DEVELOPMENT OF PELLETED ORGANO-MINERAL FERTILIZER AND ITS EFFECT ON BABY CORN (*Zea mays* L.)

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KERALA, INDIA
2023

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by

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THESIS

Submitted in partial fulfilment of the
requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM-695 522
KERALA, INDIA
2023

DECLARATION

I, hereby declare that this thesis entitled **"Development of pelleted organo-mineral fertilizer and its effect on baby corn (*Zea mays* L.)** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Place : Vellayani

Date: 17-05-2023

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Certified that this thesis entitled **"Development of pelleted organo-mineral fertilizer and its effect on baby corn (*Zea mays* L.)"** is a record of research work done independently by Miss. Anila A under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Acknowledgement

I express my sincere gratitude and indebtedness to Dr. Nishan M. A, Assistant Professor, Department of Agronomy, College of Agriculture, Vellayani and Chairperson of my advisory committee, for her inspiring guidance, valuable suggestions, constant support and ceaseless encouragement throughout the course of investigation and preparation of thesis. It was her endurable patience, dedication and perfectionism which made me improve myself in all aspects.

I express my sincere thanks to Dr. Shalini Pillai P, Professor and Head, Department of Agronomy, College of Agriculture, Vellayani for her professional guidance, valuable suggestions and constructive suggestions rendered throughout the course of this research work. I am grateful to Dr. Susha V.S, Assistant Professor, Department of Agronomy, College of Agriculture, Vellayani, for her valuable advice, whole hearted co-operation, and support during the course of work. I also thank Dr. Gowri Priya, Assistant Professor, Department of Soil Science for her valuable suggestions provided throughout the research work.

I express my deep sense of gratitude to the non-teaching staff Mr. Shibu, V., Ms. Vimala, B. and Mrs. Sarika for their help during the lab work. I sincerely thank labourers, Sri. Rajan, Sri. Udayakumar D.S and Sri. Gireesh kumar for their co-operation, generous assistance and immense help during the field work. I express my heartfelt thanks to my batch mates, Sajan S Thomas, Pallavi, Joshna, Anjali, Sagar, Surendar for their moral support during the study tenure. Words cannot express my profound indebtness to my parents and family for their unconditional support, prayers and blessings bestowed on me during the course of my study.

I bow my head before the **GOD ALMIGHTY** who guided me throughout to complete my work successfully. Once again I express my sincere gratitude to all those who helped me in one way or another for the successful completion of my research work.

Anila A.

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LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation / symbol	**Expansion**
%	per cent
₹	indian rupee
°C	degree celsius
AE	agronomic efficiency
ARE	apparent recovery efficiency
BCR	benefit cost ratio
CD	critical difference
cm	centimetre
DAE	days after emergence
DAS	days after sowing
DMP	dry matter production
dS m^{-1}	deci siemens per metre
EC	electrical conductivity
et al.	co-workers
Fig.	figure
g	gram
ha^{-1}	per hectare
kg	kilogram
kg ha^{-1}	kilogram per hectare

LAI	leaf area index
PE	physiological efficiency
m^{-2}	per square metre
nos.	numbers
NS	not significant
PGPR	plant growth promoting rhizobacteria
ppm	parts per million
RD	recommended dose
RH	relative humidity
SE m	standard error of mean
SW	sea weed powder
t ha^{-1}	tonnes per hectare
viz.	namely

APPENDIX

Introduction

1. INTRODUCTION

Soil fertility is a manageable property of soil and its management is essential to optimize short- and long-term crop nutrition for sustainable agricultural production. Traditionally, organic manures (OM) and chemical fertilizers (CF) are used to supply nutrients to crops. The application of OM increases the organic matter content of the soil and has multiple advantages. OM offers a balanced supply of nutrients, including micronutrients, and releases nutrients slowly and steadily over time, improving soil fertility by activating soil microbial biomass. Organic manure application improves soil health by increasing nutrient recycling, improving soil structure, and increasing soil water holding capacity. However, OM have several shortcomings. OM fails to satisfy the immediate nutrient needs of crops due to its slow nutrient releasing characteristics. Organic manures, due to their low nutrient content and variable nutrient composition, are required in larger quantities to meet crop nutrient demand and are often readily unavailable. Moreover, its bulkiness, handling and transportation difficulties and labour-intensive preparatory and application methods limits their extensive use in field crops. CF, on the other hand, have a higher concentration of nutrients in forms that are readily available to plants. CF are only needed in small amounts, are less expensive, and are easier to use than OM. However, the irrational use of CFs accelerated the degradation of the environment and soil health, posing a serious threat to ecological balance and agricultural sustainability (Sindhu *et al*., 2020). There is now a growing awareness of emerging hazard and interest in sustainable agricultural production practices to revitalize and restore soil fertility is increasing day by day. Present global short supply of chemical fertilizers and its higher production and procurement cost also calls for alternate solutions.

A promising approach that could be applied is to combine OM with CF. These two resources are theoretically compatible, which is the the best solution to increase agronomic efficiency and crop productivity without deteriorating soil health and fertility. Recently, this idea has received more attention, which has resulted in the creation of a brand-new class of fertilizer product known as organo-mineral fertilizers (OMFs). This strategy combines OM’s long-term values with the short-term advantages of CF. OMF have increased nutrient concentration allowing for the use of lower application rate. OMF have higher nutrient concentration than organic manures, so that lower application rates can be used. OMF products are also more stable, balanced and consistent, with predictable nutrient release. The advantage of OMF over CF is that it provides a range of macro and micronutrients in addition to organic matter (Sakurada *et al*., 2016; Smith *et al*., 2020). Thus, the use of OMF removes the disadvantages associated with both OM and CF and is widely accepted as a better fertilizer alternative for sustainable crop production.

Recently developed pelleted organo-mineral fertilizers (POMF) has proven to be a better approach to increase and maintain soil fertility. Pelletization of OMF reduces the bulk volume of the material, making it more appealing, cheaper and easier to transport or apply to the soil, as well as more convenient for storage (Nikiema *et al*., 2014).

Despite the fact that POMF has been demonstrated to be a promising technology for sustainable crop production, only limited research works has been done on field crops in Kerala. This necessitates extensive research on potential nutrient sources, optimal mixing ratios of organic manures and chemical fertilisers, and the rate and timing of POMF application on various crops. As a preliminary investigation, baby corn, a highly profitable and nutrient responsive, short-duration field crop grown in Kerala, is chosen as the test crop for the present study. Recently, the role of biostimulants in promoting plant growth has also received global attention. Hence, the present study attempts to formulate and evaluate the performance of POMF fortified with biostimulants for baby corn which will broaden the scope for replication in other field crops. With this background, the present study "Development of pelleted organo-mineral fertilizer and its effect on baby corn (*Zea mays* L.)" was undertaken with the following objectives:

1. Standardization of nutrient sources for production of pelleted organo-mineral fertilizers
2. Evaluation of the effect of pelleted organo-mineral fertilizers on growth and yield of baby corn.

Review of literature

2. REVIEW OF LITERATURE

Plant nutrition management is critical for long-term agricultural production. Organic manures (OM) and chemical fertilizers (CF) have traditionally been used to supply nutrients to crops. OM provides all the nutrients that plants require, but in limited quantities. CF, on the other hand, are relatively inexpensive, have high nutrient contents, are highly soluble in water, and are rapidly absorbed by plants. However, the nutrients in CF are susceptible to loss, resulting in environmental pollution. Furthermore, the depletion of natural resources and energy consumption associated with fertilizer production processes are driving a shift toward more sustainable resource use and nutrient recycling. Organo-mineral fertilizers (OMF) have been recommended as a potential solution in this situation. The foundation of this idea is a novel fertilizer formulation that combines nutrient sources from both organic and mineral sources.

The present study was undertaken to standardize the nutrient sources for the development of pelleted formulation of organo-mineral fertilizers, to access its nutrient release pattern and to evaluate its effect on growth and yield of baby corn. This chapter reviews the existing literature related to the above topics.

2.1 ORGANIC MANURES

Organic manures are used in agriculture as a method to promote soil fertility, preserve soil health, and provide more organic matter to agricultural soils. Organic manures are those materials of plant or animal origin that are used as sources of plant nutrients. The nutrients are available to plants from the organic materials after mineralization. Organic manures have a lower concentration of plant nutrients and provide essential nutrients in smaller amounts. The use of organic manures helps to reduce multiple nutrient deficiencies by improving the physical, chemical, and biological properties of the soil and promotes a healthier environment for growth and development. Cow dung powder, vermicompost, poultry manure, neem cake, groundnut cake and rice husk ash are the organic manures used in the present experiment. The literature that is currently available on the impact of organic manures on soil characteristics, maize growth, and yield is reviewed below.

2.1.1. Effect of Organic Manures on Soil Properties

2.1.1.1 FYM/cow dung powder

Farmyard manure (FYM) is a valuable organic nutrient source that is abundant on all farms. FYM provides all the major as well as the micronutrients required for growth of plants. Farmyard manure application improved the physical, chemical, and biological properties of the soil. FYM stimulated soil aggregate formation, increased the CEC, and worked as a buffer against changes in soil pH (Olaniyi and Ajibola, 2008). FYM released nutrients slowly and was stored in soil for a longer period, ensuring a residual effect with regard to various plant nutrients. The soil organic carbon increased after FYM application (Saha *et al*., 2010). It also increased soil water retention capacity, improved soil structure and created a better environment for root development (Tadesse *et al*., 2013).

According to Choudhary and Kumar (2013), when the crop was supplied with FYM, soil physical properties such as porosity and water holding capacity increased while the bulk density of the soil was decreased.

Farmyard manure hastened the weathering of nutrient-rich minerals, aided in the breakdown of insoluble minerals, and enhanced the availability of nutrients to plants (Choudhary and Kumar, 2013). The accumulation of secondary and micronutrients as well as the reduction of the negative effects of soil acidity, salinity, and alkalinity were the main benefits of applying FYM. Additionally, the presence of FYM improved the efficiency of applying N fertilizer (Bankoti *et al*., 2021).

2.1.1.2. Vermicompost

Vermicomposting is a process that uses earthworms to convert organic materials into humus like material. Vermicompost (VC) contains worm casts, which are a source of both macro and micronutrients, as well as several enzymes and growth regulating substances. Vermicompost is an effective and nutrient-dense organic fertilizer that is high in humus, macro- and micronutrients, growth hormones (auxins, gibberellins, and cytokinins) as well as soil microbes. It is a great soil conditioner and amendment. With the continuous application of vermicompost, the organic nitrogen and other nutrients in the accumulated humus tend to be released at a constant rate (Nasrin *et al*., 2019). Application of VC enhanced the biological, chemical, and physical characteristics of soil. Vermicompost has the potential to improve soil aeration, porosity, bulk density, infiltration rate, and water retention capacity. Application of vermicompost also improved the chemical characteristics of the soil, including its pH, electrical conductivity, and organic matter content (Lim *et al*., 2015).

2.1.1.3 Poultry Manure

The poultry manure (PM) is relatively cheap source of both macronutrients and micronutrients in forms that can easily be absorbed by plants (Mohamed *et al*., 2010). PM application enhanced nitrogen uptake and soil physical properties (Ojeniyi *et al*., 2013). Higher proportion of organic carbon present in PM improved soil organic matter content. This had a stimulatory impact on the structure of soil and aggregate stability. PM application enhanced aeration, water holding capacity, cation exchange capacity, microbial activity and buffering capacity of soil. PM also acted as a good soil conditioner, minimized the bulk density of the soil and enhanced the soil water infiltration rate (Adeyemo *et al*., 2019).

2.1.1.4 Neem Cake

Neem cake (NC) is a non-edible oil cake which can be utilised as a concentrated organic manure. It is the residue obtained after extraction of oil from fresh fruits of neem. It contains around 5.2 per cent N, 1.0 per cent P and 1.4 per cent K (Elnasikh *et al*., 2011). In addition, NC possess insect repellent, nematicidal and fungicidal properties. NC also act as nitrification inhibitor in soil. Thus, it helps to supply nitrogen for a longer time in soil (Katyayan, 2012). NC is reported to reduce the alkalinity of soil, as it produces organic acids on decomposition. NC enhanced soil microflora and improved soil fertility. NC also increased the soil organic matter content, which enhanced water-holding capacity of the soil and aeration resulting in improved root development (Lalnunpuia *et al*., 2018).

2.1.1.5 Groundnut Cake

Groundnut cake (GC) is an edible oil cake and are commonly used as concentrated organic manure. It is a by-product of groundnut oil production that is high in plant nutrients, particularly nitrogen (7 %). It also has micro-nutrients, which are very important for plant growth. It helps in maintaining C:N ratio in soil and has the highest nitrification rate. It improves physical, chemical, and biological properties of soil. It improves soil structure, water holding capacity and cation exchange capacity. Additionally, it enhances soil reaction and increases the microbial population in the soil.

2.1.1.6 Rice Husk Ash

Rice husk ash (RHA) is rich in K, P, Ca, Mg and Si, moderately alkaline in nature and has considerable neutralizing power. The addition of RHA raises the pH of the soil and counteracts soil acidity, thereby increasing nutrient availability to plants. Application of RHA increases total porosity and thereby decrease bulk density of soil. It improves aeration in the crop root zone and it raises the water holding capacity and level of available phosphorus, exchangeable potassium and magnesium in soil (Yin *et al*., 2022)

2.1.2. Effect of Organic Manures on Growth and Yield of Maize

2.1.2.1 Cow dung/FYM

Kumar and Puri (2001) observed that addition of farm yard manure (FYM) @ 15 tonnes per acre had a significant effect on yield attributes in maize when compared to no manure application.

According to Kumar *et al*. (2018), applying 50 per cent of NPK by farmyard manure reduced the number of days required by maize crop for tasseling significantly more than providing 100 per cent NPK through inorganic sources.

2.1.2.2 Vermicompost

Application of vermicompost @ 5 t ha^{-1} produced taller plants, higher dry matter accumulation, and LAI in maize (Louraduraj, 2006).

According to Kumar *et al*. (2007), application of vermicompost @ 2.5 t ha^{-1} resulted in considerably higher grain production in maize as compared to no manure application.

Snehaa *et al.* (2017) reported that application of vermicompost @ 5 t ha^{-1} could result in growth and yield parameters comparable to recommended dose of fertilizers (RDF) (150:60:40 kg NPK ha^{-1}) in baby corn.

2.1.2.3 Poultry Manure

According to Mohamoud and Sharanappa (2002), applying 5 t ha^{-1} of poultry manure increased grain and stover yield of maize.

Significantly larger cobs, number of cobs per plant, cob weight without husk and higher cob yield were obtained with application of poultry manure @ 4. 6 t ha^{-1} (Hekmat and Abraham, 2016).

According to Pal *et al*. (2017), the application of poultry manure resulted in increased growth parameters in maize.

Kumar *et al*. (2018) observed that application of 100 per cent N (150 kg N ha^{-1}) through poultry manure yielded considerably taller plants, LAI and dry matter production in baby corn than with other organic sources such as vermicompost, FYM or panchagavya foliar spray.

2.1.2.4 Neem Cake

Application of neem cake @ 2 t ha^{-1} along with one fourth recommended dose of fertilizers recorded significantly higher growth and yield attributes in maize (Garba and Oyinlola, 2014)

According to Gurjar *et al*. (2022), applying 120:60:60 kg NPK ha^{-1} + Zinc (20 kg ha^{-1}) + Neem Cake (10 q ha^{-1}) + PGPR (200 g per 10 kg seed) resulted in the higher plant height, number of leaves per plant, cob length, number of grains per cob, dry weight, grain yield, and test weight in maize.

2.1.2.5 Rice Husk Ash

Nottidge *et al*. (2011) found that the use of rice husk ash with chemical fertilizer not only increased the grain yield in maize, but also improved the nitrogen level of soil. Saranya *et al*. (2018) also reported the positive influence of rice husk ash on growth of maize in acidic soils.

2.1.3. Effect Of Organic Manures on Nutrient Uptake

According to Ashalatha (2009) application of poultry manure to baby corn resulted in a higher P uptake by the plants.

According to Choudhary and Kumar (2013) application of vermicompost increased N, P and K uptake in maize.

According to Srinivasan *et al*. (2014) combined application of poultry manure and neem cake increased N and K uptake of baby corn comparable to fertilizer treatments in cabbage-baby corn sequence.

2.1.4. Limitations of Organic Manures

One of the major disadvantages of using manure as a nitrogen source is that the nutrient concentrations are not in the range required by most crops. In most cases, the ratio of N to P_2O_5 in manure (about 2:1 to 1:1) is substantially lower than the requirements of most crops (about 4:1). Phosphorus will be overapplied if organic manures with a low N:P ratio are applied. Excess manure application has resulted in soil P increases ranging from 8 to 40 kg P ha^{-1} $year^{-1}$. In certain circumstances, manure is administered at nearly twice its P requirements (Parham *et al*., 2002). Overapplication of P raises both the labile (bioavailable) and non-labile (more recalcitrant) soil P pools (Waldrip *et al*., 2015). This is troublesome because the higher the P level in the soil test, the greater the possibility of non-point source pollution. Therefore, overapplication of manure had a direct threat to aquatic habitats.

Organic manure also has other drawbacks, such as poor nutrient content, limited availability, variable nutrient content depending on its constituent organic elements, and its bulky nature hinders long distance delivery (Chen, 2018). Because of the low availability, low nutrient content, slow mineralization and high labour requirement for processing and application, using organic manure alone is insufficient to supply the crop nutrient need over vast areas.

2.2 BIOSTIMULANTS

Biostimulants are substances that, in small amounts, enhance plant growth. Plant biostimulants, regardless of nutrient content, are any substance or microorganism administered to plants with the purpose of enhancing nutrition efficiency, abiotic stress tolerance, and crop quality attributes (Du Jardin, 2015). The main non-microbial biostimulants include (i) chitosan (ii) humic and fulvic acids (iii) protein hydrolysates (iv) phosphites (v) seaweed extracts and (vi) silicon. Among them seaweed extracts and humic acid are used for the present study. The available literature on the influence of biostimulants on soil properties, growth and yield of maize are reviewed here under.

2.2.1. Effect of biostimulants on soil properties

Biostimulants can enhance the soil's biological, chemical, and physical characteristics while promoting plant growth and preserving soil fertility. Organic matter, microbial activity, and enzymatic activity in soils were all increased by the use of biostimulants. The use of biostimulants resulted in a decrease in pH and electrical conductivity and an increase in the calcium, potassium, magnesium, and phosphorus content of the soil (Yousfi *et al*., 2021).

2.2.2. Effect of Biostimulants on Growth and Yield of Maize

2.2.2.1. Sea Weed Powder

Seaweed-based biostimulants are gaining attraction in crop production systems because of their unique bioactive components that positively effect crop development and output. The use of seaweed extracts in agriculture was reported to improve germination, root growth, leaf size, tolerance of unfavourable soil conditions and nutrient uptake from the soil. Layek *et al*. (2015) found that using seaweed extracts in conjunction with chemical fertilizers increased maize yield by 10.50 - 13.10 per cent.

They contain plant essential macronutrients and micronutrients, as well as plant growth regulators such as IAA, gibberellins, cytokinins, choline chloride, glycine and betaine, which are responsible for numerous physiological responses in plants. Seaweed extract is used for soil application, foliar spray and seed treatment (Kumar and Bardhan, 2018). It has phytostimulant property, which cause increased plant growth and yield parameters in a variety of important crop plants. It also has phytoelicitor action, which means that its components evoke defence responses in plants, assisting in resistance to a number of pests, diseases, and abiotic conditions. Seaweed extracts and products also affect soil and plant microbiome components, encouraging long-term plant growth. (Ali *et al*., 2021).

2.2.2.2 Humic Acid

Humic Acid (HA) is another naturally occurring water-soluble biostimulant formed by the breakdown of organic compounds that can be found in soil, peat, and lignites. The application of HA granules to the soil has a significant effect on plant vegetative growth, increasing photosynthetic activity and the leaf area index of maize (Unlu *et al*., 2011). Application of HA to acidic clay loam soil improved the kernel weight of maize (Azeem *et al*., 2014).

According to Niaz *et al.* (2016), the combined application of urea and HA increased the economic yield and nitrogen use efficiency of maize crop. HA is a complex mixture of many different acids with carboxyl and phenolate groups that behave as a dibasic acid or, on rare occasions, as a tribasic acid. HA forms complexes with iron in the environment, resulting in humic colloids and fulvic acid, which are commonly used in agriculture as soil supplements (Kumar and Bardhan, 2018).

Application of urea along with HA will ensure the synchrony between the nitrogen demand of the crop and the supply thus ensuring a prolonged supply of nitrogen compared to the treatment where urea is applied solely. Application of 75 per cent RDF + HA granules @ 12.5 kg ha^{-1} recorded the highest plant height, leaf area index and dry matter production in maize (Kumar and Bardhan, 2018).

Various micronutrients are further complexed with HA to form chelates, taking advantage of the complexing properties. HA acts as a catalyst for the activity of microorganisms in soil, increasing plant tolerance to stress and promoting growth by increasing nutrient uptake (Li *et al*., 2019).

2.3 CHEMICAL FERTILIZERS

Chemical fertilizers (CF) play a crucial role in building up crop productivity and soil fertility. They are very much beneficial to plants in providing deficient nutrients. Plants can absorb nutrients quickly from CF and the improvements are visible immediately. Furthermore, nutrient release from CF are highly regulated and provide nutrients required by plants.

CF are cheaper source of nutrients with higher nutrient content and solubility and is required in less amount, making it more acceptable than organic fertilizer. In addition to increasing crop yield, fertilizer use also change the physical, chemical, and biological characteristics of the soil. Thus the use of chemical fertilizers is the quickest and surest way of boosting crop production.

In the present study, CF such as urea, rock phosphate, single super phosphate, muriate of potash, rock dust and ayar, are used as nutrient sources. Very few research works on effect of sole application of chemical fertilizers on maize are available. Hence the available research works on effect of combined application of organic manures and CF on growth and yield of maize are reviewed hereunder.

2.3.1 Effect of Combined Application of OM and CF on Soil Properties

Singh *et al.* (2001) reported reduction in soil organic carbon when inorganic fertilizers were used alone. The reduction in soil organic carbon concentration may be attributable to quick mineralization (Singh *et al*., 2008).

Singh *et al*. (2010) found that supplying 50 per cent of the N through FYM and 50 per cent of the N through CF resulted in a considerable increase in available NPK in soil after harvesting baby corn.

Kannan *et al*. (2013) found that applying RD of inorganic fertilizer together with vermicompost @ 6 t ha^{-1} to maize, boosted its production while also improving soil fertility in terms of greater accessible N, P, K, organic carbon and yield of maize.

2.3.2 Effect of Combined Application of OM and CF on Growth and Yield of Maize

Verma *et al*. (2006) reported a significant increase in plant height, dry matter production, leaf area index, crop growth rate, and net assimilation rate with NPK applications of 90, 30, and 15 kg ha^{-1} at 30, 60, and 90 DAS of maize crop, respectively.

Application of 120 kg N ha^{-1} as urea and 30 kg N ha^{-1} as poultry manure improved all the growth attributes in maize (Kumar *et al*., 2008).

Ghaffari *et al*. (2011) investigated the effect of integrated nutrient management on maize growth, yield, and quality. It was found that application of recommended dose of NPK + a single spray of multi nutrient @ 1.25 L ha^{-1} had a substantial impact on growth and yield parameters of maize.

According to Tetarwal *et al*. (2011), using 150 per cent RDF resulted in significantly higher plant height, cobs per plant, grains per cob, DMP, grain, and biological yield. However, RDF + 10 t ha^{-1} FYM had significantly higher dry matter at harvest, which was comparable to 150 percent RDF.

Ravi *et al*. (2012) reported that application of 10 t ha^{-1} of FYM along with recommended doses of NPK improved plant height and total dry matter in summer maize.

Kannan *et al*. (2013) found that applying RDF by inorganic fertilizer + vermicompost @ 5 t ha^{-1} resulted in considerably higher plant height, leaf area index, 100 seeds weight (g), and grain production (kg ha^{-1}) than applying RDF through inorganic fertilizer + FYM @ 10 t ha^{-1}.

Shinde *et al*. (2014) and Maske *et al*. (2015) reported that the application of 100 per cent of recommended dose of fertilizers with 10 t ha^{-1} FYM gave higher grain and straw yield of maize.

According to Afe *et al*. (2015), applying poultry manure along with 30 kg N ha^{-1} reduced the number of days required for maize crop tasseling from 47 to 38.

The addition of FYM @ 12.5 t ha^{-1}+135:65:45 kg NPK ha^{-1} recorded significantly higher plant height, number of leaves per plant, leaf area index, dry matter production, cob length, cob girth and cob weight with husk in maize (Mavarkar, 2016).

Zinc sulphate @ 25 kg ha^{-1}, neem cake @ 200 kg ha^{-1}, and Azotobacter @ 2 kg ha^{-1} were significantly more effective at increasing the grain yield of maize when used in combination with fertilizer applied at 150 percent of the recommended dose (Kamalakannan *et al*., 2017).

Application of CF in conjunction with rice straw compost, and clinoptilolite zeolite improved nutrients availability in soil, enhanced nutrient uptake, nutrient use efficiency, and grain yield of maize (Omar *et al*., 2018).

2.3.3 Effect of Combined Application of OM and CF on Nutrient Uptake of Maize

According to Quansah (2010), applying NPK fertilizer (60:40:40 kg ha^{-1}) along with poultry manure (60 kg ha^{-1}) increased maize's absorption of NPK compared to applying PM or CF alone.

According to Tetarwal *et al*. (2011), using the recommended fertilizer dose (40-15 kg N-P ha^{-1}) + FYM 10 t ha^{-1} resulted in significant increases in organic carbon (0.74%), available N (316.0 kg ha^{-1}), available P (10.8 kg ha^{-1}) and Zn uptake in maize.

Similarly, Almaz *et al*. (2017) found that combining 50 per cent NPK with 50 per cent poultry manure boosted NPK uptake in maize compared to sole application of poultry manure and inorganic fertilizer.

2.3.4. Limitations of Chemical Fertilizers

Chemical fertilizer use has resulted in a decrease in soil organic matter (SOM) content as well as a decrease in agricultural soil quality. Chemical fertilizer overuse hardens the soil, reduces soil fertility, pollutes the air, water, and soil, and threatens the ecosystem. The high solubility of mineral fertilizers may cause nutrient losses, mainly N, because of volatilization and leaching (Lourenço, 2016), leaching of K (Rosolem, 2017) and P fixation (Borges *et al*., 2019).

Chemical fertilizer prices have risen significantly in recent years, prompting to seek alternative fertilizers. Chemical fertilizers include highly concentrated active chemicals that are delivered to the plant too quickly, resulting in a large portion of the fertilizer not being utilized efficiently (Geonadi, 2017).

Continuous use of chemical fertilizer can alter soil pH, increase pests, acidification, and soil crust, resulting in lower organic matter, humus load, and beneficial organisms, slowing plant development and even contributing to greenhouse gas emissions (Pahalvi *et al*., 2021). These will undoubtedly have an impact on soil biodiversity by disrupting soil well-being due to their long-term persistence in the soil.

Long-term use of chemical fertilizers has a negative impact on soil quality, environmental pollution, levelling off, and land productivity. Long-term mineral fertilizer use can lead to decreased fruit quality, soil nutrient imbalance, acidity, and compaction, ultimately lowering soil nutrient delivery and storage (Heena *et al*., 2021).

2.4. WAYS TO OVERCOME THE LIMITATIONS OF OM AND CF

Many researchers have found that integrating organic sources of nutrients with mineral fertilizers to form organo-mineral fertilizers (OMF), can overcome the limitations of mineral and organic fertilizers and boost fertilizer efficiency (Antille *et al*., 2017; Borges *et al*., 2019). Alternatively, biostimulants can also be added to organo-mineral fertilizer formulations to enhance desirable effects. As a result, combining organo-mineral fertilizers with biostimulants has proven to be a more successful approach of enhancing and sustaining soil fertility and yields than utilising only chemical or organic fertilizers.

2.4.1 Organo-Mineral Fertilizers

The combination of organic manures and mineral fertilizers to produce organo-mineral fertilizer (OMF) is a novel concept in sustainable nutrient management. The available literature on advantages, composition and methods of preparation of OMF and the effect of OMF on soil properties, nutrient uptake, growth and yield of crops are reviewed hereunder.

2.4.1.1. Advantages of Organo-Mineral Fertilizers

Organo-mineral fertilizer (OMF) has various advantages over organic or mineral fertilizer. OMF are safe, and their usage represents a long-term solution to increasing agricultural yield while limiting soil fertility degradation.

The combination of organic and inorganic nutrients in manure allows it to act as a slow-release fertilizer as well as a quick release fertilizer and maintain nutrient balance for healthy plant growth. Thus this method combines the short-term benefits of mineral fertilizers with the long term benefits of organic manures, reducing the need for repeated fertilizer applications to maintain soil fertility. Organic manure combined with chemical fertilizer has the potential to improve soil nutrient balance, nutrient availability, soil chemical and physical characteristics, soil organic matter, reduce fertilizer loss rate, and improve soil fertility and ecosystem productivity (Tejada *et al*., 2005; Makinde *et al*., 2007; Pagliari and Laboski, 2013).

OMFs are the result of an optimal blend of organic and mineral substances based on plant nutritional needs, resulting in products that release nutrients that, in addition to supplying deficient nutrients to plants, also can improve soil attributes.

Basal combined application of organic manures and inorganic fertilizers resulted in steady release of nutrients and reduced N losses, increasing N use efficiency (Liu *et al*., 2008).

Several studies on combined organic and inorganic fertilization found that it increased carbon storage in soils while decreasing emissions from N fertilizer use (Pan *et al*., 2009).

Many researchers reported that OMF were found to be more nutrient use efficient than organic and inorganic fertilizers owing to their slow nutrient release rate and reduced losses. Finally, the production process of OMF was found to be more energy efficient and highly sustainable. The energy consumptions for the manufacture of N, P, K fertilizers are 69.5 MJ kg^{-1}, 7.7 MJ kg^{-1}, and 6.4 MJ kg^{-1}, respectively while organic matter drying and granulation requires a lower energy consumption of 0.35 MJ kg^{-1} (Fadare *et al*., 2010).

Organo-mineral fertilizer production results in a more stable, balanced, and homogeneous product with predictable nutrient availability. Combining animal manures with mineral fertilizers to make organo-mineral fertilizers has also enhanced the nutrient concentration of organic manures, allowing for lower application rates (Antille *et al*., 2013).

Although the optimal quantity of OMF to be applied is more than double the quantity of mineral fertilizers, OMF is reported to have higher agronomic efficiency compared to mineral fertilizers (Ghiberto *et al*., 2015; Mazeika *et al*., 2016).

The returning of animal manure to the environment in the form of OMF rather than the typical raw form has many benefits, according to Mazeika *et al*. (2016). First of all, the raw manure has a high moisture content (40-70% for poultry and 75-95% for cattle). The amount of nutrients available per unit mass is impacted by this. Cattle manure typically has a nitrogen concentration of 2-7 kg t^{-1} while poultry manure has a nitrogen concentration of 5-15 kg t^{-1}. OMF have up to 30-200 kg N t^{-1} depending on the mineral fertilizer used.

It is also difficult to distribute bulky organic manure over the ground. On an average, 10-30 tons of organic manure is required per hectare, while only 1-3 t ha^{-1} is required when OMF are used, resulting in substantially cheaper application costs. The final benefit of OMF is its ability to include variable levels of primary, secondary, and micronutrients based on crop requirements. This is critical for avoiding over-fertilization, soil nutrient imbalance, and the subsequent eutrophication (Mazeika *et al.*, 2016). In addition to organic matter, OMF can provide a variety of macro and micronutrients. (Sakurada *et al*., 2016; Smith *et al*., 2020).

2.4.1.2. Methods of Preparation of Organo-Mineral Fertilizers

OMFs are made by combining mineral fertilizers having one or more primary nutrients with organic manures or soil improvers through blending, chemical reaction, granulation, or dissolution in water. Kazemzadeh (1998) described the process of producing odourless, sterilised manure pellets. The process starts by mixing dried manure with a dry binder agent material followed by the addition of steam or water. The mixture is then fed into an extruder, where it is homogenised before being subjected to high pressure (100 psi) and high temperature (125 °C). The pellets can be fused with fertilizer to create fused organo-mineral fertilizer or blended with fertilizer to create granulated manure mixed with fertilizer after drying to about 7 per cent moisture content.

In a method described by Varshovi (2005), dry chemical fertilizer and wet manure were mixed together before being put into a rotating mixer or granulation drum, and was dried during granulation process. Similar to this, liquid chemical fertilizer and dried and granulated manure can be combined before being put into a rotating mixer or granulation drum, where the mixture dries throughout the granulation process.

2.4.1.3. Composition of Organo-Mineral Fertilizers

Organo-mineral fertilizers, unlike chemical fertilizers, do not have set or specific chemical properties. The nutrient content will vary depending on the production technique, raw material type, and ratio. Consequently, OMFs can be tailored to the nutrient requirements of specific crops. Numerous scholars have published information on the components used in the manufacture of organo-mineral fertilizers.

Fernandez-Escobar *et al*. (2004) reported that OMF can be produced by mixing phospho-gypsum, urea, triple superphosphate, single superphosphate, potassium chloride, a biocatalyst, and a solubilizing catalyst with pine wood shavings, composted urban waste, and chicken manure. The final product had a pH of 6.6, contained 42 percent organic carbon, and had the formula 2-7-4 (N-P_2O_5-K_2O).

Zebarth *et al*. (2005) prepared an organo-mineral fertilizer having a final chemical composition of 7-4-4 (N-P_2O_5–K_2O) using different organic and chemical sources. Makinde *et al*. (2007) mixed cow dung with mineral fertilizer N and produced organo-mineral fertilizer having a pH of 6.1, 36 per cent organic carbon and N-P_2O_5-K_2O ratio of 4-0.5-1.

According to Sakurada *et al*. (2016), the organo-mineral fertilizer evaluated in their study had a nutrient composition of 5-20-2 (N-P_2O_5-K_2O) for fused organo-mineral fertilizer and 3-15-2 (N-P_2O_5-K_2O) for granulated manure mixed with fertilizer. In their experiment, OMF was created with poultry manure as the organic source and MAP, KCl, and Calcogran (20 % Ca and 10 % Mg) as the chemical fertilizers. The amount of organic carbon left in the final product of fused organo-mineral fertilizer and granulated manure mixed with fertilizer was 41 per cent and 44 per cent, respectively, and the pH was 6.3 and 5.1.

Ojo *et al*. (2014) also formulated two organo-mineral fertilizers having nutrient ratios 5–4-1 (N-P_2O_5–K_2O) and 1–0.7–2 (N-P_2O_5–K_2O). Ayeni and Ezeh (2017) also reported an organo-mineral fertilizer with final chemical composition of 4-3-4 (N-P_2O_5–K_2O).

2.4.1.4 Effect of Organo-Mineral Fertilizers on Soil Physical Properties

Organo-mineral fertilizers improve water retention, soil porosity, infiltration, soil aggregation and minimizes soil loss through erosion (Mandal *et al*., 2007).

In comparison to untreated plots, cumulative infiltration rates rose after the application of organo-mineral fertilizer to soils. Soil loss was reduced when organo-mineral fertilizer was used (Babalola *et al*., 2007).

When compared to mineral fertilizers alone, organo-mineral fertilizer application increased soil organic matter (Ayeni *et al*., 2012).

According to Kominko *et al*. (2017), the main benefit of organo-mineral fertilizer is the gradual release of nutrients and the large increase in soil organic matter, which ensures perfect soil physical characteristics and fertility status. Improvement in aggregate stability, water holding capacity, bulk density, infiltration, cation exchange capacity, and microbial activity are other potential benefits of increased soil organic matter content.

2.4.1.5. Effect of Organo-mineral Fertilizers on Soil Chemical Properties

Khiari and Parent (2005) reported that organo-mineral fertilizers improved the plant-mineral interaction by reducing mineral sorption of phosphorus, decreasing the transformation of phosphates into plant unavailable forms.

When an organo-mineral fertilizer was compared to a complex of organic and inorganic nutrients, inorganic N losses were decreased by 16 per cent, P losses were reduced by 55 per cent, and Mg losses were reduced by 11 per cent (Tejada *et al*., 2005).

According to Ojeniyi *et al*. (2009) organo-mineral fertilizer had a greater impact on soil pH compared to non-fertilized and chemically fertilised plots.

Okunlola *et al*. (2011) showed that the use of organo-mineral fertilizer granules reduced soil acidity, enhanced soil water and nutrient holding capacity, and boosted soil fertility.

Nutrient availability was delayed when organic and chemical fertilizers were fused together to form a single granule, and the nutrient release lasted for multiple growing seasons compared to the nutrient sources that are mixed together and two products are identifiable (Makinde *et al*., 2011). The rapid solubilization of mineral fertilizers from OMF offers a quick supply of nutrients, while the mineralization of organic manures provides a steady supply of nutrients during the critical periods of crop growth (Olaniyi and Ojetayo, 2011).

Application of organo-mineral fertilizer increased soil pH from 6.0 in control plots to 6.2, but soil pH following application of chemical fertilizer was only 5.9 (Ayeni *et al.*, 2012).

Organo-mineral fertilizer applied @ 10 tonnes per acre resulted in the maximum soil available P and K as reported by Ayeni *et al.* (2012).

Singh *et al*. (2012) reported that organic matrix entrapped urea increased organic carbon percentage, total NPK in plant and available N, P and K in soil.

Kumar *et al*. (2013) revealed that the application of organic matrix entrapped chemical fertilizers could affect the soil physical properties significantly by increasing soil pH, water holding capacity, organic carbon percentage and organic matter. These matrix also significantly increased the nitrate content in the rhizosphere at 0-15 cm depth. In addition to that soil available N, P and K significantly increased upon crop harvest when it is treated with entrapped fertilizers over unentrapped fertilizers.

Organo-mineral fertilizers serve to offset the negative environmental consequences of using mineral fertilizers alone, which often release their nutrients more quickly after soil application. The organic part of organo-mineral fertilizer preserves the inorganic components through binding and absorption, reducing the rate of plant nutrient release (Rady, 2012).

When organic and chemical fertilizers are combined, the inclusion of inorganic minerals appears to improve mineralization of organic nutrients, extending nutrient availability during the growing season (Mandal *et al.*, 2007; Ojo *et al.*, 2014).

Similarly, increased mineralization rate and decreased N loss in pelleted OMF compared with mineral fertilizer was reported by Antille *et al*. (2014).

According to Silva *et al*. (2017), organo-mineral fertilizers provide phosphorus slowly and gradually during crop development because organic matter rich in humic substances has the property of increasing the availability of negative charges in the phosphate release region of organo-mineral fertilizers. Soil pH is another factor that not only influences nutrient availability but also crop growth.

Ayeni and Ezeh (2017) revealed that the use of organo-mineral fertilizer increased soil pH from 6.8 to 7.9, while the use of chemical fertilizers decreased soil pH to 6.1.

The addition of chemical fertilizers to organic manures can increase nutrient use efficiency (Antille *et al*., 2017; Rosolem *et al.,* 2017; Borges *et al*., 2019).

Organic manures containing low molecular weight organic acids can limit P adsorption because these acids compete with phosphate for adsorption sites on soil colloids (Borges *et al*., 2019).

In rice, neem coated urea has been shown to improve nitrogen use efficiency. When used in conjunction with urea, nitrification inhibitors such as neem cake reduced nitrogen losses, resulting in increased crop yields (Reddy *et al*., 2019).

2.4.1.6. Effect of Organo-mineral Fertilizers on Soil Biological Properties

Microbial biomass was considerably greater in plots treated with organo-mineral fertilizer than in plots treated with mineral fertilizers. The increased microbial biomass carbon increased above ground growth, which resulted in increased photosynthetic rates, resulting in increased carbon transfer to the roots. As a result, more root exudates were expelled, providing a carbon source for microbial communities to thrive (Mandal *et al*., 2007).

Mandal *et al*. (2007) found higher dehydrogenase activity in soils treated with organo-mineral fertilizer. Soil samples collected from plots treated with organic matrix contained urea revealed an increase in dehydrogenase activity and alkaline phosphatase activity (Kumar *et al*., 2013).

Because of the increased availability of NPK and organic carbon, the usage of OMF increased the microbial population in the soil (Ashok *et al*., 2015). One reason could be because the organic matrix provided ample carbon sources needed for microorganisms. Furthermore, an increase in organic soil components can alter and improve soil microbial features and diversity (Rashidi *et al*. 2017).

2.4.1.7. Effect of Organo-mineral Fertilizers on Growth attributes and Yield

Organo-mineral fertilizers have the potential to boost plant development indices and yield more than manure or fertilizers alone. OMF fortified with urea and applied @ 4.5 t ha^{-1} resulted in higher growth and yield in maize (Makinde, 2007).

Sharma and Singh (2011) developed organic matrix based slow-release fertilizers (SRFs) from the agro-waste materials cow dung, clay soil, neem leaves and rice bran in 2:2:1:1 proportion to entrap the chemical fertilizers. They revealed that it was a cost-effective method as the agro-waste materials were utilized effectively and granules enhanced growth, productivity and yield in Indian mustard. The organic matrix itself acted as a nutrient source in soil and they enhance the efficiency of chemical fertilizers due to higher nutrient holding and slow releasing nature.

The use of pellet fertilizer made from urea and dry cow dung manure enhanced yield attributes and yield in wheat (Eyvazi *et al*., 2011) and corn (Bagheri *et al*., 2011).

According to Singh *et al*. (2012), granular organic matrix-entrapped urea prepared from biodegradable agro-waste materials such as cow dung, rice bran, neem leaf powder, and clay soil in a 1:1:1:1 ratio, mixed with half the recommended dose of urea, increased the efficacy of chemical urea and increased rice grain yield by 3.6 fold and productivity by 32 per cent.

Grain yields improved by 2.11 and 2.13 Mg ha^{-1} when fused organo-mineral fertilizer was given to maize @ 5 or 10 Mg ha^{-1}, respectively. Also, the use of fused organo-mineral fertilizer resulted in higher corn grain production compared to chemical fertilizer at comparable rates (Ayeni *et al*., 2012).

The entrapment of urea in organic matrix increased rice productivity and yield (Kumar *et al*., 2012). Kumar *et al*. (2013) reported that the basal application of organic matrix entrapped urea prepared in granular form with cow dung, rice bran, neem leaves, and clay soil in 1:1:1:1 ratios as matrix and acacia gum as binder entrapping half of the recommended dose of urea increased growth attributes, grain, and yield.

According to Ashok *et al*. (2015), organic matrix entrapped chemical fertilizers enhanced fertilizer use efficiency in rice. In an organic matrix encapsulated chemical fertilizer manufactured from cow dung, powdered neem leaves, and clay soil in a 1:1:1 ratio with acacia gum as a binder, even half the fertilizer dose produced a higher yield.

Azeem *et al.* (2014) reported increase in maize growth characteristics with the integration of inorganic fertilizers and organic manure granules. Entrapment of urea and DAP in an organic matrix dramatically increased FUE (Ashok *et al.*, 2015).

Sakurada *et al.* (2016) conducted a greenhouse study to evaluate the cumulative effects of fused organo-mineral fertilizer with pelletized manure mixed with chemical fertilizer, as well as chemical fertilizer alone, on maize plant development. The authors reported that corn biomass in fused organo-mineral and chemical fertilizers was not different and was both larger than that in pelletized manure mixed with chemical fertilizer for the first two cycles. However, in the third and fourth cycles, fused organo-mineral fertilizer became less effective than chemical fertilizer and pelletized manure mixed with chemical fertilizer. The findings revealed that the various processes used to produce the various organo-mineral fertilizers influenced their performance and residual effects.

According to Rashidi *et al.* (2017) applying pellet fertilizers based on animal manures can significantly boost plant growth while also benefiting organic matter and biological activity. Tomato plants which received organo-mineral fertilizer had greater plant height, root dry matter and fruit yield than plants treated with commercial fertilizers (Ayeni and Ezeh, 2017). The rapid mineralization of inorganic components found in organo-mineral fertilizer, along with the gradual nutrient release of organic ingredients, resulted in improved performance of tomato.

When manure and chemical fertilizer were combined, the blended substance outperformed either manure or chemical fertilizer when used separately (Ayinla *et al.*, 2018).

Application of chemical fertilizer in conjunction with rice straw compost and clinoptilolite zeolite improved nutrient availability in soil, enhanced nutrient uptake, nutrient use efficiency and yield of maize (Omar *et al.*, 2018).

Wu *et al.* (2018) reported that the low-cost sustainable slow-release matrix based urea fertilizer was an eco-friendly method of wheat production as it reduces the risk of nitrogen loss and increase the yield more than 11 per cent.

Adithya (2019) observed that the growth, yield and quality parameters of tomato were enhanced when 50 per cent recommended dose of fertilizer was entrapped in granular organic-matrix made up of rice husk ash, clay, cow dung, rice husk, coir pith compost and vermicompost in 1:1:0.5:0.5:0.5:0.5:0.5 ratio and applied in two splits. There was 50 per cent saving in fertilizer dose and the fertilizer load per unit area was reduced by the entrapment of fertilizers in organic matrices.

The use of fertilizer-manure blocks made with coir pith- 35 per cent, cow dung- 25 per cent, vermicompost-13 per cent, groundnut cake- 10 per cent, neem cake-10 per cent, zeolite- 2 per cent, humic acid- 5 per cent in 100 g size containing 25 per cent of the recommended dose of nutrients placed 5 cm below the level of planting and top dressing of 50 per cent of KAU POP recommendation improved growth and yield of okra in grow bags and saved 25 per cent of the fertilizers in comparison with KAU POP recommendation (Induja, 2020).

2.4.1.8. Efficacy of Organo-mineral Fertilizer on Nutrient Uptake

There are evidences to suggest that mineral uptake from organo-mineral fertilizers are more efficient than mineral uptake from chemical fertilizers.

Application of organo-mineral fertilizer @ 1.5 t ha^{-1} increased uptake of N, K, and Fe uptake in wheat compared to a mixture of organic and inorganic fertilizers (Tejada *et al*., 2005).

Ojeniyi *et al*. (2009) reported that the nutrient uptake increased in organo-mineral fertilizer plots, most likely due to increased soil nutrient levels, as compared to non-fertilized and chemically fertilised plots.

In comparison to the control, varying amounts of organo-mineral fertilizer raised the concentrations of N, P, K, Fe, Cu, and Mn in maize (Ayeni *et al*., 2012).

Tomato plants cultivated in soil with organo-mineral fertilizer absorbed more nutrients than plants grown in soil with inorganic fertilizer (Ayeni and Ezeh, 2017).

Wu *et al.* (2018) reported that the organic matrix-based fertilizer could increase the agronomic and apparent recovery efficiencies as compared to unentrapped conventional urea. This might be due to the reduced nitrogen loss and increased availability of nitrogen.

2.4.2 Pelleted Organo-Mineral Fertilizers (POMF)

The recent development of Pelleted organo-mineral fertilizers (POMF) has proven to be a more effective method of increasing and maintaining soil fertility. Pelletization is the process of biomass densification by using mechanical pressure while converting it into pellets. Generally, the final volume is only 50 to 90 per cent of the original powdered material for cylindrical pellets with a 5 mm diameter. (Hara, 2001). Thus, pelletizing OMF reduces the bulk volume of original material, making it more appealing, cheaper, and easier to transport, as well as more convenient for storage (Alemi *et al.*, 2010; Zafari and Kianmehr, 2012).

2.4.2.1. Methods of Preparation of Pelleted Organo-Mineral Fertilizers

OMF is densified or pelletized to create a dry, pathogen-free, easy-to-handle end product. Flat or ring die pellet mill extrusion is most commonly used in pelletizers. The simplicity of the design and structure of a flat die pellet mill over a ring die pellet mill makes it easy to clean. Ring die pellet mills, on the other hand, are less prone to the uneven die and roller wear seen with flat dies, lowering roller and ring die mill maintenance and repair costs. Ring die pellet mills use less energy than flat die pellet mills (Whirlston Machinery, 2018a; 2018b).

2.4.2.2. ***Advantages of Pelleted Organo-Mineral Fertilizers***

Pelleted fertilizers can be applied uniformly with better control because of its size and less moisture content than organic manures. In pellets, the nutrients are concentrated in a small band of land as opposed to spreading all over. This enhances the nutrients' efficiency by allowing the nutrients to concentrate in an area that is more accessible to the plant. The plant can use the desired amount of fertilizer since the nutrients can be provided properly. This is advantageous since less fertilizer is wasted and it is more cost-effective (UNL, 2006).

Compost pelletization can address issues such as high moisture content, high volume per unit weight, and changing nutrient composition. In general, pelletization of organic manures combined with inorganic fertilizer results in higher nutrient content as well as improved physical properties for easier transport and application. Pellet application also produces a tenth or less of the dust produced by traditional composting (Hara, 2001).

Furthermore, when compared to traditional powdered, non-pelletized fertilizers, pellets release nutrients at a consistent rate, assisting in the reduction of soil and nutrient losses from agricultural areas (Siriwattananon and Mihara, 2008). This is significant because the residual nutrient effect of pellets on a cropping season may be greater than that of powdered forms. When compared to fresh manure, pellets are easier to handle during shipment and field application. (Lopez-Mosquera *et al*., 2008).

Pelletization also facilitates broadcast application of fertilizers, making it a dust-free process (Mavaddati, 2010). Jeiran *et al*. (2010) also reported that the application of pelleted organo-mineral fertilizer resulted in higher yield attributes and yield in wheat.

Bagheri *et al.* (2011) conducted a field experiment to assess the effect of pelleted fertilizer made from urea and dry cow dung manure on corn production. Because of its slow and continuous nutrient release for plant absorption at various stages of growth, they determined that pelleted fertilizer was a better option than uncoated nitrogen fertilizer. Pelletization also reduced heavy metal and pathogen levels in organic manures.

Application of pelleted fertilizers resulted in higher yield and yield attributes and higher protein content in maize (Bagheri *et al*., 2011). The incorporation of manure-based urea pellets boosted growth, yield components, and grain protein content in wheat (Eyvazi *et al*., 2011).

The pelletization further homogenised and dehydrated organic matter (Alemi *et al*., 2010), improving its uniformity and fertilizing or amending properties (Zafari and Kianmehr, 2013).

According to Reza-Bagheri *et al*. (2011), pelletizing of powdery fertilizer has potential to kill pathogens and is easier to handle, store, transport and apply than powdered organic fertilizer.

Pelletized fertilizer acts as a slow release fertilizer, allowing nutrients to stay in the soil for a longer period. This will enable plant roots to consume nutrients when they are needed. In addition, there will be no danger of over fertilizing plants (Hammed, 2013).

Pelletization of the OMF allows reduction in bulk volume of material, making it more attractive, cheaper, and easier to transport or apply to the soil (Nikiema *et al*., 2014).

Pellets can be conveniently stored and transported because they occupy less space than their original form (Sharara *et al*., 2016), which lowers the cost of transportation and application. Pelleted organo-mineral fertilizers also facilitates subsurface band application at sowing, and reduces N loss into the environment.

Pelletizing animal manure reduced water content, weight and volume, and odour, resulting in a product preferred over fresh manure due to lower storage, shipping, handling, and application costs (Mieldazys *et al*., 2016).

To meet specific crop needs, pelleted products may be modified by adding mineral fertilizer, which may change the N/P nutritional ratio in animal manure (Mazeika *et al*., 2016; Sakurada *et al*., 2016). Pelletized composted swine manure was found to be an effective slow release fertilizer for maize (Purnomo *et al*., 2017).

Pelletizing technology transforms animal dung into a dry, pathogen-free, finished product that can be utilised as a fertilizer, soil amendment, feed addition, or energy source. Pelletizing increases the concentration of nutrients in solid fertilizers, enhancing their fertilising and amending characteristics. Pelletized fertilizers have less exposed surface area and release nutrients at a slower rate (Alemi *et al*., 2010; Pampuro *et al.*, 2017).

The application of composted animal manure is limited by two factors: low density of livestock manure and fluctuating nutrient concentration. Densification technology is a viable answer to both issues. Densification of low-density biomass material is a good technique to increase density, reduce transportation costs, and simplify storage and distribution of this material (Zafari and Kianmehr 2013; Pampuro *et al*., 2017).

Pellets of consistent length and diameter can be precisely placed beneath the soil surface near to the seed for a more immediate effect and to permit mechanical fertilisation using seeding equipment. Furthermore, compost pellets emit less dust than loose compost, making pellet handling more convenient at the farm level. Furthermore, because of their slow disintegration, densified products do not deteriorate during long-term storage, keep nutrient quality, and gradually release nutrients over time (Hettiarachchi *et al.*, 2019).

Thus, from the available literature it is clear that POMF combines the benefits of organic and inorganic fertilizers. It increases soil fertility and contributes to a more balanced supply of nutrients, resulting in improved plant growth and development. It improves crop yield and quality while having a lower environmental impact. Organo-mineral fertilizers slowly and steadily release nutrients over time, ensuring that plants receive a consistent supply of nutrients for a longer period of time, requiring fewer applications. Overall, pelleted organo-mineral fertilizers can improve soil fertility, promote plant growth, and increase crop yields in a more sustainable and environmentally friendly manner.

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled "Development of pelleted organo-mineral fertilizer and its effect on baby corn (*Zea mays* L.) was undertaken at the Department of Agronomy, College of Agriculture, Vellayani during 2020-2022. The main objectives of the study were to standardize the nutrient sources to produce pelleted organo-mineral fertilizers (POMF) and to evaluate its effect on the growth and yield of baby corn. The study comprised of two experiments: Experiment I included (A) Formulation and pelletization of organo-mineral fertilizer (B) Incubation studies of POMF (C) Characterization of POMF and Experiment II included crop response study of POMF. The materials used and methodology adopted in the conduct of the experiment are presented in this chapter.

3.1. FORMULATION AND PELLETIZATION OF ORGANO-MINERAL FERTILIZER

The study was conducted at College of Agriculture, Vellayani during November 2021 to January 2022. Organo-mineral fertilizer (OMF) was prepared by mixing organic manures with chemical fertilizers and bio stimulants. The organic manures used for the preparation of organo-mineral fertilizer were cowdung powder (CP), vermicompost (VC), poultry manure (PM), neem cake (NC), groundnut cake (GC), rice husk ash (RHA), rock dust (RD). The chemical fertilizers used were urea (U), rock phosphate (RP), single super phosphate (SSP), muriate of potash (MOP), secondary and micronutrient mixture, ayar (A). Bio-stimulants such as humic acid powder (HA) and seaweed powder (SW), were also used for the preparation of organo-mineral fertilizer.

3.1.1. Formulation of Organo-Mineral Fertilizer

The organic manures were mixed with chemical fertilizers and bio stimulants in different proportions on weight basis to make nine different combinations of organo-mineral fertilizers (OMF). Organic manures collected from different parts of the Thiruvananthapuram district were analyzed and the best sources were selected for the preparation of OMF mixtures. The nutrient content of different raw materials used in the experiment are presented in Table 1. The details of the raw materials used for the preparation of nine different combinations of OMF on percentage weight basis are furnished in Table 2 and the prepared organo-mineral fertilizer mixtures for the experiment are depicted in Plate 1.

Design : Completely Randomized Design
Treatments : 9
Replication : 3

3.1.2 Pelletization of Organo-Mineral Fertilizer

After thorough mixing of the components, different combinations of organo-mineral fertilizer mixtures were pelletized to form pelleted organo-mineral fertilizer (POMF) using a pelleting machine. The specification of pelleting machine used for the experiment is given below.

Power	: 3HP
Electrical connection	: Single phase
Output capacity	: 50-80 kg hr^{-1}
Hopper capacity	: 3-5 kg
Pellet size	: 6 mm
Hopper material	: Stainless steel
Body material	: Cast iron
Dimension	: 32 inches x12 inches x 24 inches
Machine weight	: 92 kg (approx.)

The pelleting machine used for experiment and the prepared pelleted organo-mineral fertilizer are depicted in Plate 2 and 3. During pelletization, talc was used as the filler material in 75:25 (OMF: Talc) proportion for shape retention and consistency of the final product.

Table 1. Nutrient content of raw materials, %

RAW MATERIALS	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Zn**	**B**
Cow dung powder	1.34	0.72	0.76	-	-	-	-	-
Vermicompost	1.08	0.12	1.45	-	-	-	-	-
Poultry manure	1.34	0.23	0.76	-	-	-	-	-
Neem cake	3.98	0.35	0.87	-	-	-	-	-
Groundnut cake	5.38	0.54	1.32	-	-	-	-	-
Rice husk ash	-	0.38	1.28	0.56	0.21	-	-	-
Urea	46	-	-	-	-	-	-	-
Rock phosphate	-	20	-	-	-	-	-	-
Single super phosphate	-	16	-	20	-	11	-	-
Muriate of Potash	-	-	60	-	-	-	-	-
Rock dust		0.0015	0.03	0.19	0.028	0.011	0.002	-
Ayar	-	-	-	15	5	6	1.5	0.6

Table 2. Components used for the formulation of organo-mineral fertilizer mixture, % weight basis

Treatments	**CP**	**VC**	**PM**	**NC**	**GC**	**U**	**RP**	**SSP**	**MOP**	**A**	**RD**	**RHA**	**HA**	**SW**
T_1 -OMF 1	30.00	-	-	10.00	5.00	12.00	7.00	6.00	3.00	1.00	8.00	8.00	5.00	5.00
T_2 - OMF 2	30.00	-	-	10.00	4.00	16.00	9.00	8.00	4.00	1.00	4.00	4.00	5.00	5.00
T_3 - OMF 3	30.00	-	-	10.00	-	20.00	11.00	11.00	5.00	1.00	1.00	1.00	5.00	5.00
T_4 - OMF 4	-	20.00	10.00	10.00	5.00	12.00	7.00	6.00	3.00	1.00	8.00	8.00	5.00	5.00
T_5 - OMF 5	-	20.00	10.00	10.00	4.00	16.00	9.00	8.00	4.00	1.00	4.00	4.00	5.00	5.00
T_6 - OMF 6	-	20.00	10.00	10.00	-	20.00	11.00	11.00	5.00	1.00	1.00	1.00	5.00	5.00
T_7 - OMF 7	-	-	30.00	10.00	5.00	12.00	7.00	6.00	3.00	1.00	8.00	8.00	5.00	5.00
T_8 - OMF 8	-	-	30.00	10.00	4.00	16.00	9.00	8.00	4.00	1.00	4.00	4.00	5.00	5.00
T_9 - OMF 9	-	-	30.00	10.00	-	20.00	11.00	11.00	5.00	1.00	1.00	1.00	5.00	5.00

CP- Cow dung powder, VC- Vermicompost, PM- Poultry Manure, NC- Neem Cake, GC- Groundnut Cake, RHA- Rice Husk Ash, U- Urea, RP- Rock Phosphate, SSP- Single Super Phosphate, MOP- Muriate of potash, A- Ayar, RD- Rock Dust, HA- Humic Acid, SW- Seaweed powder

Plate 1. Organo-mineral Fertilizer mixtures

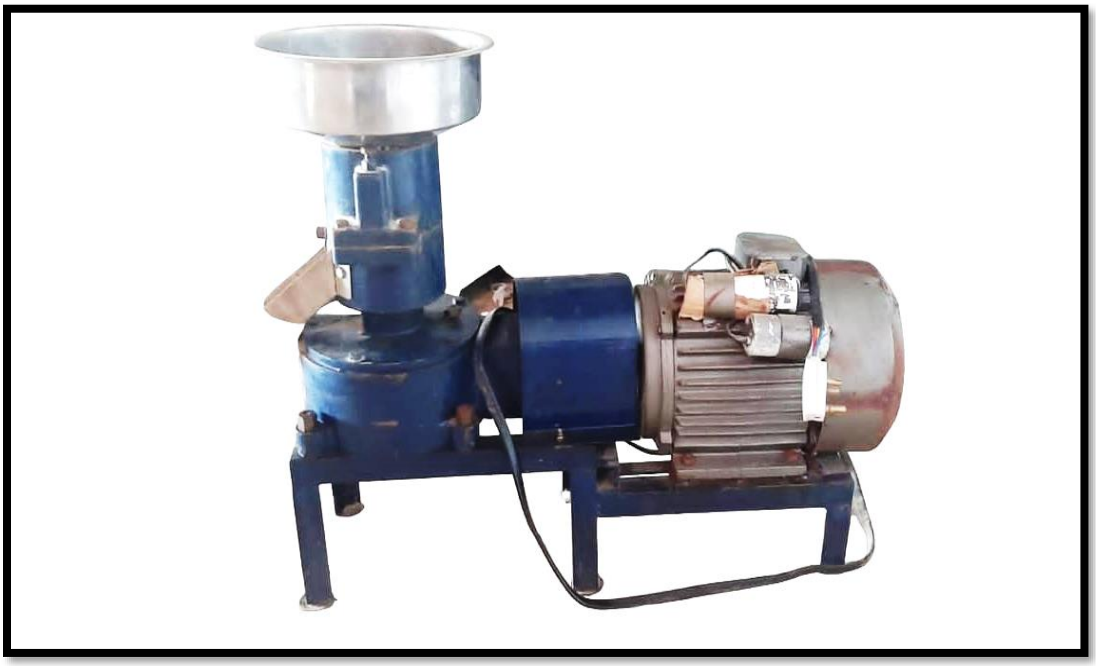


Plate 2. Pelleting machine

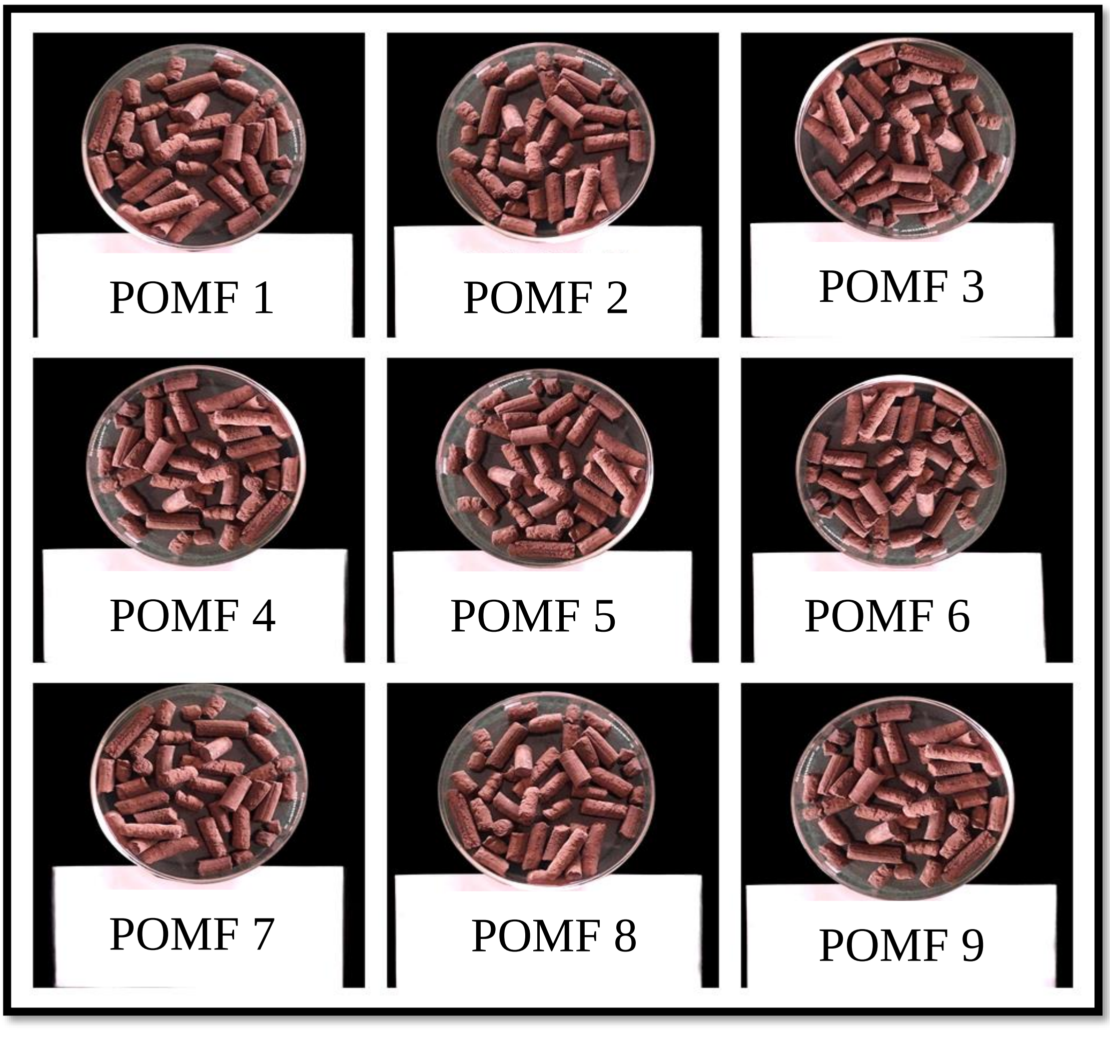


Plate 3. Pelleted organo-mineral fertilizer

The test crop selected for the study was baby corn with a nutrient recommendation of 135:65:45 kg NPK ha^{-1} (*ie*. NPK ratio of baby corn is 3:1.4:1). Among the nine treatment combinations of POMF, the best combinations suited for baby corn were selected based on the nutrient content, nutrient ratios and cost of production.

Six combinations satisfying the selection criteria were obtained and were further used for incubation studies (Plate 4). The nutrient content of six pelleted organo-mineral fertilizers selected for incubation studies are given in Table 3 and the composition of selected POMF is given in Table 4.

Table 3. Nutrient content of selected pelleted organo-mineral fertilizer, %

Treatment combinations	N	P	K
T_1 (POMF 1)	6.16	2.89	2.04
T_2 (POMF 2)	8.18	3.78	2.69
T_3 (POMF 4)	5.54	3.31	2.12
T_4 (POMF 5)	7.67	3.53	2.32
T_5 (POMF 6)	8.51	4.02	3.19
T_6 (POMF 7)	6.94	2.89	2.05

3.2. INCUBATION STUDIES OF PELLETED ORGANO-MINERAL FERTILIZERS

A pot study was conducted during January 2022 to March 2022 at the Department of Agronomy, College of Agriculture, Vellayani. The best six treatments selected from previous experiment were subjected to incubation studies to assess the nutrient release pattern. The experiment was laid out in Completely Randomized Design with 6 treatments and 3 replications. Separate pots for INM (nutrient recommendation of baby corn suggested by Mavarkar (2016) and control (No application) treatments were kept for comparison.

Procedure

For the incubation study, one kilogram of soil was filled in uniformly sized pots (height- 15cm, diameter - 18cm) having no drainage holes. The initial soil analysis was done before the start of the experiment. The treatments were applied on N equivalent basis as per the nutrient recommendation of baby corn as suggested by Mavarkar (2016). The treatments were wrapped in cloth bags for preventing the direct mixing of the materials with the soil. The individual cloth bags containing the treatment combinations were inserted into the center of the pot containing the soil. After that, sufficient quantity of soil was added to cover the cloth bags from all sides. The soil was brought to field capacity by adding measured quantity of water and the moisture content was restored gravimetrically at 3 days intervals throughout the experiment. Separate pots were kept for destructive sampling at 15, 30, 45 and 60 days after incubation. The lay out of the incubation study is depicted in Fig.1 and Plate 5.

3.2.2 Sampling

Destructive sampling was done at 15, 30, 45 and 60 days after incubation for studying the nutrient release pattern. The cloth bags were pulled out carefully from each pot at 15, 30, 45 and 60 days after incubation and the remaining soil was mixed well, dried under shade and analyzed for available N, P and K following standard analytical procedures. Based on the controlled release of nutrients, in concurrence with different stages of growth of baby corn, the best treatment combination was selected for further field studies.

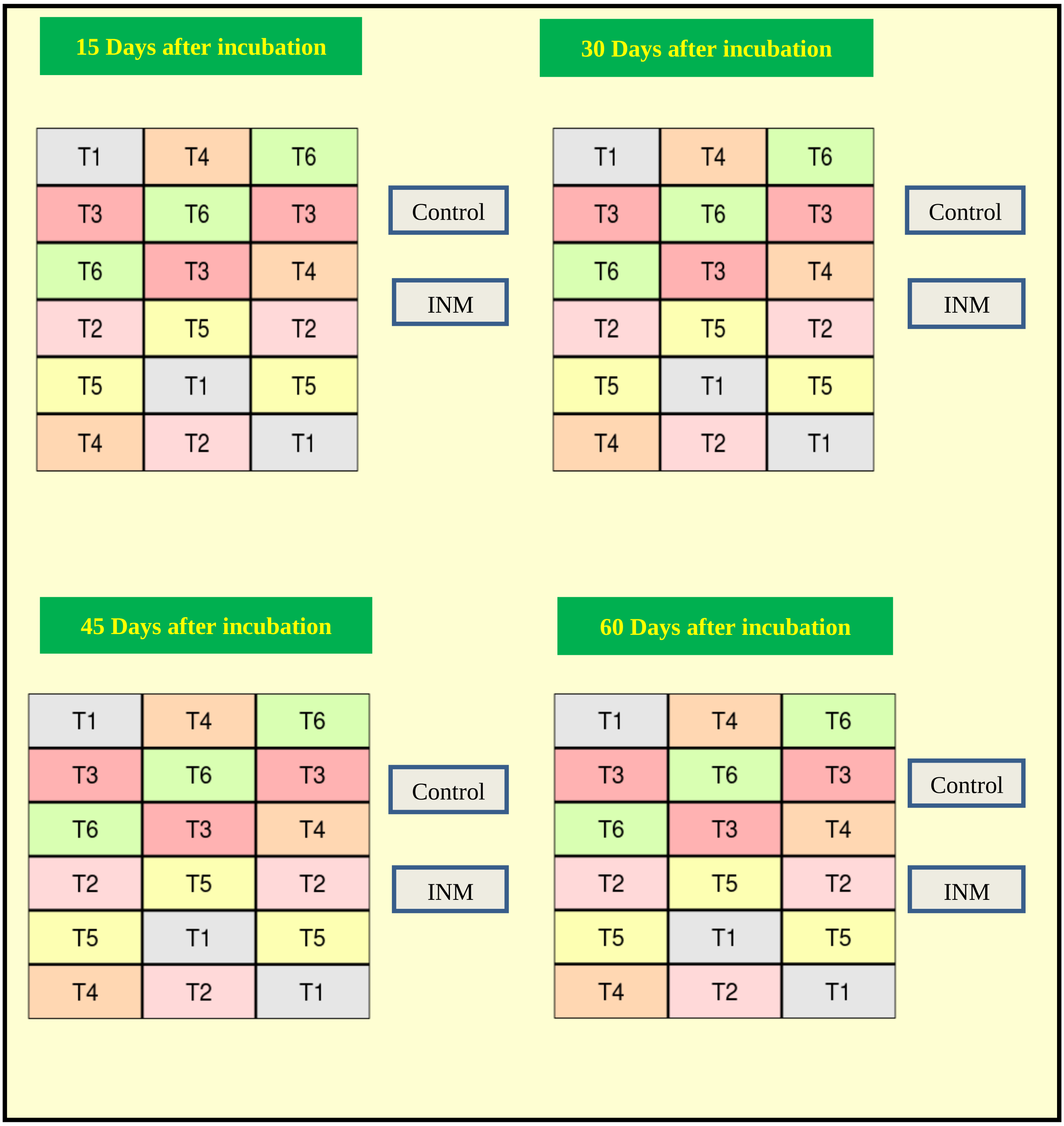
Among the different combinations of POMF studied, POMF 2 was found to release the nutrients in concurrence with the growth stage of baby corn and hence was screened for further field studies.

Plate 4. Pelleted organo-mineral fertilizer selected for incubation studies

Table 4. Composition of selected pelleted organo-mineral fertilizers, g

Treatments	**CP**	**VC**	**PM**	**NC**	**GC**	**U**	**RP**	**SSP**	**MOP**	**A**	**RD**	**RHA**	**HA**	**SW**
T_1 – POMF 1	30.00	-	-	10.00	5.00	12.00	7.00	6.00	3.00	1.00	8.00	8.00	5.00	5.00
T_2 – POMF 2	30.00	-	-	10.00	4.00	16.00	9.00	8.00	4.00	1.00	4.00	4.00	5.00	5.00
T_3 - POMF 4	-	20.00	10.00	10.00	5.00	12.00	7.00	6.00	3.00	1.00	8.00	8.00	5.00	5.00
T_4 – POMF 5	-	20.00	10.00	10.00	4.00	16.00	9.00	8.00	4.00	1.00	4.00	4.00	5.00	5.00
T_5 – POMF 6	-	20.00	10.00	10.00	-	20.00	11.00	11.00	5.00	1.00	1.00	1.00	5.00	5.00
T_6 - POMF 7	-	-	30.00	10.00	5.00	12.00	7.00	6.00	3.00	1.00	8.00	8.00	5.00	5.00

CP- Cow dung powder, VC- Vermicompost, PM- Poultry Manure, NC- Neem Cake, GC- Groundnut Cake, RHA- Rice Husk Ash, U- Urea, RP- Rock Phosphate, SSP- Single Super Phosphate, MOP- Muriate of potash, A- Ayar, RD- Rock Dust, HA- Humic Acid, SW- Seaweed powder



15 Days after incubation

T1	T4	T6
T3	T6	T3
T6	T3	T4
T2	T5	T2
T5	T1	T5
T4	T2	T1

Control

INM

30 Days after incubation

T1	T4	T6
T3	T6	T3
T6	T3	T4
T2	T5	T2
T5	T1	T5
T4	T2	T1

Control

INM

45 Days after incubation

T1	T4	T6
T3	T6	T3
T6	T3	T4
T2	T5	T2
T5	T1	T5
T4	T2	T1

Control

INM

60 Days after incubation

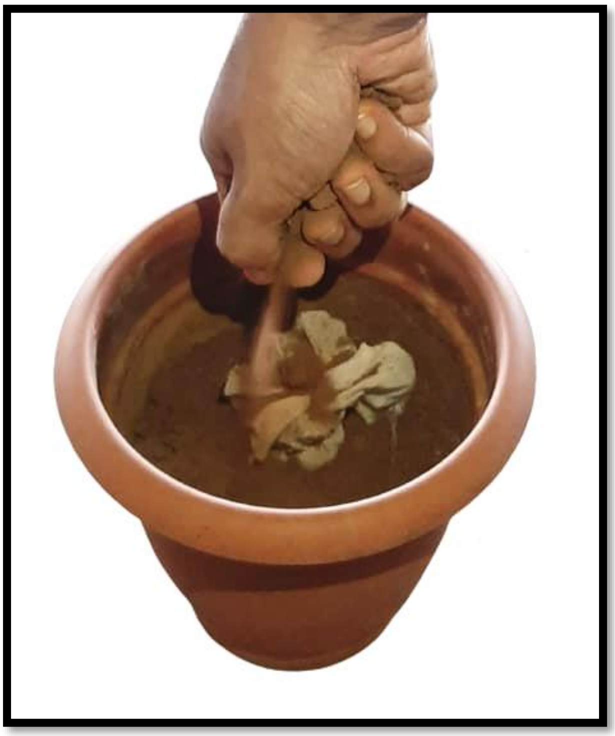
T1	T4	T6
T3	T6	T3
T6	T3	T4
T2	T5	T2
T5	T1	T5
T4	T2	T1

Control

INM

Fig 1. Lay out of incubation studies

POMF wrapped in cloth bag



Soil was added to cover cloth bag and was brought to field capacity

Separate pots kept for destructive sampling at 15, 30, 45 and 60 DAI

Plate 5. Incubation studies

3.3 CHARACTERIZATION OF SELECTED POMF 2

The physical and chemical properties of best treatment combination (POMF 2) selected from incubation study was characterized. The various physical properties such as odour, colour, moisture content, bulk density and the chemical properties such as pH, EC, organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium, zinc and boron content of POMF 2 was analyzed using standard analytical methods (Table 5).

Storage studies were also conducted to assess the shelf life of the selected treatment combination (POMF 2). The samples (100 g) were sealed in polythene bags and kept at room temperature for 6 months for shelf-life assessment (Plate 6). Visual observations on colour, odour, shape retention and microbial attack were recorded at monthly interval. The total N, P, K content of the stored product were also periodically analyzed at 1 month interval upto 6 months following standard analytical methods (Table 5).

3.4 CROP RESPONSE STUDY OF POMF 2

A field experiment was conducted in the farmers field located at Kakkamoola, Thiruvananthapuram, to determine the effect of pelleted organo-mineral fertilizer on growth and yield of baby corn.

3.4.1 Experimental Site

The geographic location of the experimental field is depicted in Plate 7. The experimental field had levelled topography with good drainage.

3.4.1.1 Climate

The experimental site experiences a humid tropical climate. Data on weather parameters like the mean bright sunshine hours, evaporation rate, total rainfall, maximum and minimum temperature, relative humidity I and relative humidity II were obtained from the Class B Agromet Observatory at the College of Agriculture, Vellayani.

The average values of the weather parameters recorded during the cropping period are given in Appendix-I and graphically presented in Fig. 2 a, Fig. 2 b, Fig. 2 c and Fig. 2 d respectively. The mean maximum and minimum temperature ranged from 30.9 ^{o}C to 33.9 ^{o}C and 21.3 ^{o}C to 25.1 ^{o}C respectively and mean RH I and RH II ranged from 87.4 per cent to 96.5 per cent and 75.4 per cent to 89.2 per cent respectively, with a mean evaporation of 4.02 mm per day. Mean bright sunshine hours varied from 2.1 h to 8.0 h. A total rainfall of 466.4 mm was received during the experimental period.

3.4.1.2 Cropping Season

The experiment was conducted from March to May 2022.

3.4.1.3 Soil

The soil of the experimental field was sandy clay loam. The data on mechanical, physical, and chemical properties of the soil of the experimental site are presented in Table 6.

3.4.1.4 Cropping History of the Field

The experimental area was under vegetables during the previous season.

3.4.2. Materials

3.4.2.1. Crop and Variety

The best combination of pelleted organo-mineral fertilizer, POMF 2 was selected for the field study, with baby corn as test crop. Baby corn (*Zea mays* L.) is the young unfertilized cob of maize, harvested within 1 to 3 days of silk emergence. It is a highly profitable crop to farmers due to its short crop duration, being harvested at the juvenile stage. The baby corn variety G-5414 was used for the present field experiment. The important characters of baby corn variety G-5414 is given in Table 7.

Table 5. Analytical methods used for the physico-chemical characterization of selected pelleted organo-mineral fertilizer

Sl. No	Estimated character	Method	Reference
1.	**Physical parameters**		
a.	Odour	Sensory evaluation	
b.	Colour	Visual description	
c.	Bulk density (Mg m^{-3})	Core method	Gupta and Dakshina moorthi, (1980)
d.	Moisture content (%)	Gravimetric method	FAI (1985)
II.	**Chemical parameters**		
a.	Organic carbon	Chromic acid wet digestion	Walkley and Black (1934)
b.	Total N (%)	Modified micro kjeldahl method	Jackson (1973)
c.	Total P (%)	Colorimetrically determined by wet digestion of the sample and developing colour by ascorbic acid method and read in a Spectrophotometer	Bray and Kurtz (1945)
d.	Total (K%)	Flame photometer	Jackson (1973)
e.	Ca (%)	Neutral normal ammonium acetate was used as extractant and estimation by atomic absorption spectrophotometry (AAS)	Jackson (1973)
f.	Mg (%)		
g.	Zn (mg kg^{-1})	Atomic absorption spectrophotometry	Jackson (1973)
h.	B (mg kg^{-1})		
i.	pH	pH meter with glass electrode	Jackson (1973)
j.	EC (dSm^{-1})	Conductivity meter	Jackson (1973)

Plate.6. Storage studies of selected pelleted organo-mineral fertilizer (POMF 2)

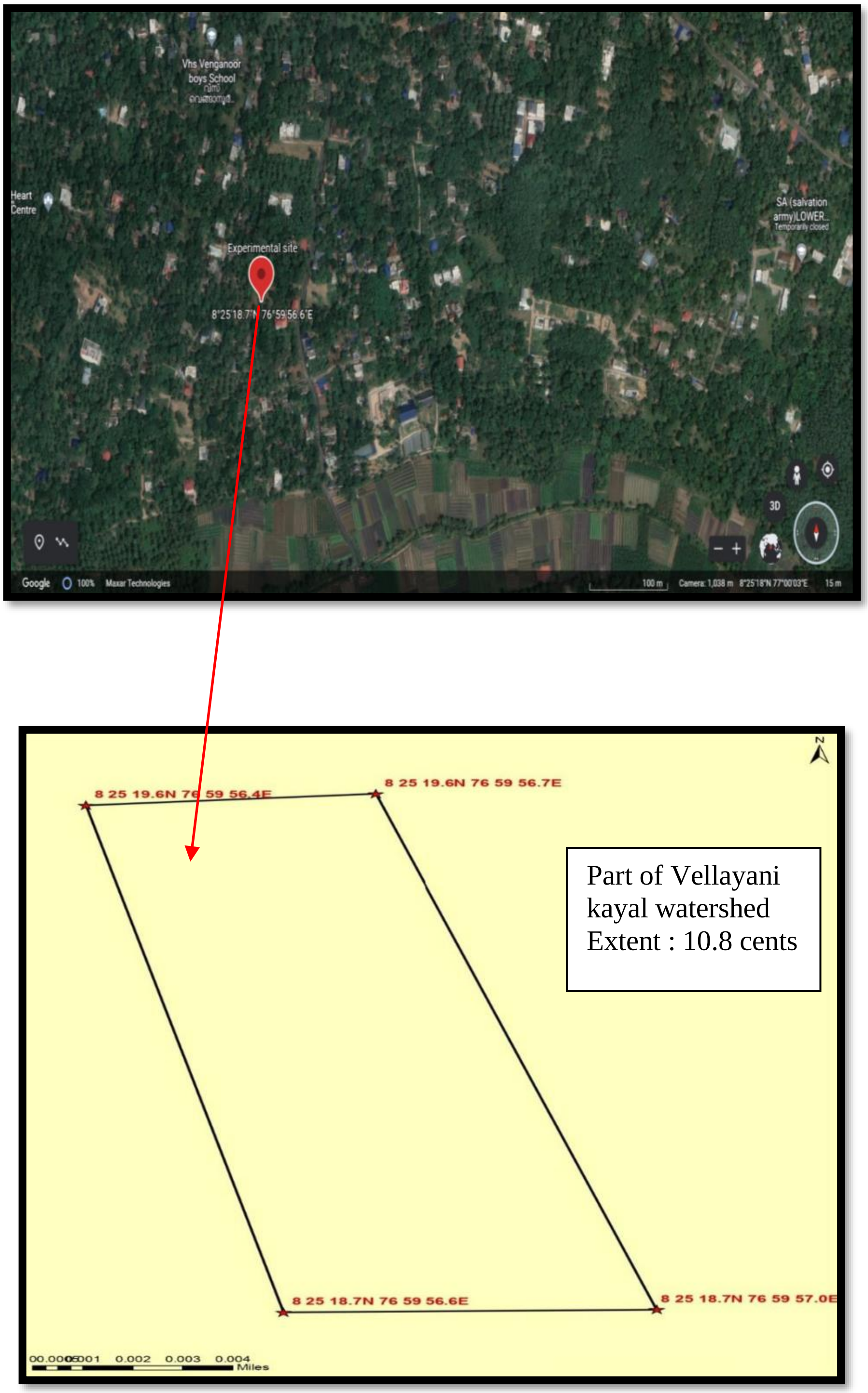


Plate 7. Geographical location of the experimental site

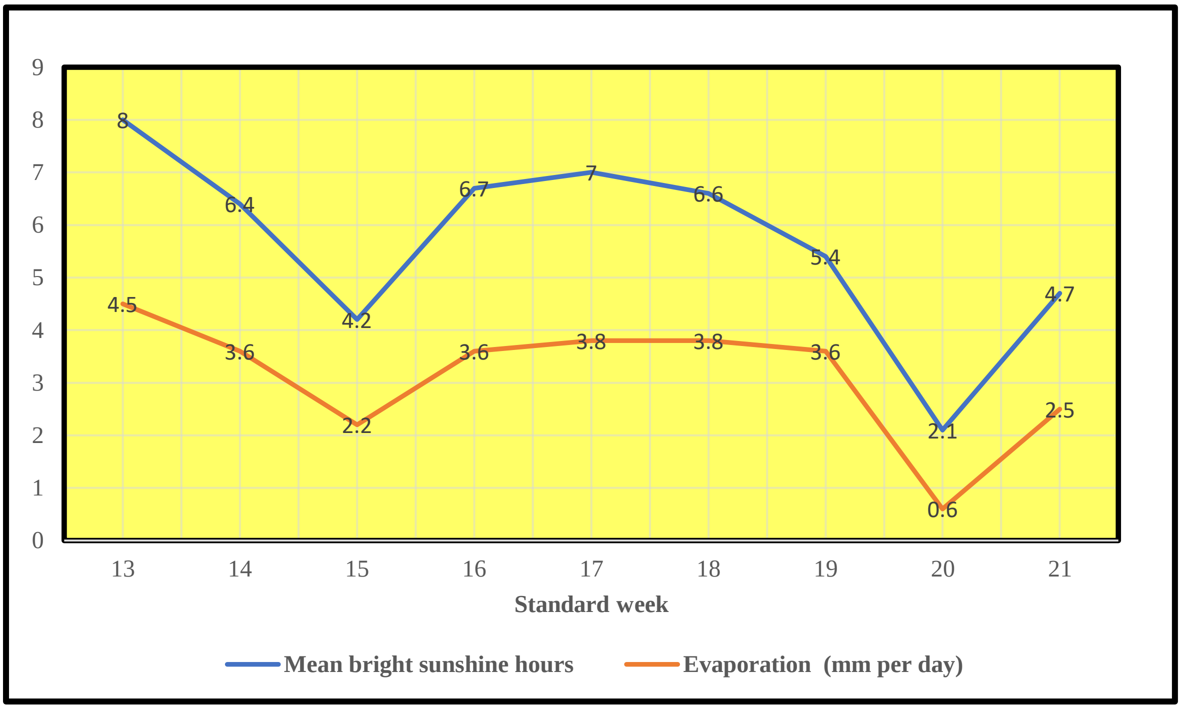


Fig 2 a. Mean bright sunshine hours and evaporation during the cropping period

Fig 2 b. Total rainfall during the cropping period

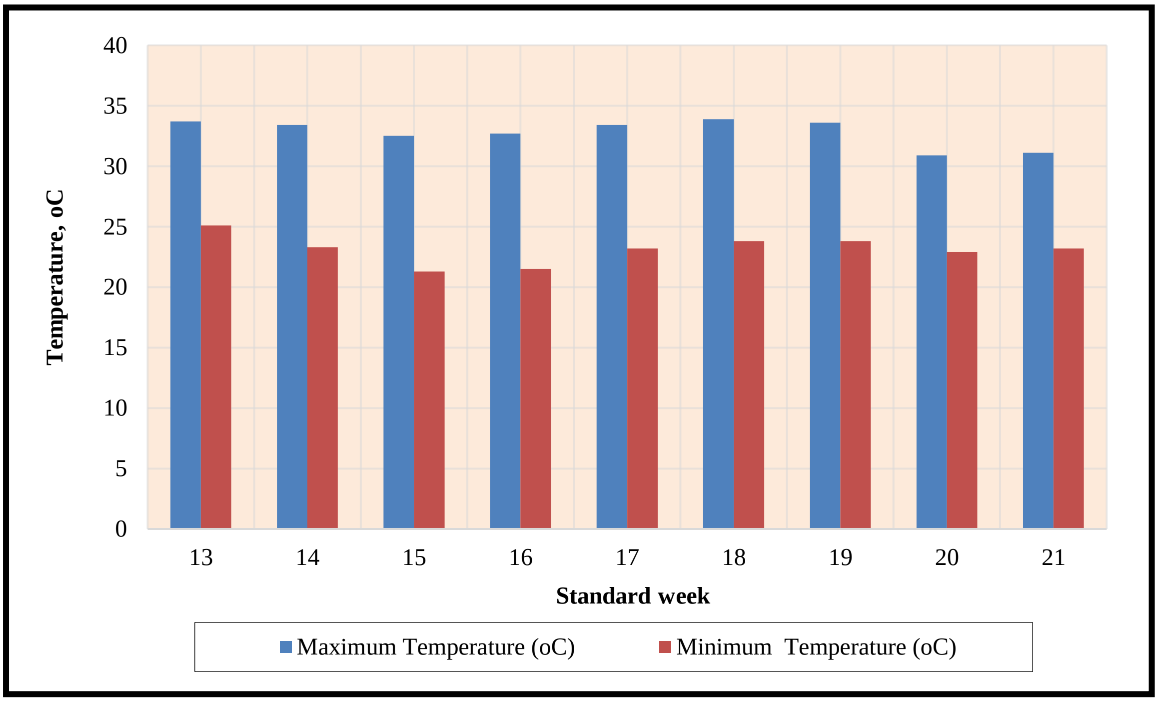


Fig 2 c. Mean maximum temperature and mean minimum temperature during the cropping period

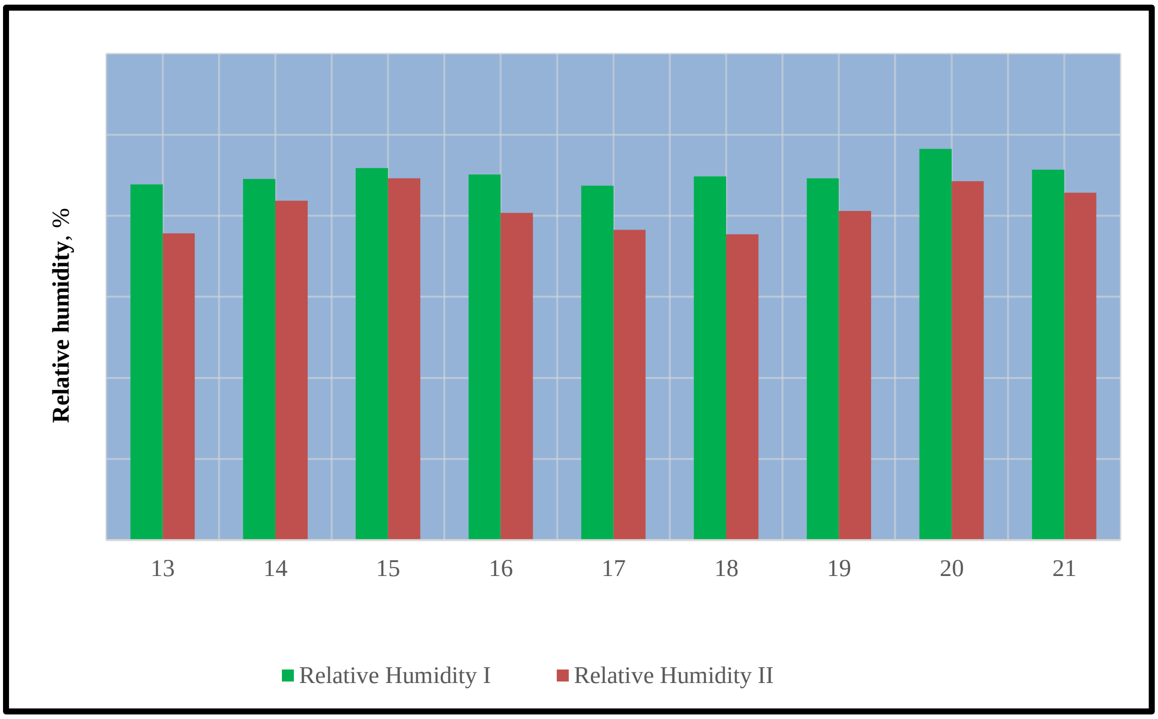


Fig 2 d. Mean maximum RH I and mean minimum RH II during the cropping period

Table 6. Soil characteristics of the experimental site

A. Mechanical Composition

Fraction	**Content in soil (%)**	**Method adopted**	**References**
Coarse sand	47.12	Bouyoucos Hydrometer method	Bouyoucos (1962)
Fine sand	9.25		
Silt	8.48		
Clay	35.15		

B. Physical properties

Parameter	**Observed values**	**Method adopted**	**References**
Bulk density	1.45 Mg m^{-3}	Undisturbed core sample	Black *et al.* (1965)
Water holding capacity	32.6 %	Keen Raczkowski box method	Piper, 1966

C. Chemical Properties

Parameter	**Observed values**	**Rating**	**Method used for extraction and estimation**	**References**
pH	5.4	Strongly acidic	The H^+ ion activity in 1:2.5 soil water suspension was measured using pH meter	Jackson (1973)
Electrical conductivity	0.18	Normal	The electrical conductivity of the supernatant solution after soil pH estimation was measuredusing a conductivity meter.	Jackson (1973)
Organic carbon (OC %)	0.48	Low	Wet digestion method	Walkley and Black(1935)
Available nitrogen (kg ha^{-1})	225.79	Low	Alkaline permanganate method	Subbiah and Asija (1956)
Available phosphorus (kg ha^{-1})	38.06	High	Bray No. 1 solution was used for extracting available phosphorus and after ascorbic acid blue colour method estimated by using spectrophotometer	Bray and Kurtz (1945)
Available potassium (kg ha^{-1})	173.47	Medium	Neutral normal ammonium acetate was used as extractant and measurement was done by usingflame photometer	Jackson (1973)

Table 7. Important characters of baby corn variety G-5414

Parameter	**Character**
Cob color	Light yellow
Uniformity of cob	Very good
Maturity days (days)	50-55
Releasing agency	Syngenta Seeds Co. Pvt Ltd
Cost of seeds (per kg)	Rs. 776/-

3.4.2.2 Manures and Fertilizers

Among the different combinations of POMF studied, POMF 2 was found to release the nutrients in concurrence with the growth stage of baby corn and hence was selected for field evaluation. The composition of POMF 2 included cow dung powder (30%) neem cake (10%), groundnut cake (4%), urea (16%), rock phosphate (9%), single super phosphate (8%), muriate of potash (4%), ayar (1%), rock dust (4%), rice husk ash (4%), humic acid (5%) and seaweed powder (5%) on weight basis.

The nutrient recommendation of baby corn (FYM @ 12.5 t ha^{-1} (basal), 135:65:45 kg NPK ha^{-1}; ½ N + ½ K basal; ½ N + ½ K at 25 DAS) suggested by Mavarkar (2016) was taken for comparison. Well decomposed FYM was used for the basal application. Urea, rajphos, and muriate of potash, were used as the inorganic sources of nitrogen (N), phosphorus (P) and potassium (K) respectively. The nutrient content of raw materials used for the experiment is given in Table 8.

3.5 METHODS

3.5.1 Design and Layout

The field experiment was laid out as detailed below. The layout of the experimental field is given in Fig 3. and Plate 8 and the general view of the experimental field is given in Plate 9.

Design : Randomized Block Design

Treatments : 8

Replication : 3

Spacing : 45 cm x 20 cm

Plot size : 4.5 m x 4 m

Season : Summer 2022

Variety : G-5414

Location **:** Farmer’s field

3.5.2. Treatments

T_1: 100 per cent RD as POMF (basal)

T_2: 75 per cent RD as POMF (basal)

T_3: 50 per cent RD as POMF (basal)

T_4: 50 per cent RD (basal) + 50 per cent RD at 25 DAS as POMF

T_5: 50 per cent RD (basal) + 25 per cent RD at 25 DAS as POMF

T_6: 25 per cent RD (basal) + 25 per cent RD at 25 DAS as POMF

T_7: FYM @ 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}

T_8: Control (No fertilizers)

3.5.3. Land Preparation and Planting

3.5.3.1. Field Preparation

The experimental area was tilled, levelled and brought to fine tilth. Plots of size 4.5 m x 4.0 m were laid out into three blocks with 8 plots each. Bunds were taken to separate individual plots. The plots were laid out into ridges and furrows at a spacing of 45 cm between two furrows. Proper irrigation facilities and drainage channels were provided.

Table 8. Nutrient content of raw materials used for the field experiment, %

RAW MATERIALS	**Nutrient content**							
	N	**P**	**K**	**Ca**	**Mg**	**S**	**Zn**	**B**
FYM	0.84	0.54	0.68	-	-	-	-	-
Cow dung powder	1.34	0.72	0.76	-	-	-	-	-
Vermicompost	1.08	0.12	1.45	-	-	-	-	-
Poultry manure	1.34	0.23	0.76	-	-	-	-	-
Neem cake	3.98	0.35	0.87	-	-	-	-	-
Groundnut cake	5.38	0.54	1.32	-	-	-	-	-
Rice husk ash	-	0.30	0.33	0.56	0.21	-	-	-
Urea	46	-	-	-	-	-	-	-
Rock phosphate	-	20	-	-	-	-	-	-
Single super phosphate	-	16	-	20	-	11	-	-
Muriate of Potash	-	-	60	-	-	-	-	-
Rock dust	-	0.0015	0.03	0.19	0.028	0.011	0.002	-
Ayar	-	-	-	15	5	6	1.5	0.6
Humic acid	-							
Seaweed powder	-							

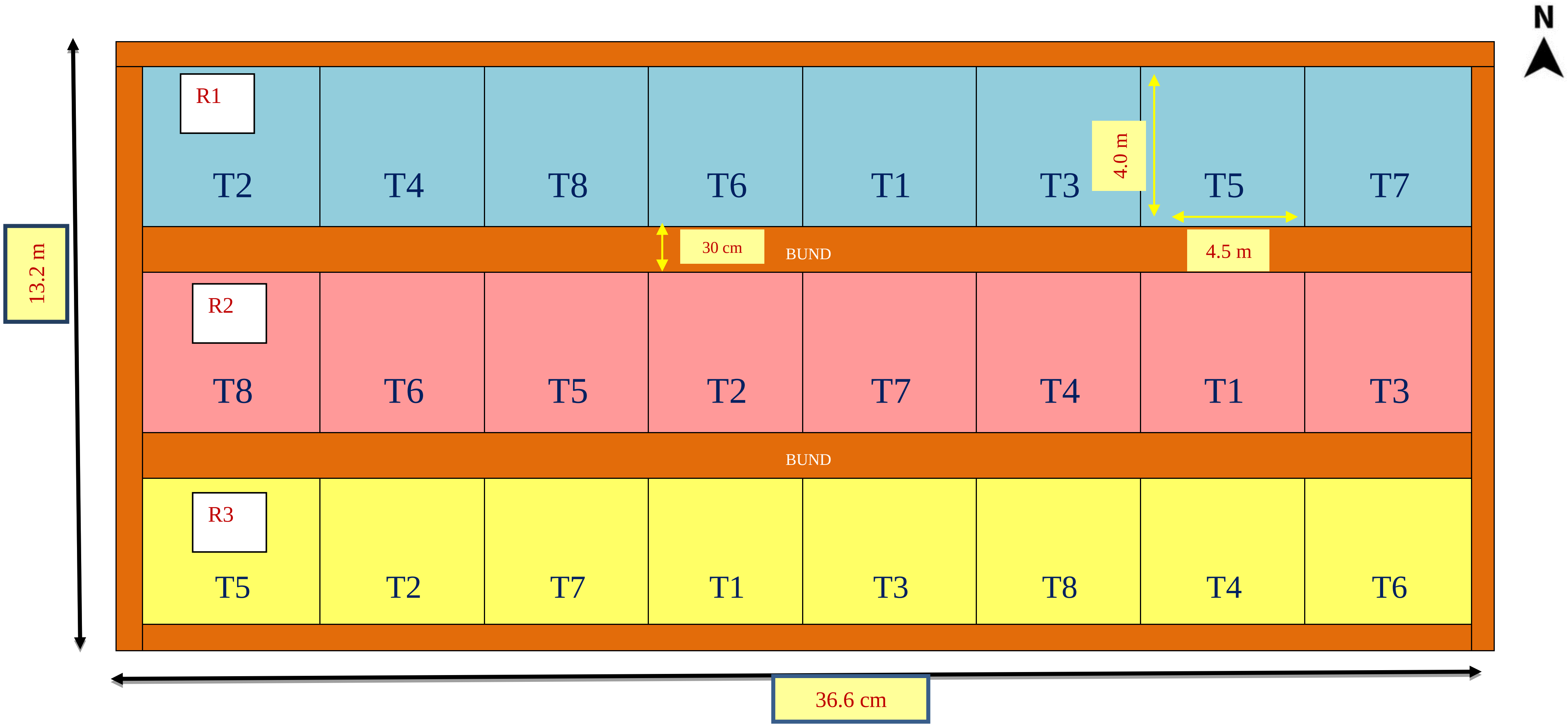


Fig 3. Layout plan of the experimental field

Plate 8. Layout of the experimental field

Seedling stage (10 DAS)

Vegetative stage (30 DAS)

Reproductive stage

Tasseling stage (42 DAS)

Silking stage (46 DAS)

Harvesting (48 DAS)

Plate 9. General view of experimental field

3.5.3.2.Seeds and Sowing

The seeds were moistened with PGPR mix I at the rate of 30 g kg^{-1} and the treated seeds were used for sowing. The seeds of baby corn were dibbled in the furrows at the rate of 20 kg ha^{-1} at a spacing of 45 cm between furrows and 20 cm between plants.

3.5.3.3.Gap Filling

Gap filling was done 10 DAS to maintain a uniform plant population.

3.5.4 CROP HUSBANDRY PRACTICES

3.5.4.1. Liming

Lime was applied at the rate of 250 kg ha^{-1} uniformly to all plots one week prior to the application of treatments.

3.5.4.2. Application of Manures and Fertilizers

The pelleted organo-mineral fertilizer (POMF 2) selected from the incubation study, was applied on N equivalent basis as per the treatments (T_1-T_6) based on the nutrient recommendation of baby corn (135:65:45 kg NPK ha^{-1}). Well decomposed farmyard manure and PGPR mix I were mixed in the ratio 50:1 and was uniformly applied to all POMF 2 treated plots at the rate of 110 g m^{-2} at sowing and at 15 days after sowing. The nutrient recommendation of baby corn, FYM @ 12.5 t ha^{-1}, 135:65:45 kg NPK ha^{-1}; ½ N + ½ K basal; ½ N + ½ K at 25 DAS suggested by Mavarkar (2016) (T_7) was taken for comparison. In control plots, no fertilizers and manures were applied.

3.5.4.3. Irrigation

First irrigation was provided on the day of sowing and subsequent irrigations were provided as and when required.

3.5.4.4. Weed Management

Hand Weeding was carried out at 20 DAS and 45 DAS.

3.5.4.5. After Cultivation

Earthing up was done at 25 DAS.

3.5.4.5.Detasseling and Harvesting

Tassels were removed from each plant at 40-45 DAS to prevent fertilization of cobs. Small unfertilized cobs were harvested from each plant at 2-3 days of silk emergence.

3.6. OBSERVATIONS

Two rows from all sides of each plot were left as border rows. Five plants were selected randomly from the net plot area of each plot and were tagged as sample plants. Observations were recorded from the sample plants and the mean values were worked out.

3.6.1. Growth and Growth Attributes

3.6.1.1. Plant Height

Five plants were randomly selected from each plot and were tagged as sample plants. Two border row plants were avoided. The plant height was taken from the ground level to the uppermost fully opened leaves upto the flowering stage and after the emergence of tassel, the height was measured from the ground level to the basal portion of tassel. The observations were taken at 15 DAE, 30 DAE and 45 DAE and were expressed in ‘cm’.

3.6.1.2. Leaf Area

Leaf area was calculated at 15 DAE, 30 DAE and 45 DAE by measuring the length and width of fully opened leaf of tagged plants.

3.6.1.3.Leaf Area Index

The leaf area index was calculated by using the formula as suggested by Balakrishnan *et al.*(1987).

$$\text{LAI} \quad = \quad \frac{L\ x\ B\ x\ KxN}{Spacing\ (cm)}$$

L=leaf length;

B=leaf breadth

K=constant (0.796)

N=total number of leaves per plant.

3.6.1.4. Dry Matter Production

The sample plants were uprooted during the final harvest of cob. It was then shade dried and oven dried until constant weight was obtained. Dry matter production was calculated and was expressed in ‘kg ha^{-1}’.

3.6.2. Yield and Yield Attributes

3.6.2.1. Cobs per Plant

The number of cobs obtained from the sample plants were noted and its average was expressed as ‘cobs per plant’.

3.6.2.2. Cob Length

Cob length was measured from the basal end of the cob to the tip of cob after dehusking and was expressed in ‘cm’.

3.6.2.3.Cob Girth

The girth of cob was measured using a thread after dehusking and expressed in ‘cm’.

3.6.2.4. Cob Weight with Husk

The weight of unhusked cobs from each tagged plants were recorded and the mean was calculated and expressed as ‘g per cob’.

3.6.2.5. Cob Yield with Husk

The weight of cobs with husk from each plot was calculated and expressed in ‘kg ha^{-1}’.

3.6.2.6. Marketable Cob Yield

The cobs collected from the sample plants were dehusked and weight of corn was recorded and the total marketable yield was expressed in ‘kg ha^{-1}’

3.6.2.7 Cob - Corn Ratio

The ratio between the weight of unhusked cob and the dehusked cob (corn) were recorded.

3.6.2.8. Green Stover Yield

Immediately after the final harvest of cobs, fresh weight of green stover was taken by cutting the plant from the ground level and the green stover yield was expressed in ‘t ha^{-1}’.

3.7. PLANT ANALYSIS

Fresh samples of baby corn including cob, stover and roots were collected separately, dried and powdered for computing the total uptake of N, P and K.

3.7.1. Uptake of N

The N content was estimated by using a modified micro-kjeldahl method suggested by Jackson (1973). This N content was then multiplied with dry matter production to obtain N uptake and expressed in ‘kg ha^{-1}’.

3.7.2. Uptake of P

The P content was analysed using Vanado molybdate phosphoric yellow colour method (Jackson, 1973) and the P content was then multiplied with dry matter production to obtain P uptake and was expressed in ‘kg ha^{-1}’.

3.7.3. Uptake of K

The K content was analysed using EEL flame photometer method (Jackson, 1973) and this K content was multiplied with dry matter production to obtain K uptake and was expressed in ‘kg ha^{-1}’.

3.8 AGRONOMIC INDICES

The agronomic indices of nutrient use efficiency were calculated as in Table 9.

Table 9. Agronomic indices of nutrient use efficiency (Dobermann and Fairhurst, 2000)

Agronomic index	Calculation
Agronomic efficiency	AE= (kg yield increase kg^{-1} nutrient applied) $= (Y-Y_0)/F$
Physiological efficiency	PE= (kg yield increase kg^{-1} fertilizer nutrient uptake) $= (Y-Y_0) / (U-U_0)$
Apparent recovery efficiency	ARE= (kg increase in uptake kg^{-1} fertilizer applied) $=(U-U_0)/F$
Partial factor productivity	PFP = (kg yield kg^{-1} nutrient applied) $= Y/F$

Y-Yield from treated plot, Y_0-Yield from control plot, U- Nutrient uptake in treated plot, U_0- nutrient uptake in control plot, F-fertilizer rate

3.9. SOIL ANALYSIS

Composite soil samples were collected from the field after the experiment and was analysed for physico-chemical properties following the procedures mentioned in Table 7.

3.9.1. Nutrient Balance Sheet

Nutrient balance sheet of soil was worked out in terms of expected balance, apparent balance and actual balance (Senthivelu and Prabha, 2007).

Expected balance = Total nutrients added - Nutrient uptake

Apparent balance = Soil nutrient status after the experiment - Expected balance

Actual balance = Soil nutrient status after the experiment - Initial soil status

Total nutrients added included both indigenous (initial soil nutrient status) and added nutrients (POMF, organic manures and chemical fertilizers). A positive actual balance indicated soil storage and a negative actual balance indicated depletion.

3.10. ECONOMIC ANALYSIS

Cost of cultivation was worked out based on the costs of various inputs at the time of experimentation. The details regarding the costs of various inputs and produce are presented in Appendix II.

3.10.1. Gross Income

Gross income was calculated by multiplying the marketable cob yield with the market price of the produce and expressed in '₹ ha^{-1}'.

3.10.2. Net income

Net income was computed using the formulae and expressed in '₹ ha^{-1}'.

Net income = Gross income – Cost of cultivation

3.10.3. Benefit Cost Ratio (BCR)

Benefit cost ratio was computed using the formulae,

$$\text{BCR} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.11. STATISTICAL ANALYSIS

Results from the incubation study and field experiment were statistically analysed using the Analysis of Variance Method (ANOVA) as applied to the CRD and RBD designs (Panse and Sukhatme, 1985). Wherever significant differences between treatments were identified, CD values at 5 per cent level of significance were reported for effective mean comparison.

Results

4. RESULTS

The present study entitled "Development of pelleted organo-mineral fertilizer and its effect on baby corn (*Zea mays* L.) was undertaken at the Department of Agronomy, College of Agriculture, Vellayani during 2020-2022 to standardize the nutrient sources for production of pelleted organo-mineral fertilizers (POMF) and to evaluate its effect on the growth and yield of baby corn. The results of the study are presented in this chapter.

4.1. FORMULATION AND PELLETIZATION OF ORGANO-MINERAL FERTILIZER

4.1.1. Nutrient Content of Organo-Mineral Fertilizer Mix

The nutrient content of nine treatment combination of POMFs were analyzed for N, P and K contents and the data are furnished in Table 10. The data showed that the nitrogen content in POMF ranged from 5.54 per cent to 9.86 per cent, phosphorus content varied from 2.89 per cent to 4.27 per cent and potassium content ranged from 2.04 per cent to 4.24 per cent. Out of the nine treatments, POMF 9 recorded the highest N content (9.86 %) and K content (4.24 %) and POMF 3 recorded the highest phosphorus content (4.27 %).

The test crop selected for the study was baby corn. The nutrient recommendation of baby corn (Mavarkar, 2016) 135:65:45 kg NPK ha^{-1} was taken for the present study. As per the recommendation, the NPK ratio required for baby corn is 3:1.4:1. Among the nine combinations, four combinations, POMF 1, POMF 2, POMF 5 and POMF 7 recorded the nutrient ratio of 3:1.4:1 or above (Table 10).

The cost of production of all the nine combinations of POMF are given in Table 10. POMF 7 recorded the lowest (₹ 20.85 kg^{-1}) and POMF 5 recorded the highest cost of production (₹ 26.85 kg^{-1}).

Table 10. Nutrient content, nutrient ratios and cost of pelleted organo-mineral fertilizers

Treatments	Nutrient content			Nutrient ratios			Cost (₹ kg^{-1})
	N	P	K	N	P	K	
T_1 (POMF 1)	6.16	2.89	2.04	3.02	1.42	1.00	22.75
T_2 (POMF 2)	8.18	3.78	2.69	3.04	1.41	1.00	23.65
T_3 (POMF 3)	9.46	4.27	3.89	2.43	1.10	1.00	23.25
T_4 (POMF 4)	5.54	3.31	2.12	2.61	1.56	1.00	25.95
T_5 (POMF 5)	7.67	3.53	2.32	3.31	1.52	1.00	26.85
T_6 (POMF 6)	8.51	4.02	3.19	2.67	1.26	1.00	26.45
T_7 (POMF 7)	6.94	2.89	2.05	3.39	1.41	1.00	20.35
T_8 (POMF 8)	7.95	3.02	3.23	2.46	0.93	1.00	21.25
T_9 (POMF 9)	9.86	3.67	4.24	2.33	0.87	1.00	20.85

Among the nine treatment combinations of POMF, the best six combinations were selected for further incubation studies. The best six treatment combinations selected for incubation studies are POMF 1, POMF 2, POMF 4, POMF 5, POMF 6, POMF 7.

4.2. Incubation experiment

The best six POMF combinations selected from the first part of the study (POMF 1, POMF 2, POMF 4, POMF 5, POMF 6, POMF 7) were subjected to pot study for assessing the nutrient release pattern. Soil samples were collected from these pots after imposing treatments at 15 days interval upto two months and was analysed for available N, P and K content. The results of the study are presented below.

4.2.1. Available Nitrogen

The available soil nitrogen showed significant differences among treatments. The data on effect of selected POMF treatments on soil available nitrogen are presented in Table 11.

At 15 days after incubation (DAI), among the POMF treatments, POMF 2 (T_2) recorded significantly higher available soil nitrogen (0.208 g kg^{-1} soil) and was followed by POMF 6 (T_5) (0.200 g kg^{-1}). The least available soil nitrogen was observed in POMF 4 (T_3) (0.158 g kg^{-1} soil). The INM and control treatments recorded 0.416 and 0.138 gram available nitrogen per kilogram of soil respectively.

At 30 DAI, T_2 (POMF 2) recorded the highest (0.482 g kg^{-1} soil) available soil nitrogen. It was followed by POMF 7 (0.438 g kg^{-1} soil) and was on par with POMF 6 (0.437 g kg^{-1} soil) and POMF 5 (0.431 g kg^{-1} soil). The INM and control treatments recorded 0.505 and 0.157 gram available nitrogen per kilogram of soil respectively.

Among the POMF treatments, at 45 DAI, the highest available soil nitrogen was observed in T_2 (POMF 2) (0.581 g kg^{-1} soil) and was on par with T_1 (0.574 g kg^{-1} soil), T_3 (0.569 g kg^{-1} soil) and T_4 (0.569 g kg^{-1} soil). The INM and control treatments recorded 0.542 and 0.164 gram available nitrogen per kilogram of soil respectively.

At 60 DAI, T_2 (POMF 2) recorded the highest available soil nitrogen (0.621 g kg^{-1} in soil). It was followed by T_1 (0.595 g kg^{-1} soil) which was on par with T_4 (0.593 g kg^{-1}). The INM and control treatments recorded 0.546 and 0.168 gram available nitrogen per kilogram of soil respectively.

4.2.2. Available Phosphorus

Available soil phosphorus varied significantly among treatments. The data on effect of selected POMF treatments on available soil phosphorus are presented in Table 12.

At 15 DAI, POMF 6 (T_5) recorded the highest (0.034 g kg^{-1} soil) available soil P and was on par with POMF 2 (T_2) (0.033 g kg^{-1}) and POMF 7 (T_6) (0.032 g kg^{-1}). Available soil P was found least in T_3, POMF 4 (0.021 g kg^{-1}). The INM and control treatments recorded 0.056 and 0.018 gram available phosphorus per kilogram of soil respectively.

At 30 DAI, T_2 (POMF 2) recorded the highest available soil P (0.055 g kg^{-1} soil) and was on par with T_6 (POMF 7) (0.052 g kg^{-1} of soil) and T_5 (POMF 6) (0.049 g kg^{-1} of soil). The least available soil P was observed in T_1, (POMF 1) (0.042 g kg^{-1} of soil). The INM and control treatments recorded 0.063 and 0.019 gram available phosphorus per kilogram of soil respectively.

At 45 DAI, T_6 (POMF 7) recorded the highest soil available P (0.065 g kg^{-1} of soil) and was on par with T_4 (POMF 5) (0.063 g kg^{-1} of soil), T_1 (POMF 1) (0.063 g kg^{-1} of soil) and T_2 (0.059 g kg^{-1}). Least soil available P was observed in T_3, (POMF 4) (0.050 g kg^{-1} of soil). The INM and control treatments recorded 0.067 and 0.021 gram available phosphorus per kilogram of soil respectively.

At 60 DAI, T_6, (POMF 7) recorded the highest (0.073 g kg^{-1} of soil) soil available P and was on par with T_3, T_4, T_1 and T_2. The available soil P was found to be least in T_5, (POMF 6) (0.052 g kg^{-1} of soil). The INM and control treatments recorded 0.068 and 0.023 gram available soil P per kilogram of soil respectively.

4.2.3. Available Potassium

The available soil potassium showed significant differences among treatments. The data on effect of selected POMF treatments on soil available potassium are presented in Table 13.

At 15 DAI, available soil K was the highest in POMF 2 (T_2) (0.139 g kg^{-1} of soil) and was on par with POMF 6 (0.138 g kg^{-1} of soil) and POMF 7 (0.134 g kg^{-1} of soil). The

Table 11. Effect of selected POMF on soil available nitrogen on incubation, g kg^{-1} soil

Treatments	Nitrogen release			
	15 DAI	30 DAI	45 DAI	60 DAI
T_1 (POMF 1)	0.187	0.411	0.574	0.595
T_2 (POMF 2)	0.208	0.482	0.581	0.621
T_3 (POMF 4)	0.158	0.322	0.569	0.581
T_4 (POMF 5)	0.168	0.431	0.569	0.593
T_5 (POMF 6)	0.200	0.437	0.542	0.554
T_6 (POMF 7)	0.186	0.438	0.559	0.580
SE m (±)	0.003	0.004	0.009	0.004
CD (0.05)	0.007	0.010	0.021	0.010
INM	0.416	0.505	0.542	0.546
Control	0.138	0.157	0.164	0.168

Table 12. Effect of selected POMF on soil available phosphorus on incubation, g kg^{-1}

Treatments	Phosphorus release			
	15 DAI	30 DAI	45 DAI	60 DAI
T_1 (POMF 1)	0.024	0.042	0.063	0.066
T_2 (POMF 2)	0.033	0.055	0.059	0.064
T_3 (POMF 4)	0.021	0.043	0.050	0.066
T_4 (POMF 5)	0.026	0.044	0.063	0.066
T_5 (POMF 6)	0.034	0.049	0.051	0.052
T_6 (POMF 7)	0.032	0.052	0.065	0.073
SE m (±)	0.003	0.003	0.003	0.003
CD (0.05)	0.007	0.008	0.007	0.008
INM	0.056	0.063	0.067	0.068
Control	0.018	0.019	0.021	0.023

least available K was observed in POMF 4 (T_3) (0.121 g potassium per kg of soil). The INM and control treatments recorded 0.426 and 0.078 gram available soil K per kilogram of soil respectively.

At 30 DAI, a similar trend was observed in the release of potassium. Highest available soil K was found in POMF 2 (0.389 g kg^{-1} of soil) and was on par with POMF 7, POMF 6 and POMF 5. Least available soil K was observed in POMF 4 (T_3) (0.341 g kg^{-1} of soil) at 30 DAI. The INM and control treatments recorded 0.446 and 0.083 gram available soil K per kilogram of soil respectively.

At 45 DAI, the highest available soil K was recorded in T_2, (POMF 2) (0.490 g kg^{-1} of soil) and was followed by T_4 (0.482 g kg^{-1} of soil). POMF 6 recorded the least (0.452 g kg^{-1} of soil) available soil K. The INM and control treatments recorded 0.449 and 0.089 gram available soil K per kilogram of soil respectively.

At 60 DAI, POMF 2 (T_2) recorded the highest (0.528 g kg^{-1} of soil) available soil K and was on par with T_6 (0.527 g kg^{-1} of soil). The least available soil K was recorded in POMF 6 (T_5) (0.487 g kg^{-1} of soil). The INM and control treatments recorded 0.453 and 0.090 gram available soil K per kilogram of soil respectively.

From the incubation studies, it was concluded that among all the POMF treatments tested, cow dung based POMF (POMF 2) released the nutrients *viz,* N, P and K in slow and steady rate, in concurrence with the growth stages of baby corn and hence was selected for further characterization and field evaluation.

Table 13. Effect of selected POMF on soil available potassium on incubation, g kg^{-1}

Treatments	Potassium release			
	15 DAI	30 DAI	45 DAI	60 DAI
T_1 (POMF 1)	0.131	0.342	0.453	0.502
T_2 (POMF 2)	0.139	0.389	0.490	0.528
T_3 (POMF 4)	0.121	0.341	0.461	0.516
T_4 (POMF 5)	0.128	0.371	0.482	0.518
T_5 (POMF 6)	0.138	0.381	0.452	0.487
T_6 (POMF 7)	0.134	0.383	0.475	0.527
SE m (±)	0.003	0.003	0.002	0.002
CD (0.05)	0.007	0.007	0.005	0.006
INM	0.426	0.446	0.449	0.453
Control	0.078	0.083	0.089	0.090

4.3. CHARACTERIZATION OF POMF 2

The physico-chemical properties of best treatment combination (POMF 2) selected from incubation studies were characterized and the data are presented in Table 14 and 15.

The pellets had a length of 15-18 mm and a diameter of 6 mm. The POMF 2 was dark brown to black in colour without any foul odour. The POMF 2 had a bulk density of 0.84 Mg m^{-3}. The organic carbon and moisture content of POMF 2 were 0.42 per cent and 10.56 per cent respectively. The total N, P, K content of POMF 2 was 8.18 per cent, 3.78 per cent and 2.69 per cent respectively. The pH of POMF 2 was 6.8 and

EC was 18.6 dSm^{-1}. Ca and Mg content of POMF 2 are 6.50 per cent and 2.82 per cent. The POMF 2 had a Zn and B content of 1015.5 mg kg^{-1} and 0.007 mg kg^{-1} respectively.

Storage studies upto six months were also conducted to assess the shelf life of POMF 2. The results are presented in Table 15. At the initial stage, the N content of POMF 2 was 8.18 per cent. At one month after storage (MAS) the value remained the same. After two and three months of storage the nitrogen content was 8.10 per cent and 8.08 per cent respectively. In the fifth and sixth month, the nitrogen content was reduced to 7.92 and 7.54 per cent respectively.

In case of phosphorus the initial P content was 3.78 per cent and it decreased to 3.74 per cent and 3.68 per cent at two and three months after storage. At four and five months after storage, the P content were 3.62 per cent and 3.60 per cent respectively. At six months after storage, the P content was reduced to 3.58 per cent.

The initial potassium content of 2.69 per cent decreased to 2.65 per cent and 2.59 per cent at at two and three months after storage, respectively. At four and five months after storage, the K content were decreased to 2.53 per cent and 2.52 per cent respectively. At six months after storage, the K content was reduced to 2.46 per cent. The pellets retained their shape during the entire period of storage study without any fungal growths.

Table 14. Physico-chemical characterization of pelleted organo-mineral fertilizer

Sl. No	**Estimated character**	**Observations**
	Dimension	
	Length (mm)	15-18
	Diameter (mm)	6
I	**Physical parameters**	
a.	Odour	No foul odour
b.	Colour	Dark Brown to black
c.	Bulk density (Mg m^{-3})	0.84
d.	Moisture content (%)	10.56
II	**Chemical parameters**	
a.	Organic carbon	0.42
b.	Total N (%)	8.18
c.	Total P (%)	3.78
d.	Total K (%)	2.69
e.	Ca (%)	6.50
f.	Mg (%)	2.82
g.	Zn (mg kg^{-1})	1015.50
h.	B (mg kg^{-1})	0.007
i.	pH	6.80
j.	EC (dSm^{-1})	18.60

Table 15. Nutrient content as POMF 2 during storage, %

Months after storage (MAS)	Nutrient content		
	N	P	K
Initial	8.18	3.78	2.69
1 MAS	8.18	3.78	2.69
2 MAS	8.10	3.74	2.65
3 MAS	8.08	3.68	2.59
4 MAS	8.00	3.62	2.53
5 MAS	7.92	3.60	2.52
6 MAS	7.54	3.58	2.46

4.4. EFFECT OF POMF 2 ON BABY CORN

A field experiment was carried out to assess the efficacy of selected pelleted organo-mineral fertilizer, POMF 2 in improving the growth and yield of crops. Baby corn was selected as the test crop. POMF 2 was tested at varying rates and time of application. It was applied on nitrogen equivalent basis for supplying the recommended dose of 135:65:45 kg NPK ha^{-1} for baby corn. PGPR mix I was also applied uniformly to all POMF applied plots at sowing and 15 DAS.

The nutrient recommendation of baby corn FYM @ 12.5 t ha^{-1}, 135:65:45 kg NPK ha^{-1}; ½ N + full P+ ½ K (basal) and ½ N + ½ K at 25 DAS suggested by Mavarkar (2016) and a control plot (No fertilizer application) was taken for comparison. The results of the study are presented below.

4.4.1. Growth and Growth Attributes

The effect of application of POMF 2 on growth attributes of baby corn are presented in Table 16 and Plate 10 and Plate 11.

4.4.1.1. Plant Height

The statistical analysis of the data revealed that the plant height differed significantly among treatments at 15, 30 and 45 DAE (Table 16). At 15 days after emergence (DAE), the plants were the tallest (54.43 cm) in T_7 (FYM @ 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}; ½ N+ full P+½ K basal; ½ N +½ K at 25 DAS) and was superior to all other treatments. Among the POMF treatments, application of 100 per cent RD as POMF 2 (basal) (T_1) recorded the tallest plants (46.97 cm) and was on par with T_2, T_3, T_4 and T_5. The treatment, T_7 recorded the tallest plants (117.40 cm) at 30 DAE, and was on par with T_1, T_2, T_3, T_4 and T_5. Application of 100 per cent RD as POMF 2 (basal) (T_1) recorded the tallest plants (171.03 cm) and was on par with T_2, T_4, and T_7 at 45 DAE. The treatment, T_8 (control) recorded significantly shorter plants at 15, 30 and 45 DAE.

4.4.1.2. Leaf Area

The treatments significantly influenced the leaf area of baby corn at 15, 30 and 45 DAE (Table 16). At 15 DAE, treatment, T_7 (FYM @ 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}; ½ N +Full P + ½ K basal; ½ N +½ K at 25 DAS) recorded the highest leaf area (78.74 cm^2) and was on par with T_1 (77.99 cm^2) and T_2 (77.48 cm^2). At 30 DAE, application of 100 percent RD as POMF 2 (basal) (T_1) recorded the highest leaf area (275.75 cm^2) which was on par with T_7, T_4 and T_2. At 45 DAE, application of 100 percent RD as POMF 2 (basal) (T_1) recorded the highest leaf area (404.51 cm^2) and was on par with T_2, T_4, and T_7. The control treatment recorded significantly lower leaf area at all the growth stages.

4.4.1.3. Leaf Area Index

The treatments had significant effect on the leaf area index of baby corn at 15, 30 and 45 DAE (Table 16). Among the different treatments, T_7 and T_1 recorded the highest leaf area index at 15 DAE (0.37) and was on par with T_2 (0.36). At 30 DAE, basal application of 100 per cent (T_1) and 75 percent (T_2) RD as POMF 2 recorded the highest leaf area index (2.14) which was on par with T_4 and T_7. At 45 DAE also, T_1 and T_4 recorded the highest leaf area index (4.05) which was on par with T_2 and T_7. At all the growth stages, the control treatment (T_8) recorded the least leaf area index.

4.4.1.4. Dry Matter Production

The result on the effect of pelleted organo-mineral fertilizer on dry matter production of baby corn are given in Table 16. The dry matter production of baby corn differed significantly among the treatments. Application of 100 per cent RD as POMF 2 (basal) (T_1) recorded the highest dry matter production (22.02 t ha^{-1}) and was on par with T_7 (21.94 t ha^{-1}), T_2 (21.27 t ha^{-1}) and T_4 (21.24 t ha^{-1}). The lowest dry matter production (11.69 t ha^{-1}) was recorded in T_8 (control).

4.4.2. Yield Attributes and Yield

The effect of application of POMF 2 on yield attributes of baby corn are presented in Table 17.

4.4.2.1. Cobs per Plant

The treatments did not influence the number of cobs per plant (Table 17). On an average, the baby corn plants produced 3 cobs per plant irrespective of the treatments.

4.4.2.2. Cob Length

The results on the variation in cob length as influenced by the POMF treatments are presented in Table 17 and Plate 12. Application of 100 percent RD as POMF 2 (basal) (T_1) recorded the highest cob length (11.70 cm) which was on par with T_7 (11.40 cm), T_2 (11.30 cm), T_4 (11.20 cm) and T_5 (11.10 cm). Lowest cob length (8.57 cm) was observed in T_8 (Control).

Table No. 16. Effect of POMF 2 on growth and growth attributes of baby corn

Treatments	Plant height (cm)			Leaf area (cm^2)			Leaf area index			Dry matter production (t ha^{-1})
	15 DAE	30 DAE	45 DAE	15 DAE	30 DAE	45 DAE	15 DAE	30 DAE	45 DAE	
T_1: 100 per cent RD as POMF 2 (basal)	46.97	117.20	171.03	77.99	275.75	404.51	0.37	2.14	4.05	22.02
T_2: 75 per cent RD as POMF 2 (basal)	46.30	114.20	167.33	77.48	275.29	403.87	0.36	2.14	4.01	21.27
T_3: 50 per cent RD as POMF 2 (basal)	45.33	112.50	158.77	76.81	256.73	393.92	0.32	1.86	3.68	18.89
T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS	46.47	115.63	167.13	76.24	274.86	404.13	0.34	2.13	4.05	21.24
T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	44.83	113.90	157.03	75.57	260.03	390.56	0.30	1.92	3.61	19.11
T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	38.80	109.83	158.33	74.63	245.56	386.22	0.29	1.71	3.49	15.44
T_7: FYM @ 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}	54.43	117.40	170.53	78.74	274.98	403.66	0.37	2.13	4.01	21.94
T_8: Control (No fertilizers)	38.40	106.93	143.00	68.18	240.43	372.88	0.25	1.61	3.22	11.69
SE m (±)	1.20	2.77	2.96	0.73	1.07	1.95	0.003	0.008	0.018	0.39
CD (0.05)	2.591	5.944	6.368	1.587	2.822	4.202	0.011	0.017	0.041	0.842

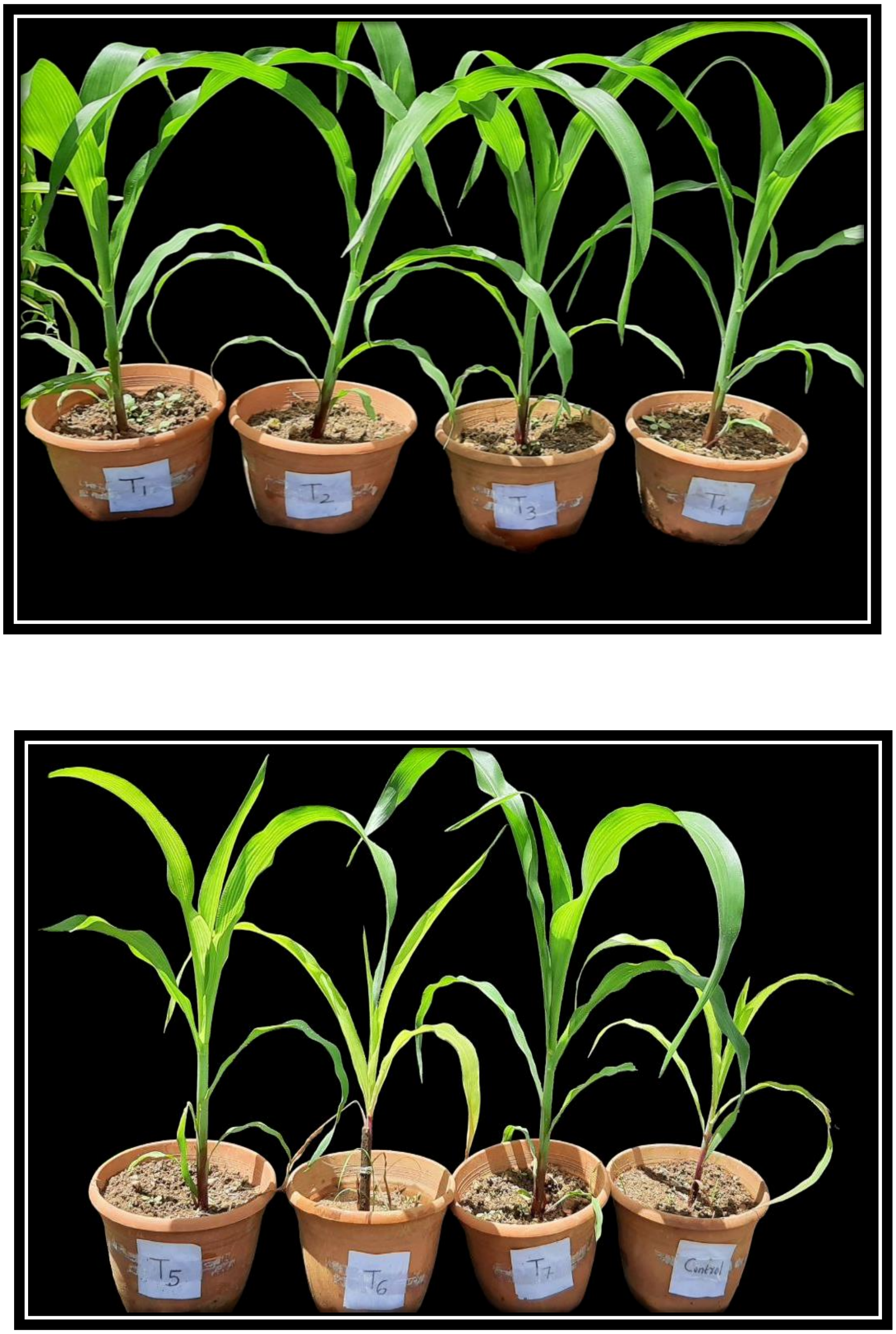


Plate 10. Effect of POMF 2 on growth attributes of baby corn at 15 DAE

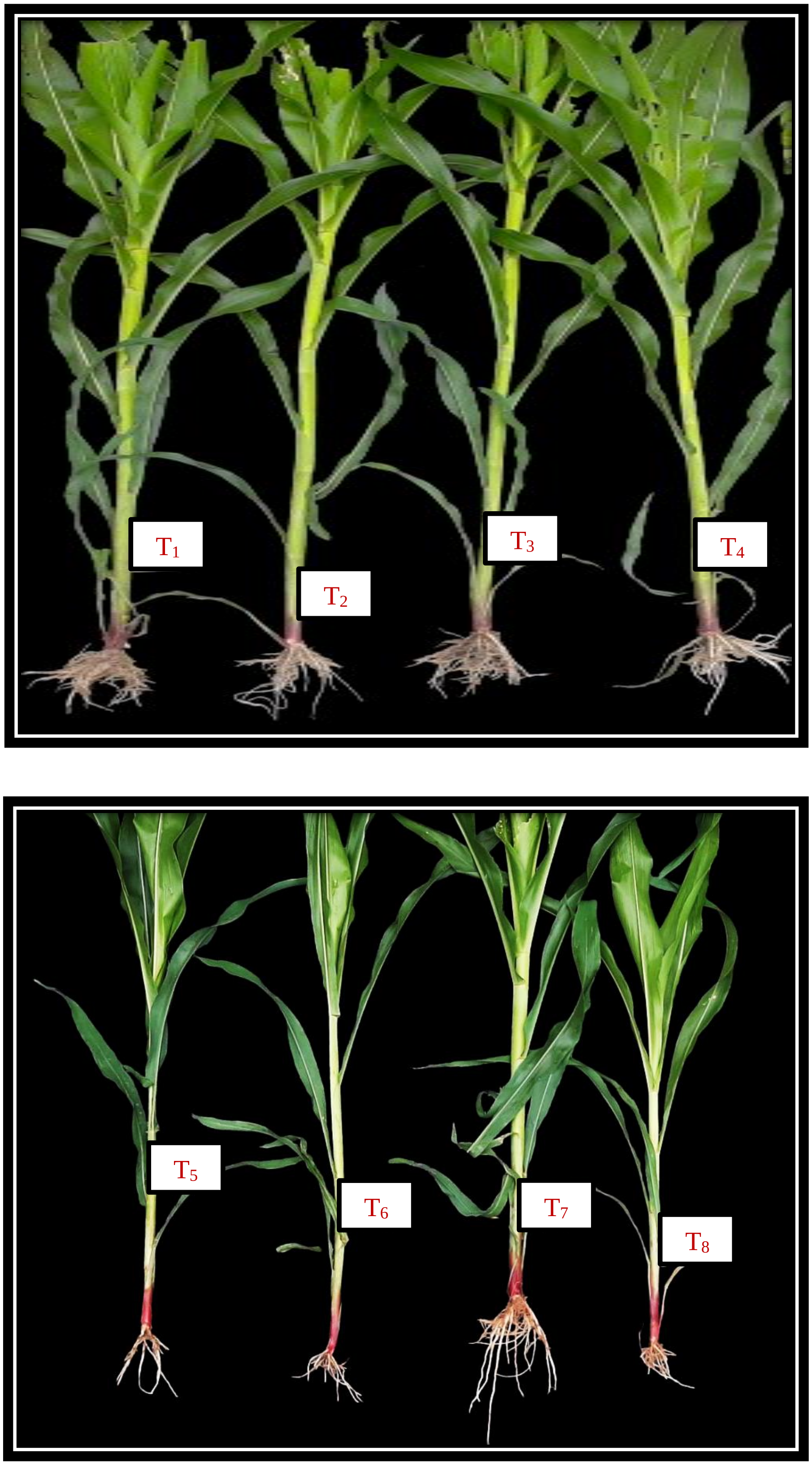


Plate 11. Effect of POMF 2 on growth attributes of baby corn at 30 DAE

4.4.2.2.Cob Girth

The results on the effect of POMF 2 on girth of cob are given in Table 17 and Plate 12. The girth of cobs showed significant difference among the treatments. The highest cob girth (5.33 cm) was recorded in T_1, 100 percent RD as POMF 2 (basal) which remained on par with T_2 (5.23 cm), T_7 (5.17 cm), T_3 (5.13 cm) and T_4 (5.0 cm). The treatment, T_8 (control) recorded the lowest cob girth among all the treatments.

4.4.2.3. Cob Weight with Husk

The results on the effect of POMF 2 on cob weight with husk is given in Table 17. The cob weight with husk varied significantly among treatments. Application of 100 percent RD as POMF 2 (basal) (T_1) recorded the highest cob weight (84.13 g) and was statistically on par with T_7 (83.07 g) and T_2 (82.31 g). Significantly lower cob weight with husk (70.55 g) was recorded in T_8 (control).

4.4.2.4.Cob Yield with Husk

The treatments significantly influenced cob yield with husk of baby corn and the data are presented in Table 17. Basal application of 100 percent RD as POMF 2 (T_1) recorded the highest cob yield with husk (11.47 t ha^{-1}) and was statistically on par with T_2 (11.36 t ha^{-1}), T_7 (11.35 t ha^{-1}) and T_4 (10.72 t ha^{-1}). Among all the treatments, the control treatment (T_8) recorded significantly lower (4.96 t ha^{-1}) cob yield with husk.

4.4.2.5.Marketable Cob Yield

The data pertaining to the effect of POMF 2 on marketable cob yield of baby corn is given in Table 17. The statistical analysis of the data revealed that the marketable cob yield of baby corn differed significantly between treatment.

Table No. 17. Effect of POMF 2 on yield and yield attributes of baby corn

Treatments	Cobs per plant	Length of cob (cm)	Girth of cob (cm)	Cob weight with husk (g)	Cob yield with husk (t ha^{-1})	Marketable cobyield (t ha^{-1})	Cob-corn ratio	Green stover yield (t ha^{-1})
T_1: 100 per cent RD as POMF 2 (basal)	3	11.70	5.33	84.13	11.47	5.34	2.15	29.32
T_2: 75 per cent RD as POMF 2 (basal)	3	11.30	5.23	82.31	11.36	5.40	2.10	27.80
T_3: 50 per cent RD as POMF 2 (basal)	3	10.10	5.13	78.44	9.50	3.23	2.94	26.88
T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS	3	11.20	5.00	81.09	10.72	5.15	2.08	28.41
T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	3	11.10	4.90	77.69	9.88	4.15	2.38	26.18
T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	3	9.83	4.83	75.94	8.12	3.63	2.24	24.00
T_7: FYM @ 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}	3	11.40	5.17	83.07	11.35	5.31	2.14	29.11
T_8: Control (No fertilizers)	3	8.57	4.33	70.55	4.96	1.65	3.01	20.87
SE m (±)	-	0.29	0.19	0.91	382.60	97.75	0.08	1.31
CD (0.05)	NS	0.626	0.421	1.971	820.692	209.694	0.182	2.825

The highest marketable cob yield (5.40 t ha^{-1}) was observed when 75 per cent RD as POMF 2 was applied as basal (T_2). It was comparable with T_1 (5.34 t ha^{-1}), T_7 (FYM @ 12.5 t ha^{-1}+135:65:45 kg NPK ha-1; ½ N+ full P+½ K basal; ½ N +½ K at 25 DAS) (5.31t ha^{-1}) and T_4 (50 per cent RD as POMF 2 (basal) and 50 per cent RD as POMF 2 at 25 DAS) (5.15 t ha^{-1}). The least marketable cob yield was recorded in T_8 (1.65 t ha^{-1}).

4.4.2.6. Cob-Corn Ratio

The data on the effect of POMF 2 on cob-corn ratio are presented in Table 17. The cob-corn ratio varied significantly with the application of different treatments. Application of 50 per cent RD as POMF 2 (basal) and 50 per cent RD as POMF 2 at 25 DAE (T_4) was found to be the most efficient nutrient schedule for getting better cob-corn ratio (2.08). The treatment T_8 (3.01) and T_3 (2.94) were the least efficient nutrient schedules for baby corn.

4.4.2.8. Green Stover Yield

The data on green stover yield as influenced by the application of POMF 2 are presented in Table 17. The green stover yield varied significantly with the application of different treatments. Application of 100 per cent RD as POMF 2 (basal) (T_1) recorded the highest green stover yield (29.32 t ha^{-1}) and was statistically on par with T_7, (29.11 t ha^{-1}), T_4 (28.41 t ha^{-1}), T_2 (27.80 t ha^{-1}) and T_3 (26.88 t ha^{-1}) respectively. The least green stover yield (20.87 t ha^{-1}) was found in T_8 which received no fertilizers.

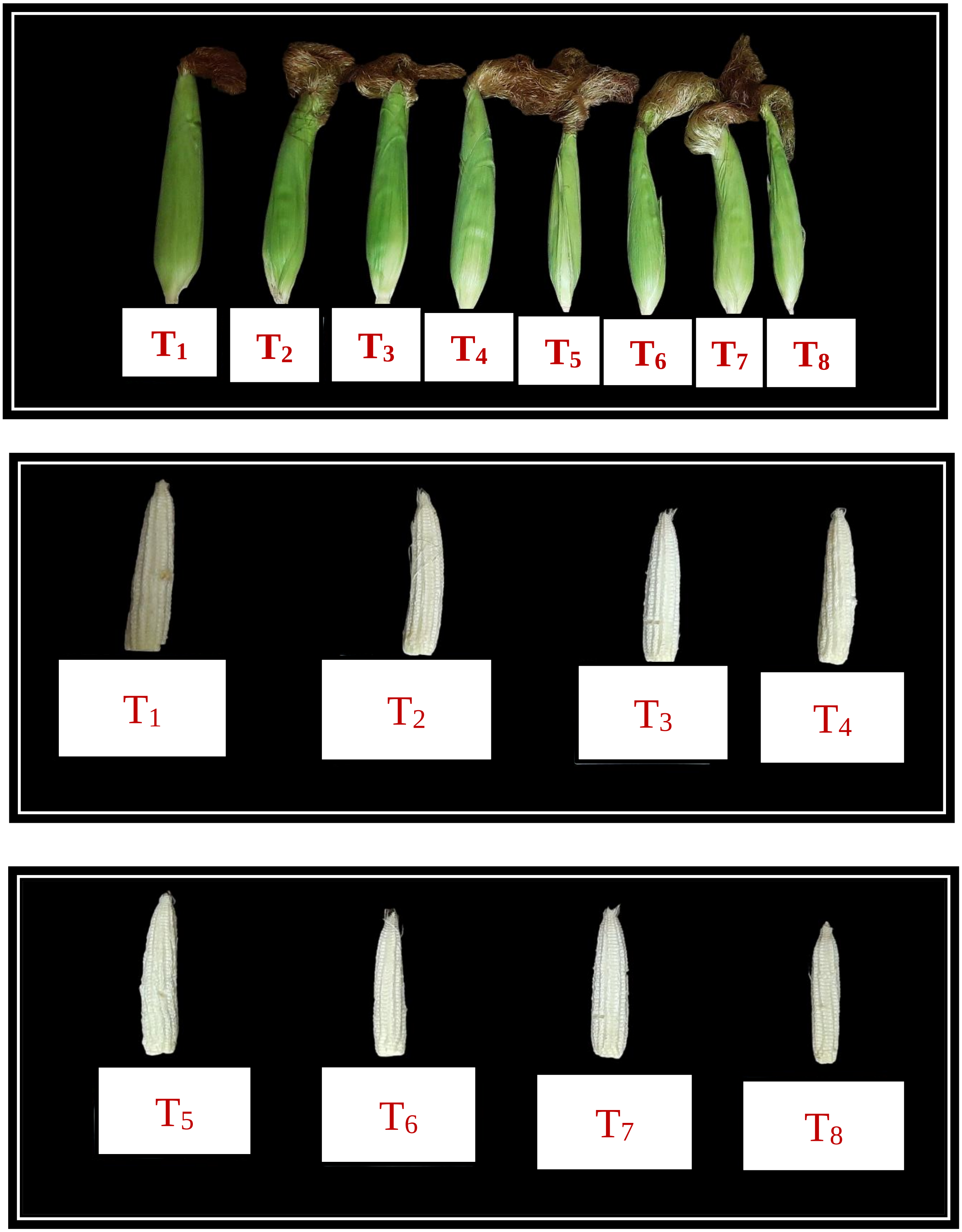


Plate 12. Effect of POMF2 on cob length and girth

4.4.3. Pest and Disease Incidence

There were no major incidence of pest and disease during the crop growing season. But a minor incidence of shoot borer was there in the field which was controlled by the prophylatic spraying of Nimbicidin at 5 mL L^{-1} done at weekly intervals.

4.2.4. Plant Analysis

The results on the effect of POMF 2 on uptake of N, P and K are presented in Table 18.

4.2.4.1. N Uptake

N uptake varied significantly among treatments (Table 18). Application of 100 per cent RD as POMF 2 (basal) (T_1) recorded the highest nitrogen uptake (285.59 kg ha^{-1}) and was on par with T_7 (283.02 kg ha^{-1}), T_2 (275.51 kg ha^{-1}), and T_4 (273.39 kg ha^{-1}). The lowest N uptake (135.60 kg ha^{-1}) was observed in T_8 (control).

4.2.4.2. *P Uptake*

The data pertaining to the effect of POMF 2 on uptake of phosphorus are presented in Table 18. The uptake of phosphorus was found significant among the treatments. Application of 100 per cent recommended dose as POMF 2 (basal) (T_1) recorded the highest P uptake (51.91 kg ha^{-1}). It remained statistically on par with T_7 (49.16 kg ha^{-1}), T_2 (48.26 kg ha^{-1}), T_4 (46.50 kg ha^{-1}) and T_5 (46.34 kg ha^{-1}). The lowest P uptake (25.71 kg ha^{-1}) was recorded in control treatment (T_8).

4.2.4.3. *K Uptake*

The total potassium uptake varied significantly between treatments (Table 18). Potassium uptake was the highest in T_1 (263.84 kg ha^{-1}) (100 per cent RD as POMF2 (basal)) and was on par with T_7 (263.14 kg ha^{-1}), T_2 (258.92 kg ha^{-1}), T_4 (257.67 kg ha^{-1}) and T_5 (254.18 kg ha^{-1}). The lowest K uptake (105.21 kg ha^{-1}) was observed in T_8 (control).

Table 18. Effect of POMF 2 on nutrient uptake of baby corn, kg ha^{-1}

Treatments	Nutrient uptake (kg ha^{-1})		
	N	**P**	**K**
T_1: 100 per cent RD as POMF 2 (basal)	285.59	51.91	263.84
T_2: 75 per cent RD as POMF 2 (basal)	275.51	48.26	258.92
T_3: 50 per cent RD as POMF 2 (basal)	253.57	42.59	231.12
T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS	273.39	46.50	257.67
T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	262.38	46.34	254.18
T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	251.12	42.94	223.05
T_7: FYM at 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}	283.02	49.16	263.14
T_8: Control (No fertilizers)	135.60	25.71	105.21
SE m (±)	6.37	3.96	6.4
CD (0.05)	13.670	8.509	13.801

4.2.5. **Agronomic Indices**

The results on the effect of POMF 2 on agronomic indices *viz.*, agronomic efficiency (AE), physiological efficiency (PE), apparent recovery efficiency (ARE) and partial factor productivity (PFP) are presented in Table 19 and 20.

4.2.5.1. *Agronomic Efficiency*

Agronomic efficiency (AE) is a short-term indicator of the impact of applied nutrients on productivity. AE is calculated as the ratio of yield increase per unit of nutrient applied as is expressed in kg kg^{-1}. Agronomic efficiency of nutrients were observed to vary significantly among treatments (Table 19).

The treatment T_2, application of 75 per cent RD as POMF 2 (basal) recorded significantly higher AE for nitrogen (36.99 kg kg^{-1}). The lowest agronomic efficiency of nitrogen was found in T_7 with an efficiency of 14.54 kg kg^{-1}.

The treatment T_6, 25 percent RD as POMF 2 applied as basal and 25 per cent RD as POMF 2 applied at 25 DAS recorded the highest AE (76.95 kg kg^{-1}) for phosphorus and was on par with T_2 (76.82 kg kg^{-1}). The lowest agronomic efficiency of phosphorus was found in T_7 with an efficiency of 26.34 kg kg^{-1}.

Agronomic efficiency of potassium was significantly higher (110.96 kg kg^{-1}) for T_2 (75 per cent RD as POMF 2 (basal). The lowest agronomic efficiency of potassium was found in T_7 with an efficiency of 26.85 kg kg^{-1}.

4.2.5.2. Physiological Efficiency

Physiological efficiency (PE) refers to the yield increase in relation to the increase in crop uptake of the nutrient in above-ground parts of the plant. The treatments had significant effect on physiological efficiency of nitrogen, phosphorus and potassium (Table 19).

The treatment T_2 (75 per cent RD as POMF 2 (basal) recorded the highest

(26.84 kg kg^{-1}) physiological efficiency and was on par with T_4 (25.39 kg kg^{-1}) and T_7 (24.81 kg kg^{-1}). The lowest PE (13.40 kg kg^{-1}) of nitrogen was recorded by T_3 which received 50 per cent of RD as POMF 2 (basal).

PE of phosphorus was higher in T_2 (170.52 kg kg^{-1}) which received 100 per cent RD as POMF 2 (basal) and was on par with T_4 (169.80 kg kg^{-1}), T_7 (160.63 kg kg^{-1}), T_1 (152.21 kg kg^{-1}) and T_5 (122.26 kg kg^{-1}).

The treatment T_2 (75 per cent RD as POMF 2 (basal) recorded the highest PE (24.37 kg kg^{-1}) for potassium and was on par with T_1 (23.28 kg kg^{-1}), T_7 (23.16 kg kg^{-1}) and T_4 (22.94 kg kg^{-1}) respectively. Lowest physiological efficiency of potassium was recorded in T_3 with an efficiency of 12.60 kg kg^{-1}.

4.2.5.3. Apparent Recovery Efficiency

Apparent recovery efficiency (ARE) is one of the more sophisticated forms of NUE expressions and is most frequently described as the difference in nutrient uptake in above-ground sections of the plant between the fertilised and unfertilized crop relative to the amount of fertilizer provided.

Significant variation was observed in the apparent recovery efficiency (ARE) of nitrogen, phosphorus and potassium in response to the different treatments (Table 20).

The highest apparent recovery efficiency for nitrogen (1.38 kg kg^{-1}) was recorded in T_2 (75 per cent RD as POMF 2 (basal)) which was on par with T_1 (1.27 kg kg^{-1}). Significantly lower apparent recovery efficiency (0.61 kg kg^{-1}) of nitrogen was observed in T_7.

The ARE of phosphorus was higher (0.46 kg kg^{-1}) in T_1 and was on par with T_2 (0.45 kg kg^{-1}). T_7 recorded the lowest apparent recovery efficiency (0.18 kg kg^{-1}) of phosphorus.

The treatment T_1, (100 per cent RD as POMF 2 (basal) recorded the highest ARE for potassium (4.72 kg kg^{-1}) and was on par with T_2 (4.44 kg kg^{-1}). The lowest

Table 19. Effect of POMF 2 on agronomic efficiency and physiological efficiency of baby corn, kg kg^{-1}

Treatments	Agronomic efficiency			Physiological efficiency		
	N	P	K	N	P	K
T_1: 100 per cent RD as POMF 2 (basal)	29.37	56.76	81.99	24.60	152.21	23.28
T_2: 75 per cent RD as POMF 2 (basal)	36.99	76.82	110.96	26.84	170.52	24.37
T_3: 50 per cent RD as POMF 2 (basal)	23.88	49.60	71.64	13.40	94.45	12.60
T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS	25.66	53.29	76.98	25.39	169.80	22.94
T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	24.66	51.21	73.97	19.71	122.26	16.82
T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	23.67	76.95	88.00	17.25	119.74	16.85
T_7: FYM at 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}	14.54	26.34	26.85	24.81	160.63	23.16
T_8: Control (No fertilizers)	-	-	-	-	-	-
SE m (±)	0.90	8.39	1.47	0.97	23.29	0.79
CD (0.05)	1.939	18.017	3.154	2.092	49.961	1.705

Table 20. Effect of POMF 2 on apparent recovery efficiency and partial factor productivity of baby corn, kg kg^{-1}

Treatments	Apparent recovery efficiency			Partial factor productivity		
	N	P	K	N	P	K
T_1: 100 per cent RD as POMF 2 (basal)	1.27	0.46	4.72	39.59	82.22	118.77
T_2: 75 per cent RD as POMF 2 (basal)	1.38	0.45	4.44	53.33	110.76	159.99
T_3: 50 per cent RD as POMF 2 (basal)	1.13	0.33	4.17	47.90	99.49	143.71
T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS	1.18	0.37	4.30	38.17	79.27	114.50
T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	1.25	0.35	4.18	41.00	85.16	123.01
T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	1.08	0.29	3.94	53.85	111.84	161.55
T_7: FYM at 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}	0.61	0.18	1.21	21.44	40.09	40.86
T_8: Control (No fertilizers)	-	-	-	-	-	-
SE m (±)	0.04	0.02	0.16	0.97	2.05	2.94
CD (0.05)	0.105	0.058	0.357	2.094	4.401	6.320

apparent recovery efficiency of potassium (1.21 kg kg^{-1}) was recorded in T_7.

4.2.5.4. Partial Factor Productivity

Partial factor productivity of fertilizer is defined as grain yield per unit fertilizer input. Significant variation was observed in the partial factor productivity (PFP) of nitrogen, phosphorus and potassium in response to the different treatments (Table 20).

Partial factor productivity (PFP) of nitrogen was the highest (53.85 kg kg^{-1}) in T_6 (25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS) and was on par with T_2 (75 per cent RD as POMF 2 (basal)) which recorded a PFP of 53.33 kg kg^{-1}. The lowest PFP for nitrogen was recorded in T_7 (21.44 kg kg^{-1}).

Partial factor productivity (PFP) of phosphorus was the highest (111.84 kg kg^{-1}) in T_6 (25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS) and was on par with T_2 (75 per cent RD as POMF 2 (basal)) which recorded a PFP of 110.76 kg kg^{-1}. The treatment T_7 recorded the lowest (40.09 kg kg^{-1}) PFP for phosphorus.

Partial factor productivity (PFP) of potassium was the highest (161.55 kg kg^{-1}) in T_6 (25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS) and was on par with T_2 (75 per cent RD as POMF 2 (basal)) which recorded a PFP of 159.99 kg kg^{-1}. The treatment T_7 recorded the lowest PFP (40.86 kg kg^{-1}) for potassium.

4.2.6. Soil Analysis

The results on the effect of POMF 2 on soil physical and chemical properties are presented in Table 21.

4.2.6.1. Bulk Density

The bulk density of the soil did not change significantly as a result of the treatments.

4.2.6.2. Water Holding Capacity

The data on water holding capacity of soil after the experiment is presented in Table 21. WHC of soil did not differ significantly among the various treatments.

4.2.6.3. Soil Reaction

The data pertaining to soil reaction (pH) of soil is presented in Table 21. The pH of soil was not influenced significantly by different treatments.

4.2.6.4.Electrical Conductivity

The data pertaining to electrical conductivity (EC) of soil after the experiment is presented in Table 21. The treatments did not show any significant effect on electrical conductivity of soil.

4.2.6.5. Organic Carbon

Organic carbon content of the soil did not vary significantly among the various treatments tested (Table 21).

4.2.6.1. Available Nitrogen

Available nitrogen showed significant variation due to the treatments. The data on soil available nitrogen after the field experiment is presented in Table 21. The highest available soil nitrogen (278.20 kg ha^{-1}) was observed in T_4 which received 50 percent RD as POMF 2 (basal) and 50 percent RD as POMF 2 at 25 DAS. It was on par with T_1 (269.24 kg ha^{-1}) and T_5 (267.98 kg ha^{-1}). The treatment, T_8 (control) recorded the least available soil nitrogen (213.44 kg ha^{-1}) after the experiment.

4.2.6.2. Available Phosphorus

The results on the effect of POMF 2 on available phosphorus are presented in Table 21. There was significant variation among treatments in available phosphorus after the field experiment. Available phosphorus was the highest (72.71 kg ha^{-1}) in T_4 (50 per cent RD as POMF 2 (basal) and 50 percent RD as POMF 2 at 25 DAS) and was on par with T_1 (68.54 kg ha^{-1}) and T_5 (68.25 kg ha^{-1}). The lowest available soil phosphorus after the experiment was recorded in T_8 (41.70 kg ha^{-1}).

Table 21. Effect of POMF 2 on soil properties after experiment

Treatments	Water holding capacity	Bulk density	pH	EC	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1: 100 per cent RD as POMF 2 (basal)	34.62	1.23	5.87	0.45	0.64	269.24	68.54	266.51
T_2: 75 per cent RD as POMF 2 (basal)	34.11	1.22	5.90	0.43	0.63	258.14	65.34	264.19
T_3: 50 per cent RD as POMF 2 (basal)	32.48	1.21	5.80	0.35	0.57	237.67	56.76	250.46
T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS	34.34	1.17	5.84	0.44	0.61	278.20	72.71	272.08
T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	34.08	1.20	5.53	0.42	0.60	267.98	68.25	268.68
T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	32.50	1.19	5.47	0.32	0.55	250.55	62.36	252.25
T_7: FYM at 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}	34.39	1.20	5.50	0.40	0.59	228.21	50.48	212.37
T_8: Control (No fertilizers)	31.62	1.30	5.37	0.31	0.52	213.44	41.70	169.58
SE m (±)	1.25	0.06	0.17	0.04	0.03	6.32	3.52	4.39
CD (0.05)	NS	NS	NS	NS	NS	13.570	7.550	9.430

4.2.6.3. Available Potassium

The data pertaining to available K after soil experiment is presented in Table 21. Significant variation was observed in available potassium among treatments after the field experiment. The available potassium (272.08 kg ha^{-1}) was the highest in T_4 (50 per cent RD as POMF 2 (basal) and 50 per cent RD as POMF 2 at 25 DAS) and was on par with T5 (268.68 kg ha^{-1}), T_1 (266.51 kg ha^{-1}) and T_2 (264.19 kg ha^{-1}). T_8 recorded the least (169.58 kg ha^{-1}) available soil potassium after the experiment.

4.2.7. Nutrient Balance Sheet

An assessment of nutrient additions, removals, and balances provides practical information on whether the nutrient status of a soil is being maintained, build up, or depleted. The influence of application of POMF 2 on nutrient balance of the soil are presented below.

4.2.7.1. Balance Sheet of Nitrogen

The effect of application of POMF 2 on nitrogen balance of soil is presented in Table 22.

The results showed that all the treatments had a positive apparent gain in soil available N. The apparent gain of soil available nitrogen was the highest in T_6 (208.38 kg ha^{-1}), and was followed by T_2 (206.61 kg ha^{-1}). However, the least apparent gain of available nitrogen was recorded in T_7 (45.44 kg ha^{-1}). The highest actual gain of soil available nitrogen was recorded in T_4 (52.41 kg ha^{-1}) followed by T_1 (43.45 kg ha^{-1}). The actual gain for soil available nitrogen in T_7 was only 2.41 kg ha^{-1}. The treatment, T_8 recorded negative gain of soil available nitrogen (-12.35 kg ha^{-1}) indicating depletion of nitrogen.

4.2.7.2. Balance Sheet of Phosphorus

The effect of application of POMF 2 on phosphorus balance of soil is presented in Table 23.

The results showed that the apparent gain of available phosphorus was the highest in T_6 (34.74 kg ha^{-1}). The treatment T_7 recorded negative apparent balance of available phosphorus (-70.92 kg ha^{-1}). The highest actual gain of soil available phosphorus was recorded in T_4 (34.65 kg ha^{-1}) and T_8 recorded the least positive gain of available phosphorus in soil (3.63 kg ha^{-1}).

4.2.7.3. Balance Sheet of Potassium

The effect of application of POMF 2 on potassium balance of soil is presented in Table 24.

The apparent balance of available potassium was higher than the expected balance in all the treatments. The apparent gain of available potassium was the highest in T_2 (315.89 kg ha^{-1}) and was followed by T_5 (315.64 kg ha^{-1}). The least apparent gain of available potassium was recorded in T_8 (101.32 kg ha^{-1}). The highest actual balance of potassium was recorded in T_1 (93.04 kg ha^{-1}) and the treatment T_5 recorded negative balance for available potassium, (-46.96 kg ha^{-1}) indicating depletion.

4.2.8 Economic Analysis

The effect of POMF 2 on the economics of baby corn is presented in Table 25.

4.2.8.1. Gross Income (₹ ha^{-1})

The results on the effect of POMF 2 on gross income are presented in Table 25. The application of 75 per cent RD as POMF 2 (basal) (T_2) recorded the highest gross income (₹ 215991 ha^{-1}) and was on par with T_1 (₹ 213784 ha^{-1}) and T_7 (₹ 212486 ha^{-1}). The lowest gross income (₹ 66196 ha^{-1}) was recorded in T_8 (control).

4.2.8.2. Net income (₹ ha^{-1})

The results on the effect of POMF 2 on net income are presented in Table 25. The highest net income (₹ 143783 ha^{-1}) was recorded in T_7 (FYM @ 12.5 t ha^{-1} +135:65:45 kg NPK ha^{-1}; ½ N+ full P+½ K basal; ½ N +½ K at 25 DAS) and was on par with T_2 (75

Table 22. Effect of POMF 2 on balance sheet of nitrogen

Treatments	Initial N (A) (kg ha^{-1})	Added N (B) (kg ha^{-1})	N uptake (C) (kg ha^{-1})	Expected balance (D) (kg ha^{-1}) [(A)+(B) -(C)]	Soil available N (E) (kg ha^{-1})	Apparent gain/loss (E-D)	Actual gain /loss (E-A)
T_1: 100 per cent RD as POMF 2 (basal)	225.79	135	285.59	75.20	269.24	194.04	43.45
T_2: 75 per cent RD as POMF 2 (basal)	225.79	101.25	275.51	51.53	258.14	206.61	32.35
T_3: 50 per cent RD as POMF 2 (basal)	225.79	67.5	253.57	39.72	237.67	197.95	11.88
T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS	225.79	135	273.39	87.40	278.2	190.80	52.41
T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	225.79	101.25	262.38	64.66	267.97	203.32	42.18
T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	225.79	67.5	251.12	42.17	250.55	208.38	24.76
T_7: FYM at 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}	225.79	240	283.02	182.77	228.20	45.44	2.41
T_8: Control (No fertilizers)	225.79	0	135.60	90.19	213.43	123.25	-12.35

Table 23. Effect of POMF 2 on balance sheet of phosphorus, kg ha^{-1}

Treatments	Initial P (A) (kg ha^{-1})	Added P (B) (kg ha^{-1})	P uptake (C) (kg ha^{-1})	Expected balance (D) (kg ha^{-1}) [(A)+(B) -(C)]	Soil available P (E) (kg ha^{-1})	Apparent gain/loss (E-D)	Actual gain /loss (E-A)
T_1: 100 per cent RD as POMF 2 (basal)	38.06	65	51.91	51.15	68.54	17.39	30.48
T_2: 75 per cent RD as POMF 2 (basal)	38.06	48.75	48.26	38.55	65.34	26.79	27.28
T_3: 50 per cent RD as POMF 2 (basal)	38.06	32.5	42.59	27.97	56.76	28.79	18.7
T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS	38.06	65	46.5	56.56	72.71	16.15	34.65
T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	38.06	48.75	46.34	40.47	68.25	27.78	30.19
T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	38.06	32.5	42.94	27.62	62.36	34.74	24.30
T_7: FYM at 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}	38.06	132.5	49.16	121.40	50.48	-70.92	12.42
T_8: Control (No fertilizers)	38.06	0	25.71	12.35	41.69	29.35	3.63

Table 24. Effect of POMF 2 on balance sheet of potassium, kg ha^{-1}

Treatments	Initial K (A) (kg ha^{-1})	Added K (B) (kg ha^{-1})	K uptake (C) (kg ha^{-1})	Expected balance (D) (kg ha^{-1}) [(A)+(B) -(C)]	Soil available K (E) (kg ha^{-1})	Apparent gain/loss (E-D)	Actual gain /loss (E-A)
T_1: 100 per cent RD as POMF 2 (basal)	173.47	45	263.84	-45.37	266.51	311.88	93.04
T_2: 75 per cent RD as POMF 2 (basal)	173.47	33.75	258.92	-51.70	264.19	315.89	90.72
T_3: 50 per cent RD as POMF 2 (basal)	173.47	22.5	231.12	-35.15	250.46	285.61	76.99
T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS	173.47	45	257.67	-39.20	272.08	311.28	98.61
T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	173.47	33.75	254.18	-46.96	268.68	315.64	-46.96
T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	173.47	22.5	223.05	-27.08	252.25	279.33	26.46
T_7: FYM at 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}	173.47	130	263.14	40.33	212.37	172.04	38.9
T_8: Control (No fertilizers)	173.47	0	105.21	68.26	169.58	101.32	68.26

% RD as POMF 2) (₹ 142691 ha^{-1}). The lowest net income was recorded in T_8 (₹ 27476 ha^{-1}).

4.2.8.3 Benefit cost ratio

The results on the effect of POMF 2 on BC ratio are presented in Table 25.

The highest BC ratio (3.09) was recorded in T_7 (135:65:45 kg NPK ha^{-1}; ½ N+ full P+½ K basal; ½ N +½ K at 25 DAS) and was on par with T_2 (2.95) (75 % RD as POMF 2). The lowest BC ratio was recorded in T_8 (1.71).

Table 25. Effect of POMF 2 on economics of baby corn.

Treatments	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	B:C ratio
T_1: 100 per cent RD as POMF 2 (basal)	213784	130584	2.57
T_2: 75 per cent RD as POMF 2 (basal)	215991	142691	2.95
T_3: 50 per cent RD as POMF 2 (basal)	129338	65938	2.04
T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS	206092	118892	2.36
T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	166059	88759	2.15
T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS	145398	77998	2.16
T_7: FYM @ 12.5 t ha^{-1} + 135:65:45 kg NPK ha^{-1}	212486	143783	3.09
T_8: Control (No fertilizers)	66196	27476	1.71
SE m (±)	3910.38	3910.38	0.06
CD (0.05)	8387.775	8387.775	0.132

Discussion

5. DISCUSSION

The investigation entitled "Development of pelleted organo-mineral fertilizer and its effect on baby corn (*Zea mays* L.)" was undertaken at Department of Agronomy, College of Agriculture, Vellayani during 2020-2022. The main objectives of the study were to standardize the nutrient sources to formulate pelleted organo-mineral fertilizers (POMF) and to evaluate its effect on the growth and yield of baby corn. The results of the study are discussed in this chapter.

5.1. FORMULATION OF PELLETED ORGANO-MINERAL FERTILIZER

Organic manure application is uneconomical due to low nutrient content and high transportation and application costs caused by its high moisture content and bulkiness. Since the concentration and availability of nutrients in organic manures vary, applying organic manures uniformly at controlled rates is difficult. Chemical fertilizers, on the other hand, have higher nutrient content and are less expensive and easier to use than organic manures. However, chemical fertilizers are highly soluble in water, and leach away without fully benefiting the plants. As a result, there are fewer nutrients available for plant growth. Considering the limitations of both organic manures and chemical fertilizers, the recent trend to replace mineral fertilizers with Organo-mineral fertilizer (OMF) products by combining organic manures with chemical fertilizers has been reported by many researchers. The organic fraction in such materials protects the inorganic components through binding and absorption, slowing the rate of release of plant nutrients and reducing the environmental impact caused by chemical fertilizers without compromising the benefits of organic manures (Antille *et al*., 2013).

Cowdung powder, vermicompost, and poultry manure were chosen as the base material for the preparation of OMF in this study because they are locally available and are less expensive organic nutrient sources. These were mixed with other organic manures (neem cake, groundnut cake and rice husk ash), chemical fertilizers (urea, single super phosphate, rock phosphate, muriate of potash, ayar, and rock dust), and biostimulants (humic acid and sea weed powder) in three different ratios to formulate

OMF and pelletized. The use of pelleted organo-mineral fertilizer (POMF) reduced the water content, weight, and volume of OMF, resulting in a product that is chosen over fresh manure due to cheaper storage, transportation, handling, and application costs. Such advantages of pelletization were also reported by Kleinman *et al*. (2012), Zafari and Kianmehr (2012) and Mieldazys *et al*. (2016). The average nitrogen content of the nine combinations of POMFs tested in the present study ranged from 5.54 per cent to 9.86 per cent, phosphorus content varied from 2.89 per cent to 4.27 per cent and potassium content ranged from 2.04 per cent to 4.24 per cent. The nutrient content of POMF were found to be more than the organic raw materials used. Inorganic fertilizer enrichment also changed the nutrient content of POMF to more favourable ratios to meet specific crop needs. Mazeika *et al*. (2016) and Sakurada *et al*. (2016) also reported similar findings.

5.2. INCUBATION STUDIES

Among the nine treatment combinations of POMF studied in the first part of the experiment, best six combinations *ie*. two cow dung based POMF (POMF 1 and POMF 2), three vermicompost based POMF (POMF 4, POMF 5 and POMF 6) and one poultry manure based POMF (POMF 6) suited for baby corn were selected for incubation studies aimed at assessing the nutrient release pattern.

5.2.1. Effect of POMF Application on Available Nitrogen Content in Soil

The available nitrogen content of the soil during the incubation period differed significantly among all tested treatments. The absolute nitrogen release during the incubation period is depicted graphically in Fig. 4. INM released 71.18 per cent and 19.96 per cent of applied nitrogen at 15 and 30 days after incubation (DAI) respectively, whereas the percentage of nitrogen released from POMF treatments ranged from 12 to 22 per cent to 34 to 53 per cent at 15 and 30 DAI. The vermicompost based POMF, T_5, recorded the highest (22.20 %) nutrient release at 15 DAI, followed by the cow dung-based POMF, T_2 (20.88 %). At 30 DAI, the cow dung-based POMF, T_2, recorded the highest nutrient release (52.49 %), followed by the poultry manure-based POMF, T_6 (52.39 %).

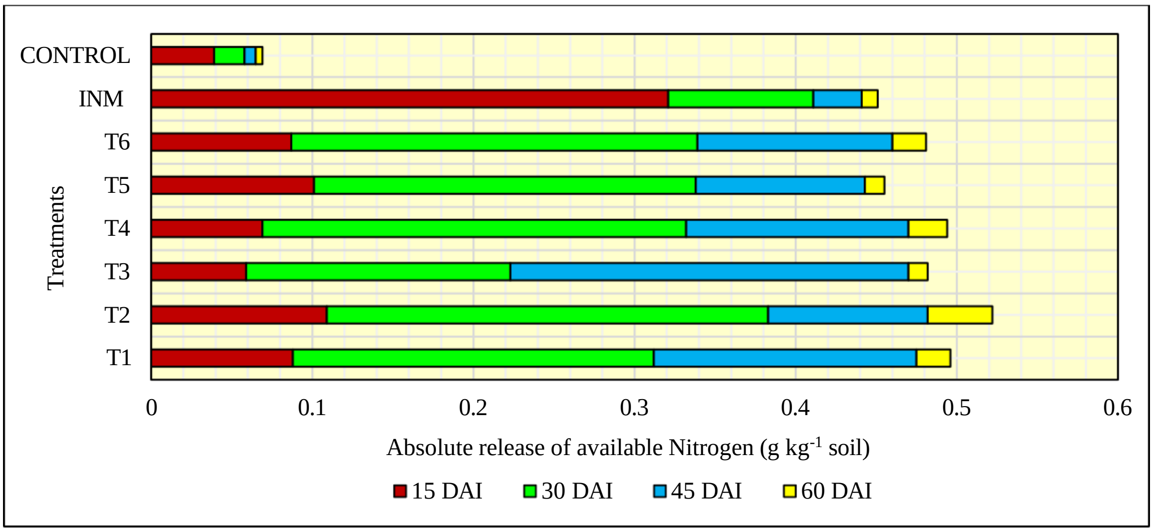


Fig 4. Absolute release of available nitrogen from POMF during incubation period, g kg^{-1}

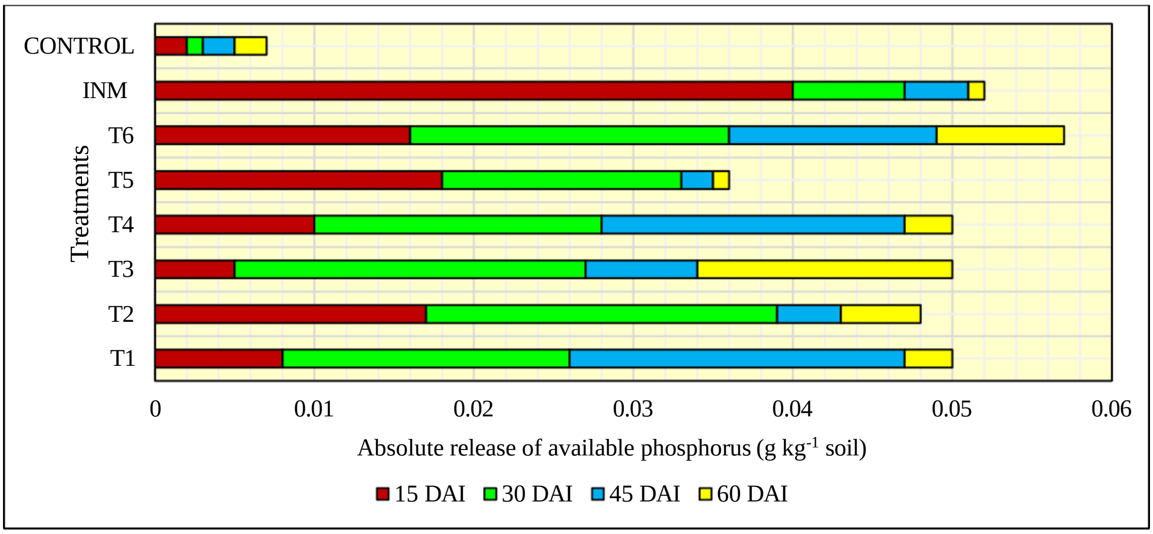


Fig 5. Absolute release of available phosphorus from POMF during incubation period, g kg^{-1}

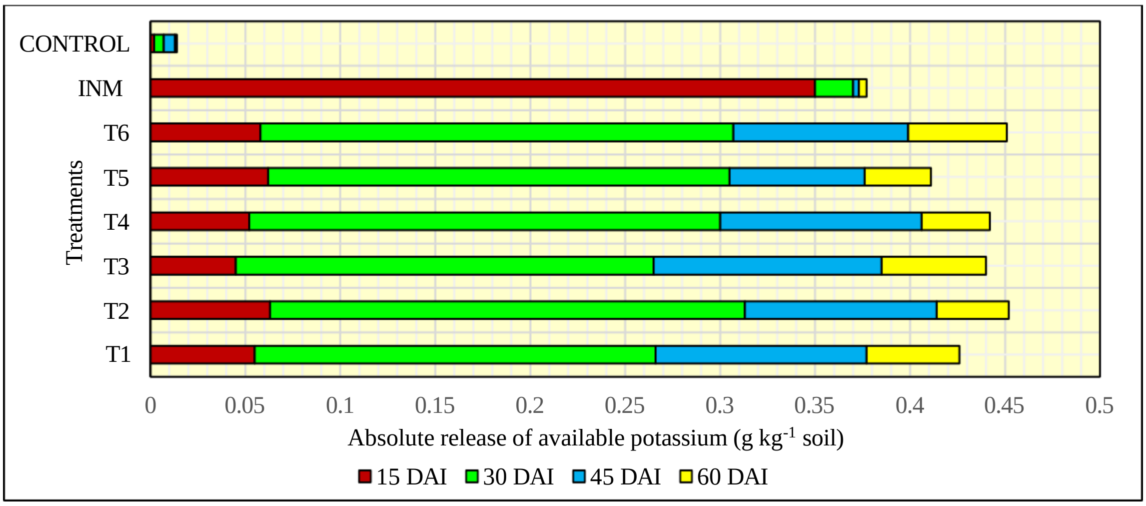


Fig 6. Absolute release of available potassium from POMF during incubation period, g kg^{-1}

During the first 15 days of incubation, it was found that chemical fertilizers released nitrogen four times faster than POMF. The POMF treatments had a slow nitrogen release at 15 DAI, followed by a peak release at 30 DAI, which corresponded to the peak nutrient requirement stage of baby corn. The binding of available nitrogen forms with the various components of organo-mineral fertilizers explains the slow release of nitrogen from OMF treatments. Sharma and Singh (2011) reported that organic-matrix based slow-release fertilizer showed prolonged nitrogen retention due to nutrient immobilisation in organic matrix, and the nutrients were released in synchrony with the crop's nitrogen needs. The slow release of nitrogen from fertilizer manure blocks compared to sole fertilizer treatment was also reported by Induja (2020) in okra. The longer nutrient release time from pelleted samples might also be attributed to the higher concentration of binding agent and higher pressure applied during the manufacturing stage, which resulted in a higher density of compacted pelleted solid samples as reported by Purnomo *et al*. (2017).

5.2.2. Effect of POMF application on Available Phosphorus Content in Soil

The available phosphorus content of the soil during the incubation period differed significantly between all tested treatments. The absolute release of phosphorus during the incubation period is graphically shown in Fig. 5. At 15 and 30 DAI, 100 per cent RD as mineral fertilizers released 76.92 per cent and 13.46 per cent of applied phosphorus, respectively. During the initial period, the percentage of phosphorus release from POMF varied greatly among treatments. At 15 and 30 DAI, it ranged from 10 to 50 per cent and 35.09 to 45.83 per cent, respectively. POMF treatments were found to release phosphorus 2.5 times slower than chemical fertilizers alone during the initial phase of incubation studies (15 DAI). Induja (2020) reported similar results on the slow release of phosphorus from fertilizer-manure blocks compared to sole fertilizer treatments in okra.

Among the POMF treatments, vermicompost based POMF (T_5) recorded the highest (50 %) phosphorus release followed by cow dung based POMF (T_2) which released 35.42 per cent phosphorus. In POMF, single super phosphate, bone meal and rock phosphate were used as the fast and slow-release source of phosphorus. The higher concentration of SSP in T_5 compared to T_2 might me the reason for higher initial release of phosphorus from T_5. The release of phosphorus from POMF treatments increased after 15 days of incubation. The cow dung based POMF, T_2 recorded the highest (45.83 %) phosphorus release at 30 DAI. Phosphorus is a nutrient which is required initially, for rooting and plant growth. T_2 showed an even release of P that was synchronised with the crop's crucial needs throughout the initial growth period.

P fixation generally affects phosphorus availability in acidic soil. However, non-availability of phosphorus due to fixation was not observed in POMF treatments. The results were in line with the findings of Erro *et al.* (2012). The association of soluble phosphate with organic matter or humic substances presented in POMF might have resulted in significant increase in the concentration of plant available phosphorus in soil. Humic acid reacts with phosphates in POMF, to form monocalcium phosphate humic complexes, which might have inhibited the phosphate fixation in soil and increased P availability. Wang *et al.* (2011) also reported that the organo-mineral matrix act as an electrostatic barrier to obstruct phosphate ion fixation in soil, which promotes soil P diffusion and increases soil P availability. Entrapment of rock phosphate in the organic matrix also might have resulted in gradual release of P into the soil, reducing fixation and increasing P availability for longer period of time.

5.2.3. Effect of POMF Application on Available Potassium Content in Soil

Available potassium content of the soil during the incubation period showed significant difference among all the tested treatments. The absolute release of potassium during the incubation period is graphically shown in Fig. 6. During the initial stages of incubation (first 15 days), the mineral fertilizer treatment released potassium faster than the POMF treatment. The mineral fertilizer treatment released 92.83 per cent of applied potassium within first 15 days of incubation while the POMF treatments slowly released potassium ranging from 10.22-15.08 per cent and 49.53-59.12 per cent at 15 and 30 DAI respectively. Similar results were also reported by Induja (2020) in okra. Fertilizer when placed alone released almost 95 per cent of applied potassium within 3 days of incubation while fertilizer-manure blocks slowly released the potassium ranging from 47.5 to 60.4 per cent. This slow-release behaviour of potassium in POMF treatments might be due to the binding of potassium ions to cation exchange sites of different organic materials used for formulating OMF. At 15 and 30 DAI, vermicompost based OMF (T_5) recorded the highest K release followed by cow dung based OMF (T_2). There was no wider variation in K release rate among the POMF treatments in present study. This shows that the POMF combinations release potassium in even manner and in concurrence with the critical needs of the crop. Furthermore, the organic sources might have increased the CEC, increasing potassium availability.

Thus, from the incubation studies it was concluded that, among all the POMF treatments tested, the treatment T_2 (POMF 2) exhibited more synchronized and sustained nutrient release in accordance with the plant nutrient demand at various stages of baby corn. The treatment T_2, also satisfied the recommended nutrient ratio of baby corn (3.04:1.41:1), and hence was selected as the best treatment for further field studies to identify the best package for its application.

5.3. CHARACTERISATION OF PELLETED ORGANO-MINERAL FERTILIZER

The physical parameters of the POMF 2 showed that the pellets were dark brown to black in color and was odourless. Initial moisture content of OMF (bulk) was found to be 21 per cent and it was reduced to 10.86 per cent when pelletized. The diameter of the pellets produced did not differ significantly (5.8 to 6 mm). This could be related to the 6 mm uniform die-hole size. And the slight variation might be due to the contraction of pellet during drying process. The pellet length varied from 15 mm to 18 mm which might be due to the variable rate at which the pellets moved out of the die of pelleting machine. Pelletization also reduced the volume of OMF 2 facilitating easier storage and transportation. Nikiema *et al*. (2013) also reported that the volume of compost pellets were reduced by 20-50 per cent compared to powdered products.

Pelletization enhanced the bulk density of OMF by 30 per cent (0.58 Mg m^{-3} to 0.84 Mg m^{-3}). Similar increase in bulk densities by 33-45 per cent in compost pellets was also reported by Hettiarachchi *et al*. (2019). POMF 2 recorded a near neutral pH (6.8) which indicated a favourable pH range for nutrient assimilation by plants. The electrical conductivity of POMF 2 was 18.6 dS m^{-1}. This might be attributed to the presence of soluble salts in the pelleted organo-mineral fertilizers. Organic carbon content of POMF 2 was 0.42 per cent. Total nitrogen, phosphorus and potassium content were 8.18 per cent, 3.78 per cent and 2.69 per cent respectively. The Ca content of POMF 2 was 6.50 per cent and Mg content was 2.82 per cent. The Zn and B content in POMF 2 were 1015.5 mg kg^{-1} and 0.007 mg kg^{-1} respectively. Smith (2020) also stated that organo-mineral fertilizers were more beneficial than mineral fertilizers since they provided a variety of macro and micronutrients in addition to organic matter.

Storage studies were conducted in air-tight polythene bags, and it was observed that there was only 0.62 per cent, 0.20 per cent and 0.23 per cent reduction in N, P and K content, six months after storage. No fungal growths were observed during the entire period of study. Low moisture content (10.86 %) of POMF 2 might have inhibited the development of microorganisms. The addition of talc as filler during pelletization might have also helped to prevent the formation of hydrate crystal bridges allowing the product to be stored longer. Kasprzycka *et al.* (2018) also recommended to store pelleted organo-mineral fertilizers in airtight containers as exposure to ambient air could negatively affect water content and microbiological properties of the materials.

5.4. EFFECT OF POMF 2 ON BABY CORN

POMF 2 was chosen as the best POMF combination based on the findings of the incubation studies. A field experiment was conducted to evaluate the effect of POMF 2 on the growth and yield of baby corn. The findings are discussed below.

5.4.1. Growth and Growth Attributes

The results of the study indicated significant differences in growth attributes of baby corn due to different treatments. The effect of POMF application on plant height is graphically shown in Fig. 7. At 15 DAE, the mineral fertilizer treatment, T_7 recorded significantly taller plants, while at 30 DAE, basal application of even 50 per cent RD as POMF 2 resulted in plant height comparable to T_7. At 45 DAE, application of 100 or 75 per cent RD as POMF 2 recorded the tallest plants and was comparable with T_7. The effect of POMF application on leaf area is graphically shown in Fig. 8. Application of 100 or 75 per cent RD as POMF 2 also recorded leaf area comparable with T_7 during 15, 30 and 45 DAE. The mineral fertilizer treatment T_7, recorded the highest leaf area at 15 DAE while the organo-mineral fertilizer treatment, T_1 recorded the highest leaf area during 30 and 45 DAE. Similar trend was observed in leaf area index also. Thus the results showed that a 25 percent lower dose of POMF could produce the growth characteristics as 100 per cent RD of mineral fertilizer.

The variation in growth between mineral and organo-mineral fertilizer treatments might be due to the differences in nutrient availability. Pelletization of OMF slowed down the release of nutrients while mineral fertilizers release nutrients more quickly. This could explain why POMF treatments exhibited comparable or even superior growth characteristics than mineral fertilizer treatments in later phases than initial phases of crop growth. Similar conclusions could be drawn from the incubation study also. Slow release properties of POMF 2 may have aided in the long-term availability of nutrients, which are frequently synced with plant physiological needs as reported by Taoukis and Assimakopoulos (2010). Many researchers have reported organo-mineral fertilizer as an important strategy for increasing fertilizer use efficiency. In OMF, nutrients are slowly released from chemical fertilizer, which initially meets the nutrient requirement of the crop and organic manure gradually decomposes, releasing nutrients in plant-available form, fulfilling the crop’s further nutrient requirement (Abedi *et al*., 2010). Thus, the use of OMF aids in the continuous supply of nutrients *via* a controlled release mechanism (Kominko *et al*., 2017; Buss *et al*., 2019). Because of its slow-release mechanism, OMF can also prevent nutrient losses. Liu *et al*. (2020), reported that ammonia volatilisation is significantly lower when organic and inorganic fertilizers were combined than application of urea alone. This might also be the reason for increased vegetative response in POMF treated plots compared to mineral fertilizer plots. Azeem *et al*. (2014) found that incorporating inorganic fertilizers and organic manure granules improved maize growth characteristics.

The results of the present study also showed that the application of 100 or 75 per cent RD of baby corn as POMF 2 accumulated biomass comparable with mineral fertilizer treatment. The effect of POMF application on dry matter production is graphically represented in Fig. 9. This indicated that 25 per cent reduced dosage of POMF could result in dry matter production as that of 100 per cent RD as mineral fertilizer. Dry matter production is a function of plant height, leaf area and yield. The consistent increments observed in these attributes might have positively influenced dry matter production. The balanced delivery of nutrients throughout the crop period, which was frequently synced with the physiological needs of plants in POMF treatments, may have contributed in increasing leaf area, resulting in higher photosynthate absorption and higher dry matter production. Such increments in values of dry matter production of maize by OMF application was also reported by Khan *et al*. (2017). The slow-release nature of POMF might have also reduced nitrogen leaching losses from the rhizosphere, resulting in more available nitrogen during the developing phase of baby corn, as reported by Fernandez-Escobar *et al.* (2004) and Kumar and Dhar (2010). The inclusion of biostimulants in POMF 2 formulation might also have promoted plant vegetative growth and increased leaf area index and photosynthetic activity in maize resulting in higher dry matter production. Similar findings on positive influence of biostimulants on growth of maize was also reported by Unlu *et al*. (2011).

Baby corn took 42, 46 and 48 days to reach 50 per cent tasseling, 50 per cent silking and harvest maturity stages, respectively in both mineral and organo-mineral fertilizer treatments. This might be indicative of the fact that these stages are more dependent on the inherent genetic characters of the crop. Similar observations were also given by Mavarkar (2016). The number of harvests also remained unaffected by the different treatments. On an average, 3 harvests were obtained from the crop, in both mineral and organo-mineral fertilizer treatments.

5.4.2. Yield and Yield Attributes

In the present study, baby corn produced three cobs per plant regardless of nutrient sources. The length and girth of the cobs, on the other hand, were found to vary significantly with nutrient schedules. Basal application of 100 per cent RD as POMF 2

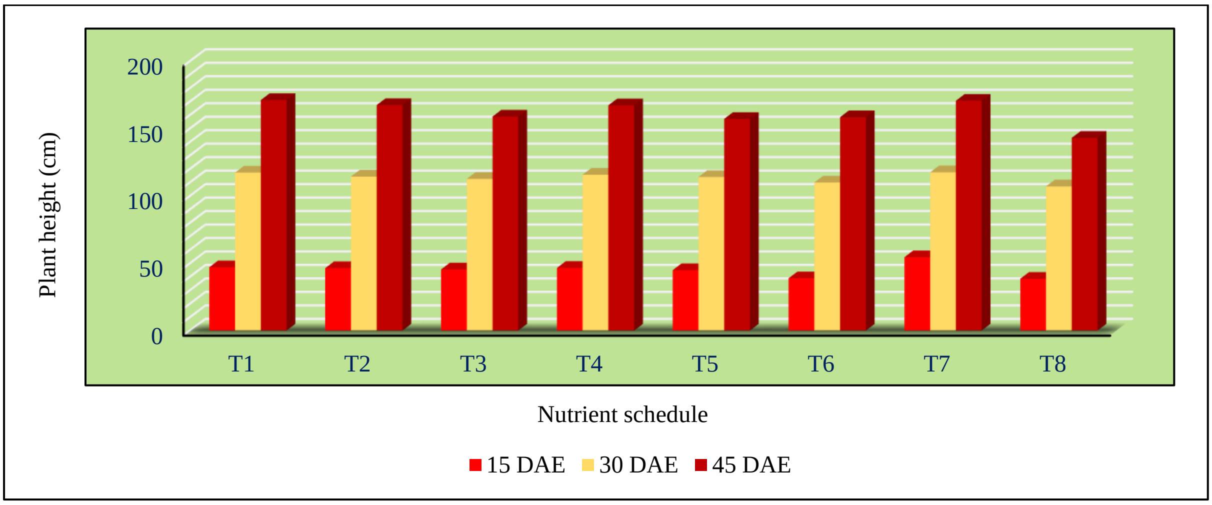


Fig. 7. Effect of POMF 2 application on plant height of baby corn, cm

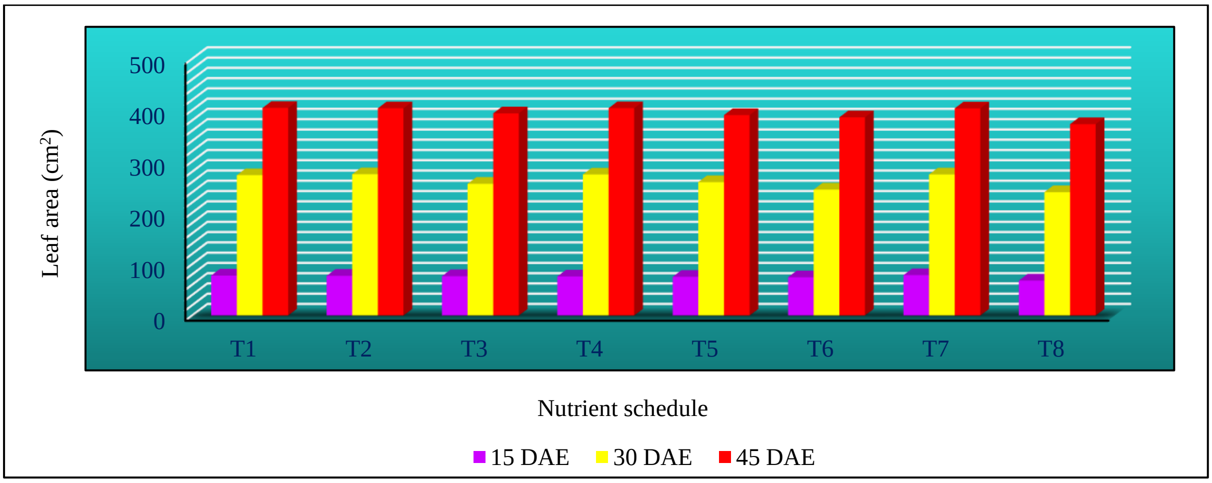


Fig. 8. Effect of POMF 2 application on leaf area of baby corn, cm^2

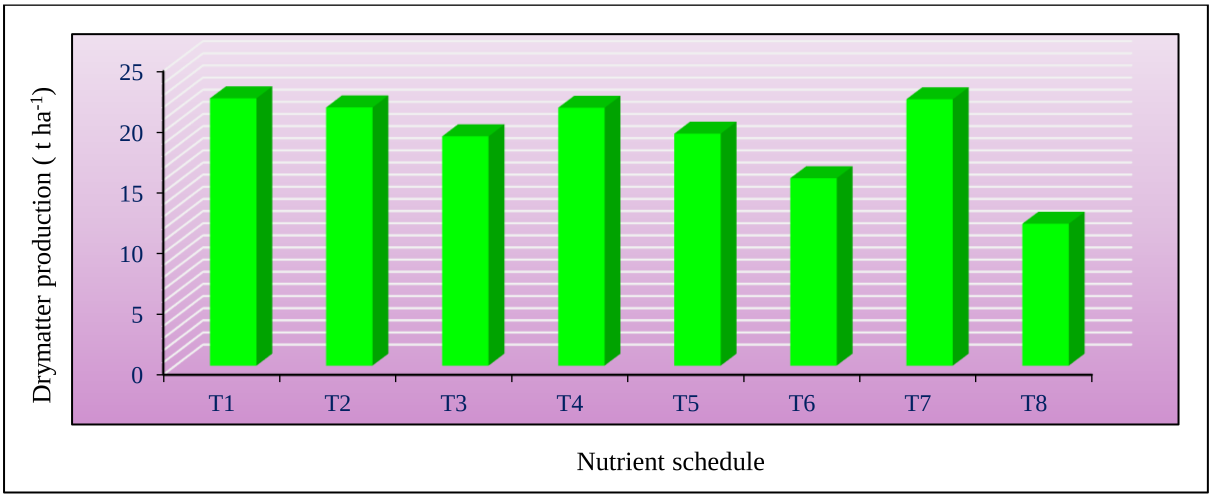


Fig. 9. Effect of POMF 2 application on dry matter production of baby corn, t ha^{-1}

(T_1) outperformed 100 per cent mineral fertilizer treatment in cob length and girth. The basal application of 75 per cent RD as POMF 2 (T_2) also resulted in cob length and girth comparable with full dose of mineral fertilizer. Neem cake acts as a nitrification inhibitor in POMF 2, allowing for a gradual release of nitrogen and reducing nitrogen losses, which might have contributed to the improved yield attributes compared to mineral fertilizer treatments. Kumar *et al.* (2013) and Adithya (2019) also stated that organic matrix entrapped fertilizers act as a slow-releasing fertilizer, providing nutrients in accordance with crop requirements during critical stages of crop growth, resulting in improved growth and yield characteristics.

According to the findings of the present study, POMF had a favourable impact on cob weight, cob yield with husk, marketable cob yield, and cob-corn ratio. The effect of POMF application on marketable cob yield, cob yield with husk and green stover yield is graphically presented in Fig. 10 and 11 respectively. The basal application of 75 per cent RD as POMF 2 resulted in cob yields that were comparable to 100 per cent RD as mineral fertilizer. The same trend was observed in green stover yield and marketable cob yield also. This increase in marketable cob yield in organo-mineral fertilizers could be attributed to higher photosynthetic rates caused by improved light interception, absorption, radiation use efficiency, and nutrient use efficiency. Comparable leaf area index and nutrient uptake observed in 75 per cent RD as POMF 2 (basal) and 100 per cent mineral fertilizer application also points out the same. Bagheri *et al.* (2011) found that applying cattle manure combined with urea to soil in pellet form increased maize production, 1000-kernel weight, and protein content. The improved maize production response was attributed to the slower release of nutrients from pellets for plant absorption at distinct corn growth stages. Similar findings were also reported by Chuan *et al.* (2013).

Many researchers reported that POMF reduced nutrient losses through its slow-release mechanism, resulting in greater nutrient use efficiency than mineral fertilizers. The findings of the present study confirmed this. When POMF was used as nutrient source, application of 75 per cent RD as POMF 2 (basal) could result in higher marketable cob yield than applying 100 per cent RD as mineral fertilizer. Ayinla *et al.* (2018) have observed that combining manure and chemical fertilizer produces a priming effect in which the blended substance outperforms the manure or chemical fertilizer when applied alone. Therefore, from the present study it can be confirmed that when POMF is used as nutrient source, 25 per cent less recommended dose of nutrients are only needed to obtain same yield as that of 100 per cent RD as mineral fertilizer. Kumar *et al*. (2013) also recorded the parity of yield between full recommended dose of urea and diammonium phosphate (DAP) and organic matrix entrapped urea and DAP containing one fourth of the recommended dose in wheat. Similar reductions in recommended dose of fertilizers by application of organic matrix entrapped fertilizers was also reported by Induja (2020).

In baby corn, 25 DAS corresponds to the knee-high stage which is very critical for the crop. The uptake of nutrients by baby corn is such that the absorption of major quantity of the nutrients are completed by the tasselling stage. The mean duration of the crop was only 48 days. According to the findings of this study, among the POMF treatments, basal application of 100 or 75 percent of the recommended nutrient dose resulted in superior growth and yield attributes and yield than split application of POMF 2 in baby corn. Abedi *et al.* (2010) reported that, when POMF was applied basally, the nutrients will be slowly released from the chemical fertilizer, initially meeting the crop's nutrient requirement, and the organic manure will undergo decomposition, gradually releasing nutrients in plant available form, meeting the crop's additional nutrient requirement. The present study also confirms the same observation. Thus, one-time basal application of POMF can be recommended for baby corn which will save more time and labour resulting in more returns. Similar results were also reported by Kumar *et al*. (2012) and Hao and He (2020). A single basal application of organic matrix entrapped fertilizers provides sufficient time for nutrient mineralization and release for current year crop uptake, resulting in increased plant growth and yield. According to Ashok *et al*. (2015), a single basal application of organic matrix entrapped chemical fertilizers significantly increased plant growth in rice in terms of fresh and dry weights, root length, shoot length, root and leaf numbers, and levels of NO_3^-, NO_2^-, NH_4^+, and PO_4- in the rhizosphere and accumulation in plant leaves.

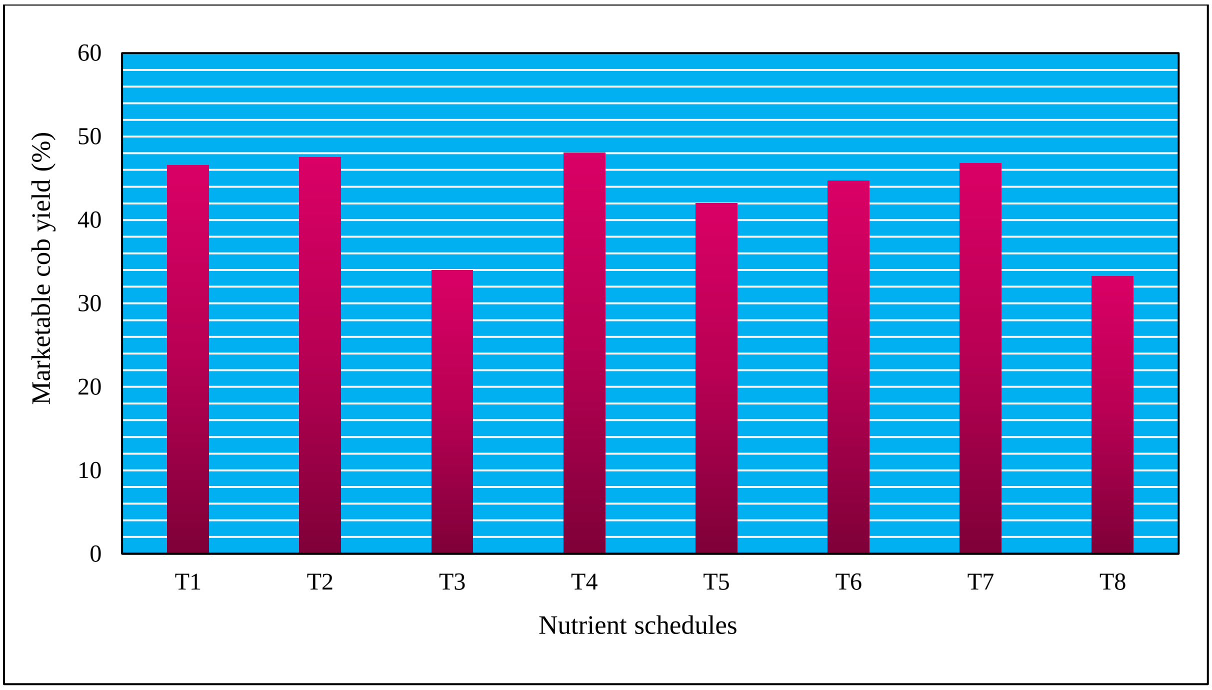


Fig. 10. Effect of POMF 2 application on marketable cob yield of baby corn, t ha^{-1}

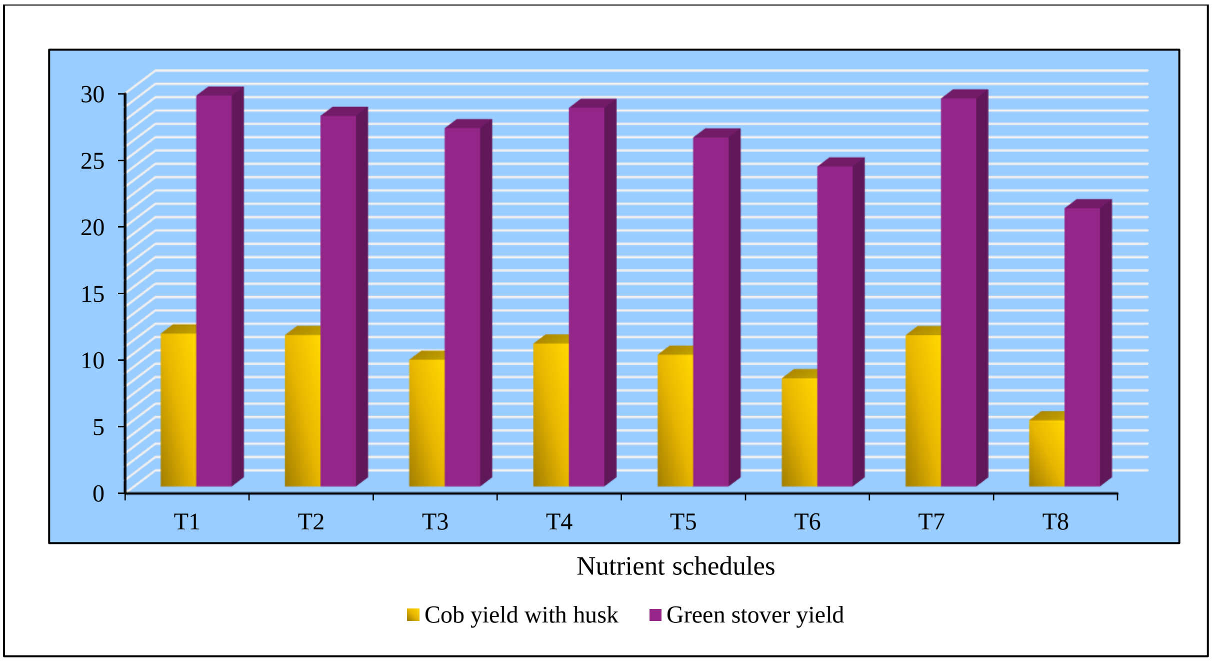


Fig. 11. Effect of POMF 2 on cob yield with husk and green stover yield of baby corn, t ha^{-1}

5.4.3. Plant Nutrient Uptake

The nutrient schedules had significant effect on nutrient uptake. The effect of POMF application on plant nutrient uptake is graphically represented in Fig. 12. Basal application of 100 per cent RD as POMF 2 (T_1) outperformed 100 per cent mineral fertilizer treatment in NPK uptake. The basal application of 75 per cent RD as POMF 2 (T_2) also resulted in NPK uptake comparable with full dose of mineral fertilizer. Similar observations were reported by Smith *et al.* (2020). Organo-mineral fertilizers can boost plant growth characteristics such as yield and nutrient uptake to a greater extent than manures or fertilizers alone. The application of organo-mineral granules improves soil physical qualities like texture, structure, and porosity, creating an ideal environment for root development, and this might have resulted in higher plant nutrient uptake. Nutrient uptake is also a function of dry matter production and nutrient content. The application of 100 per cent or 75 per cent RD of baby corn as POMF 2 accumulated comparable biomass with mineral fertilizer treatment and this might have reflected in nutrient uptake also. This is congruent with the findings of Fageria and Baligar (2005), who found that nutrient accumulation followed the dry matter accumulation pattern in plants. Ayeni *et al.* (2012) also reported that combining organic manures and synthetic fertilizers increased maize tissue nutrient concentration, nutrient uptake, growth, and yield. Memon *et al.* (2017) also found a similar increase in NPK uptake when mineral fertilizers were combined with organic manures. Iqbal *et al.* (2021) observed that organic fertilizer when used in conjunction with synthetic fertilizer enhanced the soil microbial biomass resulting in more nutrient release and greater plant nutrient uptake.

5.4.4. Agronomic Indices

Agronomic indices reflect the nutrient use efficiency of the crops. The nutrient schedules tested had significant effect on the agronomic indices *viz.*, agronomic efficiency (AE), physiological efficiency (PE), apparent recovery efficiency (ARE) and partial factor productivity (PFP) of nitrogen, phosphorus and potassium.

The agronomic efficiency (AE) depicts the direct impact of the applied fertilizer on production. It quantifies the improvement in productivity due to the addition of nutrients. In the present study, the agronomic efficiency of N, P and K were found to be higher in organo-mineral fertilizer treatments compared to mineral fertilizer treatments. The treatment T_2, recorded 36.99, 76.82 and 110.96 kg yield increase per kg of N, P and K supplied respectively. The mineral fertilizer treatment recorded only 14.54, 26.34 and 26.85 kg yield increase per kg of N, P and K supplied respectively. The results of present study indicated that, the combined application of organic manures and chemical fertilizers is the greatest approach for increasing agronomic efficiency and crop output while maintaining soil health and fertility. The same was reported by Kiehl (2008). Liu *et al*. (2020) also reported that organo-mineral fertilizers release nutrients slowly, reducing losses and improve the soil physical and chemical properties resulting in higher agronomic efficiency.

The increase in yield per unit uptake of nutrients by the plant's aboveground components is referred to as physiological efficiency (PE). It demonstrates the crop's ability to convert nutrients obtained from the applied source into economic yield. Application of 75 per cent RD as POMF 2 (basal), (T_2), recorded the highest PE of NPK and was comparable with the mineral fertilizer treatment (T_7). Nutrient uptake is the product of dry matter production and nutrient content. Application of 75 per cent RD as POMF 2 have recorded a nutrient uptake comparable to mineral fertilizer treatment by virtue of its higher dry matter. This might have in turn contributed to the higher PE.

Apparent Recovery Efficiency (ARE) is one of the most complex forms of nutrient use efficiency expressions. It is defined as the differential in plant nutrient uptake between fertilised and unfertilized crops in response to the amount of fertilizer applied. Apparent recovery efficiency signifies the quantity of nutrient taken up by the crop as against the quantity applied. Application of 100 or 75 per cent RD as POMF 2 (basal) recorded comparable apparent recovery efficiency. However, the mineral fertilizer treatment recorded the least ARE for all the three major nutrients.

Partial factor productivity (PFP) denotes the productivity of the crop in response to the nutrients received (both applied and indigenous). Application of 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS (T_6) recorded the

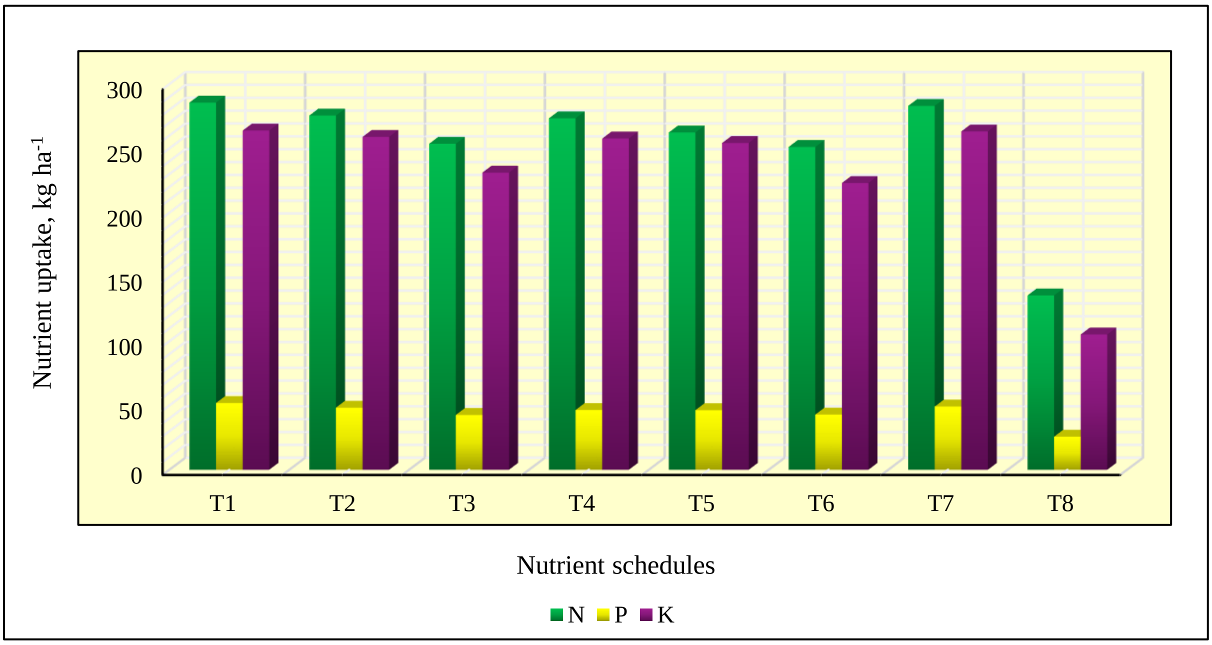


Fig. 12. Effect of POMF 2 application on NPK uptake of baby corn, kg ha^{-1}

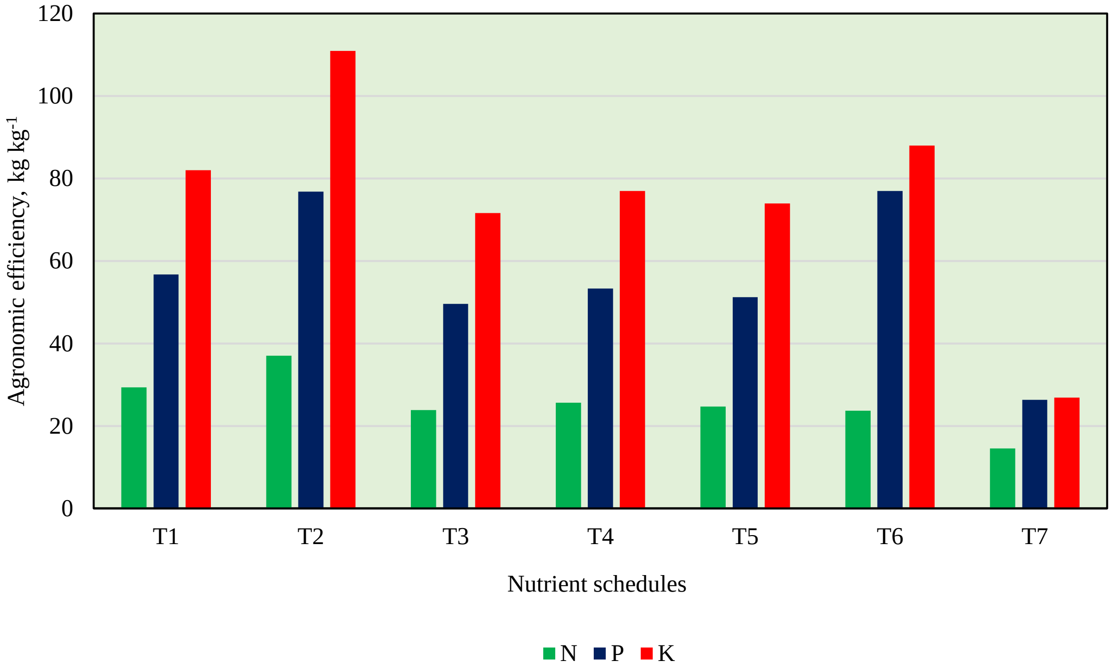


Fig. 13. Effect of POMF 2 application on agronomic efficiency of baby corn, kg kg^{-1}

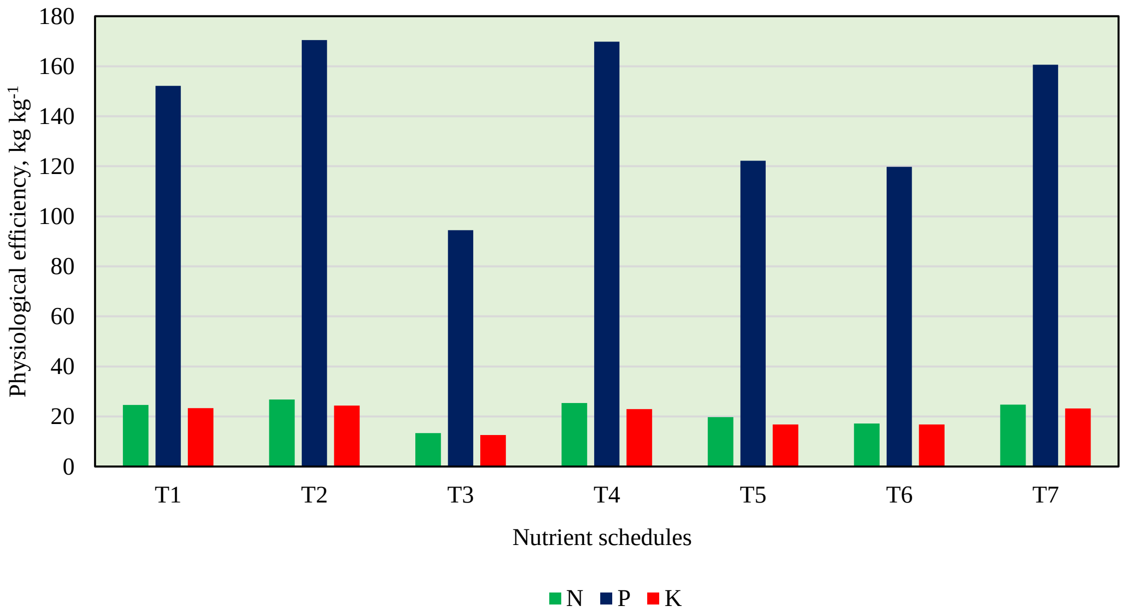


Fig. 14. Effect of POMF 2 application on physiological efficiency of baby corn, kg kg^{-1}

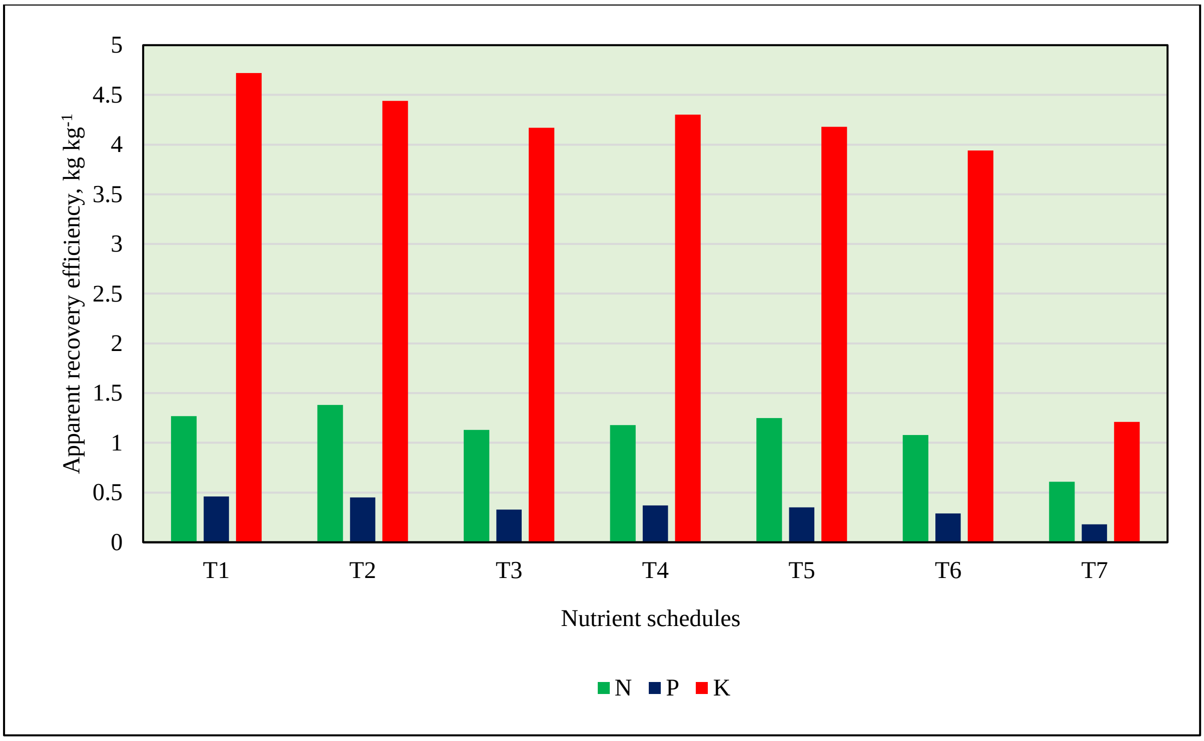


Fig. 15. Effect of POMF 2 application on apparent recovery efficiency of baby corn, kg kg^{-1}

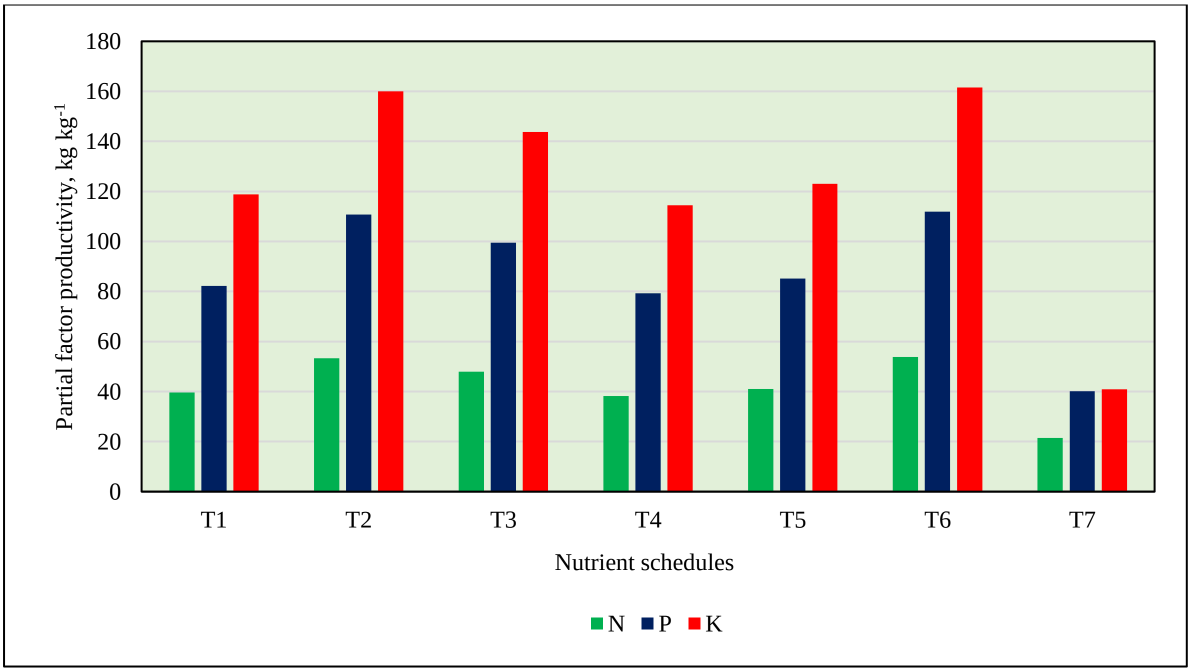


Fig. 16. Effect of POMF 2 application on partial factor productivity of baby corn, kg kg^{-1}

highest PFP and was comparable with T_2 (75% RD as POMF 2 (basal). The mineral fertilizer treatment T_7 recorded the least PFP for all the three major nutrients.

The results of the present study indicated that the organic-matrix based fertilizer aids in the enhancement of agronomic and apparent recovery efficiencies compared to conventional fertilizers. The same observation was made by Wu *et al*. (2018). This might be because of the slow nutrient release and reduced nutrient losses resulting in availability of nutrients for a prolonged period contributing to increased nutrient uptake. The application of organo-mineral fertilizers improved the soil physical and chemical properties, which also positively influenced the soil microbial population resulting in more active mineralising of the nutrients locked up in organo-mineral fertilizers (Petersen *et al*., 2003). In addition, other elements found in organo-mineral fertilizers, such as sulphur and magnesium, can help to increase nitrogen mineralisation. Because of its slow breakdown rate, the rock phosphate in POMF can operate as a slow release fertilizer, delivering available P to the plant for a longer period of time. The synergetic effect that occurs after combining organic manures and chemical fertilizers might have helped in the enhanced P use efficiency. Despite the low quantities of N, P and K in organic fertilizers, the mineral fraction contained in the organo-mineral fertilizer helped in supplementing their concentration. As a result of the gradual release of nutrients during plant growth, there is a high nutrient efficiency with the use of organo-mineral fertilizer (Hazra, 2016).

5.4.5. Soil Analysis

The organic carbon content, soil reaction (pH), electrical conductivity (EC), water holding capacity (WHC) and bulk density of the soil were not influenced significantly by the POMF treatments. The effect of POMF application on soil available NPK is graphically represented in Fig. 17.

The soil organic carbon and pH were found to increase in POMF applied plots compared to mineral fertilizer applied plots. Similar observations were made by Ayeni *et al*. (2012), Kumar *et al*. (2013), Ayeni and Ezeh (2017) and Induja (2020). Increased organic carbon levels in POMF-treated plots could be attributed to the presence of undecomposed carbon in POMF that was left over in the soil after crop harvest.

The results of present study also indicated that POMF treatments had considerable impact on the soil available NPK. When compared to plots that received mineral fertilizer, POMF treated plots had the highest soil NPK availability. This indicated that the POMF treated plots had prolonged nutrient retaining capacity than mineral fertilizer treated plots. The gradual release of nutrients, combined with reduced losses, might have increased soil nutrient availability as well as nutrient uptake in POMF treated plots. Similar observations were also reported by Jagadeeswaran *et al.* (2007), Tang *et al.* (2007) and Kumar *et al.* (2013). Adithya (2019) also reported that organic matrix entrapped slow release fertilizer possess the ability to ensure prolonged supply of nutrients and hence this fertilizer has the ability to improve nutrient use efficiency and crop productivity. Adhikari *et al.* (2016) found that when manures were mixed with NPK fertilizers, they mineralized more effectively than when they were applied alone. The organic portion mineralization of organo-mineral fertilizers can significantly contribute to increased nitrogen, phosphorus levels in soil (Antille *et al.*, 2013). This organic matter in organo-mineral fertilizers also aids in reducing phosphorus fixation and helps in the availability of P for crops (Castro *et al.*, 2015). Furthermore, the organic sources also increase the CEC, increasing potassium availability.

5.4.6. Nutrient Balance Sheet

In the present study, the POMF treated plots recorded the highest apparent gain and actual gain in soil available nitrogen compared to mineral fertilizer plots. The highest actual gain in soil available nitrogen was recorded in T_4 (52.41 kg ha^{-1}) followed by T_1. T_8 recorded a net loss in soil available nitrogen (-12.35 kg ha^{-1}) indicating depletion of nitrogen. Irrespective of the nutrient sources, the actual balance of soil nitrogen was lower than apparent balance. Nitrogen, as such is subjected to several losses like leaching, volatilization and denitrification. The dynamic nature and susceptibility of nitrogen for various kind of losses from the soil-plant system might have resulted in a lower actual balance of nitrogen in both OMF and mineral fertilizer treatments.

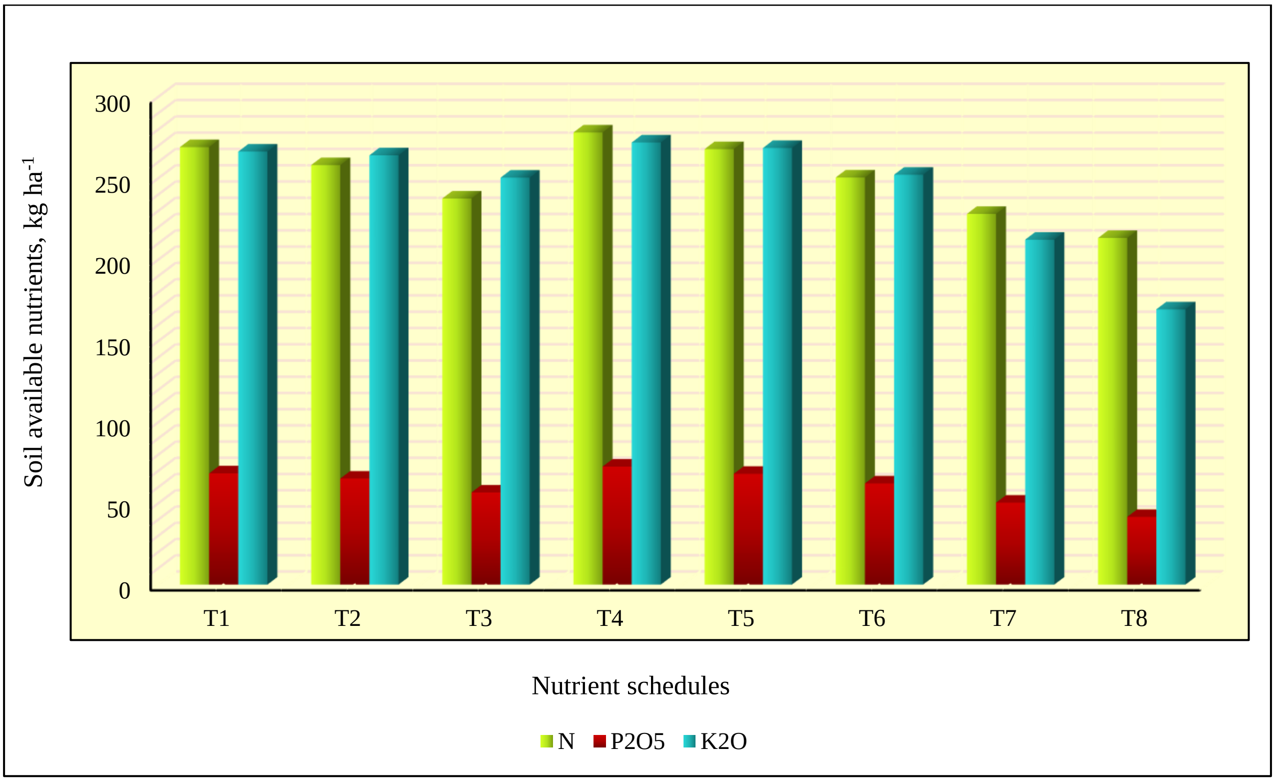


Fig. 17. Effect of POMF 2 application on soil available nutrients after the experiment, kg ha^{-1}

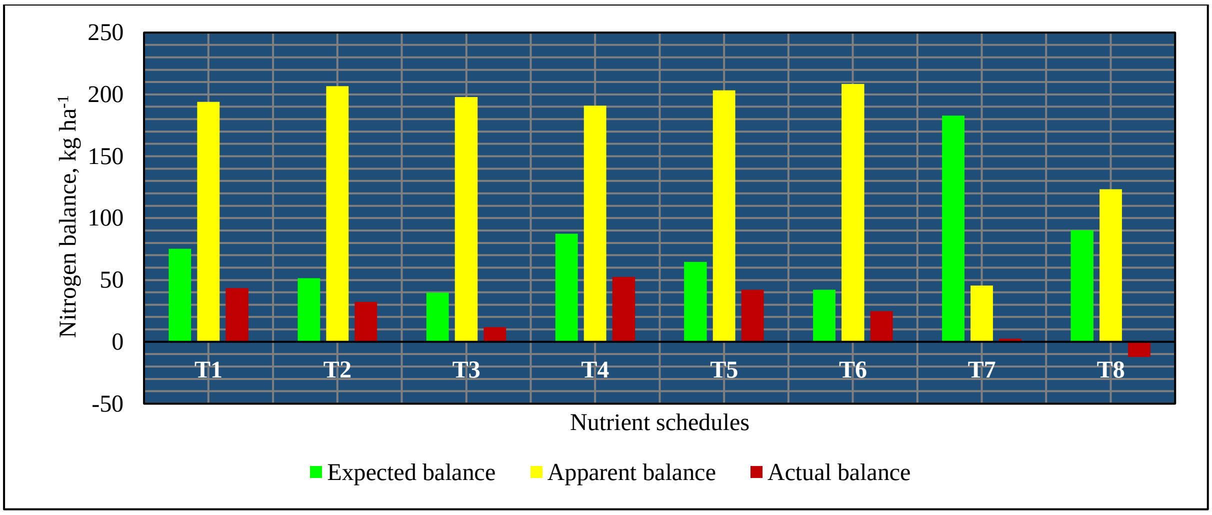


Fig. 18. Effect of POMF 2 application on nitrogen balance of soil, kg ha^{-1}

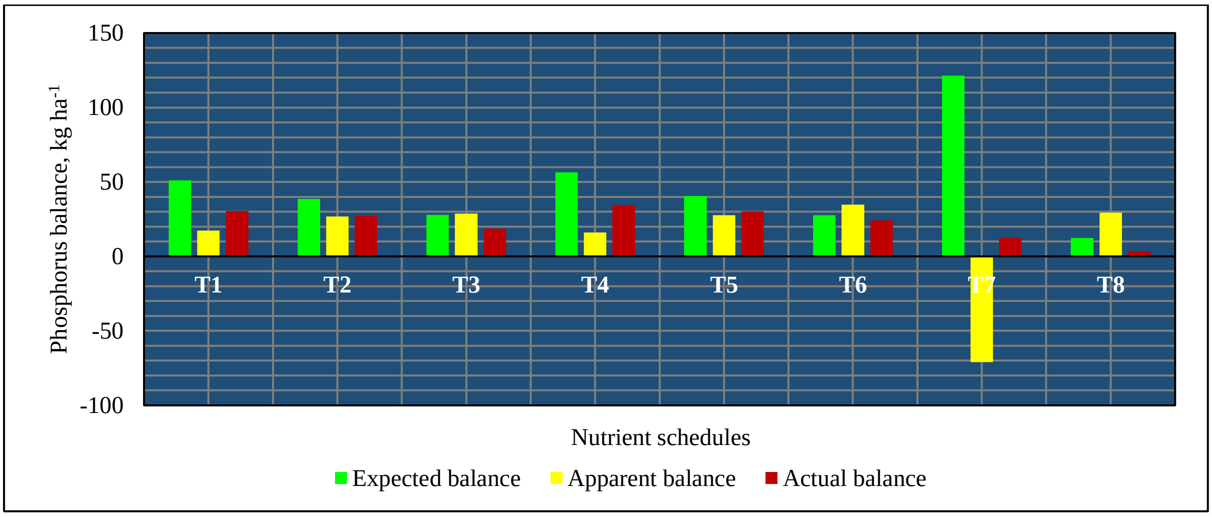


Fig. 19. Effect of POMF 2 application on phosphorus balance of soil, kg ha^{-1}

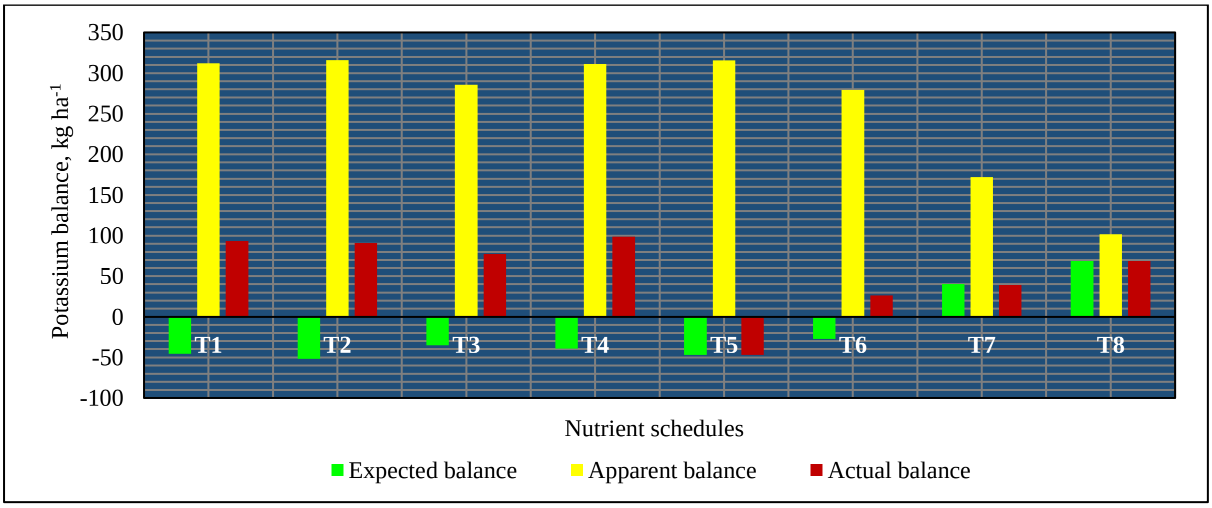


Fig. 20. Effect of POMF 2 application on potassium balance of soil, kg ha^{-1}

The apparent balance of phosphorus was observed to be positive in all organo-mineral fertilizer treatment while the mineral fertilizer treatment (T_7) recorded a negative apparent balance of -70.92 kg ha^{-1}. This might be due to P fixation in mineral fertilizer plots. The results also showed that P fixation in soil was prevented by POMF treatments. The association of soluble phosphate with organic matter or humic substances presented in POMF might have resulted in significant increase in the concentration of plant available phosphorus in soil. Humic acid reacts with phosphates in POMF, to form monocalcium phosphate humic complexes, which might have inhibited the phosphate fixation in soil and increased P availability. Wang *et al.* (2011) also reported that the organo-mineral matrix act as an electrostatic barrier to obstruct phosphate ion fixation in soil, which promotes soil P diffusion and increases soil P availability. The highest actual gain of soil available phosphorus was recorded in T_4 (34.65 kg ha^{-1}) and T_8 recorded the least positive gain of soil available phosphorus (3.63 kg ha^{-1}). The treatment T_7 recorded an actual gain of 12.42 kg ha^{-1} which is much lower than the POMF treatments.

The apparent balance of potassium was observed to be positive in all the tested treatments. POMF treatments recorded more apparent gain in potassium compared to mineral fertilizer treatments. The highest actual balance of potassium was recorded in T4 (93.04 kg ha^{-1}) and the treatment T_5 recorded negative balance of soil available potassium (-46.96 kg ha^{-1}) indicating potassium depletion. The basal application of organo-mineral fertilizer treatments showed higher actual gain in potassium compared to mineral fertilizer treatments.

Thus, from the results of present study it could be concluded that application of POMF is a better strategy for maintaining positive balance of nutrients in the soil compared to the sole application of mineral fertilizers.

5.5. ECONOMIC ANALYSIS

The results of the present study indicated that the application of POMF could result in more gross income compared to mineral fertilizer treatments. The treatment T_2, recorded the highest gross income (₹ 215991 ha^{-1}) and was on par with

T_1 (₹ 213784 ha^{-1}) and T_7 (₹ 212486 ha^{-1}). Among the POMF treatments, T_4 recorded the highest cost of cultivation. This might be due to the higher nutrient dose clubbed together with split application which increased the labour as well as the fertilizer cost. Application of 75 per cent RD as POMF 2 (basal) (T_2) recorded net income (₹ 142691 ha^{-1}) comparable with 100 per cent RD as mineral fertilizers (₹ 143783 ha^{-1}). Among the POMF treatments, application of 75 per cent RD as POMF 2 (basal) (T_2) recorded the highest BC ratio (2.95) and was on par with the mineral fertilizer treatment T_7 (3.09). Thus the present study indicated that application of 75 per cent RD of baby corn as POMF 2 (basal) can result in same economic returns as that of 100 per cent mineral fertilizer treatment. The enhanced economic benefit in POMF treatment T_2, could be attributed to the significantly high marketable cob yield and lower cost of cultivation. Sharma and Singh (2011) also reported that the use of organic matrix based slow release fertilizer can be a cost effective method. Kumar *et al.* (2012) reported that entrapping half the recommended dose of urea in organic matrix can result in equal net returns as compared to the full recommended dose of free urea. Azeem *et al.* (2014) also reported that organomineral fertilizers release nutrients in harmony with the nutritional requirements of plants, thereby enhancing the fertilizer use efficiency, ensuring the reduction in the cost of fertilizers and increasing the productivity and profitability of crop.

Thus from the study, it could be concluded that good quality POMF suited for baby corn can be prepared by mixing cow dung powder (30%), neem cake (10%), groundnut cake (4%), rice husk ash (4%), urea (16%), rock phosphate (9%), single super phosphate (8%), muriate of potash (4%), ayar (1%), rock dust (4%), humic acid (5%) and seaweed powder (5%) on percentage weight basis followed by pelletization. Basal application of cow dung based POMF @ 1.25 t ha^{-1} (equivalent to 75% RD of NPK of baby corn *ie.* 102:49:34 kg NPK ha^{-1}) could be recommended as the most productive, profitable and nutrient use efficient nutrient schedule for baby corn. Thus, twenty-five percentage reduction in recommended dose of NPK for baby corn can be achieved by using POMF rather than separate application of organic manures and chemical fertilizers. Hence, POMF can be popularized as a promising technology for enhancing nutrient use efficiency in field crops of Kerala.

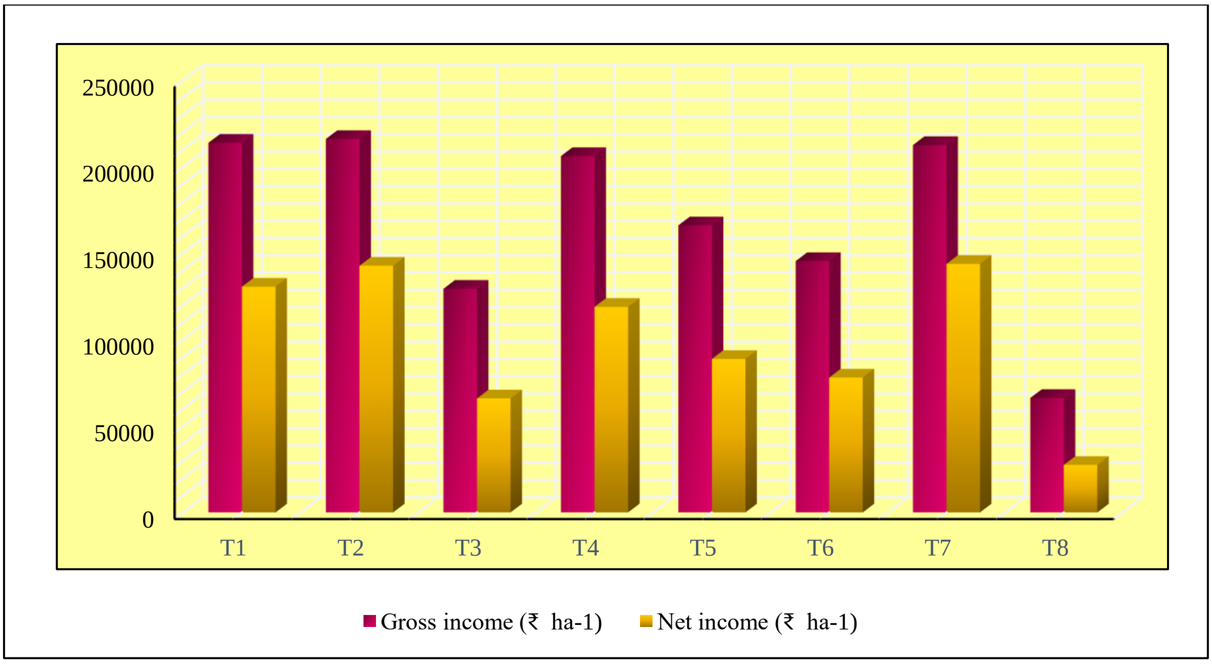


Fig. 21. Effect of POMF 2 application on gross income and net income of baby corn

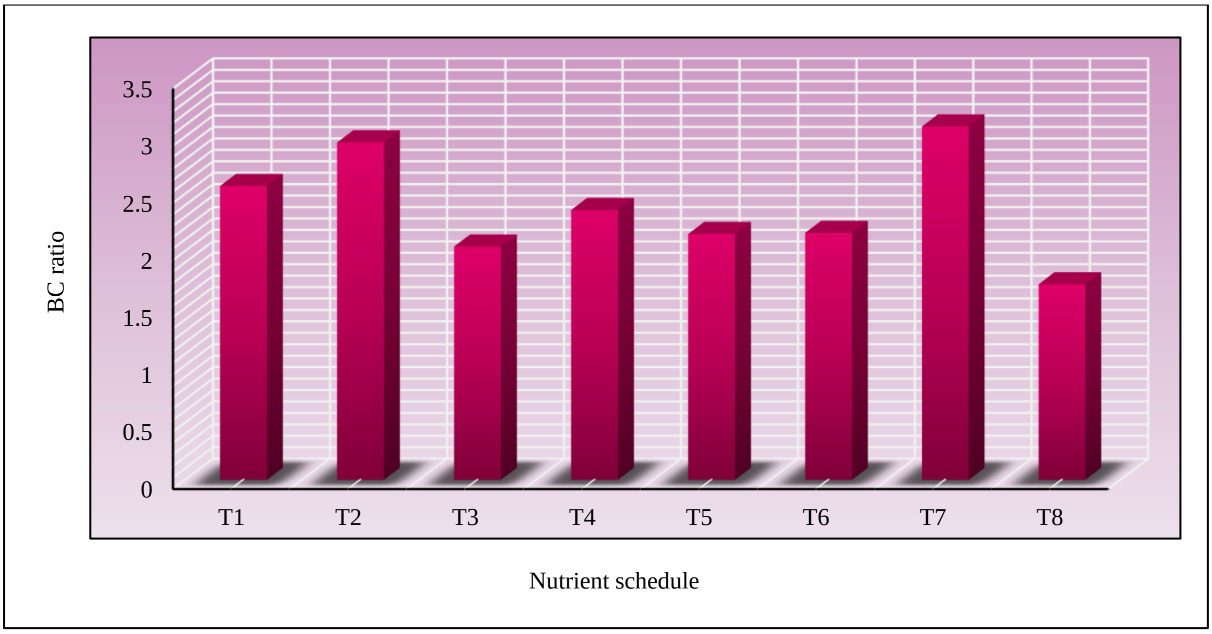


Fig. 22. Effect of POMF 2 application on BC ratio of baby corn

Summary

6. SUMMARY

The present study entitled “Development of pelleted organo-mineral fertilizer and its effect on baby corn (*Zea mays* L.) was undertaken at Department of Agronomy, College of Agriculture, Vellayani during 2020-2022. The objectives of the study were standardization of nutrient sources for production of pelleted organo-mineral fertilizer (POMF) and to evaluate its effect on growth and yield of baby corn. The study comprised of two experiments.

The Experiment I (a), was conducted at College of Agriculture, Vellayani during November 2021 to January 2022. Organo-mineral fertilizers (OMF) were prepared by mixing organic manures, chemical fertilizers, secondary and micronutrient mixtures, and bio-stimulants in varying ratios on percentage weight basis. The experiment was laid out in completely randomized design with nine treatments and three replications. After thorough mixing of the components, different combinations of organo-mineral fertilizer mixtures were pelletized to form Pelleted organo-mineral fertilizer (POMF) using a pelleting machine. The test crop selected for the study was baby corn with a nutrient recommendation of 135:65:45 kg NPK ha^{-1} (NPK ratio-3:1.4:1). The best six POMF combinations (POMF 1, POMF 2, POMF 4, POMF 5, POMF 6 and POMF 7) satisfying the nutrient ratios of baby corn were selected for further incubation studies.

The Experiment I (b), was conducted at College of Agriculture, Vellayani during January 2022 to March 2022. Incubation pot studies were carried out to assess the nutrient release pattern of selected POMF. The experiment was laid out in completely randomized design with six treatments and three replications. The selected POMF combinations were applied on N equivalent basis for supplying recommended dose of 135:65:45 kg NPK ha^{-1} for baby corn. Soil samples were collected at every 15 days interval upto two months and were analyzed for available nitrogen, phosphorus, and potassium. Separate pots for INM and control (No application) were also kept for comparison. Among the POMF treatments, POMF 2 recorded the highest available nitrogen 0.208 g kg $^{-1}$, 0.482 g kg $^{-1}$, 0.581 g kg^{-1}, 0.621 g kg $^{-1}$ at 15, 30, 45 and 60 days after incubation (DAI) respectively. At 15 DAI, POMF 6 (T_5)

recorded the highest (0.034 g kg $^{-1}$ soil) available soil P and was on par with T_2 and T_6. At 30 DAI, T_2 recorded the highest soil available phosphorus and at 45 DAI, T_6 recorded highest soil available phosphorus and was on par with T_4, T_1 and T_2. The soil available potassium was the highest in T_2 at 15, 30, 45 and 60 DAI. Thus, the results of incubation studies revealed that the nutrient release pattern of T_2 occurred in concurrence with the growth stages of baby corn and hence was screened for further characterization and field evaluation.

The Experiment I (c) was conducted at College of Agriculture, Vellayani during March 2022 to August 2022. The physico-chemical properties and shelf life of POMF 2 selected from incubation studies were characterized. POMF 2 was dark brown to black in colour without any foul odour. POMF 2 recorded a bulk density of 0.84 g cc^{-1}. The organic carbon and moisture content of POMF 2 were 0.42 and 10.56 per cent respectively. The pH of POMF 2 was 6.8 and EC was 18.6 dSm^{-1}. The initial nutrient content of POMF 2 was 8.18, 3.78 and 2.69 per cent N, P and K respectively. The calcium and magnesium content of POMF 2 were 6.50 and 2.82 per cent respectively. The POMF 2 had a Zn and B content of 1015.50 mg kg^{-1} and 0.007 mg kg^{-1} respectively. The storage study was conducted to assess the shelf life of POMF 2 and was it was found that the nutrient content of POMF 2 remained stable for four months after which it reduced to 7.92 and 7.54 per cent during fifth and sixth month of storage. The initial P (3.78 per cent) and K content (2.69 per cent) of POMF 2 were reduced to 3.58 per cent and 2.46 per cent respectively at six months after storage. POMF 2 retained its shape and no fungal growths were observed throughout the storage period.

The Experiment II was conducted at farmer’s field located at Kakkamoola, Thiruvananthapuram during March 2022 to May 2022 to determine the effect of POMF 2 on growth and yield of baby corn. The variety used was G-5414. The treatments were T_1: 100 per cent RD as POMF 2 (basal); T_2: 75 per cent RD as POMF 2 (basal); T_3: 50 per cent RD as POMF 2 (basal); T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS ; T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS; T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS; T_7: FYM @ 12.5 t ha^{-1} + 135:65:45

kg NPK ha^{-1} ½ N+ full P+½ K basal; ½ N +½ K at 25 DAS); T$_8$: Control (No fertilizers). POMF 2 was applied on nitrogen equivalent basis for supplying the recommended dose of 135:65:45 kg NPK ha^{-1} for baby corn.

The results revealed that POMF 2 had significant influence on growth attributes of baby corn. At 15 DAE, the plant height was significantly higher (54.43 cm) in T$_7$. Among the POMF treatments, T$_1$ recorded the highest plant height (46.97 cm) and was on par with T$_2$, T$_3$, T$_4$ and T$_5$. The treatment, T$_7$ recorded the highest plant height (117.40 cm) at 30 DAE, and was on par with T$_1$, T$_2$, T$_3$, T$_4$ and T$_5$. The treatment, T$_1$, recorded the highest plant height (171.03 cm) and was on par with T$_2$, T$_4$, and T$_7$ at 45 DAE. The treatments, T$_7$ and T$_1$ recorded the highest LAI at 15 DAE (0.37) and was on par with T$_2$ (0.36). At 30 DAE, application of 100 and 75 percent RD as POMF 2 recorded the highest leaf area index (2.14) which was on par with T$_4$ and T$_7$. At 45 DAE, T$_1$ and T$_4$ recorded the highest leaf area index (4.05) which was on par with T$_2$ and T$_7$. The treatment, T$_1$ recorded the highest dry matter production (22.02 t ha^{-1}) and was on par with T$_7$ (21.97 t ha^{-1}), T$_2$ (21.27 t ha^{-1}) and T$_4$ (21.24 t ha^{-1}).

Yield attributes viz., cob length, cob girth, cob weight with husk, cob yield with husk, marketable cob yield, cob-corn ratio and green stover yield were significantly influenced by POMF treatments. Basal application of 100 per cent RD as POMF 2 (T$_1$) recorded the highest cob length (11.70 cm), cob girth (5.33 cm), cob weight with husk (84.13g). T$_1$ recorded highest cob yield with husk (11.47 t ha^{-1} and was on par with T$_2$ (11.36 t ha^{-1}), T$_7$ (11.35 t ha^{-1}) and T$_4$ (10.72 t ha^{-1}). The highest marketable cob yield (5.40 t ha^{-1}) was observed when 75 per cent RD as POMF 2 was applied as basal (T$_2$) and was comparable with T$_1$ (5.34 t ha^{-1}), T$_7$ (5.31t ha^{-1}) and T$_4$ (5.15 t ha^{-1}). The treatment, T$_4$ was found to be the most efficient nutrient schedule for getting better cob-corn ratio (2.08). Basal application of 100 per cent RD as POMF 2 (T$_1$) recorded the highest green stover yield (29.32 t ha^{-1}) and was statistically on par with T$_7$ (29.11 t ha^{-1}), T$_4$ (28.41 t ha^{-1}), T$_2$ (27.80 t ha^{-1}) and T$_3$ (26.88 t ha^{-1}). The treatment, T$_1$ recorded the highest nutrient uptake (N, P and K) and was on par with T$_7$, T$_2$ and T$_4$ in case of nitrogen and in case of P and K, T$_2$, T$_5$ and T$_7$ were found on par with T$_1$.

Agronomic efficiency (AE) of N and K was significantly higher for T_2. AE for P was highest in T_6 (76.95 kg kg^{-1}) and was on par with T_2. The treatment, T_7 recorded the least AE for N, P and K. Physiological efficiency (PE) for N was the highest for T_2 and was on par with T_4 and T_7. PE for P was the highest in T_2 and was on par with T_1, T_4, T_5 and T_7. PE for K was the highest in T_2 and was on par with T_1, T_4 and T_7. Apparent recovery efficiency (ARE) of nitrogen was the highest in T_2 (1.38kg kg^{-1}) and was on par with T_1. ARE of phosphorus was the highest (0.46 kg kg^{-1}) in T_1 and was on par with T_2 (0.45 kg kg^{-1}). The treatment, T_1 recorded the highest ARE for potassium (4.72 kg kg^{-1}) and was on par with T_2 (4.44 kg kg^{-1}). Partial factor productivity (PFP) for N, P and K was the highest in T6 and was on par with T_2.

Soil available N, P and K was the highest for T_4. The treatment, T_4 was on par with T_1 and T_5 in case of soil available N and P, and for available potassium T_4 was on par with T_5, T_1 and T_2. The nutrient balance sheet of nitrogen showed that the highest actual gain of available nitrogen was in T_4 (52.41 kg ha^{-1}) followed by T_1 (43.45 kg ha^{-1}) while T_7 recorded a balance of only 2.41 kg N ha^{-1}. The highest actual gain of available phosphorus was in T_4 (34.65 kg ha^{-1}) while in T7, it was only 12.42 kg P ha^{-1}. The highest actual gain of available potassium was recorded in T_1 (93.04 kg ha^{-1}) while T_7 recorded only 38.9 kg K ha^{-1}.

The basal application of 75 per cent RD as POMF 2 (T_2) recorded the highest gross income (₹ 215991 ha^{-1}) and was on par with T_1 (₹ 213784 ha^{-1}) and T_7 (₹ 212486 ha^{-1}). The highest net income (₹ 143783 ha^{-1}) was recorded in T_7 and was on par with T_2 (₹ 142691 ha^{-1}). The highest BC ratio (3.09) was recorded in T_7 and was on par with T_2 (2.95).

Thus from the study, it could be concluded that good quality POMF suited for baby corn can be prepared by mixing cow dung powder (30%), neem cake (10%), groundnut cake (4%), rice husk ash (4%), urea (16%), rock phosphate (9%), single super phosphate (8%), muriate of potash (4%), ayar (1%), rock dust (4%), humic acid (5%) and seaweed powder (5%) on percentage weight basis followed by pelletization. Basal application of cow dung based POMF @ 1.25 t ha^{-1} (equivalent to 75% RD of

NPK of baby corn *ie*. 102:49:34 kg NPK ha^{-1}) could be recommended as the most productive, profitable and nutrient use efficient nutrient schedule for baby corn. Thus, twenty-five percentage reduction in recommended dose of NPK for baby corn can be achieved by using POMF rather than separate application of organic manures and chemical fertilizers. Hence, POMF can be popularized as a promising technology for enhancing nutrient use efficiency in field crops of Kerala.

FUTURE LINE OF WORK

1. Development and evaluation of customized pelleted organo-mineral fertilizers for major crops of Kerala.
2. Studies on long term effect of pelleted organo-mineral fertilizers on soil quality.
3. Development and evaluation of liquid formulation of organo-mineral fertilizers for foliar nutrition.

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DEVELOPMENT OF PELLETED ORGANO-MINERAL FERTILIZER AND ITS EFFECT ON BABY CORN (*Zea mays* L.)

by

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(2020-11-056)

ABSTRACT

Submitted in partial fulfilment of the
requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
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2023

ABSTRACT

The present study entitled “Development of pelleted organo-mineral fertilizer and its effect on baby corn (*Zea mays* L.) was undertaken at Department of Agronomy, College of Agriculture, Vellayani during 2020-2022. The main objectives of the study were standardization of nutrient sources for production of pelleted organo-mineral fertilizers (POMF) and evaluation of its effect on growth and yield of baby corn. The study comprised of two experiments.

The Experiment I (a), was conducted at College of Agriculture, Vellayani during November 2021 to January 2022. Organo-mineral fertilizers (OMF) were prepared by mixing organic manures, chemical fertilizers, secondary and micronutrient mixtures, and bio-stimulants in varying ratios on percentage weight basis. The experiment was laid out in completely randomized design with nine treatments and three replications. After thorough mixing of the components, OMF mixtures were pelletized to form POMF using a pelleting machine. The test crop selected for the study was baby corn with a nutrient recommendation of 135:65:45 kg NPK ha^{-1} (NPK ratio- 3:1.4:1). The best six POMF combinations (POMF 1, POMF 2, POMF 4, POMF 5, POMF 6 and POMF 7) satisfying the nutrient ratios of baby corn were selected for further incubation studies. The Experiment I (b), was conducted at College of Agriculture, Vellayani during January 2022 to March 2022. Incubation pot studies were carried out to assess the nutrient release pattern of selected POMF. The experiment was laid out in completely randomized design with six treatments replicated thrice. Among the different combinations of POMF studied, POMF 2 was found to release nutrients in concurrence with the growth stages of baby corn and hence was screened for further field studies. The Experiment I (c) was conducted at College of Agriculture, Vellayani during March 2022 to August 2022. The physico-chemical properties and shelf life of POMF 2 selected from incubation studies were characterized. The nutrient content of POMF 2 (8.18 % N, 3.78 % P and 2.69 % K) remained stable for 4 months and the pellets retained its shape and no fungal growths were observed during the storage period.

The Experiment II was conducted at farmers field located at Kakkamoola, Thiruvananthapuram during March 2022 to May 2022 to determine the effect of POMF 2 on growth and yield of baby corn. The variety used was G-5414. The treatments were T_1: 100 per cent RD as POMF 2 (basal); T_2: 75 per cent RD as POMF 2 (basal); T_3: 50 per cent RD as POMF 2 (basal); T_4: 50 per cent RD as POMF 2 (basal) + 50 per cent RD as POMF 2 at 25 DAS ; T_5: 50 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS; T_6: 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS; T_7: FYM @ 12.5 t ha^{-1}+135:65:45 kg NPK ha^{-1} ½ N+ full P+½ K basal; ½ N +½ K at 25 DAS) ; T_8: Control (No fertilizers). POMF 2 was applied on nitrogen equivalent basis for supplying the recommended dose of 135:65:45 kg NPK ha^{-1} for baby corn.

The results revealed that POMF 2 had significant influence on growth, yield and nutrient uptake of baby corn. At 15 DAE, the mineral fertilizer treatment, T_7 recorded significantly higher plant height, while at 30 DAE, basal application of even 50 per cent RD as POMF 2 (T_2) resulted in plant height comparable to T_7. At 45 DAE, application of 100 or 75 per cent RD as POMF 2 recorded the highest plant height and was comparable with the mineral fertilizer treatment (T_7). Basal application of 100 or 75 per cent RD as POMF 2 recorded leaf area index comparable with T_7 during 15, 30 and 45 DAE. The same trend was observed in dry matter production, cob length and girth also. The basal application of 75 per cent RD as POMF 2 (T_2) resulted in cob yields (5.39 t ha^{-1}) comparable to 100 per cent RD as mineral fertiliser, T_7 (5.31 t ha^{-1}). The same trend was observed in green stover yield and marketable cob yield also. The basal application of 75 per cent RD as POMF 2 (T_2) resulted in NPK uptake comparable with full dose of mineral fertiliser (T_7).

The soil organic carbon content, soil reaction (pH), electrical conductivity (EC), water holding capacity (WHC) and bulk density of the soil were not significantly influenced by the POMF treatments. The soil organic carbon and pH were found to increase in POMF applied plots compared to mineral fertilizer applied plots. When compared to plots that received mineral fertiliser, POMF treated plots had the highest soil NPK availability.

The agronomic efficiency (AE) of N, P and K were found to be higher in organo-mineral fertilizer treatments. Basal application of 75 per cent RD as POMF 2 (T_2), recorded the highest physiological efficiency (PE) of NPK and was comparable with the mineral fertilizer treatment (T_7). Application of 100 or 75 per cent RD as POMF 2 (basal) recorded comparable apparent recovery efficiency (ARE). However, the mineral fertilizer treatment, T_7 recorded the least ARE for all the three major nutrients. Application of 25 per cent RD as POMF 2 (basal) + 25 per cent RD as POMF 2 at 25 DAS (T_6) recorded the highest partial factor productivity (PFP) and was comparable with T_2. The POMF treated plots recorded the highest apparent gain and actual gain in soil available NPK compared to mineral fertilizer treated plots.

The treatment T_2, recorded the highest gross income (₹ 215991 ha^{-1}) and was on par with T_1 (₹ 213784 ha^{-1}) and T_7 (₹ 212486 ha^{-1}). Basal application of 75 per cent RD as POMF 2 (T_2) recorded the highest net income (₹ 142691 ha^{-1}) and was comparable with 100 per cent RD as mineral fertilizers (T_7) (₹ 143783 ha^{-1}). Among the POMF treatments, basal application of 75 per cent RD as POMF 2 (T_2) recorded the highest BC ratio (2.95) was on par with the mineral fertilizer treatment, T_7 (3.09).

Thus from the study, it could be concluded that good quality POMF suited for baby corn can be prepared by mixing cow dung powder (30%), neem cake (10%), groundnut cake (4%), rice husk ash (4%), urea (16%), rock phosphate (9%), single super phosphate (8%), muriate of potash (4%), ayar (1%), rock dust (4%), humic acid (5%) and seaweed powder (5%) on percentage weight basis followed by pelletization. Basal application of cow dung based POMF @ 1.25 t ha^{-1} (equivalent to 75% RD of NPK of baby corn *ie*. 102:49:34 kg NPK ha^{-1}) could be recommended as the most productive, profitable, and nutrient use efficient nutrient schedule for baby corn. Thus, twenty-five percentage reduction in recommended dose of NPK for baby corn can be achieved by using POMF rather than seperate application of organic manures and chemical fertilizers. Hence, POMF can be popularized as a promising technology for enhancing nutrient use efficiency in baby corn.

സംഗ്രഹം

വെള്ളായണി കാർഷിക കോളേജിലെ വിള പരിപാലന വിഭാഗത്തിൽ 2020 -2022 കാലഘട്ടത്തിൽ "ഓർഗാനോ-മിനറൽ പെല്ലറ്റ് വളങ്ങളുടെ നിർമ്മിതിയും ബേബി കോണിൽ അതിന്റെ സ്വാധീനവും" എന്ന വിഷയത്തെ ആസ്പദമാക്കി ഒരു പഠനം നടത്തുകയുണ്ടായി. പെല്ലറ്റ് വളങ്ങളുടെ നിർമാണത്തിന് ആവശ്യമായ പോഷക സ്രോതസുകളുടെ ക്രമീകരണവും അത് ബേബി കോണിന്റെ വളർച്ചയിലും ഉത്പാദനത്തിലും ഉളവാക്കുന്ന സ്വാധീനവും പഠിക്കുക എന്നതായിരുന്നു പ്രധാന ലക്ഷ്യം.

ജൈവവളങ്ങൾ, രാസവളങ്ങൾ, ഉപ മൂലകങ്ങൾ, സൂക്ഷ്മ മൂലകങ്ങൾ, ജൈവ-ഉത്തേജകങ്ങൾ എന്നിവ വ്യത്യസ് അനുപാതത്തിൽ കലർത്തി ഒൻപത് വിവിധ തരം ഓർഗാനോ-മിനറൽ വളക്കൂട്ടുകൾ ഉണ്ടാക്കി പെല്ലറ്റ് രൂപത്തിലാക്കി പോഷകമൂല്യ നിർണയം നടത്തി. ബേബി കോൺ വിളയുടെ പ്രധാന പോഷക മൂലകങ്ങളുടെ അനുപാതം അടിസ്ഥാനപ്പെടുത്തി ആറ് ഓർഗാനോ-മിനറൽ പെല്ലറ്റ് വളക്കൂട്ടുകൾ തിരഞ്ഞെടുക്കുകയും അവയെ ഇൻക്യൂബേഷൻ പഠനത്തിനു വിധേയമാക്കുകയും ചെയ്തു. 60 ദിവസം നടത്തിയ ഇൻക്യൂബേഷൻ പഠനത്തിലൂടെ ചാണക പൊടി ചേർത്തുള്ള ഓർഗാനോ-മിനറൽ പെല്ലറ്റ് വളം (ചാണകപ്പൊടി (30%), വേപ്പിൻപിണ്ണാക്ക് (10%), കടലപ്പിണ്ണാക്ക് (4%), ഉമി (4%), യൂറിയ (16%), റോക്ക് ഫോസ്ഫേറ്റ് (9%), സിംഗിൾ സൂപ്പർ ഫോസ്ഫേറ്റ് (8%), മ്യൂറിയേറ്റ് ഓഫ് പൊട്ടാഷ് (4%), ഉപ - സൂക്ഷ്മ മൂലക മിശ്രിതമായ അയർ (1%), പാറപ്പൊടി (4%),

ജൈവ ഉത്യേജകങ്ങളായ ഹ്യൂമിക് ആസിഡ് പൗഡർ (5%), സീവീഡ് പൗഡർ (5%) എന്നിവ തൂക്കത്തിന്റെ അടിസ്ഥാനത്തിൽ ചേർത്തുണ്ടാക്കിയ പെല്ലറ്റ് വളക്കൂട്ട് ബേബി കോണിന്റെ ഓരോ വളർച്ചാഘട്ടത്തിനനുസൃതമായി ആവശ്യമുള്ള തോതിൽ മാത്രം മൂലകങ്ങൾ പുറത്തു വിടുന്നതായ് കാണപെട്ടതിനാൽ ഈ വളക്കൂട്ടു ബേബി കോണിൽ തുടർ പരീക്ഷണങ്ങൾക്കായ് തിരഞ്ഞെടുത്തു.

ജി- 5414 എന്ന ഹൈബ്രിഡ് ഇനം ബേബി കോണാണ് പഠനത്തിനായി ഉപയോഗിച്ചത്. പരീക്ഷണത്തിനായി റാൻഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന പഠന രീതിയാണ് അവലംബിച്ചത്. എട്ട് തരത്തിലുള്ള പരിചരണ മുറകളാണ് ഈ പരീക്ഷണത്തിൽ നൽകിയത്. T_1-T_6 ട്രീട്മെന്റുകളിൽ ഓർഗാനോ-മിനറൽ പെല്ലറ്റ് വളമായാണ് പോഷകങ്ങൾ നൽകിയത്. T_1, T_2, T_3 ട്രീട്മെന്റുകളിൽ 100, 75, 50 ശതമാനം, ശുപാർശ ചെയ്തിട്ടുള്ള വളം ഓർഗാനോ-മിനറൽ പെല്ലറ്റ് രൂപത്തിൽ അടിവളമായും, T_4- 50 ശതമാനം അടിവളമായും 50 ശതമാനം നട്ട് 25 ദിവസത്തിനു ശേഷവും, T_5- 50 ശതമാനം അടിവളമായും 25 ശതമാനം നട്ട് 25 ദിവസത്തിനു ശേഷവും, T_6- 25 ശതമാനം അടിവളമായും 25 ശതമാനം നട്ട് 25 ദിവസത്തിനു ശേഷവും നൽകുകയുണ്ടായി. T_7 ൽ നിഷ്കർഷിച്ചിട്ടുള്ള പോഷകങ്ങൾ (ഹെക്ടറിന് 12.5 t കാലി വളവും, 135 കി ഗ്രാം പാക്യജനകം, 65 കി ഗ്രാം ഭാവഹം, ക്ഷാരം 45 കി ഗ്രാം എന്നിവ) രാസവള രൂപത്തിലും പ്രത്യേകം പ്രത്യേകമായ് നൽകി. T_8 ൽ യാതൊരു വിധ വളപ്രയോഗങ്ങളും നൽകിയില്ല.

ബേബി കോണിൽ 75 ശതമാനം ശുപാർശ ചെയ്ത വളം (102:49:34 kg NPK ha^{-1}) ഓർഗാനോ-മിനറൽ പെല്ലറ്റ് വള രൂപത്തിൽ അടിവളം ആയി നൽകുന്നത് (T$_2$) 100 ശതമാനം രാസവള പ്രയോഗം (T$_7$) വഴി ലഭിക്കുന്നതിന് തുല്യമായ കായിക വളർച്ചയും, വിളവും, ആദായവും നൽകുന്നതായി പഠനം തെളിയിച്ചു. രാസവള പ്രയോഗത്തെക്കാൾ ഓർഗാനോ-മിനറൽ പെല്ലറ്റ് വളങ്ങൾ ഉപയോഗിക്കുന്നത് വഴി മണ്ണിലെ കാർബണിന്റെ അളവും, പോഷക മൂലകങ്ങളുടെ ലഭ്യതയും, കാര്യക്ഷമതയും കൂടുന്നതായി പഠനത്തിൽ കണ്ടെത്തി. ബേബി കോണിന് ആവശ്യമായ പോഷകമൂലകങ്ങൾ ഹെക്ടറിന് 1.25 ടൺ ഓർഗാനോ-മിനറൽ പെല്ലറ്റ് വളക്കൂട്ടായി നൽകുന്നത് വഴി ബേബി കോൺ കൃഷി ലാഭകരവും ആദായകരവും ആക്കുവാൻ സാധിക്കുമെന്ന് ഈ പഠനത്തിൽ തെളിയിക്കാൻ കഴിഞ്ഞു.

Appendices

APPENDIX I

Weather data during the cropping period

(March 26 to May 27, 2022)

Standard week	Temperature (^{o}C)		Relative humidity (%)		Mean bright sunshine hours	Total rainfall (mm)	Evaporation (mm per day)
	Maximum	Minimum	RH I	RH II			
13	33.7	25.1	87.7	75.7	8.0	0.6	4.5
14	33.4	23.3	89.1	83.7	6.4	40.0	3.6
15	32.5	21.3	91.8	89.2	4.2	41.2	2.2
16	32.7	21.5	90.2	80.7	6.7	5.9	3.6
17	33.4	23.2	87.4	76.5	7.0	26.0	3.8
18	33.9	23.8	89.7	75.4	6.6	21.3	3.8
19	33.6	23.8	89.2	81.2	5.4	21.8	3.6
20	30.9	22.9	96.5	88.5	2.1	235.0	0.6
21	31.1	23.2	91.4	85.7	4.7	74.6	2.5

APPENDIX II

Average input cost and market price of produce

Sl. No	Items	Cost (₹)
I	**INPUT**	
A	Seed	
	Baby corn	776 per kg
B	Labour	
	Men	700 per day
	Women	500 per day
C	Manures, fertilizers and biostimulants	
	Cow dung powder	10 per kg
	Vermicompost	30 per kg
	Poultry manure	2 per kg
	Neem cake	35 per kg
	Ground nut cake	55 per kg
	Rice husk ash	3 per kg
	FYM	1 per kg
	Lime	16 per kg
	Urea	10 per kg
	Single super phosphate	30 per kg
	Rock phosphate	10 per kg
	Muriate of potash	30 per kg
	Rock dust	2 per kg
	Ayar	50 per kg
	Humic acid powder	50 per kg
	Sea weed powder	100 per kg
	PGPR mix I	80 per kg
II	**OUTPUT**	
	Market price of dehusked cob	40 per kg