EFFECT OF SPLIT APPLICATION OF NPK ALONG WITH BASAL DOSE OF Zn AND B ON SOIL PROPERTIES, YIELD AND QUALITY OF SAPOTA [*Manilkara achras* (Mill.) Forsbergin] IN LATERITIC SOILS OF KONKAN

THESIS

Submitted in partial fulfilment of the requirementsfor the Degree of

MASTER OF SCIENCE

IN

AGRICULTURE

(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

By

PAWAR SWATI VASUDEV

(ADPM/21/2830)

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURALCHEMISTRY

COLLEGE OF AGRICULTURE, DAPOLI

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NOVEMBER, 2023

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Under the Guidance of

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NOVEMBER, 2023

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled **"EFFECT OF SPLIT APPLICATION OF NPK ALONG WITH BASAL DOSE OF Zn AND B ON SOIL PROPERTIES, YIELD AND QUALITY OF SAPOTA [*Manilkara achras* (Mill.) Forsbergin] IN LATERITIC SOILS OF KONKAN"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged and that no part of the thesis has been submitted for any other degree or diploma.

Place: Dapoli
Date: 02/02/2024

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Date: 02/02/2024

CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF SPLIT APPLICATION OF NPK ALONG WITH BASAL DOSE OF Zn AND B ON SOIL PROPERTIES, YIELD AND QUALITY OF SAPOTA [*Manilkara achras* (Mill.) Forsbergin] IN LATERITIC SOILS OF KONKAN"** submitted for the degree of M.Sc. (Agri.) in Soil Science and Agril. Chemistry of the College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, is a bonafide research work carried out by **Miss Pawar Swati Vasudev (ADPM/21/2830)** under my supervision and that no part of this thesis has been submitted for any other degree. The student had completed all the Course and Research requirement as per the norms in regular.

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

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

This is to certify that the thesis entitled, **"Effect of split application of NPK along with basal dose of Zn and B on soil properties, yield and quality of sapota [*Manilkara achras* (Mill.) Forsbergin] in lateritic soils of Konkan"** submitted by **Miss Pawar Swati Vasudev (ADPM/21/2830)** to the College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, in partial fulfillment of the requirements for the degree of **M.Sc. (Soil Science and Agricultural Chemistry)** in the subject having Agronomy, Horticulture and Biochemistry as Minor subjects of Department of Agronomy, Department of Horticulture and Department of Soil Science and Agricultural Chemistry, has been approved by Student's Advisory Committee, Board of Studies of the Department and Evaluated by One External Examiner after an open Viva-Voce examination in the presence of External Examiner on the same held on dated 30 / 01 / 2024

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Acknowledgement

Emotions cannot be expressed in words; my acknowledgements are much more than what I am expressing here. Acknowledgement might be a rarely read page of a document, but at the completion of my research work and manuscript, it's time to recall path and process of work. However, it would not have been possible without the kind support and help of many gratitude towards all individuals who helped me directly and indirectly for completion manuscript. I would like to extend my sincere thanks to all of them and deep sense of research work and during the completion of this manuscript.

It has been great honour and privileged to undergo training at Dr Balasaheb Sawant Konkan Krishi Vidyapeeth Dapoli.

I take this privilege of offering my deep sense of gratitude and remain indebted to my research guide and Chairman of my advisory committee **Dr. N.H. Khobragade,** Assistant Professor, Department of Soil Science and Agricultural chemistry, College of Agriculture, Dapoli for his inspiring and scholastic guidance, timely suggestions, substantial criticism, sustained interest, constant and compassionate encouragement, ever writing help, parental affection throughout the course of this investigation and for the pains he has taken in preparation and finalising manuscript of the thesis inspite of heavy engagements. However, Sir has unchallenged mastery on the subject. I am indebted to him for his guidance, faith and confidence in me, for giving me a free hand to work and providing everything required during the course of work. **Thank You Sir!**

I am overwhelmed with sincere feelings of indebtedness to the Members of my Advisory Committee, **Dr. (Mrs.) Pooja S. Sawant**, Associate Professor (CAS), Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dapoli, **Dr. N.V. Dalvi,** Associate Professor, Department of Floriculture and Landscaping Architecture, College of Horticulture, Dapoli and **Dr. D.G. Jondhale**, Sr. Soil Scientist, Regional Agricultural Research Station, Karjat. Dist. Raigad. for their valuable guidance, constant encouragement and moral support during the course of my post-graduation studies.

I am grateful to Hon. Vice Chancellor **Dr. S.G. Bhave**, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, for his keen interest, devotion and constant efforts to do the best for the University. I also thanks to **Dr. P. S. Bodake**, Dean, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. I also place my cordial thanks to, **Dr. P. A. Sawant**, Associate Dean, College of Agriculture, Dapoli, and **Dr. U.V. Mahadkar**, Ex. Associate Dean, College of Agriculture, Dapoli. I gratefully acknowledge the co-operation and help extended by **Dr. S. B.**

Dodake, Head, Department of Soil Science and Agricultural Chemistry, Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli for the permission and all the necessary facilities in time, throughout the period of my post-graduation studies.

I am highly obliged to **Dr. R.V. Dhopavkar**, Deputy Director of Research (Agri.). Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli. I am extremely grateful to **Dr. V.G. Salvi,** Ex-Professor **Dr. M.C. Kasture,** Professor (I/C), **Dr. S.S. More,** Assistant Professor, here in golden words who worked in the same way and helped me forever. I acknowledge my sincere thanks to **Dr. N.A. Meshram,** Assistant Professor and **Dr. M.R. Wahane,** Jr. Soil Scientist, Khar Land Research station, Panvel for their constant encouragement, moral support and inspiration.

I am indebted to **S.N.Patil sir** supervisor of Nursery No.10 Department of Horticulture, college of agriculture Dapoli and all the loving labours without whose help my research would be impossible.

I am thankful to all non-teaching staff members **Bhosale madam, Dosani sir, Govale sir, Nikita Mam, Shubham sir, Suraj sir** and Mahadik Kaka, **Prakash Dada, Satish Dada, Pawar Kaka, Shamika Didi, Jaibhay kaka** Chavan kaki, **Bhuvad kaki** for their timely help and co-operation.

No research is possible without the library, the center of learning resources. I take this time to express my gratitude to all the library staff for their services. I would also like to acknowledge all the teachers I learnt from since my childhood, I would not have been here without their guidance, blessing and support. I thank the Almighty for giving me the strength and patience to work through all these years so that today I can stand proud with my head held high.

I bow my back and place my head to the feet of my visible god, my parents **Shri. Vasudev Pawar and Mrs. Chandrakala Pawar** without them I'm nothing but zero and with their blessings, my journey of life reached to this stage and I also show my affection for my brother **Girish Pawar**, who loves and cares about me. My **grandfather** and **grandmother** as well as maushi **Rekha** and mama **Sudam** have patiently supported me during my work. I am thankful to all my relatives for their encouragement and kindly blessing could conclude this research work.

I owe thanks from the depth of my heart to my batchmates **Anjali, Gouri, Akshay, Jyoti C, Jyoti Chavan, Nutan, Bhavesh.**

I avail this opportunity to express my thanks to my Ph.D. seniors **Akash sir, Shivani mam, Sagar sir, Sarika mam, Atul sir, Avadhut sir, Bhakti mam, Kishor sir, Deepali mam,** and my seniors **Pranita Didi, Dipika Didi, Sayeda Didi, Rohit sir, Aniruddha sir, Devesh sir, Krishna sir** and also juniors **Shubham, Saurabh, Shraddha, Sanika, Chetana, Kavita**

and Pragati for their excellent company, inspiration, moral support, boost up and healthy friendship and special thanks to all my seniors and my pg. friends **Komal, Pooja, Prarthana, Purva** always being there and bearing with me the good and bad times during wonderful days of M.Sc.

I wish to express heartfelt thanks to my lifetime friend **Tejashree Nate** for their love, constant encouragement, inspiration and moral support and healthy friendship. My completion of this research work could not have been accomplished without the support of my constant friends **Asmita Kamble** and **Neha Rokade**. Special thanks must be recorded to my close friends **Anuja, Nikita, Trupti** and **Neha Shivlkar** for their love, constant encouragement and help.

I am also thankful to Pleasure Scooty MH 08 Y 7670 who made journey in college campus very easily for time to time throughout the research programme at any moment and at anywhere without any problem.

This is obviously incomplete, but let me submit that the omission is inadvertent and once again, I would like to thank each and every person who helped me directly or indirectly to turn this dream come true.

Lastly, I may thankful to Mangesh Bandre (Google Computers) for excellent page set up and final finishing to my manuscript.

Place: Dapoli

Date: 02 /02/2024

(Swati Chandrakala Vasudev Pawar)

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Abbreviations

Symbols	Abbreviations
%	Per cent
@	At the rate
mg	Milligram
S.Ed	standard error of mean deviation
cv.	Cultivar
et al.	Co-workers (and other)
g	Gram
i.e.,	That is
Cm	Centimeters(s)
CD(P=0.05)	Critical Difference at 5 per cent level
dS m^{-1}	Deci-Siemen per meter
EC	Electrical conductivity
CEC	Cation exchange capacity
Fig.	Figures(s)
g kg^{-1}	gram per kilogram
viz.,	Namely
K_2O	Potassium oxide
kg ha^{-1}	kilogram per hectare
mg kg^{-1}	Milligram per kg
MOP	Muriate of Potash
NS	Non-significant
P_2O_5	Phosphorous pentoxide
t ha^{-1}	Tonne per hectare
RBD	Randomized Block Design
TSS	Total Soluble Solids
^0B	Degree Brix
Zn	Zinc
B	Boron
N	Nitrogen
P	Phosphorous
K	Potassium
Fe	Ferrous
Al	Aluminium
Ca	Calcium
Mg	Magnesium
FYM	Farm Yard Manure
RDF	Recommended dose of fertilizers
NO_3	Nitrate
NH_4	Ammonia
H_20_2	Hydrogen peroxide
MT	Metric tones
Anon.	Anonymous
L.	Linnaeus
M.S.	Maharashtra
N	North

Glossary

Decomposition: Is the process by which dead organic substances are broken down into simpler organic or inorganic matter.

Electrical conductivity: Is a measure of the amount of salts in soil which is expressed in milli Siemens or Deci Siemens per metre.

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

Lateritic soils : A soil layer rich in iron oxide, derived from various rocks that weather under intense oxidizing and leaching conditions.

Mineralization: The process whereby organic forms of nitrogen in the soil are converted to available forms of nitrogen.

Synergistic effect: Refers to the effects produced by the interaction that is greater than the sum of individual effects.

Introduction

CHAPTER I

INTRODUCTION

1.1 Background Information

Sapota, *Manilkara zapota* or *Achras sapota*, is a native of Mexico belongs to family Sapotaceae. The sapota trees yield fruit twice a year, though flowering may continue year-round. It is an open pollinated crop; a great deal of variability was thrown up in the population. Its fruits are round or oval, brown in outer appearance and very sweet in taste with almost no evident acidity. It is evergreen, tropical fruit tree spreading habit and lives longer up to 100 years.

Sapota is a tropical fruit and needs warm, humid climate for growth and development and the coastal climate is considered much suitable for Sapota cultivation. Being a hardy crop, it can be grown under wide range of soil and climatic conditions (Dutton 1976). It grows well up to an altitude of 1000 m. Sapota has become one of the important fruits in southern and western parts of country due to its wide range of adaptability, low production costs and reasonably high economic returns with very low pest and diseases susceptibility (Singh 1991).

Sapota is mainly cultivated in India for its fruit value, while in South-east Mexico, Guatemala and other countries, it is commercially grown for the production of Chickle which is a gum like substance obtained from latex and is mainly used for preparation of chewing gum. Besides, it also provides health benefits for the body such as a source of energy since it is rich in glucose and calories, it boosts immunity, skin and hair benefits, cancer benefits, promote gut health, good for bones etc.

Compound extracted from the leaves showed anti-diabetic, antioxidant and hypocholesterolemic (cholesterol-lowering) properties. Acetone extracts of the seeds exhibited in vitro antibacterial effects against strains of *Pseudomonas oleovorans* and *Vibrio cholerae*. Acetone extracts of *Manilkara zapota* and *Tamarindus indica* and methanolic extract of *Tamarindus indica* were found to have significant antibacterial in comparison to standard drug *i.e.*, streptomycin and ofloxacin (Kothari *et al.* 2010).

It is not exactly known when it was introduced to India, but its cultivation was taken up for the first time in Maharashtra in 1898 in a village, Gholwad of Thane district (Cheema *et al*.1954). In India, there was production of 935.2 thousand MT of sapota from an area of 78.3 thousand ha and the productivity of 11.9 MT/ha (Anonymous 2023). The major sapota growing states are Maharashtra, Gujarat, Tamil Nadu, Andra Pradesh, Karnataka, West Bengal, Uttar Pradesh, Punjab and Haryana. In Maharashtra it was grown under 12.80-thousand-hectare area with the production of sapota is 107.26 thousand MT with a productivity of 8.38 MT/ha (Anonymous 2023).

The leading variety of sapota in Maharashtra is ‘Kalipatti’ and it is high yielding and good quality variety, egg or oval shaped fruits having sweet mellow flesh of excellent quality and contains less seeds *i.e*., 1-4 seeds per fruits with dark green broad and thick leaves.

1.2 Importance and Need of the Study

In Indian fruit orchards, poor soil health and imbalanced nutrient application are major causes of low orchard efficiency resulting in poor productivity (Hebbar *et al*. 2006; Savita *et al.* 2013; Somasundaram *et al.* 2011). Further, imbalanced use of nutrients or excessive use of N fertilizers leads to poor quality of fruits (Ganeshamurthy *et al.* 2011). High rates of N can be utilized by plant only in the presence of required K levels. Similarly, potassium (K) is the most abundant nutrient in the fruit of sapota and it influenced the size, firmness, skin color, TSS and acidity (Brunetto *et al.* 2015). Therefore, the nutrient application has its own effect on both the nutrient status as well as on production (Bhargava 1999). Phosphorus deficiencies severe enough to produce visual symptoms are rare in fruit trees (Crassweller and Greene 1995).

Fertilizers are one of the major input’s accountings for nearly one third of the total cost of cultivation. To optimize the fertilizer efficiency, the approach of split application of fertilizer plays a very important role in a nutrient management strategy. Basal application of fertilizers leads to period of over-supply, more leaching losses and also period of under-supply. It may not be able to maintain optimum soil nutrient status at all the critical growth stages of crop. So, it is paramount important to determine the number of splits for fertilizer application in sapota.

In fruit crops, it is known that applications of NPK fertilizers are vital for fruit yield and quality. Besides, NPK plays an important role in the growth and development of the plant and requirement is high. Micronutrients can tremendously boost horticultural crop yield and improve quality and post-harvest life of horticultural produce (Raja 2009). Though extensive information is available on nutrient requirement in sapota, very little work has been done on split application of fertilizers as well as effect of Zn and B application in this crop. This necessitates research on application of nutrients at various stages of crop growth to derive maximum benefit from a given quantity of the nutrient. With this background, the present study was undertaken to standardize stage wise nutrient requirement in sapota under Konkan conditions to achieve improved yield and quality in lateritic soils of Konkan.

Sapota crop is highly responsive to fertilizers (Durrani *et al*. 1982). Nevertheless, proper nutrition of sapota orchards is very essential and crucial in order to boost up the growth and productivity of plants, but limited work has been done on this aspect.

1.3 Objectives of the study

Considering the above facts, the present investigation was proposed with the following objectives**:**

1) To study the effect of split application of NPK along with basal dose of Zn and B on properties of soil

2) To study the effect of split application of NPK along with basal dose of Zn and B on yield and quality of sapota

3) To study the effect of split application of NPK along with basal dose of Zn and B on leaf nutrients content of sapota

1.4 Hypothesis

Sapota has the problem of low fruit setting and shedding of fruits. Only about 10-12 per cent of the total fruits set, and retains until maturity. Most of the fruit drop occurs immediately after fruit set. Increase in fruit set and retention are possible by applying boron (B) that promotes the formation of chlorophyll pigments, acts as an oxygen carrier and reactions involving cell division and growth. Zinc (Zn) aids in regulating plant growth hormones and enzyme system, necessary for chlorophyll production, carbohydrate and starch formation (Thirupathaiah Guvvali *et al*. 2017).

Besides soil analysis, leaf sample analysis is considered a more direct method of plant nutritional status evaluation, especially for fruit crops as these differ from seasonal crops in nutrient requirement due to their size, population density, rate of growth and rooting pattern (Motsara and Roy 2008).

The lateritic soils are extensively distributed in the Ratnagiri and Sindhudurg districts of the South Konkan. These soils are deficient in available phosphorus, low to medium in available nitrogen (Dongale 1989 and Khadtar 1989) and low to medium in available potassium. Further, the soil is deficient in Zn and B.

Under Konkan conditions, soil nutrients are lost rapidly due to various factors such as leaching, high precipitation etc. Therefore, it is important to apply nutrients at the critical stages of crop growth in small doses, at shorter intervals to minimize loss of nutrients and cost of production. The study on leaching loss of nitrogen in lateritic soils from the applied fertilizers revealed the higher loss of native as well as applied nitrogen (Anonymous 1990). Boron content in lateritic soils varied from 0.03 to 0.29 ppm with mean value of 0.154 ppm. The bench terraced lateritic soils are reported to be deficient in available boron (Patil *et al*. 1986). Boron exists in soil in the form of highly insoluble mineral tourmaline as well as organic and inorganic forms. In fact, both boron and zinc are thought to be found deficient in soils of Konkan region. In Maharashtra, boron and zinc showed their deficiencies to the extent of 38.2% and 31.7% of analysed soil sample, respectively. Regional variation in the content of DTPA extractable zinc in soil was observed. The DTPA extractable zinc ranged from 0.13 to 3.66 mg kg^{-1} in soils of Konkan. 61% of the analysed soil samples from Konkan region were deficient in boron (Malewar *et al*. 2001).

1.5 Scope and Limitations of the study

In India, sapota is mainly cultivated for its fruit value and it is commercially grown for the production of chickle, a gum like substance obtained from latex used for preparation of chewing gum. It is regarded as a natural energy booster as it contains fructose and sucrose. (Baskar *et al.*2020). Moreover, due to its numerous beneficial characteristics, it has played a significant part in traditional Indian medicine.

Use of various organic manures and fertilizers is a good practice to obtain higher yield with good quality fruits. Micronutrients are also required by plants to perform specific biochemical reactions, metabolism required for its growth and productivity. In order to avoid yield and quality loss, nutrient requirements of sapota crop need to be carefully monitored through soil and plant analysis for evolving nutrient management strategies.

The nutritional requirements of perennial fruit crops are different from those of annual crops. For perennials fruit crops nutrients are supplied taking account of current fruiting and vegetative growth but also for food reserves. The adjustment should be made for the dose of the nutrients as per recommendation based on soil and plant tissue tests.

Time of fertilizer application ensure to make nutrients available when the plants need them. It depends upon the fertilizer physical form, solubility and mobility. In deficient soil, nutrients are applied when the available nutrients are synchronized with the demand of crop. The right time to fertilize should be close to the time of nutrient uptake by the crop. Fertilizer application in split doses during the growing season allows to growers to adjust the application of fertilizer for the physiological changes in the different growth stages of the plant.

Split fertilizer applications are vital for the restocking of nutrients that are removed from the soil pool because of the fruit harvest, tree growth, maintenance and leaching.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

In fruit crops, it is evident that applications of NPK fertilizers are vital for fruit yield and quality. To optimize the fertilizer use, the approach of split application of fertilizer plays a very important role in a nutrient management strategy as the single application of fertilizer leads to period of over-supply, more leaching losses and also period of under-supply. The present investigation on application of nutrients at various stages of crop growth to derive maximum benefit from a given quantity of the nutrients.

Sapota has the problem of low fruit setting and shedding of fruits. Only about 10-12 per cent of the total fruits set, and retains until maturity. Most of the fruit drop occurs immediately after fruit set. Increase in fruit set and retention are possible by applying boron (B) that promotes the formation of chlorophyll pigments, acts as an oxygen carrier and reactions involving cell division and growth; while zinc (Zn) aids in regulating plant growth hormones and enzyme system, necessary for chlorophyll production, carbohydrate and starch formation (Thirupathaiah Guvvali *et al*. 2017).

An attempt has been made here to review the research work carried out on the effect of split application of NPK as well as application of Zn and B either alone or in combinations on soil properties, yield and quality of sapota and other fruit crops under the following heads**:**

2.1 **:** Effect of split application of fertilizers on soil properties
2.2 **:** Effect of split application of fertilizers on yield of fruit
2.3 **:** Effect of split application of fertilizers on quality of fruit
2.4 **:** Effect of split application of fertilizers on leaf nutrients content of fruit crop

2.1 Effect of split application of fertilizers on soil properties

Addition of 680g K/tree/year increased the available soil potassium concentration (Bopaiah *et al.*1982).

In Coorg mandarin, Murthy *et al.* (1983) reported that the application of potassium at higher levels (332g/tree) increased exchangeable potassium in soil.

In two meadow experiments the relationship between the balance of available N, available P, and available K in the system fertilizer-plant and the content of available N, available P and available K in the soil was studied by Gorlach and Curylo (1988). It was found that the investigated only the phosphorus balance may constitute a basis for determination of the dose of phosphorus fertilizer with the possibility of regulating the soil supply of available phosphorus forms.

Gawande *et al.* (1998) studied the effect of NPK fertilizers, Organic Manures and Earthworms on Yield and Quality of Sapota (*Manilkara achras* Mill.) cv. Kalipatti and found that, micronutrient availability due to combined use of inorganic fertilizers and organic manure or organic manures alone was improved as compared to availability of micronutrients in soil after harvest of fruits due to application of inorganic fertilizer alone.

Hebbarai *et al*. (2006) conducted an experiment during 1998-2001 at Agricultural Research Station, Gangavati, Karnataka to study the effect of vermicompost application with varied levels of recommended dose of fertilizer on yield and quality of 'Kalipatti' sapota [*Manilkara zapota* (L.) P. Royan] and soil properties. The treatments were combinations of vermicompost @ 2.5 t/ha and 5 levels of recommended dose of fertilizer, *i.e.,* 100, 75, 50, 25 and 0% of recommended dose of fertilizer and found that soil organic carbon increased but bulk density decreased due to vermicompost application.

Stage wise requirement of N, P and K on growth, yield and quality of acid lime (*Citrus aurantifolia* Swingle.) cv. ‘PKM -1’were studied by Raja (2008) at Chitra Farm, Kullapuram during 2006-2008. The treatments comprised of three levels of recommended dose of NPK fertilizers *viz.,* 100, 80, and 60 per cent. The 100 per cent recommended dose of fertilizers in five split doses during Mar (30:40:10 per cent) + May (30:35:10 per cent) + July (20:25:30 per cent per cent) + Sept (10:0:25 per cent) + Nov (10:0:25 per cent). The results revealed that the treatment L_1T_2 *i.e.,* 100 per cent recommended dose of fertilizers exhibited superior performance over other treatments in respect of the soil chemical properties *viz.,* available NPK in the soil.

Khushboo (2011) studied the pre-bearing response of Kinnow to differential doses and application timings of fertilizers” were carried out at Punjab Agricultural University, Ludhiana during the year 2010. There were three sets of fertilizer treatments; the first set (T_1) consisted of the standard practice of applying N in two split doses (mid-February and mid-April). In the second set, there were differential fertilizer treatments (T_2 to T_7) which were given in four split doses (mid-February, mid-April, mid-June and mid-August) and in the third set (T_8 to T_{13}) there were six split doses (mid-February, mid-March, mid-April, mid-May, mid-June and mid-July). Application of fertilizer treatments in 4 splits was found to be better than 2 or 6 split doses. The treatment T_7 ($N_{125}P_{50}K_{125}$ in 4 splits) was found to be the best than all the other treatments and it was closely followed by T_6 ($N_{125}P_{50}K_{100}$ in 4 splits) for soil nutrition status.

Paradkar (2012) conducted an experiment on effect of different levels of nitrogen and potassium on yield and quality of sapota and proposed that in soil maximum macro and micro nutrient status, *i.e.*, available NPK, DTPA extractable zinc and boron were found with the application of 2250:750 N kg/plant.

An experiment was conducted by Shinde *et al.* (2018) to Study the effect of different doses and sources of potassium on yield and quality of Alphonso mango at Central Experiment Station, Wakawali during 2003 to 2007. Soil application of different doses of potassium (MOP and SOP *i.e.*, 0.5 kg K_2O tree^{-1}) along with recommended N, P were applied in the month of June. The foliar application of 1%KNO_3 and + 0.9% and 1.8% K_2SO_4 was given at peanut, marble and egg stage of fruits. The four years pooled results revealed that there was a significant difference in potassium content in soil due to potassium treatment at both the stages. Exchangeable calcium content did not vary significantly, but magnesium content and available sulphur varied significantly during post-harvest stage due to potassium treatment.

Yield and quality of sapota as well as nutrient content in soil and plant leaf as influenced by crop growth stage wise application of N, P, K fertilizers were studied by Anusha *et al.* (2022) during 2018-2019 at Department of Fruit Science, Kittur Rani Channnamma College of Horticulture, Arabhavi in sapota var. Kallipatti orchard and found that before harvest the maximum available of nitrogen (266.34 g and 264.54 g) and phosphorous (19.95 g and 19.67 g) was recorded with the application of fertilizers at the rate of NPK 20-80-20, 20-0-20, 20-0-20, 20-0-20 and 20-40-20, 20-0-20, 20-40-20, 20-0-20 and potassium (326.36 g and 322.75 g) was recorded with 20-80- 20, 20-0-20, 20-0-20, 20-0-20 and 20- 40- 20, 20- 0-20, 20-40-20, 20-0-20. After harvest maximum available of nitrogen (269.00 and 267.59 kg/ha) was recorded with 50-100-50, 25-0-25, 25-0-25, 0-0-0 and 20- 40- 20, 20- 0-20, 20-40-20, 20-0-20, phosphorous (20.45) with 20-80-20, 20-0-20, 20-0-20, 20-0-20, potassium (327.49 g and 323.12 g) was recorded with 20-80- 20, 20-0-20, 20-0-20, 20-0-20 and 20- 40- 20, 20- 0-20, 20-40-20, 20-0-20 at the vegetative flush (July), fruit set (September), fruit pea stage (November) and fruit growth (February) stages.

Gabhale (2022) studied on the stage wise requirement of nutrients in sapota variety Kalipatti at NARP Farm, Agriculture Research Station, Palghar during 2017-18 to 2021-22, Different doses of NPK were applied at vegetative flush (in June), fruit setting stage (in September), fruit pea stage (in November) and fruit growth stage (in February). The results revealed that the organic carbon, available nitrogen, available phosphorus and available potassium were increased and higher values were found in the treatment T_2 *i.e.,* application of NPK fertilizers 20-40-32, 20-0-16, 20-40-16 and 20-0-16 at vegetative flush (in June), fruit setting stage (in September), fruit pea stage (in November) and fruit growth stage (in February), respectively.

2.1 Effect of split application of fertilizers on yield of fruit

An experiment was carried out by Aziz *et al*. (1975) to study the effect of two nitrogen levels, 250 and 500 g of actual nitrogen per avocado tree per year. The nitrogen sources were calcium nitrate (as soil application) and urea (as foliage application). Nitrogen fertilization gave a highly significant increase in tree yield (kg/tree) in most treatments. Moreover, urea sprays seemed to be more effective on the yield than calcium nitrate added to the soil at the same nitrogen level. The 500 g nitrogen level of both sources gave a higher yield increase than 250 g nitrogen. Nitrogen fertilization gave a slight increase in mean avocado fruit weight and size, while urea sprays seemed to be more effective in increasing the mean fruit weight and size. A slight decrease in flesh oil content occurred as a result of nitrogen fertilization.

In a field trial at CENIAP, Venezuela, an orchard of *Manilkara achras* was given various combinations of 0, 40 or 80 kg N, 0 or 40 kg P_2O_5 and 0, 40 or 80 kg K_2O/ha. The highest yield in 1977 of 716 fruits/plant and 49.18 kg/plant was given by 40 kg each of N and P_2O_5 and 80 kg K_2O compared with 410 fruits/plant and 37.11 kg/plant with no fertilizer. In 1978 the highest yield was 495 fruits/plant with 80 kg N and 40 kg each of P_2O_5 and K_2O/ha and 45.98 kg/plant with no fertilizer (Laborem *et al*. 1981).

In the study on effect of N fertilization *i.e.*, 100, 200, 300 and 400 kg/ha per year on the growth of trees, yield, fruit quality and fruit life of Satsuma mandarin cultivar Fujinaka was examined for 9 years since 1969 by Hirobe *et al*. (1981) and found that since the 7th year of the experiments differences in the yield were seen among N levels with the order of getting more fruits; 200 = 300 > 400 > 100 kg. Mean fruit weight was large and the rate of large fruit was high with large amounts of N. A rate of 260 kg/ha per year of N is a suitable fertilization level.

Syamal *et al*. (1989) carried out an experiment to evaluate effect of NPK singly as well as in combination on mango var. Langra through soil at the rate of 0.5 kg and 1 kg N, 1 kg and 2 kg P_2O_5; 0.5 kg and 1 kg K_2O and in combination with 0.5 kg N + 1 kg P_2O_5 + 0.5 kg K_2O ($N_1P_1K_1$) and 1 kg N + 2 kg P_2O_5 + 1 kg K_2O ($N_2P_2K_2$) and the treatment combination of $N_2P_2K_2$ proved most effective and significant for producing the longest terminal shoots and maximum number of leaves per shoot as well as maximum number of flowers and fruits retained per panicle. Fruit quality was also improved the treatment-combination of $N_2P_2K_2$.

Singh and Singh (2000) discovered that the application of 1200 g N, 200 g P, and 200 g K/tree yielded the highest number of fruits per tree (203.08) in comparison to other treatments. They applied three levels of N and two levels of P & K fertilizer to the sapota.

Sheikh and Rao (2001) carried out an experiment on effect of split application of N and K on growth and yield of pomegranate and reported that the four-split application of fertilizer dose of 400:200:200g NPK at an interval of one month (P applied in one dose) per plant has resulted in highest yield (76.04 kg/plant) with maximum average fruit weight, higher juice percentage, higher total soluble solids, sugar and ascorbic acid as compared to lower number of splits or one dose application.

Hebbarai *et al.* (2006) studied the effect of vermicompost application @ 2.5 t/ha and 5 t/ha with varied levels of recommended dose of fertilizer *i.e.*, 100, 75, 50, 25 and 0% of RDF on yield and quality of 'Kalipatti' sapota and revealed that highest fruit yield was recorded under 100% recommended dose of fertilizer + vermicompost application (18.4 kg fruit/plant) that however remained on at par with 75% recommended dose of fertilizer + vermicompost and 100% recommended dose of fertilizer alone. Reduction in recommended dose of fertilizer beyond 75% resulted in significantly lower yields. Application of vermicompost alone, however, resulted in significantly lower yield (46.7% reduction over recommended dose of fertilizer + vermicompost application). Reduction in recommended dose of fertilizer levels resulted in lesser number of fruits (309, 294, 240 and 203 fruits / plant with 100, 75, 50 and 25% recommended dose of fertilizer application respectively). The fruit weight significantly reduced when the crop was fertilized alone (100 % recommended dose of fertilizer).

Effect of boron (B) fertilization as foliar or soil application by Wojcik *et al*. (2008) showed that boron fertilization, regardless of application mode, increased fruit yield; the efficiency of foliar B sprays was higher than soil B application. Apple fruits of trees fertilized with B to the soil were bigger, more coloured, richer in B, and had higher soluble solids concentration, and titratable acidity compared to those of the control trees.

Shiyamala (2008) carried out an experiment standardization of stage wise nutrient requirement in sapota (*Manilkara achras* (mill.) fosberg) 'pkm 1'and revealed that the treatment T_2 comprising 100 per cent recommended dose of fertilizers applied in three splits in the ratio of 50:100:40 (June) + 25:0:30 (August) + 25:0:30 (October) exhibited superior performance over rest of the treatments in respect of yield per tree and other yield attributing components *viz*., fruit weight, fruit set percentage and number of fruits per tree.

Dhillon *et al*. (2011) investigated the effect of fertilization on pomegranate with four levels of N (0, 20, 40 and 60 g/tree/year), three levels of P_2O_5 (0, 20, 40 g/tree/year) and four levels of K_2O (0, 20, 40 and 60 g/tree/year). They showed that nitrogen increased the growth of plant in terms of higher girth, height, spread and volume of tree as compared to rest of the treatments. The number of fruits per plant, largely contributing to the yield, increased linearly with the increase in nitrogen up to maximum level. Similarly, all the P and K treatments also recorded higher yield as compared to yield that was obtained when respective elements were omitted, though the increase was not linear. The fruit size increased under all N, P and K treatments. However, the trees receiving no K produced the lowest fruit size.

Paradkar (2012) executed an experiment on effect of different levels of nitrogen and potassium on yield and quality of sapota and stated that the yield attributing characters *viz.*, maximum flowers per shoot, fruit set with higher fruit retention were found with application of 2250:750 N K g/plant. Similarly, the maximum fruit yield in terms of number of harvested fruits per plant, fruit yield (kg/plant) were also recorded with application of 2250:750 N K g/plant.

Devashi (2012) examined the development, yield, and fruit quality of sapota trees as influenced by organic and inorganic nitrogen applied in the forms of urea and castor cake. The vegetative growth of the trees was significantly influenced when nitrogen applied in the form of urea. With the application of 900 g N/tree in the form of urea, the optimum tree height (7.26 m), tree spread (8.11 m in N-S and 8.13 m in E-W directions), fruit weight (63.65 g), fruit number (2627.56), and fruit yield per tree (163.30 kg) were observed. The fruit's total sugar and reducing sugar content was highest in the 900 g N/tree treatment, where 25% of the N came from urea.

Response of custard apple cv. Arka Sahan plants submitted to integrated nutrient management was carried out by Bhatnagar *et al.* (2014) at Fruit Research Farm, Department of Fruit science' College of Horticulture and Forestry, Jhalawar during the year 2010-11. The studies clearly revealed that To treatment (Vermicompost in combination with 50 % RDF and biofertilizers) attained significantly higher plant height, rootstock girth, scion girth, plant spread (E-w and N-s), leaf area and soil NPK content over other treatments including control. To treatment has resulted significantly better impact with respect to higher vegetative growth parameters over other treatments including control. The application of vermicompost along with 50 % N through RDF and biofertilizers provided better nutrition as it contains all the macro and micro nutrients required for growth and development of plants. it also improved physico-chemical properties of soil of the treated plants by reducing pH and EC, improving water holding capacity and enriching the organic carbon, N, P, K status of the soil over other treatments.

Yadav *et al.* (2014) reported that the maximum fruit set per cent (67.43) and fruit drop per cent (58.71) were recorded maximum with foliar application of zinc sulphate + borax 0.6% and zinc sulphate + copper sulphate + borax 0.5%. Therefore, zinc sulphate + borax 0.6 per cent and zinc sulphate + copper sulphate + borax 0.5% may be recommended to guava growers for obtaining better yield and quality during winter season crop of guava cv. Allahabad Safeda under Lucknow conditions.

Imran Arshad (2015) studied the effect of different rates of NPK fertilizers on growth and yield of sapota during the year 2012-13 at a private farmhouse located at south-east of Gharo, Sindh-Pakistan. The fruit yield per plant (kg/plant) was found maximum in those plants which were fertilized with 1200g:750g:300g NPK/plant. For the same treatment number of fruit, length of fruit, breadth of fruit, volume of fruit, weight of fruit, pulp weight, peel weight, and yield per plant was recorded maximum. Same treatment also showed the superior fruit quality traits evaluated in terms of maximum total soluble solids and total sugar was with minimum acidity. However, control plants showed unsatisfactory results regarding all the parameters. Amongst the various NPK treatments T_7 *i.e.*,1200g:750g:300g NPK/plant was observed to be more suitable and economical dose therefore, application of fertilizers beyond this level will be an uneconomical and wasteful practice.

The study of Brar *et al.* (2015) showed that the number of fruits, yield, fruit size and weight of rainy season crop of guava cv. L-49 was significantly improved with split application of inorganic fertilizers. Application of 50 per cent higher fertilizers in three splits than control exhibited increment of 43.2, 34.0, 38.5 and 41.3 per cent in yield and 23.6, 27.5, 38.7 and 40 per cent in fruit weight during rainy season crop (2010 to 2013). In winter season, the consequent increase in yield was only 11.3, 6.4 and 20.7 per cent with the same dose and splits of fertilizers than control in 2010, 2012 and 2013, respectively. In winter season, the split application had no significant effect on fruit weight except during first year of application.

In order to assess the impact of the quantity of soil application of zinc, boron, and iron on growth and yield in papaya, Preethi *et al.* (2017) conducted experiment at Haveli, College of Horticulture, Bagalkot, during 2016–2017 comprising treatments T_1-3g Zinc, T_2- 5g Zinc, T_3-10g Zinc, T_4- 15g Zinc, T_5-2g Boron, T_6 -5g Boron, T_7-8g Boron, T_8-3g Iron, T_9-5g Iron, T_{10}-10g Iron, T_{11}-15g Iron, T_{12}- 10g Zn + 5g B + 10g Fe, T_{13}-Ranadey Mixture (20g), and T_{14}-control (RDF only), where growth and yield of papaya cv Red Lady found to be improved by the micronutrient application of 10g Zn + 5g B + 10g Fe.

Khan *et al*. (2018) carried out an experiment to evaluate the impact of NPK application of different RDF levels on growth and yield of guava cv. Hisar Safeda. The treatment combinations consist of five levels of RDF *i.e.*, RDF (60%), RDF (80%), RDF (100%), RDF (120%) and RDF (140%) during 2015-16 and 2016-17. Among the different treatments RDF (120%) was optimum for plant height, plant girth and canopy spread (E-W) and (N-S). Similarly, in terms of fruit set (58.46%), fruit retention (68.51%), number of fruits, fruit weight (104.47 g) and fruit yield (55.79 kg/tree) were best with RDF 120%.

Thorat *et al*. (2018) carried out an experiment to evaluate the influence of soil and foliar application of zinc on growth and yield parameters of sweet orange (*Citrus sinensis* L. Osbeck)

Cv. Nucellar at Sweet Orange Research station, Badnapur, Dist. Jalna during 2017–18. According to the observations, the application of zinc to both the soil and the foliar surface caused considerable variations in the growth and output of sweet orange. The parameters measuring vegetative development, such as stem girth, plant spread, and number of branches per tree, did not significantly change in response to treatments, nor did plant height, canopy volume, or the number of flowers per branch the fruit drop demonstrated a notable impact of the treatments. The height of the tree and canopy volume as well as weight of one fruit, weight of five fruits, and number of fruits per tree showed that soil application of $ZnSO_4$@150g + Foliar spray of $ZnSO_4$@ 0.50% was most successful which was followed by treatments soil application of $ZnSO_4$@100g+ Foliar spray of $ZnSO_4$ @ 0.75%), soil application of $ZnSO_4$ @150g+ Foliar spray of $ZnSO_4$@ 0.75%.Kumar *et al.* (2018) conducted an experiment on response of three different levels of nitrogen (0, 75 and 150g/plant/year), phosphorus (0, 50 and 100g P_2O_5/plant/year) and potassium (0, 75 and 150g K_2O/plant/year) on fruiting, yield and fruit quality were studied in guava cv. Pant Prabhat. The results indicated that treatments with higher nitrogen level attained maximum yield and fruiting compared to treatments with lower nitrogen levels, in combination with phosphorus and potassium. Maximum yield of 69.64, 60.72 kg/plant and 22.66, 26.35 kg/plant, and, fruit set of 73.23%, 75.07%, 34.73% and 35.65% were recorded with 150g N, 50g P_2O_5 and 75g K_2O/plant/year.

Gupta *et al*. (2019) carried out study on effect of integrated nutrient management on growth and yield of guava (*Psidium guajava* L.) cv. Allahabad Safeda under high density planting at Department of Horticulture, Allahabad School of Agriculture, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad during 2016-17 and 2017-18. The experiment consisted of ten treatments *viz.*, (T_0) 100% RDF (NPK-180,90,90g), (T_1) 75% RDF+2.5 kg vermicompost, (T_2) 50% RDF+2.5 kg vermicompost, (T_3) 75% RDF+10 kg FYM, (T_4) 50% RDF+10 kg FYM, (T_5) T_3 + Micronutrients (Zn+B+Mn (0.5,0.2,0.1%), (T_6) T_4 + Micronutrients (Zn+B+Mn (0.5,0.2,0.1%), (T_7) 50% RDF+10 kg FYM+Azotobactor, (T_8) 50% RDF+10 kg FYM+ Azotobactor+ PSB (100g/P), (T_9) 50% RDF+10 kg FYM+ VAM, (T_{10}) 50% RDF+10 kg FYM + Azotobactor + VAM. The results revealed that the application of 75% RDF+10 kg FYM + Micronutrients (Zn+B+Mn (0.5,0.2,0.1%), (T_5) significantly influence the growth and yield of guava. Maximum plant height (256.80 cm), more number of branch (20.56), maximum number of leaves (150.16), maximum plant girth (2.58), higher number of flowers (79.33), more number of fruits (38.23), fruit diameter (6.51 cm), fruit length (6.05 cm) at harvest, fruit volume (121.75 mL), average fruit weight (152.84 g) and number of fruits per plant (5829.59 g) were obtained with treatment T_5. The combined application of 75% recommended dose of NPK with FYM (10 kg) and micronutrient gave significantly higher fruit yield per hectare (99.56q/ha).

In lateritic soils of Konkan, Jain *et al*. (2020a) conducted experiment at farm of Horticulture, College of Horticulture, Dapoli to study the effect of fertilizer levels on yield of sapota and nutrient status. The application of 6 kg each NPK+400 kg FYM tree ha^{-1} $year^{-1}$ in three splits *i.e.*, 1/3 in June, 1/3 in September and 1/3 in January resulted in significantly in highest yield per hectare (4.09 t) with maximum net return and B/C ratio.

The research trial was conducted during the year 2018-19 at Sapota block of Department of Horticulture, College of Agriculture, Dapoli, Maharashtra to study effect of graded doses of fertilizers on flowering and yield attributes of sapota cv. Kalipatti. The fertilizer treatments consisting T_1 (1.5 kg Each NPK + 100kg FYM $tree^{-1}$ $year^{-1}$ in June), T_2 (3 Kg each NPK +200Kg FYM $tree^{-1}$ $year^{-1}$ in June – Recommended dose), T_3 (4.5 kg each NPK+ 300 kg FYM $tree^{-1}year^{-1}$ in two splits *ie.*, ½ in June and ½ in September) and T_4 (6 kg each NPK + 400 kg FYM $tree^{-1}$ $year^{-1}$ in three splits *i.e.*, ⅓ in June, ⅓ in September and ⅓ in January. The significantly maximum number of flowers per shoot (12.52), number of fruit set (3.52), fruit set (29.69%), number of retained fruits (1.76), fruit retention (47.28%) and minimum period for fruit development (214.96 days) as well as maximum number of fruits per tree (429.46), fruit yield per tree (63.85 kg) and yield per hectare (4.09 t) were observed with application of 6 kg each NPK + 400 kg FYM $tree^{-1}$ $year^{-1}$ in three splits *i.e.*, ⅓ in June, ⅓ in September and ⅓ in January (T_4). While, the application of treatment T_1 *i.e.*, 1.5 kg Each NPK + 100 kg FYM $tree^{-1}$ $year^{-1}$ in June recorded significantly minimum number of fruits per tree (268.30), fruit yield per tree (29.63 kg) and yield per hectare (1.89 t) (Jain *et al*. 2020b).

Anusha *et al*. (2022) conducted a field trial at Department of Fruit Science, Kittur Rani Channnamna College of Horticulture, Arabhavi on standardization of stage wise application of N, P and K on yield and yield attributing characters of sapota var. Kallipatti. Application of 20-80-20, 20-0-20, 20-0-20, 20-0-20, at vegetative flush (July), fruit set (September), fruit pea stage (November) and fruit growth (February) stages, respectively, recorded the maximum number of flowers per shoots (11.38), per cent of fruit set (18.56%), per cent of fruits reached to final harvest (83.78%) and the highest number of fruits per shoot, maximum fruit weight (90.25g), fruit length, fruit girth and fruit volume, seed parameters in respect of number of seeds per fruit, seed weight, shelf life and the highest yield per tree.

Thejaswini *et al*. (2022) carried out an experiment to study the split application of NPK fertilizers and liquid bio-formulations (*Jeevamrutha*) on yield and quality of pomegranate (*Punica granatum* L.) in central dry zone of Karnataka. Among the fruit and yield parameters, fruit length, fruit diameter, fruit volume, number of fruits per plant, average fruit weight and fruit yield were found maximum in 100% RDF through split application along with *Jeevamrutha* (T_7). Therefore, application of 100% RDF as split along with *Jeevamrutha* at different stages *i.e.*, 160:80:80 N: P_2O_5:K_2O g per plant from defoliation to flowering stage, 100:60:40 N: P_2O_5:K_2O g per plant at fruit development stage proved to be promising for fetching higher yield in pomegranate *cv.*Bhagwa.

Three-year study of Fatima *et al*. (2022) from 2017-19 on evaluation of foliar and soil application of boron (boric acid @ 60g plant□¹ for soil and 0.08% foliar spray) at three growth stages (Bud initiation, fruit setting, and fruit maturity) of Sindhri cultivar of mango in Research Farm of Mango Research Institute, Multan, Pakistan revealed that the soil application of boron was found better as compared to foliar spray on most of growth, yield and fruit quality parameters. The application of boron at fruit setting stage improved fruit setting, fruit retention, yield, total soluble solids and acidity as compared to boron application on budding and fruit maturity stage. No. of fruit set per panicle (45), fruit retention (0.68 %) and yield (113 kg/plant) with the soil application of boron before fruit setting stage during 2019. However highest yield (127 kg/plant) was obtained during 2020. Therefore, soil application of boron on fruit setting stage is recommended on basis of the finding of this study for better yield and fruit quality in Sindhri cultivar of mango.

Priya *et al.* (2022) conducted an experiment to study the effect of nitrogen, phosphorus and potassium fertilization on yield and quality of custard apple Cv. Balanagar. The experiment consisted of 5 treatments comprising T_1 (control), T_2-75% RDF (188:94:94 g/plant), T_3-100% RDF (250: 125:125 g plant^{-1}), T_4-125% RDF (313:157:157 g/plant) and T_5-150% RDF (388:187:187 g plant^{-1}) and outcomes discovered that the increasing levels of N, P and K (388:187:187 g plant^{-1}) (T_5) significantly increased yield and quality of custard apple. However, maximum average fruit weight (184.93 g), fruit volume (196.73 g), number of fruits per plant (84.55) and fruit yield (6.45 t ha^{-1}) were observed in 150% RDF (388:187:187 g/plant) (T_5) as compare to control (T_1)

2.3 Effect of split application of fertilizers on quality of fruit

Boora and Singh (2000) concluded that application higher nitrogen levels to sapota cv. "Cricket Ball" resulted with a significant increase in ascorbic acid and reducing sugars over the controls.

Sheikh and Rao (2001) carried out an experiment to study the effect of split application of N and K on growth and yield of pomegranate. The result revealed that the four-split application of fertilizer dose of 400:200:200g NPK (P applied in one dose) recorded the higher juice percentage, higher total soluble solids, sugar and ascorbic acid as compared to lower number of splits or one dose application.

In an investigation on response of various combinations of NPK on fruiting, yield and fruit quality were studied by Kumar *et al.* (2008) in guava cv. Pant Prabhat and revealed that treatments having higher nitrogen content in combination with higher potassium attained higher ascorbic acid content and sugar content in the fruit. The maximum values of total sugars 8.73% and 9.03% in rainy season and 10.87% and 11.12% in winter season were recorded with the application 75g N, 50g P_2O_5 and 150 g K_2O during both the years.

According to research by Patel and Naik (2010), 5 kg of vermicompost with 400, 60, and 300 g of NPK per tree performed all other treatments with regard of TSS, acidity, reducing sugar, non-reducing sugar, and fruit shelf life.

Gosh *et al.* (2012) investigated the effects of different potassium and nitrogen levels on quality of sapota. They found that increased levels of nitrogen and potassium application in sapota cv. "Cricket Ball," various quality parameters including as pulp percentage, TSS, total sugar, and vitamin C content were improved.

Sarker And Rahim (2012) carried out an experiment at the Germplasm Centre of Bangladesh Agricultural University, Mymensingh during the fruiting season of 2005-06 to investigate the effects of fertilizer and its instalment of application on harvesting time, yield and quality of fruits of 8 years old mango plant cv. Amrapali. Four fertilizer doses *i.e.*, $T_{1:}$ 50% of the fertilizer dose, T_2: 100% of the fertilizer dose, T_3: 150% of the fertilizer dose, and T_4: control (no fertilizer) and three splits of application *i.e.*, A_1: One installment (whole fertilizer applied on 15 September), A_2: Two installments (15 September and 15 March) and A_3: Three installments (15 September, 15 March and 15 May) were included as treatments. They stated that plants receiving 150% of the recommended fertilizer dose in three installments caused delayed harvest by 11 days compared to control. However, the same treatment improved the fruit quality with regard to TSS, pH, titratable acidity, vitamin C, moisture content, dry matter content, reducing sugar, non-reducing sugar and total sugar content over the control.

2.4 Effect of split application of fertilizers on leaf nutrients content of fruit crop

Bafna *et al.* (1983) observed that N and P content in leaves of sapota were found increased with fertilizer application as compared to unfertilized plot.

Paradkar (2012) carried out an experiment on effect of different levels of nitrogen and potassium on yield and quality of sapota and suggested that leaf macro and micro nutrient composition *i.e.*, total nitrogen, phosphorous, potassium, zinc, and boron was found with the application of 2250:750 N kg/plant.

Savita *et al*. (2013) conducted an experiment on soil and plant nutritional status of sapota (*Manilkara achras* M. Fosberg) in order to identify the nutrients that are deficient/low and to formulate optimum nutrient range by surveying 106 sapota orchards, since collection of leaf and soil samples in sapota growing districts of Raichur, Dharwad and Belgaum districts/northern Karnataka and found that the optimum leaf N ranged from 1.51 to 2.09%, P from 0.06 to 0.15% and K from 0.83 to 1.44%. The optimum concentration ranged from 1.36 to 2.34% for Ca, 0.54 to 0.68% for Mg and 0.48 to 0.80% for S. Among the micronutrients, optimum Fe, Mn, Zn, Cu and B concentrations ranged from 109 to 206, 49 to 99, 13.3 to 21.9, 3.76 to 9.10 and 34.8 to 66.8 mg kg^{-1}, respectively for sapota (cv. Kalipatti). The optimum ranges developed served as a guide for routine diagnostic and advisory purpose of nutrient status of the orchards of Northern Karnataka.

Kothur *et al.* (2013) carried out an experiment on 8-year-old 'Allahabad Safeda' guava (*Psidium guajava* L.), where an increase in N level (0-80g/tree/year) significantly increased the N and K, but decreased the P and Cu contents of leaf. Calcium content of leaf increased up to 500 g N, but decreased at higher levels of N. The increase in P level (0-349 g) significantly increased the N, P and K in leaf. Calcium and Mg in leaf increased up to 131 g P, whereas higher P application decreased it. Iron content continuously decreased with increase in P application up to 262 g P/tree. Maximum Mn content was observed at 175 kg P/plant. Similarly, increase in K application (0-482 g) increased the N, P and K contents of leaf. A quadratic relationship was observed between fruit yield and nutrient applied as well as its content in leaf. Accordingly, the maximum fruit yield was obtained at 583 g N/plant 271 g P/plant and 399 g K/plant and at 1.89% N, 0.16% P and 2.34% K in the leaf. The range of nutrients associated with maximum fruit yield was 1.8-2.0% N, 0.12-0.16% P, 1.46-2.08% K, 1.13-1.69 % Ca, 0.25-0.31 % Mg, 266-345 g/g Fe, 176-267 mg/g Zn and 10-13 mg/g Cu in the leaf.

Sharma *et al.* (2013) conducted an experiment to find out the effect of organic and inorganic sources of fertilizers on yield, quality and nutrient status of winter season guava. The two years pooled data revealed that highest soil nitrogen and phosphorous (269.97 and 19.77 kg/ha), Ca and Mg (7.03 and 2.76 meq/ 100 g soil), leaf nitrogen & phosphorous (1.76 and 0.26%) and leaf Ca and Mg (2.01 and 0.86%) contents, respectively, were obtained with the treatment comprising Azotobacter + 25% of N $tree^{-1}$ through FYM + 75% of N $tree^{-1}$ through inorganic fertilizer, whereas, the highest soil potassium (148.23 kg ha^{-1}) and leaf potassium (1.25%) contents was obtained with the application of Azotobacter + 50% of N $tree^{-1}$ through FYM + 50% of N $tree^{-1}$ through inorganic fertilizer. The pooled analysis of two year data also indicates that 25% of N $tree^{-1}$ through FYM + 75% of N $tree^{-1}$ through inorganic fertilizer showed highest fruit yield (41.14 kg $plant^{-1}$) maximum fruit length (8.39 cm), breadth (7.94 cm), weight (244.24 g) and pectin (0.81%), while, Azotobacter + 50% of N $tree^{-1}$ through FYM +

50% of N $tree^{-1}$ through inorganic fertilizer showed highest TSS (12.950 Brix), total sugars (8.61%) and minimum physiological loss in weight (14.29%) after ten days under ambient conditions.

Response of soil and foliar application of silicon sources like potassium silicate and calcium silicate and Solubor as boron source and kiecite -G as micronutrient source was studied by Lalithya *et al*. (2014) and observed that 145.33 kg/ha, 9.68 kg/ha and 105.63 kg/ha of available nitrogen, phosphorous and potassium content were observed respectively in the treatment with application of potassium silicate at 8 mL per litre as foliar spray where as more nutrient contents were observed in the soils of control plots at the time of fruit harvest. This indicates that at the time of fruit harvest minimum nutrients were available in the soil and maximum uptake of nutrients were observed in the silicon treated plot resulted in maximum production and quality of fruits.

Khan *et al.* (2017) carried out an experiment on effect of different combination of nitrogen and organic manure on leaf nutrient content of Japanese pear (*Pyrus pyrifolia*) Cv. Punjab Beauty. There were 15 treatments comprised of five nitrogen levels (0, 200, 400, 600 and 800 g per plant) and three farmyard manure (30, 60 and 90 kg/plant). The nitrogen leaf content of pear increased with increasing doses of nitrogen however phosphorus and potassium leaf content decreased. The nitrogen, phosphorus, and potassium nutrient content in leaves increased with increasing doses of FYM and they were revealed maximum nitrogen 2.41%, phosphorus 0.20% and potassium 1.37% with application of 90 kg of manure/plant. The interaction between nitrogen and FYM is positive impact on leaves nutrient content. Further, analysis revealed that leaf nitrogen content influenced the fruit yield and fruit weight significantly. It is concluded from this study that 600 g nitrogen along with 90 kg FYM was optimum doses for Japanese pear for better leaves nutrient status of pear fruit crop.

Fatima *et al*. (2022) conducted an experiment to find out the influence of NPK fertilizer rates on vegetative growth, fruiting measurements and leaf nutrient content as well as fruit characteristics of some plum cultivars (Hollywood, Golden Japanese and Dorado) budded on Mariana rootstock, the trees were 20 years old, grown at El-Kanater Horticultural Research Station during 2011 and 2012 successive season. Obtained data displayed exhibited a positive effect and a significant increase in all investigated vegetative growth measurements *i.e*., (shoot length and number of leaves per shoot). Moreover, fruiting parameters (fruit set % and tree yield either kg/tree or number of fruits/tree and yield as tons/fed.) were significantly increased with increasing the level of (NPK) soil applied. Furthermore, the second level of soil application rates gave highest yield. Furthermore, Golden Japanese cv. gave the highest yield followed by Dorado and Hollywood. Furthermore, fruit quality including fruit physical properties *i.e*., fruit weight, volume, length and diameter were significantly improved as a result of the highest soil application rates of (NPK), the second level gave the best result of dimension of fruits. Whatever, the highest soil application rates of (NPK) gave the best weight and volume of fruit as well as TSS %. Fruit chemical characteristics *i.e.*, TSS/acidity ratio and total sugar content were significantly improved as a result of the lowest soil application rates of (NPK) compared to the highest level. Furthermore, fruit and leaf nutrient composition of some macro elements (N, P and K) and some micro nutrients (Fe, Mn, Zn and Cu) were improved by the different treatments under study from the standpoint of statistic during both 2011 and 2012 seasons. In general, it could be concluded that most of studied treatments of (NPK) soil application resulted in a positive and a significant influence on most investigated measurements and characteristics of some plum cultivars (Hollywood, Golden Japanese and Dorado). Since, the second level (1.5, 1.5, 0.75 kg/tree) from (NPK) was the most effective treatment for increasing growth measurements, fruiting parameters and improving both leaf nutritional status and the most of physical and chemical fruit properties of some plum cultivar’s trees grown under Qalyoubia Governorate condition.

Material and Methods

CHAPTER III

MATERIAL AND METHODS

The present investigation pertaining to the studies on the "Effect of split application of NPK along with basal dose of Zn and B on soil properties, yield and quality of sapota [*Manilkara achras* (Mill.) Forsbergin] in lateritic soils of Konkan" was conducted during *Rabi*, 2022-23 under thirty-three year old sapota plantation at Nursery No.10, Department of Horticulture, College of Agriculture, Dapoli. The analytical work was done in the research laboratory of Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dapoli. The details regarding material used and methods followed during the present investigation are presented in this chapter.

3.1 Material

3.1.1 Experimental site

The experimental trial was conducted under thirty-three year old sapota plantation of variety Kalipatti planted with spacing of 12.5m x 12.5m at Nursery No.10, Department of Horticulture, College of Agriculture Dapoli, during June 2022 to May 2023.

3.1.2 Topography and Soil

The topography of sapota plantation can be described as a plain is a broad area of relatively flatland that is a region in which the land is predominantly flat. In general, there is an even terrain. According to the Agro-climatic zone of Maharashtra, the soil comes under high rainfall with lateritic soil type. The soil under the sapota plantation, is classified as "Gimhavane Series", which is a member of fine, mixed, Isohyperthermic family of Fluventic Ustropepts (Bhattacharjee *et al*. 1978). The representative soil sample was collected at vegetative stage of sapota before application of fertilizers in the month of June 2022 for knowing the initial fertility status of the soil. The soil after necessary laboratory processing such as dried in shade processed for analysis assessing for different physico-chemical properties (Table 1).

The initial properties of experimental soil presented in (Table 1) and revealed that the soil was strongly acidic having normal electrical conductivity, high in organic carbon, available potassium and moderate in available nitrogen and very low in available phosphorus and high in.

Table 1. Physico-chemical properties of initial soil sample of the experimental field

i)	pH (1: 2.5)	5.12
ii)	Electrical conductivity (dS m^{-1})	0.20
iii)	Organic carbon (g kg^{-1})	33.41
iv)	Available N (kg ha^{-1})	295.52
v)	Available P_2O_5 (kg ha^{-1})	5.86
vi)	Available K_2O (kg ha^{-1})	592.64
vii)	Available Zn (mg kg^{-1})	1.13
viii)	Available B (mg kg^{-1})	0.22

3.1.3 Climate

Dapoli is situated in the tropical region and lies between 17^{o} $45^{'}$ N latitude and 73^{o} 11’ E longitude. The town is located at altitude of 800 ft. (240m) and 8 km from Arabian sea having hot and humid climate with well-expressed three seasons *viz.,* Summer (March to May), Rainy (June to October) and Winter (November to February). The region receives very high rainfall (above 3000 mm, annually). The weather parameters recorded at the Meteorological Observatory of Department of Agronomy, College of Agriculture, Dapoli during the experimental period are presented in Appendix I.

3.1.4 Selection of Sapota trees for investigation

Total fourty uniform sapota trees of variety Kalipatti were selected from the thirty-three year old sapota orchard at Nursery No.10, Department of Horticulture, College of Agriculture Dapoli. For every five treatments, two trees were chosen with four replications.

Kalipatti, the variety of sapota is high yielding and good quality variety, egg shaped fruits *i.e.,* fruits are in oval shaped and contains less seeds. *i.e.,* 1-4 seeds per fruits. The variety has dark green broad and thick leaves. Fruits having sweet mellow flesh of excellent quality. Fragrance is mild, and main harvesting in winter. Generally flowering seasons in the month of October– November and February – March. Fruiting during February to May; having average fruit weight 144.5 g. TSS-23.1^{0}Brix and Acidity-0.16%.

3.1.5 Vermicompost

In the present investigation, vermicompost @50 kg per tree was applied in all treatments (treatments T_2, T_3, T_4 and T_5) except T_1 *i.e.,* absolute control. Well decomposed vermicompost was procured from Department of Animal Husbandry and Dairy Science, College of Agriculture, Dapoli

3.1.6 Fertilizers

The fertilizers used in the present investigation and their nutrient content are given the in Table 2.

3.1.7 Application of vermicompost

Vermicompost @50 kg per tree was applied by ring method 150 cm away from the main trunk covering the periphery of the plants in the treatments T_2, T_3, T_4 and T_5 in the month of June 2022.

Table 2. Nutrient content (%) of manure and fertilizers used in the study (oven dry basis)

Sr. No.	Source	Nutrient Content (%)				
		N	P_2O_5	K_2O	B	Zn
A)	Manure					
1.	Vermicompost	1.35	0.47	0.66	-	-
B)	Fertilizers					
1.	Urea	45.68	-	-	-	-
2.	Single Super Phosphate	-	15.86	-	-	-
3.	Muriate of Potash	-	-	59.82	-	-
4.	Borax	-	-	-	10.55	-
5.	Zinc sulphate	-	-	-	-	20.64

3.1.8 Experimental details

3.1.8.1 Layout of the experiment

The field experiment was laid in Randomized Block Design (RBD) with five treatments and four replications. Two trees were selected for each treatment (Fig.1).

3.1.8.2. Details of treatment

Table 3. The details of the treatments

Treatment	Treatment details
T_1	Absolute control (No fertilizer)
T_2	3 kg NPK each tree^{-1} in two equal splits in June and September and Vermicompost @ 50 kg tree^{-1} in June
T_3	3 kg NPK each tree^{-1} in two equal splits in June and September and 50 g $ZnSO_4$ + 25 g Borax tree^{-1} in June and Vermicompost @ 50 kg tree^{-1} in June
T_4	3 kg NPK each tree^{-1} in three equal splits in June, September and January and Vermicompost @ 50 kg tree^{-1} in June
T_5	3 kg NPK each tree^{-1} in three equal splits in June, September and January and 50 g $ZnSO_4$ + 25 g Borax tree^{-1} in June and Vermicompost @ 50 kg tree^{-1} in June

3.1.8.3 Time of fertilizer application

Nitrogen, phosphorus and potassium @ 3:3:3 kg each per tree were applied in two equal splits in the month of June 2022 and September 2022 in the treatments T_2 and T_3; while 3 kg NPK each tree^{-1} were applied in three equal splits in the month of June 2022, September 2022 and January 2023 in the treatments T_4 and T_5. Nitrogen, phosphorus and potassium were applied through urea, single super phosphate and muriate of potash, respectively.

The soil application of boron through borax @ 25g tree $^{-1}$ and zinc through zinc sulphate @ 50g was done in the pertinent treatments (T_3 and T_5) in the month of June 2022.

The split doses of fertilizers according to treatment were mixed and applied in a ring which covered an area of 150 cm away from main trunk and covering the periphery of the plants. Soil was dug to a depth of approximately 25cm and fertilizers were properly mixed in the soil.

3.1.8.4 Intercultural operations

The sapota orchard was kept weed free with the help of power tiller and tractor mounted implements from time to time.

3.1.8.5 Harvesting

The fruits were harvested at full maturity stage, when developed a dull potato colour. The skin of mature fruit turns light yellow colored tinge. In general, a mature fruit is dull brown in colour and the colour immediately below the skin when scratched is of lighter shade, while in the immature fruits it is green. As the fruit matures, the milky latex content reduced. The mature fruits were harvested with the help of Atul Sapota Harvester. The final yield per tree (kg) was obtained by sum of all the pickings.

3.1.9 Leaf Sampling

Five branches were selected randomly from each experimental tree and marked by tagging paper strips. 10 to 15 number of healthy and physiologically mature leaves were collected by plucking 10^{th} number of leaf from selected branches around the tree from the middle of the whorl and composite sample was made at each stage (Table 4).

3.1.10 Soil Sampling

The soil samples were collected at various stages *viz*., at vegetative stage, at flowering stage and at harvesting of sapota (Table 4). Treatment wise composite soil samples were collected from fertilized ring of the tree at 30 cm depth from 4 spots. Then the treatment wise representative samples were prepared by following quartering method. These samples were air dried in shade, pounded in wooden mortar and pestle, sieved through 2 mm sieve and 0.5 mm sieve (for organic carbon) and stored in plastic bags in corrugated boxes for physical and chemical analysis.

Table 4. Schedule of soil and plant sampling as well as manure and fertilizers application during experimental period

Sr. No	Particulars	Date/year 2022-23
1	Collection of soil and plant samples at vegetative flush stage before1st split application of fertilizers (*i.e.*, N, P, K, B and Zn)	01/06/2022
2	Application of vermicompost @ 50 kg tree^{-1}	27/06/2022
3	1st Split application of NPK fertilizers	27/06/2022
4	Application of Boron and Zinc	27/06/2022
5	Collection of soil and plant samples at flowering stage before 2nd split application of NPK fertilizers	03/09/2022
6	2nd Split application of NPK fertilizers	11/09/2022
7	Collection of soil and plant samples before 3rd split application of NPK fertilizers	08/01/2023
8	3rd Split application of NPK fertilizers	10/01/2023

3.2 Methods

3.2.1 Fruit yield

3.2.1.1 Fruit yield (kg plant^{-1})

Treatment-wise matured sapota fruits from each selected plant were harvested and weighed on electronic balance at each harvesting and expressed in kilogram based on the total weight of fruit harvested. Treatment-wise fruit yield as kilogram per plant was worked out from the yield of selected two plants.

3.2.1.2 Fruit yield (t ha^{-1})

The yield in ton per hectare was worked out from the fruit yield in kilogram per plant by considering the spacing of 12.5m x 12.5m of the present thirty-three year old sapota plantation.

3.2.2. Chemical properties

1. Soil reaction

The pH of soil was determine potensiometrically using pH meter (combined electrode) with 1**:**2.5 soil**:** water suspension ratio (Jackson 1967).

2. Electrical conductivity (dS m^{-1})

Electrical conductivity of soil was determined with the help of Systronic Conductivity Meter-306 using 1**:**2.5 soils**:**water suspension ratio (Jackson 1973).

3. Organic carbon (g kg^{-1})

It was determined by adopting wet digestion with chromic acid followed by Walkley and Black's rapid back titration method (Black 1965).

3.2.2.1 Available nutrient status

1. Available nitrogen (kg ha^{-1})

Available nitrogen was determined by alkaline permanganate (0.32% $KMnO_4$) method (Subbiah and Asija 1956).

2. Available phosphorus (kg ha^{-1})

Available phosphorus (Bray's P) was determined by extracting the acid soil P in dilute acid fluoride (Bray and Kurtz, 1945) phosphorus in the extract was determined colorimetrically at 660 nm as described by Black (1965).

3. Available potassium (kg ha^{-1})

It was estimated on Systronics Flame Photometer-128 using neutral-normal-ammonium acetate (NH_4OAc pH 7.0) as per procedure given by Jackson (1973).

4. Hot Water Extractable Boron (mg kg^{-1})

It was determined by hot water extractable method of Berger and Troug (1939) using Azomethine-H reagent. Air dried soil was extracted with $CaCl_2$ by using water cooled reflux condenser. The filtrate was evaporated with $Ca(OH)_2$ in silica crucible on hot water bath up to dryness and HCl diluted aliquot was taken for determination of boron by using Azomethine-H and B was estimated by colorimetrically at 420 nm.

5. DTPA Extractable Zinc (mg kg^{-1}):

The available Zn in the soil was extracted with extract containing 0.005M DTPA (diethylene triamine penta-acetic acid), 0.1 M Triethanolamine and 0.01 M $CaCl_2$ (pH 7.3). Then it was determined by Atomic Absorption Spectrophotometer as described by Lindsay and Norvell (1978).

3.2.3 Leaf Analysis

The treatment wise leaf samples were collected at three stages *viz.* at vegetative stage, at flowering, and at harvesting stage of sapota which were used for chemical analysis. After recording the dry weight, the leaf samples were ground in Willey mill and stored in plastic bags for chemical analysis. The samples were analyzed for total N, P, K, Zn, and B by using following methods.

Digestion of plant samples:

Leaf N: The plant samples (0.25 g) were digested using concentrated H_2SO_4 and H_2O_2 (wet digestion) and volume was made to 25.0 mL after digestion.

Leaf P, K, B and Zn: The plant samples (0.5g) were digested with 10 mL nitric acid and 5 mL of perchchloric acid and after digestion diluted up to 50 mL.

Estimation of nutrients:

1. Leaf nitrogen

The plant samples were digested with conc. H_2SO_4 + H_2O_2 (30%) and the total nitrogen content was determined by using Pelicon make distyl EM distillation unit (Tandon 1993).

2. Leaf phosphorus, potassium and boron

For determination of P and K 0.5 g plant sample was digested with nitric and perchchloric acid(di-acid), the final volume was made to 50 ml with distilled water and P, K and B in extract were determined Singh *et al*.(1999).

3. Leaf Phosphorus

It was determined by using known quantity of di-acid extract as mentioned above and the yellow colour was developed with combined HNO_3 vanadomolybdate reagent. Phosphorus was determined colorimetrically by using spectrophotometer at 420 nm wave length (Chopra and Kanwar 1978).

4. Leaf Potassium

It was estimated flame photometrically by feeding diluted di-acid digested solution duly diluted 10 times (Piper 1966).

5. Leaf Boron

Boron was estimated from plant samples colorimetrically by using 1 mL of Azomethine-H reagent with 1 mL of Buffer solution in the 1 mL of aliquot prepared for B estimation and made final volume 25 mL on 420 nm (Berger and Troug 1939).

6. **Leaf Zn**

Zinc was determined with Atomic Absorption Spectrophotometer as per procedure given by Lindsay and Norvell (1978).

3.2.4 Quality Parameter

The treatment wise collected fruit samples were used for analysis of quality parameters such as protein, T.S.S, titratable acidity, reducing sugar, and total sugar by following the standard process in given below.

1. Protein (%)

Dried sapota pulp (0.25 g) was digested in minimum volume of conc. H_2SO_4 using H_2O_2. The volume of digested sample was made to 25 mL with DW and 10 mL of aliquots from the digested sample were used for estimation of nitrogen by Micro-Kjeldahl method (Jackson, 1973). Per cent protein was obtained by multiplying per cent nitrogen with 6.25

2. Total soluble solids (TSS^{0}B)

Total soluble solids of the fruit was determined with the help of hand refractometer (Erma Japan, 0 to 32 ^{0}B) One drop of fruit juice was put on the prism of the refractometer and the TSS in per cent was recorded directly. The values were corrected at 20^{0}C and expressed as degree brix (A.O.A.C. 1990).

3. Titratable acidity (%)

A known quantity of liquid sample pulp was titrated against 0.1 *N* NaOH solution using phenolphthalein as an indicator. In case of solid sample, a known sample was blended in mortar and pestle with 20-25 mL of distilled water. It was then transferred to 100 mL volumetric flask, made up volume and filtered. A known volume of aliquot (10mL) was titrated against 0.1 *N* NaOH solution using phenolphthalein as an indicator. The results were expressed as per cent anhydrous citric acid (A.O.A.C., 1990) (Ranganna1997).

4. Reducing sugars (%)

For the determination of reducing sugar, Ranganna (1997) describes the titremetric approach of Lane and Eynon. Making use of lead acetate (45%) to precipitate foreign particles and potassium oxalate (22%), which de-leaded the solution, A known weight of pulp was combined with distilled water. By evaluating this lead-free extract to the standards (Fehling's A and B) and using methylene blue as an indicator to a brick red end point, reducing sugars were determined.

5. Total sugars (%)

The total sugars were estimated by the same procedure as that reducing sugar. After acid hydrolysis of an aliquot, de-leaded sample with 35 per cent hydrochloric acid, followed by neutralization with sodium hydroxide (40%). This filtrate was used for titration against standard Fehling's mixture (Fehling's A and B) using methylene blue as an indicator to brick red end point (Ranaganna 1997).

3.2.5 Statistical Analysis

The data obtained were subjected to statistical analysis by following the procedure pertinent to Randomized Block Design as given by Panse and Sukhatme (1967).

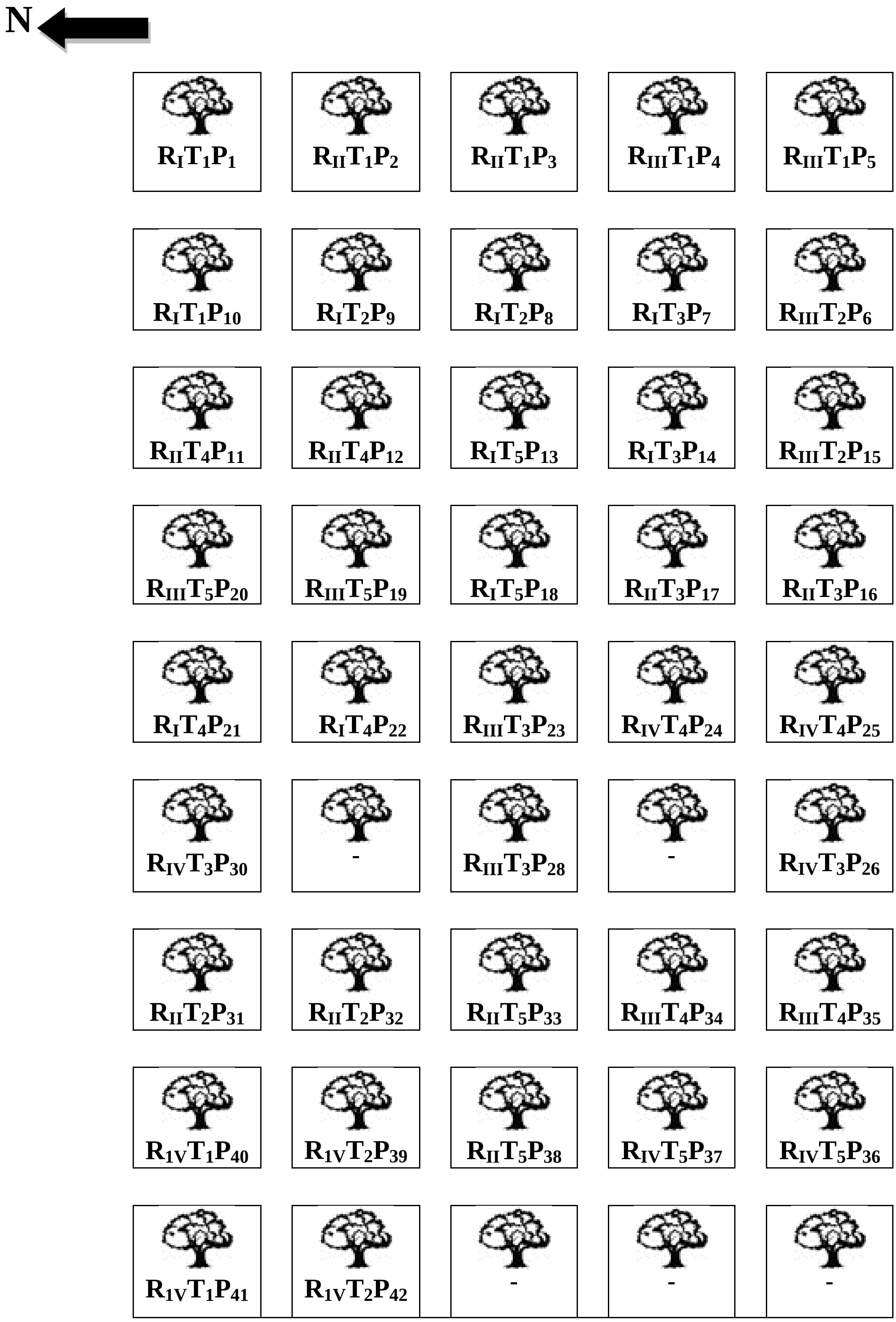


Fig.1. Layout plan of experimental field

T_1 to T_5 = Treatments
P_1 and P_2 = Plant 1 and Plant 2 selected for the respective treatment
R_1 to R_{IV} =Replications

Plate 1: General view of experimental plot

Plate 2: Ring prepared for fertilizer application

Plate 3: Fertilizer application by ring method

Plate 4: Flowering and Fruit development



T_1 T_2 T_3


T_4 T_5

Plate 5: Size of fruit under different treatments

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

In the present investigation, an attempt has been made to study the "Effect of split application of NPK along with basal dose of Zn and B on soil properties, yield and quality of sapota [*Manilkara achras* (mill.) Forsbergin] in lateritic soils of Konkan" in the year 2022-23 at Nursery No.10, Department of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri.

The observations and analytical values obtained during the course of study were analyzed statistically, described and contemplated to discuss the variations observed with an attempt to establish the 'effect and cause' relationship in the light of available evidences and literature. For brevity, the entire results and discussion has been divided into the following heads:

4.1 : Effect of split application of NPK with or without Zn and B on soil properties

4.2 : Effect of split application of NPK with or without Zn and B on yield of sapota

4.3 : Effect of split application of NPK with or without Zn and B on quality of sapota

4.4 : Effect of split application of NPK with or without Zn and B on leaf nutrient content of sapota

4.1 : Effect of split application of NPK with or without Zn and B on soil properties

4.1.1 Soil pH

The soil pH determined periodically at vegetative flush, at flowering and at harvest indicated that it varied from 5.07 to 5.19, 5.18 to 5.46 and 5.31 to 5.61, respectively (Table 5). In general, the pH of lateritic soils of Konkan region ranged from 4.75 to 6.50 (Anonymous 1990). The data indicated that the soils are acidic in nature. The acidic nature of soils might be attributed to leaching of soluble salts due to heavy precipitation (Anonymous 1990). Further, parent materials also contribute soil acidity in Konkan region.

In the present investigation, the chemical analysis of soil at vegetative flush stage showed non-significant result in almost all the parameters as the soil sampling was done in the month of June at vegetative flush stage before the split application of 3 kg NPK each with vermicompost @ 50 kg tree^{-1} with or without Zn + B in the respective treatments. However, the split application of NPK with and without Zn + B in the respective treatments in the month of June at vegetative flush stage exhibited significant difference on soil pH due to split application of NPK with and without Zn + B was observed at flowering stage and at harvest stage.

The significantly highest pH *i.e.*, 5.46 at flowering stage and 5.61 at harvest were noted with treatment T_5 where 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ + Borax in June, which was found to be at par with the treatments T_2, T_3 and T_4 during both observational stage of plant growth. The treatment absolute control (T_1) recorded the lowest value of pH *i.e.*, 5.18 at flowering stage and 5.31 at harvest.

Table 5. Soil pH at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	5.07	5.18	5.31
T_2	3 kg NPK in two splits	5.11	5.23	5.37
T_3	3 kg NPK in two splits + Zn & B	5.12	5.40	5.46
T_4	3 kg NPK in three splits	5.14	5.44	5.58
T_5	3 kg NPK in three splits + Zn & B	5.19	5.46	5.61
	S.E.	0.08	0.08	0.08
	C.D. at 5%	**N.S.**	**0.23**	**0.25**

The close scrutiny of the data indicated that soil pH increased from vegetative flush stage to harvest stage irrespective of the treatments. The increase in soil pH from vegetative flush stage to harvest stage in the current study are close to the findings of Puranik (2018) in mango and Gavit (2017) in cashew in lateritic soils of Konkan. This increase in soil pH may be due to increased microbial growth and activity during the growth period of the crop as there was increase in organic matter due to accumulation of leaf litter fall during the growth period.

The data also indicated that application of zinc and boron (in treatment T_3 and T_5) increased the soil pH over the sole application of NPK either in two or three splits (in treatment T_2 and T_4). This increase in soil pH with the application of zinc and boron might be due to the fact that in the present investigation boron was applied through Borax which is known as sodium borate which increases the soil pH and make it more alkaline due to its alkaline nature.

4.1.2 Electrical conductivity (dS m^{-1})

The electrical conductivity of the soil at different growth stages as affected by the application of NPK in two or three splits with and without Zn plus B (Table 6) indicated that the electrical conductivity of the soil ranged from 0.18 to 0.22 dS m^{-1} at vegetative flush stage, 0.16 to 0.27 dS m^{-1} at flowering stage and 0.16 to 0.24 dS m^{-1} at harvest. In general, the EC values indicated that the experimental soil contains normal soluble salts, which might be attributed to leaching of soluble salts due to heavy precipitation (Anonymous 1990). As such, the value reported for lateritic soils are low and varying between 0.01to 0.38 dS m^{-1} with mean ranging from 0.031 to 0.048 dS m^{-1} (Patil *et al.* 1987).

Table 6. Soil EC (dS m^{-1}) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	0.18	0.16	0.16
T_2	3 kg NPK in two splits	0.21	0.24	0.17
T_3	3 kg NPK in two splits + Zn & B	0.22	0.25	0.21
T_4	3 kg NPK in three splits	0.21	0.25	0.22
T_5	3 kg NPK in three splits + Zn & B	0.22	0.27	0.24
	S.E.	0.02	0.02	0.02
	C.D. at 5%	N.S.	0.059	0.057

In the present investigation the soil sampling was done before the split application of 3 kg NPK with vermicompost @ 50 kg $tree^{-1}$ with or without Zn + B in the month of June at vegetative flush stage. So, the EC of soil found non-significant at vegetative flush stage. However, the significant difference on soil EC due to split application of NPK with and without Zn + B in the month of June at vegetative flush stage was observed at flowering stage and at harvest stage.

The application of 3 kg NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June (treatment T_5) recorded the significantly highest EC *i.e.,* 0.27 dS m^{-1} at flowering stage and 0.24 dS m^{-1} at harvest. But, treatment T_5 was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage, while with the treatments T_3 and T_4 at harvest. The treatment absolute control (T_1) recorded the lowest value of EC *i.e.,* 0.18dS m^{-1} at vegetative flush stage and 0.16 dS m^{-1} at flowering stage and 0.16 dS m^{-1} at harvest.

The electrical conductivity initially increased from vegetative flush stage to flowering stage and thereafter decreased to harvest irrespective of the treatments with exception of absolute control. Similar trend was also reported by Palkar (2014) in cashew in lateritic soils of Konkan. The increase in EC with the application of NPK in two or three splits along with vermicompost @ 50 kg $tree^{-1}$ during the study might be due to possible buildup of the soluble nutrients drawn from manure or mineralization. The decrease in EC from flowering stage to harvest may, probably, be due to partial washing away of the salts from the surface soils, besides uptake of the salts from the soil by the plant.

In this context, Dalvi *et al*. (2015) noted increased EC under *Acacia mangium* plantation in lateritic soils of Konkan compared with the open field, which may be due to accumulation of high biomass under *Acacia mangium* plantation and further decomposition built up the soluble nutrient on mineralization.

It is inferred from the data that application of zinc and boron increased the EC over the sole application of NPK either in two or three splits. The increase in EC with application of zinc and boron might be possible due to contribution of more ions.

4.1.3 Organic carbon (g kg^{-1})

The organic carbon content in the soil ranges from 31.45 to 34.40 g kg^{-1} at vegetative flush stage, 35.38 to 44.90 g kg^{-1} at flowering stage and 29.85 to 38.20 g kg^{-1} at harvest (Table 7). The organic carbon in soils was in ‘very high’ range as per the ranges proposed by Bangar and Zende (1978). In general, the very high organic carbon content of the soils might be attributed to the humid climate of the Konkan region (Anonymous 1990).

Similar to soil pH and EC, organic carbon content in the soil also recorded the non-significant effect at vegetative flush stage as the soil sampling was done before the split application of 3 kg NPK with vermicompost @ 50 kg $tree^{-1}$ with or without Zn + B were applied in the month of June at vegetative flush stage. However, the significant difference in organic carbon content due to split application of fertilizers in June at vegetative flush stage was observed at flowering stage and at harvest stage. The addition of organic manures such as vermicompost encouraged the proliferation in soil microbial environment and biomass of the root system.

Table 7. Soil Organic Carbon (g kg^{-1}) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	31.45	35.38	29.85
T_2	3 kg NPK in two splits	32.73	41.15	36.35
T_3	3 kg NPK in two splits + Zn & B	34.03	42.50	37.05
T_4	3 kg NPK in three splits	34.48	44.55	38.15
T_5	3 kg NPK in three splits + Zn & B	34.40	44.90	38.20
	S.E.	1.31	2.45	2.01
	C.D. at 5%	N.S.	7.55	6.18

The treatment T_1 (*i.e.,* absolute control) recorded the lowest values of organic carbon content in soil (31.45 g kg^{-1} at vegetative flush stage, 35.38 g kg^{-1} at flowering stage and 29.85 g kg^{-1} at harvest), where organic matter was not applied. From treatment T_2 to T_5, vermicompost @ 50 kg $tree^{-1}$ was applied, which significantly increased the organic carbon content over the absolute control.

The highest organic carbon *i.e.,* 44.90 g kg^{-1} at flowering stage and 38.20 g kg^{-1} at harvest were noted with the application of 3 kg NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June (treatment T_5), was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest. Experimental results are in agreement with the findings of Jain *et al*. (2014) who reported the highest organic carbon content with application vermicompost in Nagpur mandarin orchard soil. The highest soil organic carbon due to application of vermicompost has been also confirmed by Ramesh *et al*. (2005).

Close scrutiny of the data indicated that the organic carbon of the soil increased at flowering stage over vegetative growth stage irrespective of treatments. The soil enrichment in organic carbon content could be reason of several factors such as addition of litter fall, find root biomass recycled and root exudates and its reduced oxidation of organic matter. In this connection, Preethi *et al.* (1998) ascribed that the high amount of organic carbon content in these soils might be attributed to luxurious growth of grasses and vegetation due to heavy rainfall and thus addition of organic matter through litter, residues and cover crops and thereby subsequent increased humification.

In general, irrespective of the treatments organic carbon content tended to decline with advancement of crop growth (*i.e.,* from vegetative flush stage to harvest). The establishment of plantations comprising invasive plants reduces tree and shrub layers, exposes the leaf litter layer in this habitat to high temperatures. If this happens, the breakdown of leaf litters will be accelerated (Smith *et al*. 1998) and faster decomposition rates could contribute to a decrease in OM content (Butterfield 1999; Singwane and Malinga 2012).

The higher organic carbon content recorded in sapota fruit orchard soils may be due to the continuous addition of organic matter by continuous falling of leaves of evergreen sapota tree, which leads to accumulate more organic matter to the soil. In this connection, Mutanal *et al*. (2018) also attributed the higher organic matter in sapota orchard soil to the continuous addition of litter, succulent twigs and leaves of trees as well as other vegetation like grasses residues in the soil and their decomposition.

4.1.4 Available Nitrogen (kg ha^{-1})

The periodic observations of available nitrogen in soil showed that its content varied from 282.01 to 309.46 kg ha^{-1} at vegetative flush stage, 275.76 to 377.21 kg ha^{-1} at flowering stage and 280.76 to 397.84 kg ha^{-1} at harvest (Table 8) indicating available nitrogen rating from 'low' to 'moderately high' (Bangar and Zende 1978). In general, the content of available nitrogen in lateritic soil ranges from low to moderately high and the values vary between 149.0 to 674.0 kg ha^{-1} (Anonymous 1990).

Table 8. Available nitrogen (kg ha^{-1}) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	282.01	275.76	280.76
T_2	3 kg NPK in two splits	293.99	333.35	359.89
T_3	3 kg NPK in two splits + Zn & B	309.46	352.83	362.94
T_4	3 kg NPK in three splits	290.86	367.18	386.10
T_5	3 kg NPK in three splits + Zn & B	301.32	377.21	397.84
	S.E.	8.71	16.37	22.99
	C.D. at 5%	N.S.	50.43	70.84

Similar ranges of available nitrogen were also reported by Palkar (2014) and Palsande (2011) in cashew grown under lateritic soils of Konkan. Available nitrogen in the soil found to be non-significant at vegetative flush stage because the soil sampling was done before the split application of 3 kg NPK with vermicompost @ 50 kg tree^{-1} with or without Zn + B in the month of June. However, the significant difference on available nitrogen due to split application of fertilizers in the month of June was observed at flowering stage and at harvest stage.

No application of fertilizers and vermicompost (*i.e.*, absolute control) recorded the lowest nitrogen content in soil *i.e.*,282.01 kg ha^{-1} at vegetative flush stage, 275.76 kg ha^{-1} at flowering stage and 280.76 kg ha^{-1} at harvest. But, the application of vermicompost and fertilizers in two or three splits (from treatment T_2 to T_5) significantly increased the nitrogen content in the soil over the absolute control.

The application of 3 kg NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June (treatment T_5) recorded the significantly highest nitrogen content in soil *i.e.*, 377.21 kg ha^{-1} at flowering stage and 397.84 kg ha^{-1} at harvest and was found to be at par with the treatments T_3 and T_4 at flowering stage and at harvest.

It was observed from the data that the nitrogen content of the soil increased at flowering stage over vegetative growth stage in all treatments with the exception of absolute control (T_1). Sheeba and Chellamuthu (1999) ascribed such build up in the available N status of the soil value to mineralization of N from added organic matter like vermicompost. The increase in available N status of the soil with combined use of fertilizers and organic manures may be explained in terms of their residual effect and build up in organic N fractions of the soil due to biochemical degradation and mineralization. Increase in available nitrogen under horticultural plantation as compared to open system was attributed to addition of organic matter in the form of leaf litter fall, twigs, small branches etc. to the soil. The mineralization of organic matter release nutrients to the soil (Osman *et al*. 2001)

The results of present investigation are supported by findings of Shivakumar *et al*. (2012) in papaya.

4.1.5 Available Phosphorus (kg ha^{-1})

As an influence of split application of NPK with and without Zn + B under lateritic soils of Konkan, the available phosphorus oscillated from 5.62 to 6.06 kg ha^{-1} at vegetative flush stage, 5.74 to 7.99 kg ha^{-1} at flowering stage and 5.49 to 7.74 kg ha^{-1} at harvest (Table 9), which was rated as 'low to medium' (Bangar and Zende 1978). The available P_2O_5 content in lateritic soils ranges from 0.35 to 74.14 kg ha^{-1} with an average value of 14.14 kg ha^{-1} (Anonymous 1990).

Available phosphorus content in soil at vegetative flush stage found to be non-significant as the soil sampling was done before the split application of 3 kg NPK with vermicompost @ 50 kg tree^{-1} with or without Zn + B were applied in the month of June at vegetative flush stage. However, the significant difference was observed at flowering stage and at harvest stage.

Table 9. Available phosphorus (kg ha^{-1}) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	5.62	5.74	5.49
T_2	3 kg NPK in two splits	5.75	7.33	7.15
T_3	3 kg NPK in two splits + Zn & B	5.97	7.47	7.22
T_4	3 kg NPK in three splits	5.93	7.75	7.50
T_5	3 kg NPK in three splits + Zn & B	6.06	7.99	7.74
	S.E.	0.52	0.38	0.28
	C.D. at 5%	N.S.	1.18	0.86

The lowest values of available phosphorus content in soil (5.62 kg ha^{-1} at vegetative flush stage, 5.74 kg ha^{-1} at flowering stage and 5.49 kg ha^{-1} at harvest) were reported in the treatment T_1 (*i.e.*, absolute control), which may be due to no addition of fertilizers or vermicompost, causing reduction in the available P status of the soil. But, the application of NPK in two or three splits with or without Zn + B noted the significant increase in available phosphorus content in the soil over the absolute control from the treatment T_2 to T_5.

The application of treatment T_5 *i.e.*, 3 kg NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June were recorded the highest phosphorus content in soil *i.e.*, 7.99 kg ha^{-1} at flowering stage and 7.74 kg ha^{-1} at harvest and was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest. Increase in available phosphorus with fertilizer application might be attributed to the direct addition of phosphorus through fertilizer to the available pool of the soil. The increase in phosphorous availability might be also due to synergistic effect of N with phosphorus which increased the availability of P in the soil (Shrivastava 2002).

However, available phosphorus status of orchard at various growth stages shows the increase in available phosphorus after fertilizer application at flowering stage and decrease at harvest. The results were close conformity to the Gavit (2017) in cashew in lateritic soils of Konkan. Organic matter mineralization provides a continuous, although limited, supply of plant available P also Tisdale *et al*. (1995). The decline in available phosphorus may be due to the uptake of P_2O_5 by plants which usually takes place intensively after flowering (Barbatzkii 1959).

In general, the lateritic soils have high phosphorus fixing capacity (91%) (Kadrekar and Talashilkar,1977). Phonde (1987) reported it to be 95 per cent. The preponderance of less active (reductant phosphorus and occluded phosphorus) and inactive (residual phosphorus) phosphorus fractions over active phosphorus fractions, dominance of iron phosphorus over aluminum phosphorus, low concentration of solid phosphorus and high phosphorus fixing capacity of soils are some of the important reasons for low phosphorus availability in lateritic soils of Konkan (Dongale 1989 and Anonymous 1990). Tisdale *et al*. (1995) also explained that in soils with significant Fe and Al oxide contents, the less crystalline the oxides are or the more amorphous they are, the larger their P fixation capacity because of their greater surface area.

4.1.6 Available Potassium (kg ha^{-1})

The effect of split application of NPK with and without Zn + B under lateritic soils of Konkan influenced the available potassium, which gone around 582.51 to 600.22 kg ha^{-1} at vegetative flush stage, 608.11 to 872.32 kg ha^{-1} at flowering stage and 598.11 to 887.32 kg ha^{-1} at harvest (Table 10), indicating fertility rating from 'medium' to 'high' (Bangar and Zende

1978). In general, the available K_2O content in lateritic soils ranges from 11 to 1152 kg $ha^{-1}$with an average of 226 kg ha^{-1} (Anonymous 1990). Elsewhere, the available K_2O content in lateritic soil ranges from 162.8 to 854.9 kg ha^{-1} with an average 474.95 kg ha^{-1} Patil *et al*. (1987) Similar ranges of available potassium were also reported by Palsande (2011), Palkar (2014) and Gavit (2017) in cashew in lateritic soils of Konkan.

In the present investigation, the soil sampling was done in the month of June at vegetative flush stage before the split application of fertilizers and manure. That is why, the chemical analysis of soil at vegetative flush stage showed non-significant result. However, the split application of NPK with and without Zn + B in the respective treatments in the month of June at vegetative flush stage exhibited significant difference on available potassium content in soil due to split application of NPK with and without Zn + B was observed at flowering stage and at harvest stage.

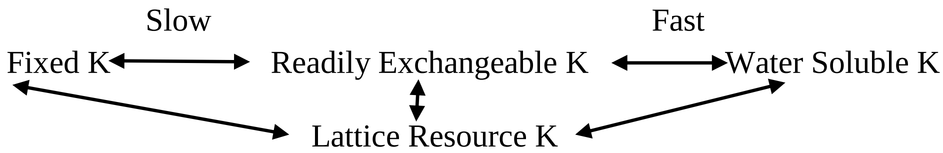
The treatment T_1 (*i.e.,* absolute control) recorded the lowest values of available potassium content in soil (608.11 kg ha^{-1} at flowering stage and 598.11kg ha^{-1} at harvest, where fertilizers and organic matter was not applied. Significant increase in available potassium content was observed with the application of vermicompost with two or three splits of NPK with or without Zn + B from the treatments T_2 to T_5 over the absolute control. Increase in available potassium with fertilizer application might be attributed to the direct addition of potassium through fertilizer to the available pool of the soil.

Table 10. Available potassium (kg ha^{-1}) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	590.19	608.11	598.11
T_2	3 kg NPK in two splits	582.51	809.51	837.01
T_3	3 kg NPK in two splits + Zn & B	587.83	829.99	849.99
T_4	3 kg NPK in three splits	602.48	840.13	855.13
T_5	3 kg NPK in three splits + Zn & B	600.22	872.32	887.32
	S.E.	38.15	50.58	37.00
	C.D. at 5%	N.S.	155.85	113.99

The application 3 kg NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June (treatment T_5) recorded the significantly highest potassium content in soil *i.e.,* 872.32 kg ha^{-1} at flowering stage and 887.32 kg ha^{-1} at harvest and was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest.

Available K tended to increase with time irrespective of different treatments. The increased in potassium availability with nitrogen might be also due to synergistic effect of N with potassium which increased the availability of K in the soil (Shrivastava 2002). In addition to this, Varalakshmi *et al*. (2005) reported that the higher availability of potassium in the treatment of package of practice where along with NPK fertilizers and 50 kg per tree vermicompost was applied might be due to the beneficial effect of application of FYM along with inorganic fertilizer. It may be ascribed to the reduction of K fixation and release of K due to the interaction of organic matter with clay besides the direct addition of potassium to available pool of the soil (Tandon 1987). According to Tisdale *et al*. (1995), organic matter improves CEC, which reduces potential leaching losses of element such as K^+, Ca^{2+} and Mg^{2+} and increase its availability. Balaguraiah *et al*. (2005) reported significant increase in soil available K due to organic matter application. The increase in available K in the soil may, probably, due to the fact that solubility of K is dependent on wetting and drying regimes which behaves in soils as follows (Kanwar 1976).



In some soils, non-exchangeable K becomes available as the exchangeable and solution K^+ are removed by cropping or lost by leaching (Tisdale *et al*. 1995).

Chavan *et al*. (1995) also reported that the soils under forest cover or plantation crops showed higher available K_2O content in lateritic soils of Konkan. The enhanced availability of nutrients under forest cover or plantation crops resulting from production and decomposition of tree biomass, greater uptake and utilization of nutrients from deeper soil layers by the tree.

In this regard, Albretch and Kandji (2003) and Khalafalla and Hamed (2015) reported that soils with tree coverage show an increase in carbon and nitrogen. Additionally, residue retention can increase the proportion of SOC with a lower decomposition degree and higher C:N ratio. Thus, even a relatively small increase or decrease in soil carbon content due to changes in management practices may result in a significant net exchange of C between the soil C pool and the atmosphere. Moreover, Romil Sood (2003) pointed out the non-significant organic carbon in spite of addition of FYM to turmeric under open field conditions which may be attributed to the fact that in turmeric, the economic portion is rhizome and at the time of harvesting, rhizomes are removed from the soil.

4.1.7 DTPA Extractable Zinc (mg kg^{-1})

DTPA Extractable Zn at different stages of sapota as influenced by the effect of split application of NPK with and without Zn + B under lateritic soils of Konkan varies from 1.12 to 1.17 mg kg^{-1} at vegetative flush stage, 1.17 to 2.09 mg kg^{-1} at flowering stage and 1.20 to 1.82 mg kg^{-1} at harvest stage (Table 11). Palsande (2011), Pawar (2012), Joshi (2012) and Palkar (2014) reported similar ranges of DTPA extractable Zn in lateritic soils of Konkan.

Considering 0.60 mg kg^{-1} as critical level for zinc deficiency (Lindsay and Norvell 1978), these soils could be classified as sufficient in zinc content. The relatively high content of available zinc may be attributed to variable intensity of the pedogenic processes and more complexing with organic matter which resulted in chelation of Zn (Srinivasan *et al.* 2013).

Table 11. DTPA extractable zinc (mg kg^{-1}) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	1.12	1.17	1.20
T_2	3 kg NPK in two splits	1.13	1.58	1.28
T_3	3 kg NPK in two splits + Zn & B	1.17	2.07	1.74
T_4	3 kg NPK in three splits	1.13	1.63	1.30
T_5	3 kg NPK in three splits + Zn & B	1.14	2.09	1.82
	S.E.	0.08	0.19	0.16
	C.D. at 5%	N.S.	0.58	0.50

Among the growth stages, vegetative flush stage recorded the lowest values of DTPA Extractable Zn, which could not reach the level of significance, since the soil sampling was done in the month of June before the split application of 3 kg NPK with vermicompost @ 50 kg tree^{-1} with or without Zn + B.

The lowest values of DTPA Extractable Zn content in soil (1.12 mg kg^{-1} at vegetative flush stage, 1.17 mg kg^{-1} at flowering stage and 1.20 mg kg^{-1} at harvest) were reported in the treatment T_1 (*i.e.,* absolute control), where fertilizers and organic matter was not applied. Further, application of RDF alone in two splits (T_2) and three splits (T_4) recorded increase in DTPA Extractable Zn. This might be due to efficient utilization of micronutrients in the presence of all other essential elements (Guvvali and Shirol 2017). However, the maximum DTPA Extractable Zn content was recorded in treatments T_3 and T_5, where Zn was applied though zinc sulphate along with boron. Increase in DTPA Extractable Zn with Zn application might be attributed to the direct addition of Zn through fertilizer to the available pool of the soil.

Significantly highest DTPA Extractable Zn was recorded with three split applications of NPK with Zn + B (treatment T_5) with the values of 2.09 mg kg^{-1} at flowering stage and 1.82 mg kg^{-1} at harvest stage, which was found to be at par with T_2, T_3 and T_4 at flowering stage and T_2 andT_3 at harvest stage.

At high pH, Zn precipitate as insoluble amorphous soil Zn, Zn Fe_2O_4 and /or $ZnSiO_4$, which reduces Zn^{2+} in soils and the availability of Zn^{2+} decreases with increased soil pH (Tisdale *et al*. 1995). The action of organic matter on Zn^{2+} can be expected to vary depending on the characteristics and amount of the organic materials involved. Substance presents in or derived from freshly applied organic material have the capacity to chelate Zn^{2+} Tisdale *et al*. (1995)

Further, the available Zn content of soil gradually enhanced in all the treatment at flowering stage over vegetative flush stage and further declined at harvest. The results were close conformity with Gavit (2017) in cashew in lateritic soils of Konkan. By and large, Zn deficiencies are generally more pronounced during cool, wet season and often disappear in warmer weather. Climatic conditions like poor light, as well as low temperature and excessive moisture contribute to Zn deficiency. Increasing soil temperature increases the availability of Zn to crops by increasing solubility and diffusion of Zn^{2+} (Tisdale *et al*. 1995).

4.1.8 Available Boron (mg kg^{-1})

Available Boron was influenced by the effect of split application of NPK with and without Zn + B under lateritic soils of Konkan and differ from 0.20 to 0.25 mg kg^{-1} at vegetative flush stage, 0.22 to 0.47 mg kg^{-1} at flowering stage and 0.20 to 0.38 mg kg^{-1} at harvest stage (Table 12). The range value of hot water extractable boron reported here are in agreement with Kadrekar *et al*. (1981), Diwan (1982), Mahajan (2001), Shinde (2006), Kadu (2015), Savkare (2018) and Jadhav (2019).

Das (2007) reported that the ability of clay minerals to adsorb boron has been found to be highest in micaceous type illite clay minerals closely followed by montmorillonite clay minerals, whereas kaolinite has the lowest boron adsorption capacity. The laterite and lateritic soils of Ratnagiri and Sindhudurg district of Konkan are dominant in kaolinite clay (Anonymous 1990).

Qertli and Grgurevic (1975) explained that boric acid is the form of boron that plant roots absorb most efficiently. Because of its non-ionic nature once boron is released from soil minerals it can be leached from the soil fairly rapidly. This explains why soil in high rainfall areas is often deficient in boron (Gupta 1979).

Further, Das (2007) also reported that boron availability is decreased under dry soil conditions. So, boron deficiency is often associated with dry weather and low soil moisture condition and this behavior may be related to restricted release of boron from organic complexes and to impaired ability of plants to extract boron from soil due to lack of moisture in root zone. Although boron levels in soil may be high, low soil moisture impairs transport of boron to absorbing root surfaces.

Table 12. Available boron (mg kg^{-1}) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	0.20	0.22	0.20
T_2	3 kg NPK in two splits	0.25	0.32	0.27
T_3	3 kg NPK in two + Zn & B	0.23	0.45	0.37
T_4	3 kg NPK in three splits	0.24	0.33	0.28
T_5	3 kg NPK in three splits + Zn & B	0.22	0.47	0.38
	S.E.	0.04	0.03	0.05
	C.D. at 5%	N.S.	0.10	0.14

Among the growth stages, vegetative flush stage recorded the lowest values of available boron, which could not reach the level of significance, since the soil sampling was done in the month of June before the split application of 3 kg NPK with vermicompost @ 50 kg tree^{-1} with or without Zn + B.

The lowest values of available boron content in soil (0.20 mg kg^{-1} at vegetative flush stage, 0.22 mg kg^{-1} at flowering stage and 0.20 mg kg^{-1} at harvest) were reported in the treatment T_1 (*i.e.*, absolute control), where fertilizers and organic matter was not applied. Further, application of RDF alone in two splits (T_2) and three splits (T_4) recorded increase in available boron content. However, the maximum available boron content was recorded in treatments T_3 and T_5, where boron was applied though borax along with zinc sulphate. Increase in available boron with borax application might be attributed to the direct addition of boron through fertilizer to the available pool of the soil.

Significantly highest available boron was recorded with three split applications of NPK with Zn + B (treatment T_5) with the values of 0.47 mg kg^{-1} at flowering stage and 0.38 mg kg^{-1} at harvest stage, which was found to at par with T_3 at flowering stage and T_2. T_3 and T_4 at harvest stage.

Savkare (2018) also observed increase in hot water extractable boron content in soil with the increasing levels of boron (*i.e.*, 0, 2, 4 and 6 kg B ha^{-1}) applied to three different types of soils *i.e.*, low, medium and high in boron content.

In the present investigation, available boron in soil increased with application of boron @ 25 g plant^{-1} through Borax in the treatment T_3 and T_5. However, boron in soil increased with the only application of RDF in two or three splits with vermicompost without addition of boron in treatments T_2 and T_4 over the absolute control. Das (2007) explained that organic matter forms a complex with B and it is one of the main sources of boron in acid soils. Application of organic materials to soils can raise substantially the concentration of boron in plants. Berger and Pratt (1963) reported that a large part of the total boron in soils was associated with organic matter in tightly bound form. However, this boron can be released to soil solution in forms available to plants by microbial activities. Olsen and Berger (1946) also found that oxidation of soil organic matter resulted in a significant release of boron in forms available to plants by microbial activities. Further in this context, Guvvali and Shirol (2017) ascribed that this increase in available boron might be due to efficient utilization of micronutrients in the presence of all other essential elements and this was supported by findings of Sayed *et al.* (2012).

The availability of B depends upon adsorption-desorption processes, which are influenced by various physico-chemical properties of soils (Arora and Chahal 2005). The extent of B adsorption in soils depends on solution pH, soil texture and their mineral composition (Communar and Keren 2006). Of these, the soil pH has been reported as the main factor affecting the B adsorption in the soil Soares *et al*. (2008) mainly by influencing in the control of the predominant B species in solution and attributes related to its adsorption such as charge balance on colloids surface. Other factors, such as the clay content, Al and Fe (hydroxides), clay minerals, calcium carbonate and organic matter of soil also influence B sorption in agricultural soils (Arora and Chahal 2010).

Boron concentration in the soil solution is controlled by B adsorption reactions. These reactions restrict the amount of water-soluble B available for plant uptake, because plants respond directly to the B concentration in soil solution and only indirectly to the amount of B attached to soil surfaces. Thus, the soil adsorption complex acts as both a source and a sink for dissolved B (Keren and Bingham 1985).

The data also indicated that the hot water extractable boron was decreased over the periods of crop growth from flowering stage to harvest. The availability of boron decreases sharply under drought conditions, possible because of both a decrease in B mobility by mass flow to the roots and polymerization of boric acid (Das 2007).

4.2 : Effect of split application of NPK with or without Zn and B on yield of sapota

The fruit yield of sapota was significantly affected due to split application of NPK with or without Zn and B (Table 13).

4.2.1 Yield kg per tree

The fruit yield kg per tree was influenced by the effect of split application of NPK with and without Zn + B in lateritic soils of Konkan and differ from 20.63 to 46.02 kg per tree (Table 13). Similar fruit yield kg per tree of sapota Cv. Kalipatti was also reported by Jain (2019) in lateritic soils of Konkan.

The lowest values of fruit yield 20.63 kg per tree was reported in the treatment T_1 (*i.e.*, absolute control), where fertilizers and organic matter was not applied. Further, application of RDF alone in two splits (T_2) and three splits (T_4) recorded increase in fruit yield kg per tree. However, the highest fruit yield (46.02 kg/tree) was obtained with the application of treatment T_5 *i.e.*, (3 kg NPK in three splits + Zn & B), which was significantly superior over rest of the treatments and followed by the treatment T_4 (38.45 kg/tree), T_3 (36.33 kg/tree) and T_2 (33.44 kg/tree).

Increase in fruit yield of sapota with increase in split application of fertilizers in the current study are close to the findings of Jain (2019) in sapota in lateritic soils of Konkan, where increasing doses of fertilizers were applied in one, two and three splits.

Table 13. Yield of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	Yield kg per tree	Yield (t/ha)
T_1	Absolute control	20.63	1.32
T_2	3 kg NPK in two splits	33.44	2.14
T_3	3 kg NPK in two + Zn & B	36.33	2.33
T_4	3 kg NPK in three splits	38.45	2.46
T_5	3 kg NPK in three splits + Zn & B	**46.02**	**2.95**
	S.E.	1.57	0.10
	C.D. at 5%	4.84	0.31

4.2.2 Yield ton per hectare

The fruit yield ton per hectare was influenced by the effect of split application of NPK with and without Zn + B in lateritic soils of Konkan and differ from 1.32 to 2.95 t/ha (Table 13). Similar fruit yield ton per hectare of sapota Cv. Kalipatti was also reported by Jain (2019) in lateritic soils of Konkan.

The lowest values of fruit yield 1.32 t ha^{-1} were reported in the treatment T_1 (*i.e.*, absolute control), where fertilizers and organic matter was not applied. Further, application of RDF alone in two splits (T_2) and three splits (T_4) recorded increase in fruit yield t ha^{-1}. However, the highest fruit yield 2.95 t ha^{-1} was obtained with the application of treatment T_5 *i.e.*, (3 kg NPK in three splits + Zn & B), which was significantly superior over rest of the treatments and followed by the treatment T_4 (2.46 t ha^{-1}), T_3 (2.33 t ha^{-1}) and T_2 (2.14 t ha^{-1}). Possible explanation for increase in yield with Zn and B application could be attributed to the fact that Zn is an essential element required by plants for different metabolic process and play vital part in enzyme activation and biosynthesis of specific growth hormones (Noor and Tariq 2019; Ranja and Das 2003). Similarly, B is also involved in metabolism and translocation of carbohydrate, hormonal activities and pollen tube elongation. It also enhances flower initiation, fruit production, N absorption, growth of plants and indirectly influences fruit set (Cakmak and Romheld 1997; Simmons 1998; Anonymous 2007).

Noor and Tariq (2019) reported significant enhancement in number of flowers per tree, fruit set (%), fruit drop (%) and fruit retain (%) of citrus with Zn application when used in integration with B and similar results were also reported by Sourour (2000). Due to the involvement of these micronutrients in a number of plant metabolic processes, enhancement in plant growth and yield with their application is apparent. Boron fertilization improve metabolites synthesis that also benefits the fertilization process and subsequent fruit set (Swietlik 1995). Metabolites are low-molecular-weight organic and inorganic chemicals that are the reactants, intermediates, or products of enzyme-mediated biochemical reactions (Fanos and Atzori 2012). In disparity, Zekri (2002) reported that inadequate supply of B drastically reduced the fruit set, while squatted sugar and disproportionate fruit drop of orange fruits due to B deficiency are also reported by Ali *et al.* (1999). In the light of all these investigations it is reasonable to attribute the increase in fruit set to integrated application of Zn and B. Due to the optimum supply of Zn and B, along with other biochemical processes, the rate of carbohydrates production and its translocation increased which ultimately increased the fruit set and reduced the fruit drop Gupta *et al*. (1993); Heitholt (1994).

Alike significant effect of vermicompost and inorganic fertilizers on fruit yield has also been reported by Satisha *et al.* (2014) in sapota. Increase the yield might be due to attributed to the optimum supply of plant nutrients through application of NPK in two or three splits with or without Zn + B along with vermicompost in desired amount during the fruit growth period resulting in accumulation of more photosynthates leading to increase in fruit yield. Besides nutrients, vermicompost is also rich in vitamins, antibiotics and growth hormones which promote plant growth and hence improved fruit yield. Increase in fruit yield by organic manure application has been also reported by Hebbarai *et al.* (2006) in sapota.

Increase in fruit yield of sapota with increase in split application of fertilizers in the current study are close to the findings of Jain (2019) in sapota in lateritic soils of Konkan, where increasing doses of fertilizers were applied in one, two and three splits.

The results of the present study indicated as it is, essential that sapota trees are supplied with suitable and adequate nutrients for ensuring its sustained productivity and their requirement has to be supplied through external sources in order to avoid any yield loss.

4.3 : Effect of split application of NPK along with basal dose of Zn and B on quality of sapota

The effect of split application of NPK along with basal dose of Zn and B on quality of sapota *viz.*, protein, total soluble solids, titratable acidity, reducing sugar and total sugar is presented in (**Table 14)**.

4.3.1 Protein (%)

The various application of NPK in two or three splits with or without Zn + B influenced significantly the protein content in sapota (Table 14), which varies from 0.69 to 1.27 per cent.

The minimum fruit protein 0.69% was measured in T_1 *i.e.,* (absolute control), where fertilizers and organic matter was not applied. The application of RDF in two splits and three splits with or without application of zinc and boron noted the increase in protein over absolute control (T_1). The significant increase in protein in fruit with the application of NPK (from treatment T_2 to T_5) could be attributed to increasing availability of nutrients from organic matter that after decomposition release macro and micro-nutrients to soil solution, besides the direct addition of nitrogen through fertilizer to the available pool of the soil; which becomes available to the plants, resulting in higher uptake.

The application of 3 kg NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June *i.e.*, treatment T_5, recorded the highest content of protein (1.27%) and found to be at par with the treatments T_3 (1.15%), T_4 (1.12%) and T_2 (1.01%). The reason for higher protein content might be due to increased activity of nitrate reductase enzyme. Higher nitrogen in fruit is directly responsible for higher protein because it is a primary component of amino acids which constitute the basis of protein. The influence of applied nitrogen and phosphorus, the availability of these nutrients in soil increased and consequently resulted to higher uptake by plants. Moreover, phosphorus being an energy source also plays an important role in protein synthesis Meena *et al.* (2006).

Table 14. Quality parameters of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	Protein (%)	T.S.S. (°B)	Titratable acidity (%)	Reducing sugar (%)	Total sugar (%)
T_1	Absolute control	0.69	22.80	0.128	11.97	14.49
T_2	3 kg NPK in two splits	**1.01**	24.08	**0.119**	**12.62**	**16.95**
T_3	3 kg NPK in two + Zn & B	**1.15**	**25.33**	0.115	**13.04**	**17.49**
T_4	3 kg NPK in three splits	**1.12**	**24.85**	**0.117**	**12.72**	**17.57**
T_5	3 kg NPK in three splits + Zn & B	1.27	25.75	0.110	13.10	18.05
	S.E.	0.12	0.35	0.0037	0.15	0.35
	C.D. at 5%	0.36	1.07	0.01	0.47	1.06

4.3.2 Total Soluble Solids (°B)

The effect application of NPK in two or three splits with or without Zn + B significantly affected the total soluble solids (T.S.S.) of sapota (Table 14), which varied from 22.80 to 25.75 °B.

The minimum total soluble solid 22.80 °B was observed in T_1 *i.e.*, (absolute control), where fertilizers and organic matter was not applied. The application of RDF in two splits and three splits with or without application of zinc and boron noted the increase in total soluble solid over absolute control (T_1).

The highest total soluble solid 25.75°B was recorded in treatment T_5 *i.e.*, 3 kg NPK in three splits + Zn & B, which was found statistically at par with the treatments T_3 (25.33°B) and T_4 (24.85°B). The increase in TSS may be due to combination of nutrients that enhanced the conversion of complex polysaccharides into simple sugar through translocation of sugars from leaves to developing fruits as reported by Jadhav (2018).

Integrated application of vermicompost and inorganic fertilizers might have enhanced the absorption and translocation of various metabolites affecting fruit quality. At the same time vermicompost is rich source of micronutrients such as Zn, Mn, Bo and Cu which play an important role in balanced nutrition and ultimately improve the fruit quality Gupta (2003). Mehraj *et al.* (2014) reported that availability of micronutrients through vermicompost increased sweetness along with other chemical characters in strawberry. Hebbarai *et al.* (2006) in sapota, Yadav *et al.* (2011) in mango, Ghosh *et al.* (2012) in pomegranate, Pawar *et al.* (2014) in acid lime and Khachi *et al*. (2015) in kiwifruit also reported positive impact on TSS of vermicompost supplied trees. And the results are in accordance in with Mitra and Bose (1985) in guava, Kumar *et al*. (1996) in guava and Singh *et al*. (2001) in sapota.

4.3.3 Titratable acidity (%)

The titratable acidity of sapota varied from 0.110 to 0.128 % as a result of significantly influenced by split application of NPK with or without Zn + B (Table 14).

The treatment T_1 *i.e.*, absolute control, where organic manure and fertilizers were not applied, recorded the highest titratable acidity of 0.128%. The titratable acidity declined with the application of RDF either in two or three splits with or without Zn and B in treatment T_2, T_3, T_4 and T_5, thereby indicating the role of nutrients in decreasing the titratable acidity of fruit. The lowest titratable acidity (0.110 %) was obtained in the treatment T_5 *i.e.*, 3 kg NPK in three splits + Zn & B, which was followed by treatment T_3 (0.115%), T_4 (0.117%) and T_2 (0.119%).

Results obtained are in accordance with the results of earlier workers Mitra and Bose (1985) in guava, Singh *et al.* (2001) in sapota and Kumar *et al.* (1996) in guava. Superior quality fruits with respect to TSS, total sugar and reduced acidity might be due to the increased levels of nitrogen and potassium which improves nutrient absorption and carbohydrate synthesis. The accumulation of these soluble solids improves the quality of fruits (Sanadgol 1991; Carpenter 1981). The crucial importance of potassium in quality formation stems from its role in promoting synthesis of photosynthates and their transport to fruits and storage organs and to enhance their conversion into starch, protein, vitamins, oil etc. (Mengel and Kirkby 1987).

4.3.4 Reducing sugar (%)

The reducing sugar content varied from 11.97 to 13.10 % as it was significantly affected by split application of NPK with or without Zn + B (Table 14).

The minimum reducing sugar 11.97% was observed in T_1 *i.e.*, (absolute control), where fertilizers and organic matter was not applied. The application of RDF in two splits and three splits with or without application of zinc and boron noted the increase in reducing sugar content over absolute control (T_1). The maximum reducing sugars content 13.10%was recorded in treatment T_5 *i.e.*, (3 kg NPK in three splits + Zn & B) but it was at par with the treatment T_2 (12.62%), T_3 (13.04%) and T_4 (12.72%).

The steady and gradual release of nutrients from vermicompost during the growth period might have been better in the treatment T_5 which contribute to a higher C:N ratio that led to increased synthesis of carbohydrates due to enhanced plant metabolism. The findings are in conformities with the results reported by Patel and Naik (2010) in sapota.

4.3.5 Total sugar (%)

The total sugar varied from 14.49 to 18.05 % as significantly affected by split application of NPK with or without Zn + B (Table 14).

The minimum total sugar 14.49 % was observed in T_1 *i.e.,* (absolute control), where fertilizers and organic matter was not applied. The application of RDF in two splits and three splits with or without application of zinc and boron noted the increase in reducing sugar content over absolute control (T_1). Amongst the different treatments, extreme total sugar 18.05% was found with the application of 3 kg NPK in three splits + Zn & B along with vermicompost (*i.e.,* treatment T_5) and was found to be at par to treatment T_2 (16.95%), T_3 (17.49%) and T_4 (17.57%).

According to Giraddi (1993) addition of vermicompost in soil increase the density of microbes and provides essential macro (N, P, K, Ca, Mg) and micro nutrients (Fe, Cu, Mo, Zn). The faster mobilization of nitrogen from vermicompost and inorganic sources in T_5 might have increased the synthesis of assimilates due to enhanced rate of photosynthesis and thereby increasing the rate of translocation of photosynthetic products from leaves to developing fruits which ultimately increased the total sugars content. Similar results have also been reported by Barne *et al.* (2011) in sapota.

4.4 : Effect of split application of NPK with or without Zn and B on leaf nutrient content of sapota

In order to avoid any yield loss, nutrient requirements have to be carefully monitored through soil or leaf analysis for nutrient management strategies. Leaf analysis is considered a more direct method of plant nutritional status evaluation than soil analysis especially for fruit crops (Hallmark and Beverly 1991) as they differ from seasonal crops in their nutrients requirement due to their size, population density, rate of growth and rooting pattern. Savita *et al.* (2013) surveyed 106 sapota orchards in sapota growing districts of Raichur, Dharwad and Belgaum districts/northern Karnataka and studied soil and plant nutritional status of sapota in order to identify the nutrients that are deficient/low and to formulate optimum nutrient ranges and then the ranges developed served as a guide for routine diagnostic and advisory purpose of nutrient status of the orchards of Northern Karnataka.

4.4.1 Leaf Nitrogen (%)

The nitrogen content of leaves of sapota as affected by split application of NPK with and without Zn + B under lateritic soils of Konkan indicated that its content varied from 1.25 to 1.29 % at vegetative flush stage, 1.30 to 1.74 % at flowering stage and 1.27 to 1.63% at harvest stage (Table 15).

As per the leaf nutrient content serving as a guide for routine diagnostic and advisory purpose of nutrient status of sapota orchards developed by Savita *et al.* (2013), the N concentration ranged from 1.36 to 2.31% with a mean value of 1.79%. The optimum N leaf nutrient concentration ranged from 1.51 to 2.09%. The leaf N content less than 1.22% and more than 2.37% was considered as deficient and excess, respectively.

In the present investigation, the leaf N content ranged within 1.25 to 1.29% at vegetative flush stage. This range of leaf N content was close to deficient (*i.e.,* less than 1.22%) as per the formulated guideline of Savita *et al.* (2013). This non-significant leaf N status at vegetative flush stage was due to the leaf sampling done in the month of June prior to the split application of 3 kg NPK with vermicompost @ 50 kg tree^{-1} with or without Zn + B. But, the significant difference in leaf N content was observed at flowering stage and at harvest stage. At flowering stage, the leaf N content reached the optimum range in the respective treatments *i.e.*, T_2, T_3, T_4 and T_5 due to split application of fertilizers at vegetative flush stage in the month of June over the absolute control.

Table 15. Leaf nitrogen (%) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	1.26	1.30	1.27
T_2	3 kg NPK in two splits	1.25	1.67	1.32
T_3	3 kg NPK in two splits + Zn & B	1.27	1.70	1.36
T_4	3 kg NPK in three splits	1.26	1.72	1.61
T_5	3 kg NPK in three splits + Zn & B	1.29	1.74	1.63
	S.E.	0.03	0.04	0.10
	C.D. at 5%	N.S.	0.137	0.309

The treatment T_1 (*i.e.*, absolute control) recorded the significantly lowest values of nitrogen content of leaf (1.30 % at flowering stage and 1.27 % at harvest), where fertilizers and organic matter was not applied.

Significantly highest total nitrogen (%) content was recorded with three split applications of NPK with Zn + B (treatment T_5) with the values of 1.74 % at flowering stage and 1.63% at harvest stage, which was found to be at par with T_2, T_3 and T_4 at both flowering stage and at harvest stage. The enhanced N contents in leaf under N application might be due to easy availability of the essential nutrient from the soil-applied inorganic fertilizer and their unhindered distribution to the foliage might have resulted in the higher uptake of these nutrients.

The increase in N content in plant in the present investigation under 33 years old orchard in lateritic soils of Konkan could be also attributed to increasing availability of nutrients from leaf litter that the leaf litter after decomposition release macro and micro-nutrients to soil solution, besides the direct addition of nitrogen through fertilizer to the available pool of the soil; which becomes available to the plants, resulting in higher uptake.

In this context, Shah Jahan Leghari *et al*. (2016) explained that plants consist of three principal organs, roots, stem and leaves. Nitrogen is primarily absorbed from roots and leaves. Further, process of photosynthesis also occurs in leaves. They also involve in nitrogen (N) assimilation by reduction of NO_3 and NH_4 into amino acids which are building block of proteins. Third major organ of plants is stem that connects roots and leaves and encourages shoot. Plant has two physiological pathways for transportation of energy, xylem (vessels) and the phloem (tubes). Soil applied N (nutrient) are move from the roots to leaves in the process of xylem (drink to up) after absorption of roots, while foliar applied N are transported from leaves to roots by the process of phloem (living cells). Moreover, Aulakh and Malhi (2005) noted that temperature increased the N concentration in plants primarily by enhancing their uptake rate per unit of root rather than increasing the rate of root growth.

Application of vermicompost along with inorganic fertilizers significantly increased the amount of available N in the soil due to the mineralization of nitrogen from vermicompost resulting in its better absorption. Besides, two and three split doses of N through fertilizers were coupled with vermicompost which might also have played a part in increasing leaf nitrogen content. The significant effect of vermicompost application along with inorganic fertilizers has also been reported by Meena *et al*. (2013) and Sharma *et al*. (2013) in guava and Khachi *et al*. (2015) in kiwifruit, and Bhattarai and Tomar (2009) in walnut.

4.4.2 Leaf Phosphorous (%)

The effect of split application of NPK with and without Zn + B in lateritic soils of Konkan specified that total phosphorous (%) content wide-ranging from 0.09 to 0.11 % at vegetative flush stage, 0.11 to 0.27 % at flowering stage and 0.11 to 0.19 % at harvest stage (Table 16).

As per the leaf nutrient ranges serving as a guide for routine diagnostic and advisory purpose of nutrient status of sapota orchards developed by Savita *et al.* (2013), the P concentration ranged from 0.064 to 0.229% with a mean value of 0.109%. The optimum P leaf nutrient concentration ranged from 0.061 to 0.150 %. The leaf P content less than 0.008 % and more than 0.21 % was considered as deficient and excess, respectively.

Table 16. Leaf phosphorous (%) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	0.09	0.11	0.11
T_2	3 kg NPK in two splits	0.10	0.22	0.14
T_3	3 kg NPK in two splits + Zn & B	0.11	0.23	0.15
T_4	3 kg NPK in three splits	0.10	0.25	0.17
T_5	3 kg NPK in three splits + Zn & B	0.09	0.27	0.19
	S.E.	0.01	0.02	0.02
	C.D. at 5%	N.S.	0.05	0.05

In the present investigation, the leaf P content ranged within 0.09 to 0.10 % at vegetative flush stage. This range of leaf P content was optimum (0.061 to 0.150 %) as per the formulated guideline given by Savita *et al.* (2013). The non-significant leaf P status at vegetative flush stage was due to the leaf sampling done in the month of June prior to the split application of 3 kg NPK with vermicompost @ 50 kg tree^{-1} with or without Zn + B. However, the significant difference in leaf P content was observed at flowering stage and at harvest stage. At flowering stage, the leaf P content reached the high range in T_2, T_3, T_4 and T_5 treatments due to split application of fertilizers at vegetative flush stage in the month of June over the absolute control.

No application of fertilizers or vermicompost (*i.e.*, absolute control) recorded the lowest total phosphorous (%) in leaf *i.e.*, 0.09% at vegetative flush stage, 0.11% at flowering stage and 0.11% at harvest. The application of 3 kg NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June i.e., treatment T_5, recorded the highest content of phosphorous (%) in leaf *i.e.*, 0.27% at flowering stage and 0.19% at harvest and was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest.

It was observed from the data that the total phosphorous (%) in leaf increased at flowering stage over vegetative growth stage in all treatments with the exception of absolute control (T_1), while decrease in all treatments at harvest exception of absolute control (T_1).

The enhanced P contents in leaf under split application of NPK with and without Zn + B under lateritic soils of Konkan over control might be due to increase the availability of these essential nutrients from the soil-applied organic and inorganic fertilizer and their unhindered distribution to the foliage might have resulted in the higher uptake of these nutrients.

The maximum phosphorous was recorded at flowering stage. This might be due to the fact that vermicompost is a rich source of soil microorganisms which helped in the solubilization of fixes P to soluble form as a result of reaction of organic acids produced after decomposition of vermicompost. Thus, the availability of soil phosphorous increased in the root rhizosphere which was absorbed by the plants and this process might have occurred at higher rate (Bora 2016). The results are accordance with the findings of Bhattarai and Tomar (2009) in walnut, Das *et al*. (2015) in guava and Kundu *et al*. (2015) in Ber. The higher P content in leaf intensified the leaf protein synthesis at the start of growth, but high nitrogen content enhanced it throughout the growth period by direct participation as an ingredient of protein. (Patnaik and Farooqui, 1964).

In general, the total phosphorus content in leaves appear to decrease from flowering stage to harvest stage. This decrease may be due to uptake of native phosphorus translocated for metabolic activities.

4.4.3 Leaf Potassium (%)

The potassium content of sapota leaves as affected by split application of NPK with and without Zn + B under lateritic soils of Konkan indicated that its content varied from 1.03 to 1.11 % at vegetative flush stage, 1.16 to 1.54 % at flowering stage and 1.14 to 1.26 % at harvest stage (Table 17).

As per the leaf nutrient ranges serving as a guide for routine diagnostic and advisory purpose of nutrient status of sapota orchards developed by Savita *et al.* (2013). The K concentration ranged from 0.65 to 1.55 % with a mean value of 0.99%. The optimum K leaf nutrient concentration ranged from 0.83 to 1.44 %. The leaf K content less than 0.51% and more than 1.82 % was considered as deficient and excess, respectively.

In the present investigation, the leaf K content ranged within 1.03 to 1.11 % at vegetative flush stage. This range of leaf K content was optimum (0.83 to 1.44 %) as per the formulated guideline of Savita *et al*. (2013). The non-significant leaf K status at vegetative flush stage was due to the leaf sampling done in the month of June prior to the split application of 3 kg NPK with vermicompost @ 50 kg tree^{-1} with or without Zn + B. However, the split application of fertilizers at vegetative flush stage in the month of June showed the significant difference in leaf K content was observed at flowering stage and at harvest stage. At flowering stage, the leaf K content reached the high range in T_2, T_3, T_4 and T_5 treatments due to split application of fertilizers at vegetative flush stage in the month of June over the absolute control.

The lowest values of potassium content (%) of sapota leaves 1.03% at vegetative flush stage in the treatment T_3, 1.16% at flowering stage and 1.14% at harvest were reported in the treatment T_1 (*i.e.,* absolute control). The application of treatment T_5 *i.e.,* 3 kg NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June were recorded the highest potassium (%) content of sapota leaves *i.e.,* 1.54 % at flowering stage and 1.26% at harvest and was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest. The higher potassium (%) content of sapota leaves under treatment T_5 might be due to higher conversion of exchangeable K to soluble K forms in the soil Bhasker *et al*. (1992).

The enhanced K contents in leaf under application of NPK in two or three splits with Zn + B over control might be due to increase in availability of this essential nutrients from the soil-applied inorganic fertilizer and their unhindered distribution to the foliage might have resulted in the higher uptake of these nutrients.

Table 17. Leaf Potassium (%) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	1.11	1.16	1.14
T_2	3 kg NPK in two splits	1.05	1.48	1.21
T_3	3 kg NPK in two splits + Zn & B	1.13	1.52	1.25
T_4	3 kg NPK in three splits	1.03	1.50	1.22
T_5	3 kg NPK in three splits + Zn & B	1.09	1.54	1.26
	S.E.	0.05	0.04	0.03
	C.D. at 5%	N.S.	0.13	0.08

It was seen from the data that potassium content (%) in sapota leaves slight increase at flowering stage over vegetative flush stage, but decreased thereafter at harvest. Further, the increase in leaf potassium content could be attributed to the decomposition and liberation of potassium as organic matter content into the soil leading to better potassium uptake thereby adding leaf potassium content. Increase in potassium uptake might be also due to better utilization of applied inorganic fertilizers.

Plants can absorb N either in cationic (NH_4^+) or in anionic (NO_3^-) form. There is a unique possibility of anion-cation as well as cation-cation interactions with K^+. Most of the findings have illustrated that K^+ does not compete with NH_4^+ for uptake, rather it increases NH_4^+ assimilation in the plants.

The combined application of vermicompost and inorganic fertilizers might have increased its availability and resulted in better plant uptake. Increase in leaf potassium content by integrating vermicompost in nutrient management programs has also been reported by Singh *et al*. (2003) in sapota, Das *et al*. (2015) in guava and Khachi *et al*. (2015) in kiwifruit.

4.4.4 Leaf Zinc (mg kg^{-1})

The effect application of NPK in two or three splits with or without Zn + B significantly affected the Zn content in leaves of sapota at different growth stages such as at flowering stage and at harvest stage however non-significant effect at vegetative flush stage. The Zn content in leaves of sapota diverse from 13.91 to 14.98 mg kg^{-1} at vegetative flush stage, 15.70 to 26.15 mg kg^{-1} at flowering stage and 15.00 to 24.15 mg kg^{-1} at harvest stage (Table 18) indicating thereby that Zn content in sapota leaves increased from vegetative flush stage to flowering stage and thereafter decreasing at harvest.

Table 18. Leaf zinc (mg kg^{-1}) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	14.70	15.70	15.00
T_2	3 kg NPK in two splits	14.67	18.63	16.60
T_3	3 kg NPK in two splits + Zn & B	14.98	25.19	23.21
T_4	3 kg NPK in three splits	13.91	19.12	17.09
T_5	3 kg NPK in three splits + Zn & B	14.94	26.15	24.15
	S.E.	2.06	1.56	1.44
	C.D. at 5%	N.S.	4.81	4.44

As per the leaf nutrient ranges serving as a guide for routine diagnostic and advisory purpose of nutrient status of sapota orchards developed by Savita *et al.* (2013), the Zn concentration ranged from 10.0 to 43.0 mg kg^{-1} with a mean value of 17.1 mg kg^{-1}. The optimum Zn leaf nutrient concentration ranged from 13.3 to 21.9 mg kg^{-1}. The leaf Zn content less than 9.0 mg kg^{-1} and more than 26.2 mg kg^{-1} was considered as deficient and excess, respectively.

In the present investigation, the leaf Zn content ranged within 13.91 to 14.98 mg kg^{-1} at vegetative flush stage. This range of leaf Zn content was on the higher edge of low 9.1 to13.2mg kg^{-1} and lower edge of optimum 13.3 to 21.9 mg kg^{-1} as per the formulated guideline of Savita *et al.* (2013). The non-significant leaf Zn status at vegetative flush stage was due to the leaf sampling done in the month of June prior to the split application of 3 kg NPK with vermicompost @ 50 kg tree^{-1} with or without Zn + B. However, the split application of fertilizers at vegetative flush stage in the month of June showed the significant difference in leaf Zn content was observed at flowering stage and at harvest stage. At flowering stage, the leaf Zn content reached the high range in the respective treatments *i.e.*, T_2, T_3, T_4 and T_5 due to split application of fertilizers in the month of June over the absolute control.

The lowest values of Zn content in leaves of sapota 14.67 mg kg^{-1} at vegetative flush stage in the treatment T_2, 15.70 mg kg^{-1} at flowering stage and 15.00 mg kg^{-1}at harvest were reported in the treatment T_1 (*i.e.*, absolute control), where fertilizers and organic matter was not applied. The application of RDF alone in two splits (T_2) and three splits (T_4) without application of zinc noted the increase in Zn content in leaves over absolute control (T_1) at flowering stage and harvest stage. This shows that for maximum utilization of native soil Zn, the presence of adequate amount of N is essential (Aulakh and Malhi, 2005). In this connection, Tisdale *et al*. (1995) clarified that application of N fertilizer can stimulate plant growth and increase Zn requirements. Further, acid forming N fertilizers will increase the uptake of Zn. In this context, Tisdale *et al*. (1995) cleared that increasing soil temperature increases the availability of Zn to crops by increasing solubility and diffusion of Zn^+.

Close scrutiny of the data indicated that split application of RDF alone enhanced the leaf Zn content in treatment T_2 and T_4 without being applied with zinc fertilizer. Increase in Zn content in plants with the application of nitrogen thereby indicating the positive relationship between Zn and N. Diwale (1994) and Khobragade (1999) reported the positive relationship between Zn and N in lateritic soils of Konkan.

Significantly highest Zn content in leaves of sapota was recorded with three split applications of NPK with Zn + B (treatment T_5) with the values of 26.15 mg kg^{-1} at flowering stage and 24.15 mg kg^{-1} at harvest stage, which was found to be at par with T_3 at flowering stage and at harvest stage. The remaining treatments were at par with each other. The increase in Zn concentration with the application of Zn may be attributed to its enhanced supply through $ZnSO_4$ added externally. One of the reasons that it is a well-known fact that external addition of nutrients certainly increases the leaf nutrient status of the plant.

The reason behind increase in zinc content in sapota leaves at flowering stage might be due to incorporation of vermicompost with NPK in optimum amount. This might have improved soil microbial population and enzymatic activities especially dehydrogenase and hydrolase Chaudhary *et al*. (2004) which in turn led to higher availability of zinc in plants. Bhattarai and Tomar (2009) in walnut, Beer and Singh (2015) in strawberry and also observed that zinc availability was improved in integrated nutrient management when vermicompost was incorporated as one of the components.

4.4.5 Leaf Boron ((mg kg^{-1})

The total boron content in leaves of sapota diverse from 29.05 to 30.61 (mg kg^{-1}) at vegetative flush stage, 33.68 to 59.61 mg kg^{-1} at flowering stage and 32.81 to 61.51 mg kg^{-1} at harvest stage (Table 19) indicating thereby that B content in sapota leaves increased from vegetative flush stage to harvest stage. Boron is relatively immobile in plants and frequently the B content increase from the lower to the upper plant parts (Wilkinson, 1957).

Table 19. Leaf boron (mg kg^{-1}) at different growth stages of sapota as influenced by split application of NPK with or without Zn and B

Treat Code	Treatment	At vegetative flush stage	At flowering stage	At harvest
T_1	Absolute control	30.31	33.68	32.81
T_2	3 kg NPK in two splits	29.11	40.86	55.28
T_3	3 kg NPK in two splits + Zn & B	29.05	58.05	61.51
T_4	3 kg NPK in three splits	30.58	42.83	59.02
T_5	3 kg NPK in three splits + Zn & B	30.61	59.61	63.59
	S.E.	1.77	2.16	6.53
	C.D. at 5%	N.S.	6.67	20.14

As per the leaf nutrient ranges serving as a guide for routine diagnostic and advisory purpose of nutrient status of sapota orchards developed by Savita *et al.* (2013), the B concentration ranged from 21.6 to 82.7 mg kg^{-1} with a mean value of 48.8 mg kg^{-1}. The optimum B leaf nutrient concentration ranged from 34.8 to 66.8 %. The leaf B content less than 18.7 mg kg^{-1} and more than 82.9 mg kg^{-1} was considered as deficient and excess, respectively.

In the present investigation, the leaf B content ranged within 29.05 to 30.61 mg kg^{-1} at vegetative flush stage. This range of leaf B content was found to be low (*i.e.* 18.7 to 34.7 mg kg^{-1}) as per the guideline of Savita *et al.* (2013). The non-significant leaf B status at vegetative flush stage was due to the leaf sampling done in the month of June prior to the split application of 3 kg NPK with vermicompost @ 50 kg tree^{-1} with or without Zn + B. However, the split application of fertilizers at vegetative flush stage in the month of June showed the significant difference in leaf B content was observed at flowering stage and at harvest stage. At flowering stage, the leaf B content reached the optimum range in the respective treatments *i.e.*, T_2, T_3, T_4 and T_5 due to split application of fertilizers at vegetative flush stage in the month of June over the absolute control.

The lowest values of B content in leaves of sapota 30.31 mg kg^{-1} at vegetative flush stage in the treatment T_2, 33.68 mg kg^{-1} at flowering stage and 32.81 mg kg^{-1} at harvest were reported in the treatment T_1 (*i.e.,* absolute control), where fertilizers and organic matter was not applied. The application of RDF alone in two splits (T_2) and three splits (T_4) without application of boron noted the increase in boron content in leaves over absolute control (T_1) at flowering stage and harvest stage. This signifies the role of organic matter in the availability of boron content in soil. Das (2007) explained that organic matter forms a complex with B and it is one of the main sources of boron in acid soils. Application of organic materials to soils can raise substantially the concentration of boron in plants.

The application of 3 kg NPK in three splits with $ZnSO_4$ + Borax (treatment T_5) recorded the significantly highest content of boron in leaf *i.e.* 59.61mg kg^{-1} at flowering stage and 63.59 mg kg^{-1} at harvest, which was followed by application of 3 kg NPK in two splits with $ZnSO_4$ + Borax (treatment T_3) 58.05 mg kg^{-1} at flowering stage and 61.51 mg kg^{-1} at harvest. The increase in B concentration with the application of B may be attributed to its enhanced supply through Borax added externally. However, the treatments T_5 and T_3 were at par at flowering stage and at harvest.

Close scrutiny of the data indicated that split application of RDF alone enhanced the leaf B content in treatment T_2 and T_4 without being applied with boron fertilizer (borax). In this connection, Ying Long and Jiashi Peng (2023) explained that the influences of B on N absorption and distribution vary with the N source. Ammonium salt and nitrate are two vital inorganic N sources. Plants excrete protons while absorbing ammonium salt, leading to reduced pH in the rhizosphere, and B mainly exists in the form of $B(OH)_3$ in the rhizosphere soil. The pH in the rhizosphere is increased when plants absorb nitrate, and B in the rhizosphere soil is mainly converted to $B(OH)_4^-$. If B is abundant enough in the environment, B is mostly absorbed by plants via the free diffusion of boric acid. Hence, plants have lower B absorption when nitrate serves as the N source than when ammonium salt is the N source.

In addition, B absorption by B. napus has been found to be promoted by an appropriate amount of P, probably because (1) P can promote water absorption by plants and boost their growth and transpiration, and B absorption can be enhanced by the improvement of these physiological processes; and (2) P can influence the biochemical characteristics of plant rhizosphere, and hence raise the B availability in soil. In tobacco, K can promote the accumulation of B, which is more significant under a high concentration of B (Ying Long and Jiashi Peng 2023). A synergistic interaction between Zn and B in Brassica nigra under extreme B deficiency has been also reported by Sinha, *et al.* (2000).

Boron concentration in the soil solution is controlled by B adsorption reactions. These reactions restrict the amount of water-soluble B available for plant uptake, because plants respond directly to the B concentration in soil solution and only indirectly to the amount of B attached to soil surfaces. Thus, the soil adsorption complex acts as both a source and a sink for dissolved B (Keren and Bingham, 1985).

In sand culture studies, Mozafar (1989) reported that with increasing B levels the concentration of plant nutrients were changed in the leaves as well as in the roots of maize plants. While, in soil studies, Miller and Smith (1977) reported that applied B did not consistently affect the concentration of elements in tips, upper and lower leaves, upper and lower stem of alfalfa plants. It is clear from the reported conflicting statements of the investigators, that B effects on the behavior of nutrients vary depending on crop species or genotypes, plant part analyzed, various growth stages and the use of different types of growth media.

The enhanced B contents in leaf under application of NPK in two or three splits with Zn + B over control might be due to easy availability of these nutrients from the soil-applied inorganic fertilizer and their unhindered distribution to the foliage might have resulted in the higher uptake of these nutrients.

Thus, in the present investigation, leaf nutrient content at vegetative growth stage before the application of manure and fertilizers found to be deficient in case of nitrogen content, optimum in case of phosphorus and potassium content, near to low in case of zinc and low in case of boron content as per the guidelines of Savita *et al.* (2013) for sapota. Two or three split application of RDF with and without Zn + B enhanced the leaf nutrients content and reached the level of optimum in case of nitrogen and boron content while high in case of phosphorus, potassium and zinc content in leaves. This enhancement in leaf nutrient content due to split application of fertilizers supposed to be necessary for evolving nutrient management strategies for realizing high yield, where the optimum ranges developed to serve as a guide for a quick, routine diagnostic and advisory purpose of nutrient status of the sapota orchards by Savita *et al.* (2013). In order to avoid any yield loss, its nutrient requirements have to be carefully monitored through soil or leaf analysis for evolving nutrient management strategies.

Summary and Conclusions

CHAPTER V

SUMMARY AND CONCLUSION

In the present study, an effort has been made to study the impact of split application of NPK along with basal dose of Zn and B on soil properties, yield and quality of sapota (*Manilkara achras* (Mill.) Forsbergin) in lateritic soils of the Konkan. The research trial was conducted at Nursery No.10, Department of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri during June 2022 to May 2023 and it was laid out in Randomized Block Design comprising five treatments. RDF @ 3:3:3 kg NPK per tree was applied in two or three splits along with basal application of vermicompost @ 50 kg per tree and $ZnSO_4$ @ 50 g per tree + Borax @ 25g per tree in June in corresponding treatments (except absolute control T_1) by ring method to the depth of 25-30 cm. Nitrogen, phosphorus, potassium, zinc and boron were applied through urea, single super phosphate, muriate of potash, zinc sulphate and borax, respectively.

Considering two trees per treatment, a total of 40 uniform sapota trees of the variety Kalipatti were selected from the thirty-three years old sapota orchard. Soil and plant samples collected at vegetative stage, flowering stage, and harvest stage were analysed for different chemical parameters and analytical values obtained during the course of study were analysed statistically using methods outlined by Panse and Sukhatme (1985).

In the present investigation, all the parameters showed non-significant result at vegetative flush stage as soil and leaf sampling were done in the month of June before the split application of 3 kg NPK each with vermicompost @ 50 kg $tree^{-1}$ with or without Zn + B in the respective treatments. However, the significant effect of split application of fertilizers were observed at flowering stage and at harvest stage.

The major facts that emerged from the present research are given below:

5.1 : Effect of split application of NPK with or without Zn and B on soil properties

By and large, no application of fertilizers and vermicompost (treatment T_1 *i.e.,* absolute control) recorded the lowest values of soil parameter or nutrient content in the soil. But, the application of vermicompost and fertilizers in two or three splits (from treatment T_2 to T_5) significantly increased the soil parameter or nutrient content in the soil over the absolute control.

5.1.1 Soil pH

The soil pH determined periodically at vegetative flush, at flowering and at harvest indicated that it varied from 5.07 to 5.19, 5.18 to 5.46 and 5.31 to 5.61, respectively and increased from vegetative flush stage to harvest stage irrespective of the treatments.

The significantly highest pH *i.e.*, 5.46 at flowering stage and 5.61 at harvest were noted with treatment T_5 where 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ + Borax in June, which was found to be at par with the treatments T_2, T_3 and T_4 during both observational stages.

5.1.2 Electrical conductivity

The electrical conductivity of the soil ranged from 0.18 to 0.22 dS m^{-1} at vegetative flush stage, 0.16 to 0.27dS m^{-1} at flowering stage and 0.16 to 0.24 dS m^{-1} at harvest.

The application of 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ + Borax in June (treatment T_5) recorded the significantly highest EC *i.e.*, 0.27 dS m^{-1} at flowering stage and 0.24 dS m^{-1} at harvest. But, treatment T_5 was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage, while with the treatments T_3 and T_4 at harvest.

5.1.3 Organic carbon

The organic carbon content in the soil ranges from 31.45 to 34.40 g kg^{-1} at vegetative flush stage, 35.38 to 44.90 g kg^{-1} at flowering stage and 29.85 to 38.20 g kg^{-1} at harvest.

The significantly highest organic carbon *i.e.*, 44.90 g kg^{-1} at flowering stage and 38.20 g kg^{-1} at harvest were noted with the application of 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ + Borax in June (treatment T_5) and was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest.

5.1.4 Available Nitrogen

The periodic observations of available nitrogen in soil showed that its content varied from 282.01 to 309.46 kg ha^{-1} at vegetative flush stage, 275.76 to 377.21 kg ha^{-1} at flowering stage and 280.76 to 397.84 kg ha^{-1} at harvest.

The application of 3 kg each NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June (treatment T_5) recorded the significantly highest nitrogen content in soil (377.21 kg ha^{-1} at flowering stage and 397.84 kg ha^{-1} at harvest) and was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest.

5.1.5 Available Phosphorus

As an influence of split application of NPK with and without Zn + B under lateritic soils of Konkan, the available phosphorus oscillated from 5.62 to 6.06 kg ha^{-1} at vegetative flush stage, 5.74 to 7.99 kg ha^{-1} at flowering stage and 5.49 to 7.74 kg ha^{-1} at harvest.

The application of treatment T_5 *i.e.*, 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ + Borax in June were recorded the highest phosphorus content in soil *i.e.*, 7.99 kg ha^{-1} at flowering stage and 7.74 kg ha^{-1} at harvest and was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest.

5.1.6 Available Potassium

The available potassium, which gone around 582.51 to 600.22 kg ha^{-1} at vegetative flush stage, 608.11 to 872.32 kg ha^{-1} at flowering stage and 598.11 to 887.32 kg ha^{-1} at harvest.

The application 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ + Borax in June (treatment T_5) recorded the significantly highest potassium content in soil *i.e.*, 872.32 kg ha^{-1} at flowering stage and 887.32 kg ha^{-1} at harvest and was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest.

5.1.7 DTPA Extractable Zinc

DTPA extractable zinc (mg kg^{-1}) varies from 1.12 to 1.17 mg kg^{-1} at vegetative flush stage, 1.17 to 2.09 mg kg^{-1} at flowering stage and 1.20 to 1.82 mg kg^{-1} at harvest stage.

Significantly highest DTPA extractable Zn was recorded with three split applications of NPK each with Zn + B (treatment T_5) with the values of 2.09 mg kg^{-1} at flowering stage and 1.82 mg kg^{-1} at harvest stage, which was found to be at par with T_2, T_3 and T_4 at flowering stage and T_3 at harvest stage.

5.1.8 Available Boron

Available boron differs from 0.20 to 0.25 mg kg^{-1} at vegetative flush stage, 0.22 to 0.47 mg kg^{-1} at flowering stage and 0.20 to 0.38 mg kg^{-1} at harvest stage.

Significantly highest available boron was recorded with three split applications of NPK each with Zn + B (treatment T_5) with the values of 0.47 mg kg^{-1} at flowering stage and 0.38 mg kg^{-1} at harvest stage, which was found to be at par with T_3 at flowering stage and T_2, T_3 and T_4 at harvest stage.

5.2 : Effect of split application of NPK with or without Zn and B on yield of sapota

5.2.1 Yield (kg per tree)

The fruit yield kg per tree differs from 20.63 to 46.02 kg per tree. The lowest values of fruit yield 20.63 kg per tree was reported in the treatment T_1 (*i.e.*, absolute control).

The significantly highest fruit yield (46.02 kg/tree) was obtained with the application of treatment T_5 *i.e.*, (3 kg NPK in three splits + Zn & B), which was significantly superior over rest of the treatments and followed by the treatment T_4 (38.45 kg/tree), T_3 (36.33 kg/tree) and T_2 (33.44 kg/tree).

5.2.2 Yield ton per hectare

The fruit yield ton per hectare differs from 1.32 to 2.95 t ha^{-1}.

The highest fruit yield (2.95 t ha^{-1}) was obtained with the application of treatment T_5 *i.e.*, (3 kg NPK in three splits + Zn & B), which was significantly superior over rest of the treatments and followed by the treatment T_4 (2.46 t ha^{-1}), T_3 (2.33 t ha^{-1}) and T_2 (2.14 t ha^{-1}). However, the lowest values of fruit yield 1.32 t ha^{-1} were reported in the treatment T_1 (*i.e.*, absolute control).

5.3 : Effect of split application of NPK with or without Zn and B on quality of sapota

By and large, no application of fertilizers and vermicompost (treatment T_1 *i.e.*, absolute control) recorded the lowest values in relation to quality of sapota with the exception of titratable acidity. But, the application of vermicompost and fertilizers in two or three splits (from treatment T_2 to T_5) significantly increased the quality parameter over the absolute control.

5.3.1 Protein

The various application of NPK in two or three splits with or without Zn + B influenced significantly the protein content in sapota which varies from 0.69 to 1.27 per cent.

The application of 3 kg each NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June *i.e.*, treatment T_5, recorded the highest content of protein (1.27%) and found to be at par with the treatments T_3 (1.15%), T_4 (1.12%) and T_2 (1.01%).

5.3.2 Total Soluble Solids

The total soluble solids (T.S.S.) of sapota varied from 22.80 to 25.75 °B. The highest total soluble solid (25.75°B) was recorded in treatment T_5 *i.e.,* 3 kg NPK in three splits + Zn & B, which was found statistically at par with the treatments T_3 (25.33°B) and T_4 (24.85°B).

5.3.3 Titratable acidity

The titratable acidity of sapota varied from 0.110 to 0.128 %. The lowest titratable acidity (0.110 %) was obtained in the treatment T_5 *i.e.,* 3 kg NPK in three splits + Zn & B, which was followed by treatment T_3 (0.115%), T_4 (0.117%) and T_2 (0.119%).

5.3.4 Reducing sugar

The reducing sugar content varied from 11.97 to 13.10 %. The maximum reducing sugars content (13.10%) was recorded in treatment T_5 *i.e.*, (3 kg NPK in three splits + Zn & B) and was at par with the treatment T_2 (12.65%), T_3 (13.04%) and T_4 (12.72%).

5.3.5 Total sugar

The total sugar varied from 14.49 to 18.05 %. The highest total sugar (18.05%) was found with the application of 3 kg NPK in three splits + Zn & B along with vermicompost (*i.e.*, treatment T_5) and was found to be at par to treatment T_2 (16.95%), T_3 (17.49%) and T_4 (17.57%).

5.4 : Effect of split application of NPK with or without Zn and B on leaf nutrient content of sapota

By and large, treatment T_1 *i.e.*, absolute control recorded the lowest values of leaf nutrient content with no application of fertilizers. The application of fertilizers in two or three splits (from treatment T_2 to T_5) significantly increased the leaf nutrient content over the absolute control.

5.4.1 Leaf Nitrogen

The nitrogen content of leaves of sapota content varied from 1.25 to 1.29 % at vegetative flush stage, 1.30 to 1.74 % at flowering stage and 1.27 to 1.63% at harvest stage.

Significantly highest total nitrogen (%) content was recorded with three split applications of NPK with Zn + B (treatment T_5) with the values of 1.74 % at flowering stage and 1.63% at harvest stage, which was found to be at par with $T_{2,}$ T_3 and T_4 at flowering stage and at harvest stage.

5.4.2 Leaf Phosphorous

Total phosphorous (%) content wide-ranging from 0.09 to 0.11 % at vegetative flush stage, 0.11 to 0.27 % at flowering stage and 0.11 to 0.19 % at harvest stage.

The application of 3 kg each NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June *i.e.*, treatment T_5, recorded the highest content of phosphorous (%) in leaf *i.e.*, 0.27% at flowering stage and 0.19% at harvest and was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest.

5.4.3 Leaf Potassium

The potassium content of sapota leaves varied from 1.03 to 1.11 % at vegetative flush stage, 1.16 to 1.54 % at flowering stage and 1.14 to 1.26 % at harvest stage.

The application of 3 kg NPK in three splits in June, September and January with $ZnSO_4$ + Borax in June (*i.e.*, treatment T_5) were recorded the highest potassium (%) content of sapota leaves *i.e.*, 1.54 % at flowering stage and 1.26% at harvest and was found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest.

5.4.4 Leaf Zinc

The Zn content in leaves of sapota diverse from 13.91 to 14.98 (mg kg^{-1}) at vegetative flush stage, 15.70 to 26.15 (mg kg^{-1}) at flowering stage and 15.00 to 24.15 (mg kg^{-1}) at harvest stage.

Significantly highest Zn content in leaves of sapota was recorded with three split applications of NPK with Zn + B (treatment T_5) with the values of 26.15 mg kg^{-1} at flowering stage and 24.15 mg kg^{-1} at harvest stage, which was found to be at par with T_3 at flowering stage and at harvest stage.

5.4.5 Leaf Boron

The total boron content in leaves of sapota diverse from 29.05 to 30.61 (mg kg^{-1}) at vegetative flush stage, 33.68 to 59.61 (mg kg^{-1}) at flowering stage and 32.81 to 61.51 (mg kg^{-1}) at harvest stage.

The application of 3 kg NPK in three splits with $ZnSO_4$ + Borax (treatment T_5) recorded the significantly highest content of boron in leaf at flowering stage 59.61(mg kg^{-1}) and at harvest 63.59(mg kg^{-1}), which was followed by application of 3 kg NPK in two splits with $ZnSO_4$ + Borax (treatment T_3) 58.05 (mg kg^{-1}) at flowering stage and 61.51 (mg kg^{-1} at harvest).

Thus, the leaf nutrient content at vegetative growth stage before the split application of fertilizers found to be deficient in case of nitrogen content, optimum in case of phosphorus and potassium content, while very close to low in case of zinc and low in case of boron content as per the formulated guideline of Savita *et al.* (2013) for sapota, which enhanced with the two or three split application of RDF with and without Zn + B and reached the level of optimum in case of nitrogen and boron content while high in case of phosphorus, potassium and zinc content in leaves.

Conclusion:

On the basis of data obtained from the present investigation, the following conclusions may be drawn **:**

- The application of 3 kg NPK each tree $^{-1}$ in three equal splits in the month of June, September and January along with 50 kg vermicompost and 50 g $ZnSO_4$ + 25 g Borax tree $^{-1}$ in June was found to be significantly superior for enhancing the yield and quality of sapota variety Kalipatti.
- Leaf nutrient content at vegetative growth stage before the application of manure and fertilizers found to be deficient in case of nitrogen content, optimum in case of

phosphorus and potassium content, near to low in case of zinc and low in case of boron content. Two or three split applications of RDF with and without Zn + B enhanced the leaf nutrients content and reached the level of optimum in case of nitrogen and boron content while high in case of phosphorus, potassium and zinc content in leaves, where application of 3 kg NPK each tree $^{-1}$ in three equal splits in June, September and January with 50 kg vermicompost and 50 g $ZnSO_4$ + 25 g Borax tree $^{-1}$ in June noted the maximum values.

- Increase in soil pH, EC and organic carbon, available NPK, DTPA extractable Zn and available B indicating the built up of soil fertility with the application of 3 kg NPK each tree $^{-1}$ in three equal splits in June, September and January with 50 kg vermicompost and 50 g $ZnSO_4$ + 25 g Borax tree $^{-1}$ in June.

Thus, considering the yield and quality of sapota, leaf nutrient content and soil available nutrient status, application of 3 kg NPK each tree $^{-1}$ in three equal splits in June, September and January with 50 kg vermicompost and 50 g $ZnSO_4$ + 25 g Borax tree $^{-1}$ in June was found to be superior and beneficial in lateritic soils of Konkan from the view point of getting higher fruit yields and maintaining the soil fertility.

Data being preliminary in nature, need further confirmation.

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*Original not seen

Appendix

APPENDIX- I

WEEKLY METEROLOGICAL DATA
(Jun 2022 to December 2022)

Period	MW	T.max	T.min	RH-I	RH-II	Wind speed	Rain	RD	BSS
		(ºC)	(ºC)	(%)	(%)	(Kmph)	(mm)	day	(hrs.)
28.05 - 03.06	**22**	32.9	23.0	87	66	5.7	2.2	0	8.2
04.06 - 10.06	**23**	33.2	23.4	84	60	5.6	6.2	1	7.5
11.06 - 17.06	**24**	31.8	23.3	90	71	5.9	83.8	6	6.1
18.06 - 24.06	**25**	29.8	22.5	94	79	5.0	148.4	5	2.7
25.06 - 01.07	**26**	27.9	22.8	97	95	5.2	489.2	7	0.5
02.07 - 08.07	**27**	28.3	22.9	97	93	8.6	625.2	7	0.8
09.07 - 15.07	**28**	27.3	22.7	98	95	11.0	265.4	7	0.0
16.07 - 22.07	**29**	28.0	23.2	93	89	8.8	121.4	7	1.1
23.07 - 29.07	**30**	28.9	23.2	94	83	6.3	120.8	5	2.5
30.07 - 05.08	**31**	30.1	23.5	93	83	4.4	81.6	4	4.7
06.08 - 12.08	**32**	26.9	22.5	97	96	12.0	655.6	7	0.0
13.08 - 19.08	**33**	27.9	22.5	95	92	8.6	202.0	7	0.7
20.08 - 26.08	**34**	27.9	22.2	96	90	7.0	154.3	7	1.2
27.08 - 02.09	**35**	29.7	22.1	93	85	3.8	2.6	0	4.6
03.09 - 09.09	**36**	30.2	23.1	93	86	3.7	31.8	4	4.6
10.09 - 16.09	**37**	28.8	23.1	94	89	7.0	239.2	6	1.9
17.09 - 23.09	**38**	27.8	21.4	92	85	3.4	89.9	4	2.4
24.09 - 30.09	**39**	28.9	21.4	93	82	3.2	79.8	2	4.1
01.10 - 07.10	**40**	29.8	21.0	91	82	4.2	34.8	3	5.5
08.10 - 14.10	**41**	29.1	21.6	94	81	2.6	22.6	2	2.6
15.10 - 21.10	**42**	31.2	22.1	92	82	2.8	53.1	3	6.5
22.10 – 28.10	**43**	32.3	17.2	92	70	2.2	28.6	1	8.9
29.10 – 04.11	**44**	31.9	15.2	88	62	5.5	0.0	0	10.2
05.11 – 11.11	**45**	33.0	15.4	86	55	2.2	0.0	0	10.0
12.11 – 18.11	**46**	32.8	15.0	91	50	2.2	0.0	0	9.9
19.11 – 25.11	**47**	32.0	13.9	92	56	2.4	0.0	0	9.6
26.11 – 02.12	**48**	32.9	16.6	93	52	2.4	0.0	0	8.5
03.12 – 09.12	**49**	33.2	16.6	93	50	2.3	0.0	0	6.8
10.12 – 16.12	**50**	32.1	17.7	92	53	2.5	0.0	0	5.5
17.12 – 23.12	**51**	34.1	16.8	94	51	2.7	0.0	0	8.6
24.12 – 31.12	**52**	32.2	14.4	92	55	2.7	0.0	0	8.4
							3559.5	**98**	

WEEKLY METEROLOGICAL DATA

(Jan 2023 to 30 June 2023)

Period	MW	T.max	T.min	RH-I	RH-II	Wind speed	Rain	RD	BSS
		(ºC)	(ºC)	(%)	(%)	(Kmph)	(mm)	day	(hrs.)
01.01 -07.01	**1**	31.7	14.7	95	52	2.6	0.0	0	7.6
08.01 -14.01	**2**	30.8	11.6	93	49	2.8	0.0	0	7.8
15.01 -21.01	**3**	29.9	11.0	92	51	2.4	0.0	0	8.6
22.01 -28.01	**4**	28.9	12.9	93	53	3.3	0.0	0	7.5
29.01 -04.02	**5**	32.0	15.3	89	50	3.3	0.0	0	6.0
05.02 -11.02	**6**	33.6	12.7	88	42	2.7	0.0	0	9.2
12.02 -18.02	**7**	35.6	11.8	84	31	3.5	0.0	0	10.0
19.02 -25.02	**8**	35.3	12.9	89	44	3.2	0.0	0	10.0
26.02 -04.03	**9**	35.4	15.0	85	39	3.2	0.0	0	10.6
05.03 -11.03	**10**	35.8	17.7	75	34	4.1	0.0	0	9.9
12.03 -18.03	**11**	34.6	18.5	90	51	3.9	0.0	0	9.2
19.03 -25.03	**12**	30.6	16.6	88	61	4.8	2.8	1	9.2
26.03 - 01.04	**13**	30.2	15.0	89	60	4.8	0.0	0	10.8
02.04 - 08.04	**14**	31.8	18.3	86	56	5.0	0.0	0	10.4
09.04 -15.04	**15**	35.6	21.5	81	55	4.3	0.0	0	7.7
16.04 22.04	**16**	34.5	19.8	82	54	4.4	0.6	0	8.9
23.04 -29.04	**17**	27.8	20.1	89	60	5.2	0.0	0	9.6
30.04 -06.05	**18**	32.1	20.0	80	59	5.2	0.0	0	10.6
07.05 -13.05	**19**	32.6	22.6	89	66	5.2	31.6	1	7.0
14.05 -20.05	**20**	33.2	22.7	82	64	5.8	0.0	0	11.0
21.05 -27.05	**21**	33.3	22.8	82	64	5.9	4.6	1	10.8

Source: Weekly Meteorological Data, Department of Agronomy, Dr. BSKKV, Dapoli
BSS*: Bright Sun Shine hours
RH I: Morning Relative Humidity
RH II: Evening Relative Humidity

T max: Temperature Maximum
T min: Temperature Minimum

Abstract

THESIS ABSTRACT

a) Title of the thesis	:	**EFFECT OF SPLIT APPLICATION OF NPK ALONG WITH BASAL DOSE OF Zn AND B ON SOIL PROPERTIES, YIELD AND QUALITY OF SAPOTA [*Manilkara achras* (Mill.) Forsbergin] IN LATERITIC SOILS OF KONKAN**
b) Name of the student	:	**Miss Pawar Swati Vasudev**
c) Name and address of the major advisor	:	Dr. N.H. Khobragade Assistant Professor, Department of Soil Science and Agricultural Chemistry. College of Agriculture, Dapoli
d) Degree to be awarded	:	M.Sc. (Agri.)
e) Year of award of degree	:	2023
f) Major subject	:	Soil Science and Agricultural Chemistry
g) Total number of pages in the thesis	:	79
h) Number of words in the abstract	:	418
i) Signature of student	:	
j) Signature, Name and address of forwarding authority	:	Dr.S.B.Dodake Head, Department of Soil Science and Agricultural Chemistry. Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli

---

An attempt has been made to study "effect of split application of NPK along with basal dose of Zn and B on soil properties, yield and quality of sapota [*Manilkara achras* (Mill.) Forsbergin] in lateritic soils of Konkan" at Nursery No.10, Department of Horticulture, College of Agriculture Dapoli in Randomized Block Design comprising of five treatments replicated four times during June 2022 to May 2023, where NPK @3:3:3 kg NPK each per tree were applied in two equal splits in June and September and in three equal splits in June, September and January along with basal application of vermicompost @50 kg per tree and $ZnSO_4$ @ 50 g per tree + Borax @ 25g per tree in June by ring method to the depth of 25-30 cm.

Application of 3:3:3 kg NPK tree $^{-1}$ in three equal splits in June, September and January with 50 kg Vermicompost and 50 g $ZnSO_4$ + 25 g Borax tree $^{-1}$ in June was found to be significantly superior for enhancing the yield of sapota variety Kalipatti and recorded the higher values for quality of sapota as well as increase in soil pH, EC and organic carbon, available NPK, DTPA extractable Zn and available B indicating the built up of soil fertility.

Leaf nutrient content at vegetative growth stage before the application of manure and fertilizers found to be deficient in case of nitrogen content, optimum in case of phosphorus and potassium content, near to low in case of zinc and low in case of boron content. Two or three split applications of RDF with and without Zn + B enhanced the leaf nutrients content and reached the level of optimum in case of nitrogen and boron content while high in case of phosphorus, potassium and zinc content in leaves, where application of 3 kg NPK each tree $^{-1}$ in three equal splits in June, September and January with 50 kg Vermicompost and 50 g $ZnSO_4$ + 25 g Borax tree $^{-1}$ in June noted the maximum values.

Thus, considering the yield and quality of sapota, leaf nutrient content and soil available nutrient status, application of 3 kg NPK each tree $^{-1}$ in three equal splits in June, September and January with 50 kg Vermicompost and 50 g $ZnSO_4$ + 25 g Borax tree $^{-1}$ in June was found to be superior and beneficial in lateritic soils of Konkan from the view point of getting higher fruit yields and maintaining the soil fertility.

Key words: Vermicompost, Sapota, Boron, Zinc, Split application, fertilizers

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Similarity	14%
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Similarity	14%
Paper ID	1126902
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Place :Dapoli

Date : 02/02/2024

Pawar Swati Vasudev

International Journal of Research in Agronomy

Peer Reviewed Journal, Refereed Journal, Indexed Journal

P-ISSN: 2618-060X, E-ISSN: 2618-0618, Impact Factor: RJIF 5.24, NAAS (2024): 5.20

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Issue	:	**1**
Year	:	**2024**
Page Number	:	**428-431**

Certificate No.: **7-1-99**

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Manager
International Journal of Research in Agronomy
www.agronomyjournals.com

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(1): 428-431
Received: 24-10-2023
Accepted: 29-11-2023

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Effect of split application of NPK along with basal dose of Zn and B on yield of sapota [*Manilkara achras* (Mill.) Forsberg] and soil properties

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i1f.252

Abstract
In order to understand the effect of split application of NPK along with basal dose of Zn and B on soil properties and on yield of sapota in lateritic soils of Konkan, an experiment in randomized block design with five treatments replicated four times was conducted at Department of Horticulture, College of Agriculture Dapoli, during June 2022 to May 2023 on thirty three years old sapota orchard of variety Kallipatti, where NPK @ 3:3:3 kg NPK each per tree were applied in two equal splits in June and September and in three equal splits in June, September and January along with basal application of vermicompost @ 50 kg per tree and $ZnSO_4$ @ 50 g per tree + Borax @ 25g per tree in June by ring method to the depth of 25-30 cm. The data revealed that the application 3 kg NPK each tree^{-1} in three equal splits in June, September and January with 50 kg Vermicompost and 50 g $ZnSO_4$ + 25 g Borax tree^{-1} in June was found to be significantly superior for enhancing the yield of sapota and the increase in soil pH, EC and organic carbon, available NPK, DTPA extractable Zn and available B indicating the built up of soil fertility in lateritic soils of Konkan.

Keywords: Sapota, split application, boron, zinc, fertilizers, vermicompost, lateritic soil

Introduction

Sapota, a native of Mexico belonging to family Sapotaceae, is a tropical fruit, yields fruit twice a year, though flowering may continue year-round and needs warm, humid climate for growth and development. Being a hardy crop, it can be grown on wide range of soil and climatic conditions (Dutton 1976) [6]. Sapota is mainly cultivated in India for its fruit value, while in South-east Mexico, Guatemala and other countries it is commercially grown for the production of gum like substance obtained from latex called chickle and is mainly used for preparation of chewing gum. Its fruits are round or oval, brown in outer appearance and very sweet in taste with almost no evident acidity.

In India there was production of 935.2 thousand MT of sapota from an area of 78.3 thousand ha and the productivity of 11.9 MT/ha. In Maharashtra it was grown under 12.80-thousand-hectare area with the production of sapota is 107.26 thousand MT with a productivity of 8.38 MT/ha (Anonymous, 2023) [1].

In Indian fruit orchards, poor soil health and imbalanced nutrient application are major causes of low orchard efficiency resulting in poor productivity. To optimize the fertilizer use, the approach of split application of fertilizer plays a very important role in a nutrient management strategy. Single application of fertilizer leads to period of over-supply, more leaching losses and also period of under-supply. It may not be able to maintain optimum soil nutrient status at all the critical growth stages of crop. So, it is paramount important to determine the number of splits for fertilizer application in sapota. Micronutrients can tremendously boost horticultural crop yield and improve quality and post-harvest life of horticultural produce (Raja, 2009) [12]. With this background, the present study was undertaken to standardize stage wise nutrient requirement in Sapota as well as requirement of Zn and B under Konkan conditions to achieve improved yield and soil properties in lateritic soils of Konkan.

Material and Methods

The experiment was conducted at nursery of Department of Horticulture, College of Agriculture Dapoli, during June 2022 to May 2023 on thirty-three years old sapota orchard of variety Kallipatti planted at spacing of 12.5m X 12.5m. The experiment was laid in RBD design comprising five treatments replicated four times *viz.* T_1- Absolute control (No fertilizer), T_2 -3 kg NPK each tree^{-1} in two equal splits in June and September and Vermicompost @ 50 kg tree^{-1} in June, T_3- 3 kg NPK each tree^{-1} in two equal splits in June and September and 50 g $ZnSO_4$ + 25 g Borax tree^{-1} in June and Vermicompost @ 50 kg tree^{-1} in June, T_4- 3 kg NPK each tree^{-1} in three equal splits in June, September and January and Vermicompost @ 50 kg tree^{-1} in June, T_5- 3 kg NPK each tree^{-1} in three equal splits in June, September and January and 50 g $ZnSO_4$ + 25 g Borax tree^{-1} in June and Vermicompost @ 50 kg tree^{-1} in June. Two trees were selected for each treatment. The split doses of fertilizers according to the treatment were mixed and applied in the ring dug to a depth of 25-30 cm covering the periphery of the plants and about 150 cm away from main trunk. The mature fruits were harvested with the help of Atul Sapota Harvester. The final yield per tree (kg) was obtained by sum of all the pickings. Treatment wise representative soil samples were collected from fertilizer ring of the tree at 30 cm depth from 4 spots at various stages *viz.*, at vegetative stage, at flowering stage and at harvesting of sapota. Available nitrogen was determined by alkaline permanganate (0.32% $KMnO_4$) method (Subbiah and Asija, 1956) [16], Available phosphorus (Bray's P) was determined by extracting the acid soil P in dilute acid fluoride (Bray and Kurtz, 1945) [5] phosphorus in the extract was determined colorimetrically at 660 nm as described by Black (1965) [4]. Potassium was determined by Systronics Flame Photometer-128 using neutral-normal-ammonium acetate (NH_4OAc, pH 7.0) as per procedure given by Jackson (1973) [8]. The available Zn in the soil was determined by Atomic Absorption Spectrophotometer as described by Lindsay and Norvell (1978) [9]. Hot water extractable boron method of Berger and Troug (1939) [3] using Azomethine-H reagent. The data obtained were subjected to statistical analysis by following the procedure pertinent to Randomized Block Design as given by Panse and Sukhatme (1967) [11].

Results and Discussion

Yield of sapota

The fruit yield of sapota was significantly influenced by the effect of split application of NPK either sole or with Zn + B (Table 1). Application of RDF alone in two splits (T_2) and three splits (T_4) recorded an increase in fruit yield kg per tree as well as t ha^{-1}. However, the significantly highest fruit yield (46.02 kg/tree and 2.95 t ha^{-1}) was obtained in treatment T_5, where 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ @ 50 g + Borax @ 25 g in June was applied, which was significantly superior over rest of the treatments and followed by the treatment T_4, T_3 and T_2. However, the lowest value of fruit yield was reported in the treatment T_1 (*i.e.*, absolute control). Possible explanation for increase in yield with Zn and B application could be attributed to the fact that Zn is an essential element required by plants for different metabolic process and play vital part in enzyme activation and biosynthesis of specific growth hormones (Noor and Tariq, 2019) [10]. Similarly, B is also involved in metabolism and translocation of carbohydrate, hormonal activities and pollen tube elongation. It also enhances flower initiation, fruit production, N absorption, growth of plants and indirectly influences fruit set (Simmons, 1998) [14].

Table 1: The effect of split application of NPK along with basal dose of Zn and B on yield of sapota

Treat Code	Treatment	Yield kg per tree	Yield (t/ha)
T_1	Absolute control	20.63	1.32
T_2	3 kg NPK in two splits	33.44	2.14
T_3	3 kg NPK in two + Zn & B	36.33	2.33
T_4	3 kg NPK in three splits	38.45	2.46
T_5	3 kg NPK in three splits + Zn & B	46.02	2.95
	S.E.	1.57	0.10
	C.D. at 5%	4.84	0.31

Physico-chemical properties of soil

Application of first split dose of NPK with vermicompost @ 50 kg tree^{-1} with or without Zn + B in the month of June at vegetative flush stage exhibited significant effect on physico-chemical properties and nutrient status of soil at flowering stage and at harvest (Table 2, 3 and 4).

The split application of NPK with and without Zn + B showed significant increase in pH, electrical conductivity and organic carbon content in the soil. Significantly highest pH (5.46 at flowering stage and 5.61 at harvest), EC (0.27 dS m^{-1} at flowering stage and 0.24 dS m^{-1} at harvest) and organic carbon (44.90 g kg^{-1} at flowering stage and 38.20 g kg^{-1} at harvest) were noted in treatment T_5 with the application of 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ + Borax in June, which was found to be at par with the treatments T_2, T_3 and T_4 during both observational stages (with the exception of EC at harvest) (Table 2). The treatment absolute control (T_1) recorded the lowest values of pH, electrical conductivity and organic carbon.

Soil pH increased from vegetative flush stage to harvest stage irrespective of the treatments, which may be due to increased microbial growth and activity during the growth period of the crop as there was increase in organic matter due to accumulation of leaf litter fall during the growth period. The increase in EC with the application of NPK at flowering stage might be due to possible buildup of the soluble nutrients drawn from manure or mineralization, while decrease in EC at harvest may, probably, be due to partial washing away of the salts from the surface soils, besides uptake of the salts from the soil by the plant. The increased organic carbon at flowering stage may probably be due to the soil enrichment in organic carbon content due to several factors such as addition of litter fall, find root biomass recycled and root exudates and its reduced oxidation of organic matter. The establishment of plantations comprising invasive plants reduces tree and shrub layers by exposing the leaf litter layer in this habitat to high temperatures, which accelerated the breakdown of leaf litters and faster the decomposition rates and thus contribute to a decrease in OM content (Singwane and Malinga, 2012) [15].

Application of NPK in two or three splits with or without Zn + B noted the significant increase in available nitrogen, available phosphorus, available potassium content in the soil over the absolute control due to the direct addition of the nutrient through fertilizer to the available pool of the soil. Significantly highest available nitrogen (377.21 kg ha^{-1} at flowering stage and 397.84 kg ha^{-1} at harvest), available phosphorus (7.99 kg ha^{-1} at flowering stage and 7.74 kg ha^{-1} at harvest) and available potassium (872.32 kg ha^{-1} at flowering stage and 887.32 kg ha^{-1} at harvest) were noted with the application of 3 kg NPK each in three splits in June, September and January with $ZnSO_4$ + Borax in June (T_5), which were found to be at par with the treatments T_2, T_3 and T_4 at flowering stage and at harvest in case of above available nutrients (Table 3). No application of fertilizers and vermicompost (*i.e.,* absolute control) recorded the lowest nutrient content in the soil.

The increase in available N status of the soil up to harvest stage with combined use of fertilizers and organic manures may be explained in terms of their residual effect and build up in organic N fractions of the soil due to biochemical degradation and mineralization. Further, organic matter mineralization provides a continuous, although limited, supply of plant available P at flowering (Tisdale *et al*. 1995) [17]. The decline in available phosphorus at harvest may be due to the uptake of P_2O_5 by plants which usually takes place intensively after flowering (Barbatzkii, 1959) [2]. The increase in phosphorous and potassium availability might be also due to synergistic effect of N (Shrivastava, 2002) [13].

The lowest values of DTPA Extractable Zn and available boron content in soil were reported in the treatment T_1 (*i.e.,* absolute control), where fertilizers and organic matter was not applied (Table 4). Further, application of RDF alone in two splits (T_2) and three splits (T_4) recorded increase in DTPA Extractable Zn and available boron. This might be due to efficient utilization of micronutrients in the presence of all other essential elements (Guvvali and Shirol, 2017) [7]. However, the maximum DTPA Extractable Zn and available boron were recorded in treatments T_3 and T_5, where zinc and boron were applied though zinc sulphate and borax. Increase in available boron with borax application might be attributed to the direct addition of boron through fertilizer to the available pool of the soil. Significantly highest DTPA Extractable Zn (2.09 mg kg^{-1} at flowering stage and 1.82 mg kg^{-1} at harvest stage) and available boron (0.47 mg kg^{-1} at flowering stage and 0.38 mg kg^{-1} at harvest stage) were recorded with three split applications of NPK with Zn + B (treatment T_5), which was found to be at par with T_2, T_3 and T_4 in case of DTPA Extractable Zn and with T_3 in case of available boron at flowering stage, while at harvest stage with T_3 in case of DTPA Extractable Zn and T_2, T_3 and T_4 in case of available boron.

Table 2: The effect of split application of NPK along with basal dose of Zn and B on physico-chemical properties of soil

Treatments	pH			EC (dS m^{-1})			OC g kg^{-1}		
	At vegetative flush stage	At flowering stage	At harvest	At vegetative flush stage	At flowering stage	At harvest	At vegetative flush stage	At flowering stage	At harvest
T_1 Absolute control	5.07	5.18	5.31	0.18	0.16	0.16	31.45	35.38	29.85
T_2 3 kg NPK in two splits	5.11	5.23	5.37	0.21	0.24	0.17	32.73	41.15	36.35
T_3 3 kg NPK in two splits + Zn & B	5.12	5.40	5.46	0.22	0.25	0.21	34.03	42.50	37.05
T_4 3 kg NPK in three splits	5.14	5.44	5.58	0.21	0.25	0.22	34.48	44.55	38.15
T_5 3 kg NPK in three splits + Zn & B	5.19	5.46	5.61	0.22	0.27	0.24	34.40	44.90	38.20
S.E.	0.08	0.08	0.08	0.02	0.02	0.02	1.31	2.45	2.01
C.D. at 5%	N.S.	0.23	0.25	N.S.	0.059	0.057	N.S.	7.55	6.18

Table 3: The effect of split application of NPK along with basal dose of Zn and B on physico-chemical properties of soil

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	At vegetative flush stage	At flowering stage	At harvest	At vegetative flush stage	At flowering stage	At harvest	At vegetative flush stage	At flowering stage	At harvest
T_1 Absolute control	282.01	275.76	280.76	5.62	5.74	5.49	590.19	608.11	598.11
T_2 3 kg NPK in two splits	293.99	333.35	359.89	5.75	7.33	7.15	582.51	809.51	837.01
T_3 3 kg NPK in two splits + Zn & B	309.46	352.83	362.94	5.97	7.47	7.22	587.83	829.99	849.99
T_4 3 kg NPK in three splits	290.86	367.18	386.10	5.93	7.75	7.50	602.48	840.13	855.13
T_5 3 kg NPK in three splits + Zn & B	301.32	377.21	397.84	6.06	7.99	7.74	600.22	872.32	887.32
S.E.	8.71	16.37	22.99	0.52	0.38	0.28	38.15	50.58	37.00
C.D. at 5%	N.S.	50.43	70.84	N.S.	1.18	0.86	N.S.	155.85	113.99

Table 4: The effect of split application of NPK along with basal dose of Zn and B on physico-chemical properties of soil

Treatments	DTPA extractable Zn (mg kg^{-1})			Available B (mg kg^{-1})		
	At vegetative flush stage	At flowering stage	At harvest	At vegetative flush stage	At flowering stage	At harvest
T_1 Absolute control	1.12	1.17	1.20	0.20	0.22	0.20
T_2 3 kg NPK in two splits	1.13	1.58	1.28	0.25	0.32	0.27
T_3 3 kg NPK in two splits + Zn & B	1.17	2.07	1.74	0.23	0.45	0.37
T_4 3 kg NPK in three splits	1.13	1.63	1.30	0.24	0.33	0.28
T_5 3 kg NPK in three splits + Zn & B	1.14	2.09	1.82	0.22	0.47	0.38
S.E.	0.08	0.19	0.16	0.04	0.03	0.05
C.D. at 5%	N.S.	0.58	0.50	N.S.	0.10	0.14

Conclusion

Considering the yield of sapota, physico-chemical properties of soil and soil available nutrient status, application of 3 kg NPK each tree $^{-1}$ in three equal splits in June, September and January with 50 kg Vermicompost and 50 g $ZnSO_4$ + 25 g Borax tree $^{-1}$ in June was found to be superior and beneficial in lateritic soils of Konkan from the view point of getting higher fruit yields of sapota variety Kalipatti and maintaining the soil fertility.

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