshram, M. K., Pal, A., Pandey, N. and Ghosh. A. 2014. Impact of natural organic fertilizer (seaweed saps) on productivity and nutrient status of blackgram (*Phaseolus mungo* l.).The Bioscan, 9(4):1535-1539.

El-Helaly, M. A. 2018. Effect of foliar application of humic and fulvic acids on yield and its components of some carrot (*Daucus carota* L.) cultivars. J. of Hort. Sci.& Orn. Pl. 10(3):159-166.

Eshwar, M., Shrilata, M., Rekha, B. K. and Harish, K. S. 2016. Effect of humic substances (humic, fulvic acid) and chemical fertilizers on nutrient uptake, dry matter production of aerobic rice (*Oryza sativa* L.). J. of Pharma. and Phytochem. 6(5): 1063-1066.

Gawade, N. V., Varu, D. K. and Devdhara. U. 2019. Response of biostimulants and biofertilizers on yield and quality of chrysanthemum cv. Ratlam selection. Int. J. Curr. Microbiol. App. Sci. 8(9): 2732-2742.

Hidangmayum, A. and Sharma, R. 2017. Effect of different concentrations of commercial seaweed liquid extract of Ascophyllum nodosum as a plant bio stimulant on growth, yield and biochemical constituents of onion (*Allium cepa* L.). J. of Pharma. and Phytochem 6(4): 658-663.

Ivana, K., Dino, H., Vida, T., Senad, M., Izudin, K., Nada, P. and Biljina, K. 2017. Biostimulant prevents yield loss and reduces oxidative damage in tomato plants grown on reduced NPK nutrition. J. of Pl. Interact. 12(1): 209–218

Jackson, M.P. 1973. Soil chemical analysis Pentice Hall of India Pvt. Ltd., New Delhi. pp. 134-182.

Jayanta, L., Anup, D., Ramkrishna, G. I., Dibyendu, S., Anup, G., Sudhakar. T. Z., Rattan, L., Gulab, S. Y., Azad, S. P., Ngchan, S. and Ram, S. M. 2017. Seaweed extract as organic biostimulant improves productivity and quality of rice in eastern Himalayas. J. Appl Phycol :1-12

Kavitha, M. P., Ganesaraja, V. and Paulpandi, V.K. 2008. Effect of foliar spraying of sea weed extract on growth and yield of rice. Agric. Sci. Digest. 28(2):127-129.

Khan, O. A., Sofi, J. A., Kirmani, N. A., Hassan, G. I., Bhat, S. A., Chesti, M, H. and Ahmad, S. M. 2019. Effect of N, P and K nano-fertilizers in comparison to humic and fulvic acid on yield and economics of red delicious (*Malus* x *domestica Borukh*). J. of Pharma. and Phytochem 8(2): 978-981.

Kocira, A., Swieca, M., Kocira, S., Złotek, U. and Jakubczyk, A. 2018. Enhancement of yield, nutritional and nutraceutical properties of two common bean cultivars following the application of seaweed extract (*Ecklonia maxima*). Saudi. J. Biol. Sci. 25:563-571.

Kumar, U., Gulati, I. J., Kumar, H. and Kumar, G. 2016. Role of humic acid and salicylic acid on yield attributes yield and economics of tomato under saline stress condition. Ann. of Pl. and S. Res. 18(2):118-122.

Layek, J., Das, A., Ghosh, A., Marak, M. R., Krishnappa, R., Ramkrushna, G. I., Panwar, A. S. and Devi, S. 2018. Evaluation of sea weed saps on performance of tomato (*Lycopersicon esculentum*) under organic production system. Innov. Farm. 3(4):185-191

Lima, S. F., Jesus, A. A., Eudardo, P. V., Tabata, R. O., Maria, G. O. and Simon, C. A. 2019. Development and production of sweet corn applied with biostimulant as seed treatment. Hort. Bras. 38:94-100.

Mahmood, N., Abbasi, N. A., Hafiz, I.A., Ali, I. and Zakia, S. 2017. Effect of bio-stimulants on growth, yield and quality of bell pepper cv. Yolo wonder. Pak. J. Agri. Sci. 54(2): 311-317.

Mariotti, F., Tome, D. and Mirand, P. 2019. Converting Nitrogen into Protein – Beyond 6.25 and Jones' Factors. Cri. Rev. in Food Sci. and Nut. 48(2): 177-184.

Matsushima, S. 1976. High yielding rice cultivation: a method for maximizing rice yield through ideal plants. University of Tokyo press, Japan. 367.

Mishra, M. M., Mohanty, M., Gulati, J. M. L. and Nanda, S. S. 2013 Evaluation of various rice (*Oryza sativa*) based crop sequences for enhanced productivity, profitability and energy efficiency in eastern plateau and hill zone of India. Ind. Jour. of Agril. Sciences. 83(12):1279-1284.

Mona, M. A. 2013. The potential of *Moringa oleifera* extract as a bio-stimulant in enhancing the growth, biochemical and hormonal contents in rocket (*Eruca vesicaria* subsp. sativa) plants. Int. J. of Plant Physio. and Biochem. . 5(3): 42-49.

Mujathoub, M. 2004. Effect of bio-stimulants on production of wheat (*Triticum aestivum* L.). CIHEM.org. 60:147-150.

Nayak,P., Biswas,S. & Dutta,D. 2020. Effect of seaweed extracts on growth, yield and economics of kharif rice (*Oryza sativa* L.). J. of Pharma. and Phytochem .9(3): 247-253.

Nikbakht, A., Kafi, M., Babalar, M., Xia, Y. P., Luo, A. and Etemadi, N. 2008. Effect of humic acid on plant growth, nutrient uptake, and postharvest life of gerbera. J. of Plant Nutri. 31: 2155–2167.

Nori, S., Kumar, S., Khandelwal, S. and Suryanarayan, S. 2019. A biostimulant formulation for improving plant growth and uses thereof, https:// patents.google.com.

Pal, A., Dwivedi, S. K., Maurya, P. K. and Kanwar, P. 2015. Effect of seaweed saps on growth, yield, nutrient uptake and economic improvement of maize (sweet corn). J. of appl. And nat. sci. 7(2): 970-975.

Panse, V. G. and P. V. Sukhatme 1967. Statistical methods for agricultural workers, I.C.A.R. New Delhi.

Paradikovi, N., Vinkovi, T., Vrcek, I. V., Zuntar, I., Boji, M. and Medi, M. 2011. Effect of natural biostimulants on yield andnutritional quality: an example of sweet yellow pepper (*Capsicum annuum* L.) plants. J. Sci. Food Agric. 91:2146–2152.

Pascual, P. R. L., Carabio, D. E., Abello, N. F. H., Remedios, E. A. and Pascual, V. U. 2021. Enhanced assimilation rate due to sea weed biostimulant improves growth and yield of rice bean (*Vigna umbellate*). Agron. res. 19(10): 1-10.

Perumal, P., Ahmad, O. H., Majid, N. M., Mohamadu, B. J. and Kasim, S. 2015. Improving lowland rice (*O. sativa* L. cv. MR219) Plant growth variables, nutrients uptake, and nutrients recovery using crude humic substances. The Sci. World Jour. 2015: 1-14.

Piper, C.S. 1966. Soil and Plant Analysis, Hans Publisher Mumbai, India. Asian Reprint.

Popko, M., Michalk, I., Wilk, R., Gramza, M., Chojnacka, K. and Gorecki, H. 2018. Effect of the new plant growth bio-stimulants based on amino acids on yield and grain quality of winter wheat.Jor. of Molecules. 23:1-13.

Pramanick, B., Brahmachari, K. and Ghosh, A. 2013. Effect of sea weed saps on growth and yield improvements of green gram. Afri. J. of Agril. Res. 8: 1180-1186

Rachelle, M. 2018. Profitability analysis of irradiated carrageenan as a bio-stimulant in small scale rice farming in selected provinces in the Philippines. J. Glob. Bus. Trade 14(2): 15-30.

Rajpar, I., Bhatti, M. B., Zia-ul-hassan., Shah, A. N. and Tunio, S. D. 2011. Humic acid improves growth, yield and oil content of Brassica compestris L. Pak. J. Agri., Agril. Engg., Vet. Sci. 27(2):125-133.

Rehman, H., Alharby, H. F., Alzahrani, Y. and Rady, M. M. 2018. Magnesium and organic biostimulant integrative application induces physiological and biochemical changes in sunflower plants and its harvested progeny on sandy soil. Plant Physiol. Biochem. 126:97-105.

Saha, R., Saieed, M. A. U. and Chowdhury, M. A. K. 2013. Growth and yield of rice (*Oryza sativa* l.) as influenced by humic acid and poultry manure. Univ. Jour. of Plant Sci. 1(3): 78-84.

Selladurai, R., Purakayastha, T. J. 2015. Effect of humic acid multinutrient fertilizers on yield and nutrient use efficiency of potato. J. of Plant Nutri. 1-23.

Shah, M. T., Zodape, S. T. Chaudary., D. R. Eswaran., K. and Chikara, J. 2013. Sea weed sap as an alternative liquid fertilizer for yield and quality improvement in wheat. J. Plant. Nutri. 36:192-200.

Shah, S., Hookway, S., Wilkinson, S. and Eletcher, J. 2017. The effect of biostimulants on crop vigor, disease incidence and grain yield of wheat and winter oilseed rape. Aspects of applied biology. 134:59-69

Shrotri, C. K., Shrotri, K. and Jain, R. 2013. Effect of shilajeet and moringa leaf extract on pearl millet (*Pennisetum typhoides* L.). National Jour. of Life Sci. 10(1):117-120.

Silva, S. F., Olivares, F. L. and Canellas, L. P. 2017. The bio-stimulant manufactured using diazotrophic endophytic bacteria and humates is effective to increase sugarcane yield. Chem. Biol. Technol. Agric. 4(24):1-6.

Sivakumar, K., Devarajan, L., Dhanasekaran, K., Venkatakrishnan, D. and Sudarshan, U. 2007. Effect of humic acid on yield and nutrient uptake of rice. Int. Jou. of Rice. 44(3): 277-279.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available Nitrogen in Soil. Curr. Sci. 25(8): 259-260.

Suseendran, K., Kalaiyarasan, C., Hari Priya, M., Jawahar, S. and Vinodkumar, S. R. 2020. Effect of foliar application of plant growth regulator on yield, nutrient uptake and nutrient use efficiency of rice. Plant archieves. 20(2):8729-8734.

Szczepanek, M. And Ziomek, A. S. 2019. P and K accumulation by rapeseed as affected by biostimulant under different NPK and S fertilization doses. Agronomy. 477(9):1-11.

Szczepanek, M., Wszelaczynska, E. and Poberenzy, J. 2018. Effect of sea weed biostimulant application in spring wheat. AgroLife Sci. J. 7(1). 131-136.

Szparaga, A., Kubon, M., Kocira,S., Czerwinska, E., Pawlowska, A., Hara, P., Kobus, Z. and Kwasniewski, D. 2019. Towards sustainable agriculture-agronomic and economic effects of biostimulant use in common bean cultivation. Sustainability. 11(4575). 1-21.

Tajeda, M., Burno, R. M., Patricia, P. and Parradob, J. 2018. Effect of foliar fertilization of a bio-stimulant obtained from chicken feathers on maize yield. Eur. J. of Agron. 96: 54–59.

Talha, L. A., Gomma, M. A., Nada, A. M. and Dalia, M. T. 2020. Enhancement the productivity of some rice varieties by using some growth promoter supplements. Alexandria sci. Exch. J. 41(4):553-572.

Tandon, HLS. (Ed.) (1993), Methods of Analysis of Soils, Plants, Water and Fertilizers. FDCO, New Delhi, India.

Tejada, M., Rodriguez-Morgado, B., Gomez, I., Franco-Andreu, L., Benitez, C. and Parrado, J. 2016 Use of biofertilizers obtained from sewage sludges on maize yield. Eur. J. Agron. 78:13-19

Vijayakumar, P., Ramaiyan, S. and Balasubramanian, R. B. 2021. Soil fertility and nutrient uptake of rice influenced by plant growth promoting microbe, seaweed extract and humic acid fortified in situ rice residue compost. Intl. J. of Recycl. of Organic Waste in Agri. 10: 215-232.

Xiao, T., Boada, R., Liugany, M. and Valiente, M. 2021. Co-application of Se and a biostimulant at different wheat growth stages: Influence on grain development. Plant Physio. and Biochem. 160(2021):184-192

Xu, L. and Geelen D. 2018. Developing biostimulants from agro-food and industrial by-products. Front. Plant Sci. 9:1567.

Zandonadi, D. B., Santos, M. P., Busato, G, J., Peres, L. E. P. and Facanha, A. R. 2013. Plant physiology as affected by humied organic matter. Theor. and exptl. Plant. Physio. 25(1): 12-25

Zarzecka, K., Gugala, M., Grzywacz, K. and Sikorska, A. 2020. Agricultural and economic effects of the use of biostimulantsof herbicides in cultivation of the table potato cultivar Gavin. Acta Sci. Pol. Agricultura. 19(1):3–10.

Zeljkovic, S., Paradikovic, N., Vinkovic,T., Tkalec, M., Maksimovic, I. and Haramija, J. 2013. Nutrient status, growth and proline concentration of French marigold (*Tagetes patula* L.) as affected by biostimulant treatment. Jour. of Food, Agril & Env. 11(3&4): 2324-2327.

Zodape, S. T., Gupta, A., Bhandari, S. C., Rawat, U. S., Eswaran, K. and Chikara, J. 2011. Foliar application of sea weed sap as a bio-stimulant for enhancement of yield and quality of tomato (*Lycopersicon esculentum* Mill.). Jour. of sci. and indus. res. 70:215-219.

APPENDICES

APPENDIX-I

Appendix I: Prices of inputs and outputs for rice production per unit as of *kharif*, 2021.

Sr. No.	Resources	Unit	Rate (Rs.)
1	Seed	Rs. kg^{-1}	56/-
2	Labour :		
	a) Male	Rs. day^{-1}	248/-
	b) Female	Rs. day^{-1}	248/-
3	Machinery charges	Rs. $hour^{-1}$	600/-
4	Fertilizers :		
	a) Urea	Rs. kg^{-1}	7/-
	b) SSP	Rs. kg^{-1}	9/-
	c) MOP	Rs. kg^{-1}	20/-
5	FYM	Rs. kg^{-1}	2/-
6	Plant protection :		
	a) Lambda cyhalothrin 5% EC	Rs. $litre^{-1}$	600/-
7	Bio-stimulant :		
	a) Laatu	Rs. kg^{-1}	150/-
	b) Tricontanol	Rs. kg^{-1}	500/-
8	Price of the produce :		
	a) Rice grain*	Rs. $quintal^{-1}$	1940/-
	b) Straw	Rs. $quintal^{-1}$	500/-

* Price of rice grain was considered based on MSP prevailing during that period.

APPENDIX-II

Appendix II: Detailed composition of bio-stimulant (Laatu):

Sr. No	Composition	Per cent
01	*Humic* acid	38%
02	Seaweed extract	26%
03	Vitamins (C, B_1,& E)	19%
04	Amino acid	10%
05	Myo-inositol	5%
06	Microbial fermented extract	2%
Total		**100 %**

THESIS ABSTRACT

a)	Title of the thesis	: **EFFECT OF HUMIC ACID BASED BIO-STIMULANT ON GROWTH, YIELD AND QUALITY OF *KHARIF* RICE (*Oryza sativa* L.) UNDER LATERITIC SOILS OF KONKAN**
b)	Full name of the student	: KARENNAVRSACHIN SURESH
c)	Name and address of the major advisor	: Dr. V.G. CHAVAN Assistant Professor Department of Agronomy, College of Agriculture, Dapoli.
d)	Degree to be awarded	: M.Sc. (Agri.)
e)	Year of award of degree	: 2022
f)	Major subject	: Agronomy
g)	Total number of pages in the thesis	: 73
h)	Number of words in the abstract	: 241
i)	Signature of student	:
j)	Signature, Name and address of forwarding authority	:

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Field experiment was conducted during *kharif*, 2021 at Instructional Farm, Department of Agronomy, College of Agriculture, Dapoli, Ratnagiri, Maharashtra in lateritic soils of Konkan to study the effect of humic acid based bio-stimulant on growth, yield and quality of *kharif* rice. Experiment was laid out on Randomized Block Design with three replications. The treatments comprised of various levels of bio-stimulants *viz*., 0, 2.5, 5, 10, 15, 20 kg ha^{-1} and tricontanol @ 25 kg ha^{-1} along with RDF under transplanted condition of rice crop. Significantly positive effects and higher values were observed on plant height, number of tillers hill^{-1}, number of functional leaves hill^{-1}and dry matter production at 60 DAT, 90 DAT and at harvest stage of rice crop with the application of bio-stimulant @ 20.0 kg ha^{-1} (T_5) whereas, least values were recorded with untreated control or RDF only (100: 50: 50 NPK kg ha^{-1}) treatment.

Protein content in rice grain, nutrient content (N, P, K) and uptake in grain and straw was found significantly higher with the application of bio-stimulant @ 20.0 kg ha^{-1}. Also significantly higher grain yield (4753.33 kg ha^{-1}) and straw yield (6156.63 kg ha^{-1}) was observed when bio-stimulant @ 20.0 kg ha^{-1} (T_5) was applied over rest of the treatments. Lower grain and straw yields were observed with respect to untreated (applied RDF only) treatment. Higher gross returns (₹ 95292.98ha^{-1}) and net returns (₹ 30148.98ha^{-1}) were observed with application of bio-stimulant @ 20 kg ha^{-1}.

Key words: Bio-stimulant, Rice, RDF, Economics www.ThePharmaJournal.com

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Effect of humic acid based bio-stimulant on growth, yield and yield attributing characters of kharif rice (*Oryza sativa* L.)

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Abstract
Field experiment was conducted during *kharif*, 2021 at Instructional Farm, Department of Agronomy, College of Agriculture, Dapoli, Ratnagiri, Maharashtra in lateritic soils of Konkan to study the effect of humic acid based bio-stimulant on growth, yield and yield attributing characters of *kharif* rice. The treatments comprise of various levels of bio-stimulant *viz*., 0, 2.5, 5, 10, 15, 20 kg ha-1 and tricontanol @ 25 kg ha^{-1} along with RDF which are applied on rice under transplanted condition. Significantly positive effects and higher values were observed on plant height, number of tillers hill^{-1}, number of functional leaves hill^{-1} and dry matter production at 60 DAT (Days after transplanting) and 90 DAT of rice crop with the application of bio- stimulant @ 20.0 kg ha^{-1} (T_5) whereas, least values were recorded with untreated control or RDF only (100: 50: 50 NPK kg ha^{-1}) treatment. Significantly higher grain yield (4753.33 kg ha^{-1}) and straw yield (6156.63 kg ha^{-1}) were observed when bio-stimulant @ 20.0 kg ha^{-1} (T_5) was applied over other treatments and lower grain and straw yields were observed with respect untreated T_7 (applied RDF only) treatment.

Keywords: Bio-stimulant, rice (*Oryza sativa* L.), RDF, growth

1. Introduction

Rice (*Oryza sativa* L.) is the world's single most important crop, a primary food source for half of the world's population. A total of 49 per cent calories consumed by the world human population come from rice, wheat, and maize, where 23 per cent are provided by rice, 17 per cent by wheat and 9 per cent by maize. Thus almost 25 per cent of the calories consumed by the entire world human population come from rice. Rice cultivation needs urgent emphasis regarding its revamp in productivity. The concernment of uplifting rice productivity is more prominent under the scenarios of increasing food demand in response to consistent population growth as well as agricultural land shrinkage. Moreover, in the present context of changing climate, unsatisfactory performance of rice crop is a major challenge which needs to be addressed with competent agro- technological interventions. India is the largest producer of rice in terms of area (43.79 million hectare) in the world with production.

India has the largest area of land under rice cultivation in the world. In India the area occupied under rice cultivation is 44 million hectares with production of 102.32 million tonnes and an average productivity of 2550 kg ha^{-1} (Anonymous, 2020a) [1]. In Maharashtra area under rice is 1.53 million hectares with production of 3.51 million tonnes with average productivity of 1873 kg ha-1 during 2019-2020. The average productivity of the Maharashtra state is low as compared to other rice growing states viz., West Bengal, Uttar Pradesh, Punjab, Odisha, Tamil Nadu, Haryana, Andhra Pradesh etc. West Bengal is highest rice producing state in India (Anonymous, 2020b) [2]. In Konkan rice is cultivated over an area of 0.39 million hectares with an annual production of about 1.52 million tonnes with average productivity around 2930 kg ha-1. The area, production and average productivity of the Konkan region is more as compared to Western Maharashtra, Marathwada and Vidarbha. The Konkan region comprises five districts *viz*., Palghar, Raigad, Thane, Ratnagiri and Sindhudurg. The area under rice in Raigad districts is 0.11 million hectares with a production of 0.31 million, which is the highest in Konkan region.

Bio-stimulants have increasingly been considered as valuable advanced farming techniques used in worldwide agricultural production. They enhance crop health, quality and grower profitability and can effectively contribute to overcome the challenges posed by the increasing demand for food by the world's population in continuous growth.

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