Identification of the geographical origin of jackfruit (*Artocarpus heterophyllus* Lam.) through multielemental fingerprinting using ICPMS

A Thesis Submitted

To

Sikkim University

In partial fulfillment of the requirements for the Degree of

Doctor of Philosophy

By

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CERTIFICATE

This is to certify that the thesis entitled **"Identification of the geographical origin of jackfruit (*Artocarpus heterophyllus* Lam.) through multielemental fingerprinting using ICPMS"** submitted to the **Department of Horticulture, Sikkim University, Gangtok,** in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy in Horticulture,** embodies the result of *bonafide* research work carried out by **Ms. Nadia Debbarma** under my guidance and supervision. No part of the thesis has been submitted for any other degree, diploma, associateship or fellowship.

All the assistance and help received during the course of the investigation has been duly acknowledged by her.

I recommend this thesis to be placed before the examiners for evaluation.

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DECLARATION

I, Ms. Nadia Debbarma, hereby declare that the thesis entitled **"Identification of the geographical origin of jackfruit (*Artocarpus heterophyllus* Lam.) through multielemental fingerprinting using ICPMS"** was done by me and the contents of this thesis did not form basis of the award of any previous degree to me or, to the best of my knowledge, to anybody else and that the thesis has not been submitted by me for any other research degree in any other University/ institute.

The contents of this thesis have also been subjected to plagiarism check.

This is being submitted in partial fulfilment of the requirements of the degree of Doctor of philosophy in the Department of Horticulture, School of Life sciences, Sikkim University.

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PLAGIARISM TEST CERTIFICATE

This is to certify that the plagiarism check has been carried out for the following Ph.D thesis with the help of **URKUND software** and the result is **2% tolerance rate**, which is with in the permissible limit (Below 20% tolerance rate) as per the norms of Sikkim University.

"Identification of the geographical origin of jackfruit (*Artocarpus heterophyllus* Lam.) through multielemental fingerprinting using ICPMS"

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Place: Gangtok,

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(NADIA DEBBARMA)

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ABBREVIATIONS USED

%	Percentage
Al	Aluminium
B	Boron
Ba	Barium
Ca	Calcium
Co	Cobalt
Cs	Cesium
Cu	Copper
Fe	Iron
Fig.	Figure
g	Gram
Ga	Gallium
i.e	*id est* (that is)
ICAR	Indian Council of Agricultural Research
ICPMS	Inductively Coupled Plasma Mass Spectrometry
K	Potassium
Kg	Killogram
LDA	Linear Discriminant Analysis
Li	Lithium
m	Meter
Mg	Magnesium
mg	Miligram

mm	Millimeter
Mn	Manganese
Mo	Molybdenum
MSL	Mean Sea Level
Mt/Ha	Metric Tonnes per Hactare
Na	Sodium
Ni	Nickel
PCA	Principal Component Analysis
Rb	Rubidium
S	Sulfur
SD	Standard Deviation
Si	Silicon
Ti	Tillium
TSS	Total Soluble Solids
U	Uranium
Xe	Xenon
Zn	Zinc

INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam.), belongs to the family Moraceae, with the basic chromosome number 14. It is a tetraploid and its somatic chromosome number is 56. Moraceae family comprises of 55 genera and approximately 1000 species of mostly topical nature. The genus *Artocarpus* contains about 50 species and most of them are native to Asia, out of which only 15 bear edible fruits. The three most important species are bread fruit, jackfruit and its close relative, chempedak. The word *Artocarpus* is derived from the Greek words 'artos' (bread) and 'carpos' (fruit). The name "Jackfruit" is derived from the Protuguese jaca, which in turn, is derived from the Malayalam language term, chakka (Anonymous, 2006 and Pradeepkumar and Kumar, 2008).

The jackfruit (*Artocarpus heterophyllus* Lam.) is native to South and Southeast Asia and is believed to have originated in the rainforests of Western Ghats of India (Chandler, 1958 and Rowe-Dutton, 1985) and is cultivated throughout the low lands in South and Southeast Asia (Samadar, 1985; Soepadmo, 1991 and Acedo, 1992). Jackfruit is popular fruit and ranks third in total annual production after mango and banana in South India (Morton, 1987). It is the national fruit of Bangladesh and is considered to be an extremely important tree by the natives (Bose, 1985). The plant is frequently referred to as "poor man's food" as it cheap and plentiful during the summer season when food is scarce (Samaddar, 1985; Rahman *et al.,* 1995 and Jagtap *et al.,* 2010). Jackfruit is a prized food in regions where it does not grow, but is unfortunately considered to be a trivial in areas where it is found in abundance (Morton 1987 and Jagtap *et al.,* 2010).

In India, it has widely distributed in Assam, Tripura, West Bengal, Bihar, Uttar Pradesh, foothills of the Himalayas, Kerala, Tamil Nadu and Karnataka (Wangchu *et al*., 2013). The region comprises of Assam, Tripura and West Bengal produces major share of jackfruit in India (APAARI, 2012). Jackfruit plays a significant role in Indian agriculture with increasing their nutritional value in human diet and these fruit are gaining commercial importance (Salunkhe and Desai, 1984). Asati and Yadav (2004) reported the large number of tropical and subtropical fruits are found growing wild in North Eastern region (including *Artocarpus*) and opinioned that jackfruit, which grows abundantly in Tripura, Assam and Meghalaya with a large number of cultivars require attention.

Jackfruit is a cross pollinated crop and it is propagated by seeds. (Haque *et al.*, 2004; Haq, 2006 and Wangchu *et al.,* 2013). Jackfruit is a multipurpose tree and all parts of the plant are equally important (Wangchu *et al.,* 2013). It is a good source of vitamins like A, C, thiamine, riboflavin, niacin and minerals like calcium, potassium, iron, sodium and zinc (Azad, 2000; Haq, 2006; Swamy *et al.,* 2012). The leaves and fruit waste provide valuable fodder for cattle, pigs and goats. Jackfruit wood chips yield a dye which is used to give the famous orange-red colour to the robes of Buddhist priests (Craig and Harley, 2006)

Flakes of ripe fruits are high in nutritive value; every 100 g of ripe flakes contains 287-323 mg potassium, 30.0-73.2 mg calcium, 11-19 g carbohydrates, vitamin A (540 IU) and minerals (K, P. Fe and Ca). When unripe (green), it is remarkably similar in texture to chicken, making jackfruit an excellent vegetarian substitute for meat, In fact, canned jackfruit (in brine) is sometimes referred to as vegetable meat. The nutritious seeds are boiled or roasted and eaten like chestnuts, added to flour for baking, or cooked in dishes.

It is now widely accepted that the beneficial effects of jackfruit as fruits and vegetables for the prevention of certain diseases (like cure of ulcers,. indigestion and cancer-fighting properties) are due to the bioactive compounds they contain (Galaverna *et al.,* 2008). *Artocarpus* species are rich in phenolic compounds. The extracts and metabolites of *Artocarpus* particularly those from leaves, bark, stem and fruit possess several useful bioactive compounds and recently additional data are available on exploitation of these compounds in the various biological activities including antibacterial, anti tubercular antiviral, antifungal, anti platelet and anti arthritic.

In spite of such a vast potential and usefulness, jackfruit remains an underutilized fruit species and deserves to be given the needed thrust for research and development. Attention on this crop was created when the Leipzig conference in June 1996, IPGRI (International Plant Genetic Resources Institute-presently, Biodiversity International) and UTFANET (Underutilized Tropical Fruits in Asia Network) agreed to work on the development and joint publication of descriptors for jackfruit. In 2000, IPGRI issued a list of descriptor. With the support of UTFANET nine countries involved for about three year work plan on three crops (i.e. Jackfruit, pommelo and mangosteen) on different aspects.

Among all nine countries, highest no. of elite lines of jackfruit was identified in India fallowed by Bangladesh and Pakistan. In India, even though highest numbers of clones are available and potential for commercialization there was no scientific work carried out in the variety identification/type identification. Most of the jackfruits are identified based on the place from which they grown. As the varieties are identified based on the geographical location and their quality also determined based on their place of growth, designing an easy, cheap and reliable method to identify the variety and possibly linking with place of its growing will be a useful tool. Though, it can be done with different techniques, ionomics is a cheap and reliable tool. Hence, it was proposed to test the effectiveness of ionomics in linking the genotypes with its geographical origin of jackfruit genotypes in India, by carrying out a study of multi elemental fingerprinting of the jackfruit from different places of origin.

Ionomics study involves the quantitative and simultaneous measurement of the elemental composition of plants and changes in this composition in response to physiological stimuli, developmental state, and genetic modifications and it requires the application of high-throughput elemental analysis technologies and their integration with both bioinformatic and genetic tools (Salt *et al.,* 2008). Ionome is the mineral nutrient and trace element composition of an organism, which includes elements nonessential for plant growth (Salt *et al.,* 2008). The combination of ionome and chemometrics has been widely used to trace the geographical origins of wine (Coetzee *et al.,* 2005), vegetables and fruits (Di Giacomo *et al.,* 2007; Perents et al., 2013: Yan *et al.,* 2015), nuts (Anderson and Smith, 2005), beverages (Anderson and Smith, 2002), and cereals like barley (Husted *et al.,* 2004), wheat (Zhao *et al.,* 2011) and rice (Li *et al.,* 2012). In addition, ionome profiling is particularly sensitive to the soil and climate condition under which agricultural crops are grown. Ionome profiling followed by multivariate analysis, has previously been shown to differentiate between countries of origin (Anderson *et al.,* 1999; Kelly *et al.,* 2005). According to Febani *et al.,* (2010) study of both soil and agricultural crop composition is very useful to obtain reliable markers of agricultural crop provenance. The correlation of geographical origin with ionome profile is of new avenue in the paradigm of research arena. Keeping above mentioned facts in view the present study was designed with following objectives:

OBJECTIVES

1. To survey and collect the fruit and soil from different jackfruit growing regions of India.
2. To Profile the ionome of the fruit and soil samples collected from different jackfruit growing regions.
3. To correlate the ionome profile of jackfruit with geographical origin.

The present investigation entitled **"Identification of the geographical origin of jackfruit (*Artocarpus heterophyllus* Lam.) through multielemental fingerprinting using ICPMS"** was carried out during 2016-17 and 2017-18. Keeping in view of the objectives of the present investigation, relevant literature on various aspects of characterization, including ionomics of jackfruit and other related crops has been reviewed here

2.1. Morphological characters

2.1.1. Fruit weight

Fruit of the jackfruit was studied by various workers as an important quality parameter. Hossain and Hoque (1977) studied ten different selected plants of jackfruit and found out the weight of the fruits was ranging from3. 24 to 7.39 kg. Haque, (1991) studied jackfruit trees of Bhaluka, Trishal and Kotwali in Mymensingh district and found that fruits were about 4.5 to 11.5 kg in weight. Anonymous, (1995) studied physico-chemical characteristics of three types of jackfruit *viz.* Ghila, Dorosa and Khaja at different stage of ripening as well as during the storage of different conditions. They reported that the average weight of the jackfruits was 5.2 kg. Muralidharan *et al.,* (1997) studied 95 accessions in Western Ghats of Kerala, Karnataka and Tamil Nadu and they reported that the maximum fruit weight was observed in Varikka (10.40 kg) and lowest in wild (2.9 kg). Bal, (2003) studied on the genetic resources of under-utilized fruit crops and recorded wide diversity among four genotypes of jackfruit with varying fruit weight from 4.9 kg (JFC-2) to 8.2 kg (JFS-1). Mannan *et al.,* (2006) conducted an investigation to evaluate 28 selected off season jackfruit germplasm of Bangladesh and they observed significant variation in fruit weight which ranged from 13.63 kg to 3.00 kg. Jagadeesh *et al.,* (2010) surveyed and studied the natural variability in fruit weight of 30 jackfruit selections from Coastal zone Karnataka and reported that the maximum fruit weight was noted in UKB – 24 (18.74 kg) followed by DKB – 5 (14.86 kg), UDK – 4 (14.32 kg), UDK – (12.62 kg) and the minimum in UDB – (2.15 kg). Wangchu *et al.,* (2013) studied forty four superior jackfruit genotypes and reported average fruit weight ranged from 1.6-16.47 (kg). Krishnan *et al.,* (2015) studied 21 firms fleshed jackfruit types at Kumarakom, Kerala and reported individual fruit weight ranged from 1.69 to 17.50 kg. Saji *et al.,* (2015) studied on quality attributes of jackfruit accessions of Kerala and reported significant variation in fruit weight ranging from 3.95 kg to 20.13 kg.

2.1.2. Fruit length

Sarker and Zuberi (2011) recorded the highest fruit length of 70.42 cm and 51.42 cm in older trees of Madanhati and of Upashahar regions of Bangladesh. Hossain and Hoque (1977) studied length of jackfruit in ten different selected plants and found that it was ranging from 18 to 41 cm with 31.6 cm as average length. Muralidharan *et al.,* (1997) conducted an experiment on 95 accessions in Western Ghats of Kerala, Karnataka and Tamil Nadu and reported that the longest fruit was found in Navarikka (46 cm) and shortest in Rudrakshavarikka (24.5 cm). Bal (2003) recorded wide diversity among four genotypes of jackfruit with varying fruit length range from 32.8 cm (JFC-3) to 48 cm (JFS-1). Mannan *et al.,* (2006) observed longest fruit length as 51.67 cm and shortest as 21.33 cm. Jagadeesh *et al.,* (2007A) reported maximum fruit length as 45.50 cm and minimum fruit length as 32.33 cm in their study. Khan *et al., (*2010) recorded maximum fruit length in homestead garden (56.82 cm) and minimum in forest/fallow areas (35.11 cm). Wangchu *et al.,* (2013) studied forty four superior jackfruit genotypes and reported fruit length ranged from 19-58.50 cm. Saji *et al.,* (2015) reported fruit length ranged from 28.68 cm to 52.66 cm.

2.1.3. Fruit width

Bal (2003) recorded wide diversity among four genotypes of jackfruit with varying fruit breadth ranged from 18 cm (JFC-4) to 24.1 cm (JFS-1). Mannan *et al.,* (2006) reported that the broadest fruit measured 20.81 cm and the narrowest fruit measured 6.58 cm, whereas Jagdeesh *et al.,* (2007 A) reported that the broadest fruit was at 24.11 cm and the narrowest fruit was at 19.50 cm. Khan *et al., (*2010) recorded maximum fruit diameter in homestead garden fruit (165.18 cm) and minimum was in forest/fallow areas (66.61 cm). Older trees had more diameter ranging from 50.72 cm to 29.94 cm in Madanhati and of Upashahar regions (Sarker and Zuberi, 2011). Wangchu *et al.,* (2013) reported average fruit diameter ranged from 13.17 to 24.17 cm in their study. Saji *et al.,* (2015) reported fruit diameter ranged from 18.46 cm to 30.50 cm.

2.1.4. Number of flakes per fruit

Hossain and Hoque (1977) reported that the number of flakes of jackfruit varied from 30 to 185. Another study reported that it was in the range of 61 to 108 (Anonymous, 1995). Maiti *et al.,* (2002) studied 44 genotypes of jackfruit and reported the maximum number of bulbs per fruit was 425 and the lowest was 26. Reddy *et al.,* (2004) found significant variation in the number of bulbs per kg of fruit. It was ranging from 36 to 42. Azad *et al.,* (2007) studied on morphological variation of jackfruit and recorded the highest number of bulbs in some elite germplasm. Wangchu *et al.,* (2013) recorded bulbs per fruit ranged from 6 to 60.3 kg. Saji *et al.,* (2015) reported varied number of bulbs and maximum was 300 and the minimum was 48.

2.1.5. Pulp weight

Several researchers in the past studied about pulp weight of jackfruits and had reported the range of pulp weight was 5.73 to 74.33g. Muralidharan *et al.,* (1997) reported maximum individual bulb weight was in Rudrakhavarikka (23.0 g) and the lowest was in wild (5.80). Jagdeesh *et al.,* (2007A) reported the heaviest individual mass of pulp at 26.42 g and the lightest individual bulb mass was recorded as 8.20 g. Jagadeesh *et al.,* (2010) surveyed and studied the significant variation in single bulb mass of 30 jackfruit selections from Coastal zone of Karnataka. The highest single bulb mass was recorded as 59.04 g and minimum as 12.16 g. Wangchu *et al.,* (2013) reported bulb weight ranged from 5.73 – 74.33 g, whereas, Krishnan *et al.,* (2015) reported individual bulb weight ranged from 13.20 to 48.36 g in the Kumarakom region of Kerala.

2.1.6. Seed weight

Earlier reports had revealed that the individual seed weight was varying from 0.5g to 12 g. Islam, (1993) studied on seed germination and seedling morphologies of jackfruit and stated that the individual weight of the seeds of Khaja and Gila types were 5.5 and 5.0g respectively. Reddy *et al.,* (2004) recorded the seed weight and it ranged from 0.5 g in Dorichandra to 12 g in Namanahalli areas of Karnataka.

2.2. Biochemical characters

2.2.1. Total soluble solids

In the previous studies the range of total soluble solids found to be 12.60 to 35° Brix. Maiti *et al.,* (2002) studied 44 genotypes of jackfruit and evaluated based on variation in the total soluble solids (TSS) and reported the maximum TSS was measured to be 25.9º Brix and lowest was found to be 15.1º Brix. Mitra and Maity (2002) characterized thirty-five types of jackfruit over a ten-year period in 1460 trees and found that highest TSS was at 26 to 27 º Brix. Ball (2003) studied on the genetic resources of under-utilized fruit crops and recorded wide diversity among four genotypes of jackfruits with varying fruit TSS from 9 to 9.5 º Brix. Reddy *et al.,* (2004) studied on physico-chemical characteristics of jackfruit clones of South Karnataka and found maximum TSS recorded as 40.5º Brix and lowest recorded as 24.8º Brix. Jagdeesh *et al.,* (2007B) studied on chemical composition of jackfruit selections of Western Ghats of India and reported that the range of TSS was from 19.87º Brix to 35º Brix. In another study, Jagdeesh *et al.,* (2007) reported that the TSS of ninety five jackfruit types selected from Western Ghats of India ranged from 34.33º Brix to 22.23 º Brix. Jagadeesh *et al.,* (2010) surveyed and studied the natural variability in TSS of 30 jackfruit selections from Coastal zone Karnataka and noticed TSS ranging from16.13º Brix to 35º Brix. Wangchu *et al.,* (2013) observed bulb's TSS ranged between 20 - 28.67º Brix and another worker Krishnan *et al.,* (2015) reported TSS ranged from 12.60 – 31.80º Brix. Saji *et al.,* (2015) observed highest total soluble solids as 30.2º Brix and the lowest as 20.0º Brix in his study.

2.2.2. Titratable acidity

Chandan, (2001) studied genetic resources of jackfruit in West Bengal and recorded 0.53% as the highest acidity and Mitra and Maity (2002) also reported 0.53% as the highest titratable acidity in their study. Ball, (2003) recorded wide diversity among four genotypes of jackfruit with varying titratable acidity ranging from 0.28% to 0.34%. Reddy *et al.,* (2004) recorded maximum acidity was measured as 0.68%, while the lowest was recorded as 0.18%, whereas Jagadeesh *et al.,* (2010) reported titratable acidity ranged from 0.16%-0.55%. Similarly, Wangchu *et al.,* (2013) recorded titratable acidity ranged from 0.13 to 0.42 %. However, Krishnan *et al.,* (2015) found maximum titratable acidity in selection KVJ-2 as 17.50% and the minimum was in selection KKJ-2 as 0.20%. Likewise, Saji *et al.,* (2015) recorded the highest titratable acidity as 1.12% and the lowest as 0.16%.

2.2.3. Total sugars

Hossain and Haque (1979) reported average total sugar contents of jackfruit were 19.26%. Hoque, (1993) through his study had revealed that the total sugar content in green jackfruit bulbs as 9.4% and in ripe jackfruit bulb as 15%. Chandan, (2001) recorded total sugar content of flesh varied from 7.60-23.60%, whereas, Bal, (2003) recorded total sugar ranging from 6.5% to 6.9%. Jagdeesh *et al.,* (2007) reported that the total sugar of ninety – five jackfruit types selected from Western Ghats of India ranged from 22.23% to 31.33%. Chrips et al., (2008) studied five varieties of jackfruit for the total sugar content of the bulbs and observed maximum content in variety Valayan (21.3%) and minimum in variety Venkanni (15.3%). Jagadeesh *et al.,* (2010) reported that the total sugar content of selections from Coastal Zone of Karnataka ranged from 18.10% to 25.10 %. Krishnan *et al.,* (2015) studied 21 firm fleshed jackfruit types at Regional Agricultural Research Station, Kumarakom and reported total sugar ranged from 20.84% - 61.88%.

From the review of the reports of earlier workers had suggested that the morpho-physiological characters like Fruit weight, fruit length, fruit width, no of flakes, pulp weight, seed weight, TSS, acidity and total sugars vary due to several fctors like so, climate, germplasm difference, age of the tree , season etc. However, quality of most of the commercial jackfruits was mainly based on the interactive effect of soil, climate and germplasm.

2.3. Mineral characters

2.3.1. Ionome Profiling

Ionome is the mineral nutrient and trace element composition of an organism, which includes elements nonessential for plant growth (Salt *et al.,* 2008) and it involves the quantitative and simultaneous measurement of the elemental composition of plants and changes in this composition in response to physiological stimuli, developmental state, and genetic modifications and also requires the application of high-throughput elemental analysis technologies and their integration with both bioinformatics and genetic tools (Salt *et al.,* 2008). Singh *et al.,* (2013) also reported that ionomics is essential to identify potential gene(s) responsible for the uptake, transport and storage of ions in plants and it involves the measurement of elemental composition of an organism and change in their composition relation to physiological developmental, environmental and generic factors.

Elemental composition of fruit and vegetables depends on different factors, e.g. genetic, weather, soil, and the harvesting stage of maturity (Pramanick *et al.,* 2014). Studies have proved that the nutritional composition among jackfruit varies depending on the cultivar as well as a region (Arkoyd *et al*., 1966; Narasimhan, 1990; Azad, 2000; Haq, 2006 and Baliga *et al.,* 2011). Arkroyd, *et al.,* (1996) analyzed the nutritive value of Indian food and revealed that the concentration of Ca, Mg, P, K, Na and Fe were at 20.0 -37.0 mg, 27 mg, 38.0 - 41.0 mg, 191-407 mg, 2.0-41.0 mg and 0.4 -1.9 mg per 100 g of ripe jackfruit. Similar results were found by Narasimham, 1990; Soepadmo, 1992; Gunasena *et al.,* 1996; Azad, 2000 and Haq, 2006. Jackfruit was found to be a rich source of potassium with 303 mg per 100 g of fruit (Swami *et al.,* 2012).

Geographical Origin and Multi elemental Fingerprinting

Multi-element analysis is a promising method to provide reliable origin information (Zhao *et al.,* 2011). The combination of ionome and chemometrics has been widely used to trace the geographical origins of beverages (Anderson and Smith, 2002), nuts (Anderson and Smith, 2005), wine (Coetzee *et al.,* 2005; Martin *et al.,* 2012; Kruzlicova *et al.,* 2013 and Shen *et al.,* 2013), oil (Jiang *et al.,* 2014), tea (Ma *et al.,* 2016), vegetables and fruits (Bibak *et al.,* 1999; Di Giacomo *et al.,* 2007; Tormen *et al.,* 2011; Perents et al., 2013; Todea *et al.,* 2014 and Yan *et al.,* 2015) and cereals like barley (Husted *et al.,* 2004), wheat (Zhao *et al.,* 2011) and rice (Kokot and Phuong 1999; and Li *et al.,* 2012).

In addition, ionome profiling is particularly sensitive to the soil and climate conditions under which agricultural crops are grown (Coetzee *et al.,* 2014 and Yan *et al.,* 2015). According to Febani *et al.,* (2010) study of both soil and agricultural crop composition is very useful to obtain reliable markers of agricultural crop provenance. The calcium (Ca) content in soil is strongly influenced by rock composition (Kment et al., 2005 and Yan *et al.,* 2015). The magnesium (Mn) concentrations are highest in ultrabasic and basic rocks such as serpentine and basalt, respectively, and lowest in acidic rocks such as granite (Alloway, 2013 and Yan *et al.,* 2015). Uncovering a significant correlation between plant and soil was difficult because of distractions in topsoil from industrial wastewater irrigation, aerial deposition, and use of fertilizers and pesticides (Mench *et al.,* 1994; Ulrich *et al.,* 1999 and Yan *et al.,* 2015). Element content in soil is greatly influenced by geographical environment and variations in the distribution of these trace elements among different geographical locations can give distinct elemental signatures in organic tissues (Sun et al., 2011 and Yan et al., 2015). Calcium leaching is more significant in lateric red soil than red soil (Yan and Liang, 1992 and Li *et al.,* 2012).

Husted *et al.,* (2004) stated that inductively coupled plasma mass spectrometry is a sensitive, accurate, and rapid method for determination of the multi-elemental composition of a wide variety of different sample types. Inductively coupled plasma mass spectrometry (ICP-MS) constitutes as a promising novel analytical tool, which has the potential to mature into a routine procedure for testing e.g. the authenticity and adulteration of food products (Kment *et al*., 2005; Ekholm *et al.,* 2007; Laursen *et al.,* 2009; Furia *et al.,* 2011; Magdas *et al.*, 2011; Tormen *et al.,* 2011; Zhao *et al.,* 2011; Li *et al.,* 2012; Martin *et al.,* 2012; Mishra *et al.,* 2012; Dehlean snd Magdas 2013; Guo *et al.,* 2013; Shen *et al.,* 2013; Jarosova *et al.,* 2014; Jiang *et al.,* 2014; Pramanick *et al.,* 2014; Todea *et al.,* 2014 and Ma *et al.,* 2016).

Ionome profiling followed by multivariate analysis has previously been shown to differentiate between countries of origin (Anderson *et al.,* 1999; Kelly *et al.,* 2005; Perez *et al.,* 2006; Gonzálvez, *et al.,* 2011; Zhao *et al.,* 2011; Li *et al.,* 2012; Martin *et al.,* 2012; Muniz-Valencia *et al.,* 2013; Shen *et al.,* 2013; Jarosova *et al.,* 2014; Jiang *et al.,* 2014; Yan *et al.,* 2015 and Ma *et al.,* 2016).

Principal Component Analysis condenses the variance of the data set and allows visualization of the data trends with lesser dimensionally (Jolliffe, 2002). Kokot and Phuong (1999) revealed that PCA analysis could discriminate the white rice from Australia and Vietnam. The application of multivariate statistics using PCA enabled only vague discrimination between the two cropping system (Husted *et al.,* 2004). Linear Discriminant Analysis computes linear combinations of the data discriminant functions via a linear combination of the original variables and it can be constructed trough a stepwise approach by selecting only the most discriminating variables and reducing the numbers of variables used as chemical descriptors (Massart, 1998). Several linear discriminant function models classified the data sets with 95% or higher accuracy and the development of a method combining elemental analysis and classification techniques that may be widely applied to the determination of the geographical origin of foods (Anderson and Smith 2005; Furia *et al.,* 2011 and Tormen *et al.,* 2011). The effect of growth conditions was also examined by Bibak *et al*., (1999) who used a combination of multi-elemental analysis and multivariate statistics to separate potatoes on the basis of the types and levels of nitrogen fertilization used. Elemental fingerprinting was also used to characterize the tomato quality as related to cultivation in soil or in an inert growth medium such as rock wool (Gundersen et al., 2001).

The present investigation entitled **“Identification of the geographical origin of jackfruit (*Artocarpus heterophyllus* Lam.) through multielemental fingerprinting using ICPMS”** was carried out during 2016-17 and 2017-18 in plant nutrition and ionome laboratory of Department of Horticulture, Sikkim University, Gangtok, Sikkim. The details of materials used and methods employed during the course of investigation are described below.

3.1. Sample collection

Seventy accessions of jackfruit from seven geographic locations famous for the jack fruit production belonging to five states of India were collected to study the identification of the geographical origin of jackfruit (*Artocarpus heterophyllus* Lam.) through a multi - element fingerprinting using ICPMS. Fully matured, ripened and fresh edible quality jackfruits from the bearing trees aged about 15 to 30 years old orchards and soil samples from the basin of the trees were collected during the month of May to June of 2016 for the first year and May to June of 2017 for the second year from different jackfruit growing regions of India. (Table. 3.1 & 3.2).

3.1.1. Fruit sample preparation

All the jackfruit samples were harvested at physiologically matured stage. The ripen jackfruits were cleaned, peeled, stone were separated and kept in self sealing polythene bags at -20^{o} C until all the analysis were carried out. The same procedure was followed during the second year.

3.2. Physico-chemical and ionome analysis

Collected fruits of the accessions were subjected to physico-chemical analysis *viz.* estimation of fruit weight, fruit length, number of flakes per fruit, flake, pulp and seed weight, total soluble solids (TSS), titratable acidity, total sugars as well as multi elemental analysis.

3.2.1. Estimation of physical parameters

3.2.1.1. Fruit weight (kg): The weight of the fruit was measured by electronic weighing balance (Mettler Toledo) and recorded in kilograms.

3.2.1.2. Fruit length (cm): Fruit length and fruit width were measured manually by using meter tape.

3.2.1.3. The number of flakes: Counted manually after removal of the fruit skin.

3.2.1.4. Flake, pulp and seed weight: The weight of the flake, pulp and seed were measured by electronic weighing machine (Mettler Toledo).

3.2.2. Estimation of chemical parameters

3.2.2.1 Extraction of Juice: From each treatment and respective replications, fruit pulp was separated by removal of fruit peel and then the juice was extracted by crushing it manually. The extracted juice was strained, making it free of pulp by passing through muslin cloth and the filtered juice was collected in a beaker. Beakers were labeled properly indicating the respective treatment number and replication. The juice was used for further analysis.

3.2.2.2. Determination of TSS: Total soluble solids (TSS) were determined from the juice by using a hand refractometer (ERMA) and expressed in ^{o}Brix (Ranagnna, 1986).

3.2.2.3. Estimation of Titrable acidity: The acidity percentage of the fruit juice was determined by titrating the known quantity of the fruit juice against 0.1N NaOH using phenolphthalein as an indicator (Sadasivam and Manickam, 1996) and expressed as percentage.

3.2.2.4. Total sugars (%): Total sugars were determined following the method described by Lane and Eyon (AOAC, 1965). A quantity of 50 ml juice filtrate was taken in a 100 ml volumetric flask and to it 5 ml of concentrated HCL was added, mixed well and then kept for 24 hours at ambient temperature. Acid was then neutralized with NaOH using a drop of phenolphthalein as an indicator till the pink color persisted for at least a few seconds. The volume was made up to 100 ml with distilled water and the total sugars were then estimated by taking this solution in a burette and titrating it against standard Fehling's solution mixture of A and B (1:1) using methylene blue as an indicator and taking brick red color as an end point.

3.3. Multi elemental analysis through ICPMS

3.3.1. Soil sample preparation

Soil samples from different geographical locations were collected in polythene bags. Sampling depth was 40 to 60 cm. Soils were air-dried completely and dried soils were milled into powder with wooden mallet, homogenized and sieved through 2 mm sieve.

3.3.2. Plant sample preparation

Flakes of the fruits were extracted from the fruits and known quantity was taken for digestion.

3.3.3. Sample digestion

The microwave digestion of the samples was performed with the multiwave digestion system (Anton Par, Multiwave 3000) as per the manufacturer's manual. Digested samples were cooled and made up to volume of 50 ml with DDW (Double distilled water) in volumetric flask and then transferred to narrow mouth bottle with details of the sample for further analysis. These samples were subjected to inductively coupled plasma mass spectrometry (ICP-MS) analysis to elucidate profile ions.

3.3.4. Multi-element analysis

Ionome profiling was carried out with the help of Inductively Coupled Plasma Mass Spectrometry (Perkin Elemer, Nex ION 300X) system with cross flow nebulizer. Before analysing the sample the instrument was calibrated using standard reference material (peach level-NIST, 1547). Digested samples were analysed for 24 elements *vz.* Ba, Al, Ca, Co, Cs, Cr, Cu, Fe, Ga, S, K, Li, Mg, Mn, Na, Ni, Mo, Rb, Ti, U, B, Zn, Si and Xe using multi elemental standard solution no.1 , 3 and 5 supplied by Perkin Elmer containing Ag, Al, B, Ba, Be, Bi, Ca, Cd, Cr, Cs, Cu, Fe, Ga, Ge, In, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Rb, S, Si, Ta, Ti, V, Zn, Zr and Hg analytes. The results were obtained directly in the units of ppm**.**

3.4. Statistical analysis

Three trees each in one location constituted one treatment and each tree was considered as replication. Hence, numbers of treatment were 70 with 3 replications. The data obtained from Pysico-chemical analysis and multielemental analysis were analyzed using two di-mensional multivariate methods such as Principal Component Analysis

(PCA) and Linear Discriminant Analysis (LDA). All the analysis was performed by JMP software (version 14.1) in all experiment were.

The present investigation titled **"Identification of the geographical origin of jackfruit (*Artocarpus heterophyllus* Lam.) through multielemental fingerprinting using ICPMS"** was undertaken to characterize the jackfruit collected from different geographical locations of India through profiling of multielements using ICPMS including physico-chemical parameters. The results of the different parameters observed during experimentation have been presented below:

4.1. Morphological characters

4.1.1. Fruit weight

Experimental data pertaining to the fruit weight (Tables 4.1, 4.2 & 4.3) revealed that among the analyzed accessions, it varied from 1.00 (SDTJ 61) to 17.30 kg (PANJ 48) in the first year and 0.92 kg (SDTJ 61) to 16.45 kg (PANJ 48) in the second year. On an average it was varying from 1.00 kg (SDTJ 61) to 16.87 kg (PANJ 48) when both the years were combined (Tables 4.1, 4.2 & 4.3).

When comparing the variation among the locations, it was found that maximum fruit weight was noted in accessions collected from Panruti (10.67 kg and 12.00 kg) followed by Khowai (4.16 kg and 4.28 kg) during first and second years of study. Whereas, the minimum weight was recorded in accessions of South Sikkim (2.39 kg and 2.13 kg) during first and second years of study. On an average, it was varying from 11.34

kg in Panruti to 2.26 kg in South Sikkim when both the years were combined (Tables 4.4, 4.5 & 4.6).

4.1.2. Fruit Length

The result of the experiment showed that the fruit length of different accessions was in the range of 17.30 cm (SDTJ 61) to 73.60 cm (PANJ 48) in the first year and 21.10 cm (SDTJ 61) to 75.20 cm (PANJ 48) in the second year of study. The mean value was varying from 19.91 cm (PARJ 9) to 74.40 cm (PANJ 48) when both years data were combined (Tables 4.1, 4.2 & 4.3).

Among the accessions of different locations, highest fruit length was noted in accessions collected from Panruti (53.13 cm and 54.55 cm) followed by accessions collected from Varkala (38.11 cm and 40.42 cm) during first and second years of study. Minimum fruit length was recorded in accessions collected from West Tripura (28.83 cm) during the first year and from North 24 Parganas (29.15 cm) during the second year of study. Similarly, when data of both years were combined, accessions collected from Panruti showed highest length (53.84 cm) followed by Varkala (39.26 cm) and the least length (29.19 cm) were observed in West Tripura (Tables 4.4, 4.5 & 4.6).

4.1.3. Fruit width

The observation on fruit width had shown that it was in range of 29.50 (SDTJ 61) cm to 86.20 cm (PANJ 47) in the first year and 39.60 cm (SDTJ 63) to 87.30 cm (PANJ 47) in the second year of study. On an average, it was varying from 30.11 cm (NADJ 14) to 86.75 cm (PANJ 47) when both the years data were combined (Tables 4.1, 4.2 & 4.3).

Comparing the variation among the locations, it was found that the maximum fruit width (70.83 cm and 72.08 cm) was observed in the accessions collected from Panruti followed by West Tripura (61.75 cm and 61.57 cm) in first and second years of study. On the contrary, it was lowest in accessions collected from South Sikkim (50.06 cm and 50.95 cm) in first and second years of study. On an average, the accessions collected from Panruit (71.46 cm) followed by West Tripura (61.66 cm) recorded highest fruit width. Whereas, the lowest width (50.51 cm) was recorded in accessions collected from South Sikkim (Tables 4.4, 4.5 & 4.6).

4.1.4. Numbers of flakes

The data obtained for number of flake segments per fruit of different accessions were found to be in the range of 27 (SDTJ 61) to 223 (PANJ 48) in the first year and it was 40 (SDTJ) to 236 (PANJ 48) in the second year of study. On an average, it was varying from 25 (NADJ 16) to 230 (PANJ 48) when both the years data were combined (Tables 4.1, 4.2 & 4.3).

Among the accessions of the different locations, highest number of flakes was noted in accessions collected from Panruti (156.80 and 146.26) in the first and second years of study followed by Khowai (81.10) in the first year and West Tripura (83.75) in the second year of study. The lowest number of flakes observed in South Sikkim (57.41 and 55.87) accessions in the first and second years of study. When both the years were combined the accessions collected from Panruti (151.80) recorded the highest number of flakes per tree followed by Khowai (82.20) and the lowest number of flakes per tree (56.80) were recorded in South Sikkim (Tables 4.4, 4.5 & 4.6).

4.1.5. Flake weight

In the present experiment weight of the flake in respect of the accessions was ranging from 10.3 g (SDTJ 63) to 47.22 g (PANJ 47) in the first year and 9.52 g (SDTJ 63) to 47.52 g (PANJ 47) in the second years of study. Flake weight of the accessions were ranging from 9.91 g (SDTJ 63) to 47.29 g (PANJ 47) when both the years data were combined (Tables 4.1, 4.2 & 4.3).

When comparing the variation among the locations, it was found that highest value of flake weight was observed in accessions collected from Panruti (39.37 g and 38.27 g) in the first and second years of study followed by accession collected from Khowai (30.16 g) in first year and Varkala (33.48 g) in the second year of study. Minimum value of flake weight was recorded in accessions of South Sikkim (13.73 g and 14.35 g) in the first and second years of study. On an average, the accessions collected from Panruti (38.82 g) showed the maximum value followed by Varkala (30.99 g) and the minimum value were observed in South Sikkim (14.05 g) when data of both the years were combined (Tables 4.4, 4.5 & 4.6).

4.1.6. Pulp weight

Pulp weight of various accessions was in the range of 6.00 g (SDTJ 63) to 38.41 g (PANJ 47) in the first year and 4.99 g (SDTJ 63) to 40.80 g (PANJ 47) in the second year of study (Tables 4.1, 4.2 & 4.3). When both the years were combined the accessions ranged from 5.50 g (SDTJ 63) to 38.79 g (PANJ 47).

Comparison of accessions based on the location yielded that the maximum pulp weight was in accessions collected from Panruti (29.44 g and 32.92 g) in the first and second years of study followed by accession collected from Khowai (26.51 g) in the first year and Varkala (26.14 g) in the second year of study. On the contrary, the minimum value was observed in South Sikkim (13.73 g and 14.35 g) in the first and second years of study. In addition, when both the years data were combined together the accessions collected from Panruti (31.18 g) followed by Khowai (26.09 g) recorded highest value of pulp weight and the lowest (14.05 g) was noted in accessions collected from South Sikkim (Tables 4.4, 4.5 & 4.6).

4.1.7. Seed weight

The data observed through this present experiment revealed differences in seed weight among the accessions studied. The range was found to be between 2.7 g in SDTJ 61 to 9.07 g in PANJ 46 in the first year and 2.89 g in SDTJ 61 to 9.13 g in PANJ 46 in the second year (Tables 4.1, 4.2 & 4.3). On an average the range of the accessions was varying from 2.80 g (SDTJ 61) to 9.10 g (PANJ 46) when both the years data were combined together.

When comparing the variation among the locations, it was found that the seed weight was observed maximum in accessions collected from Panruit (6.48 g and 6.68 g) followed by West Tripura (4.81 g and 4.91 g) and the minimum was observed in South Sikkim (3.95 g and 4.07 g) in the first and second years of study. Similarly, the accessions collected from Panruti (6.58 g) followed by West Tripura (4.86 g) showing maximum value of seed weight and minimum were noted in South Sikkim (4.01 g) when both the years were combined together (Tables 4.4, 4.5 & 4.6).

4.2. Chemical characters

4.2.1. Total soluble solids (^{o} Brix)

Analysis total soluble solids (TSS) of different accessions under investigation revealed that it varied in the range of 10.00^o Brix (KHWJ 34) to 25.40^o Brix (VARJ 59) in the first year and 10.60^o Brix (KHWJ 34) to 27.80^o Brix (VARJ 59) in the second year of study (Tables 4.1, 4.2 & 4.3). On the same way, when data of both the years were combined together the TSS ranged from 10.70^o Brix (KHWJ 34) to 26.60^o Brix (VARJ 59).

Among the accessions of different locations, the highest value of total soluble solids was observed in accession collected from Varkala (20.76^o Brix and 22.39 ^{o} Brix) in the first and second years of study followed by accession collected from Nadia (19.91^o Brix) in the first year and Panruti (20.68 ^{o} Brix) in the second year of study. On the contrary, the minimum value was present in the accessions of West Tripura (13.42^o Brix and 13.91^o Brix) in the first and second years of study. When both the years were combined together the accessions collected from Varkala (21.58 ^{o} Brix) recorded highest followed by Nadia (20.23^o Brix) and the lowest (13.66^o Brix) was recorded in accessions collected from West Tripura (Tables 4.4, 4.5 & 4.6).

4.2.2. Titratable acidity

The observation of the experiment reported that the titratable acidity was at the range of 0.3% (PANJ 44) to 1.2% (SDTJ 68) in the first year and 0.4% (PANJ 46) to 1.2% (KHWJ 36) in the second year of study. On an average, it was varying from 0.4% (PANJ 46) to 1.2% (SDTJ 68) when both the years data were combined together (Tables 4.1, 4.2 & 4.3).

Among the accessions of different locations the maximum titratable acidity was noted in accessions collected from West Tripura (0.97 %) followed by South Sikkim (0.81 %) in the first year and South Sikkim (0.85%) followed by West Tripura (0.77 %) in the second year of study. On the other hand, the minimum titratable acidity was observed in accessions of Panruti (0.48 % and 0.55 %) in the first and second years of study. Similarly, when data of both the years were combined together the accessions collected from West Tripura (0.87) followed by South Sikkim (0.85 %) showed highest and the lowest (0.51%) was observed in accessions collected from Panruti (Tables 4.4, 4.5 & 4.6).

4.2.3. Total Sugar

The differences in the total sugar content among the jackfruit accessions investigated was found and the results presented in (Tables 4.1, 4.2 & 4.3) and revealed that the total sugar contents were range of 10.14% (KHWJ 34) to 17.26 % (VARJ 59) in the first year and 10.56% (KHWJ 34) to 18.32% (VARJ 59) in the second year of study. On an average, the accessions were ranges from 10.35% (KHWJ 34) to 17.79% (VARJ 59) when both the years were combined together (Tables 4.1, 4.2 & 4.3).

When comparing the variation among the locations, it was found that the maximum total sugar was noted in accessions collected from Panruti (16.54 %; 17.38 %) followed by Varkala (16.28%; 17.06 %) in the first and second year of study and the minimum was noted in West Tripura (13.77 %; 14.35 %). Similarly, when both the years were combined together the maximum total sugar was noted in accessions collected from Panruti (16.96 %) followed by Varkala (16.67%) and the minimum (14.07 %) total sugar was observed in West Tripura (Tables 4.4, 4.5 & 4.6).

4.3. Multi-elemental profiling of soil

Soil samples collected from basins of 70 different accessions were analyzed for their multi elemental profile to know about their elemental concentrations and to assess their influence on the elemental concentration on the jackfruit. A total of 24 elements were analyzed (Tables. 4.10, 4.11, 4.12, 4.13, 4.14 & 4, 15).

4.3.1. Barium (Ba)

The element (Ba) was observed maximum in accessions collected from Nadia (44.78 mg kg^{-1} and 50.89 mg kg^{-1}) followed by South Sikkim (37.21 mg kg^{-1} and 37.62 mg kg^{-1}) in the first and second years of study. Whereas, the least concentration of barium was noted in accessions collected from West Tripura (8.26 mg kg^{-1} and 8.15 mg kg^{-1}) in the first and second years of study. On the similar fashion, the highest concentration of Ba was noted in Nadia (47.58 mg kg^{-1}) followed by South Sikkim (37.41 mg kg^{-1}) and the least concentration of barium was noted in accessions collected from West Tripura (8.21 mg kg^{-1}) when both the years were combined together.

4.3.2. Aluminium (Al)

Highest Al concentration was noted in accessions collected from Nadia (2329.13 mg kg^{-1} and 2401.32 mg kg^{-1}) followed by accessions collected from North 24 Parganas (2228.75 mg kg^{-1} and 2003.71 mg kg^{-1}) and the minimum aluminium concentration was recorded in accessions collected from Panruti (367.24 mg kg^{-1} and 370.76 mg kg^{-1}) in the first and second years of study. Likewise, the highest concentration of Al was noted in Nadia (2365.23 mg kg^{-1}) followed by accession collected from North 24 Parganas (2116.23 mg kg^{-1}) and the minimum concentration was recorded in accessions collected from Panruti (369.00 mg kg^{-1}) when both the years were combined together.

4.3.3. Calcium (Ca)

Calcium concentration under present experiment was recorded maximum in accession collected from North 24 Parganas (29.25 mg kg^{-1} and 30.16 mg kg^{-1}) followed by accessions collected from Nadia (27.23 mg kg^{-1} and 27.80 mg kg^{-1}) and the lowest concentration was observed in accessions collected from Khowai (4.51 mg kg^{-1} and 4.52 mg kg^{-1}) in the first and second years of study. Similarly, the highest concentration of Ca was recorded in accession collected from North 24 Parganas (29.70 mg kg^{-1}) followed by Nadia (27.51 mg kg^{-1}) and the lowest data was observed in accession collected from Khowai (4.52 mg kg^{-1}) when both the years were combined together.

4.3.4. Cobalt (Co)

Highest copper concentration was recorded in the accessions collected from Nadia (2.61 mg kg^{-1} and 2.58 mg kg^{-1}) followed by North 24 Parganas (1.96 mg kg^{-1} and 1.093 mg kg^{-1}) and the lowest was observed in accessions collected from Panruti (0.36 mg kg^{-1}

and 0.35 mg kg^{-1}) in the first and second years of study. Similarly, the highest concentration of Co was recorded in accessions collected from Nadia (2.60 mg kg^{-1}) followed by North 24 Parganas (1.95 mg kg^{-1}) and the lowest was observed in accession collected from Panruti (0.36 mg kg^{-1}) when both the years were combined together.

4.3.5. Chromium (Cr)

Highest chromium concentration was noted in accessions collected from Varkala (57.35 mg kg^{-1} and 55.24 mg kg^{-1}) in the first and second years of study followed by accession collected from North 24 Parganas (45.68 mg kg^{-1}) in the first year and Nadia (45.74 mg kg^{-1}) in the second year of study. Whereas, the least chromium concentration was recorded in accessions collected from Panruti (22.77 mg kg^{-1} and 24.31 mg kg^{-1}) in the first and second years of study. Likewise, the highest concentration of Cr was noted in accession collected from Varkala (56.29 mg kg^{-1}) followed by accessions collected from North 24 Parganas (45.24 mg kg^{-1}) and the least chromium concentration was recorded in accessions collected from Panruti (23.54 mg) when both the years were combined together.

4.3.6. Cesium (Cs)

Highest cesium concentration was recorded in accessions collected from South Sikkim (2.24 mg kg^{-1} and 2.64 mg kg^{-1}) followed by in the accessions of Nadia (1.72 mg kg^{-1} and 2.09 mg kg^{-1}) and the lowest cesium concentration was recorded in accessions collected from Panruti (0.08 mg kg^{-1}) in the first and second years of study. Likewise, the highest concentration of Cs was noted in accessions collected from South Sikkim (2.51 mg kg^{-1}) followed by Nadia (1.97 mg kg^{-1}) and the lowest cesium concentration was recorded in accessions collected from Panruti (0.08 mg kg^{-1}) when both the years were combined together.

4.3.7. Copper (Cu)

Copper concentration was observed to be the highest in accessions collected from Nadia (21.88 mg kg^{-1} and 23.98 mg kg^{-1}) followed by North 24 Parganas (15.26 mg kg^{-1} and 17.04 mg kg^{-1}) and the lowest concentration was noted in Varkala (5.50 mg kg^{-1} and 5.39 mg kg^{-1}) in the first and second years of study. A similar trend was noted when both the years were combined together. The highest concentration of Cu was noted in accessions collected from Nadia (22.48 mg kg^{-1}) followed by North 24 Parganas (16.15 mg kg^{-1}) and lowest concentration was noted in Varkala (5.45 mg kg^{-1}).

4.3.8. Iron (Fe)

The highest value of Iron was observed in accessions collected from Nadia (1930.16 mg kg^{-1} and 1907.70 mg kg^{-1}) followed by accessions collected from Varkala (1462 mg kg^{-1} and 1457.30 mg kg^{-1}) and the minimum concentration was present in Panruti (192.15 mg kg^{-1} and 191.20 mg kg^{-1}) in the first and second years of study. Similarly, the highest concentration of Fe was noted in accession collected from Nadia (1918.93 mg kg^{-1}) followed by accession collected from Varkala (1459.89 mg kg^{-1}) and the minimum concentration was present in Panruti (191.68 mg kg^{-1}) when both the years were combined together.

4.3.9. Gallium (Ga)

Gallium concentration under present experiment was recorded maximum in accessions collected from Panruti (4.74 mg kg^{-1} and 5.04 mg kg^{-1}) and the lowest data was observed in accessions collected from Khowai (0.74 mg kg^{-1} and 0.80 mg kg^{-1}) in the first and second years of study. Similarly, the highest concentration of Ga was noted in accessions collected from Panruti (4.89 mg kg^{-1}) and the lowest data was observed in accessions collected from Khowai (0.77 mg kg^{-1}) when both the years were combined together.

4.3.10. Sulfur (S)

Sulfur concentration under present experiment was recorded maximum in accessions collected from Varkala (15.45 mg kg^{-1} and 14.39 mg kg^{-1}) and minimum concentration of sulfur was recorded in accessions collected from Khowai (12.40 mg kg^{-1} and 50.51 mg kg^{-1}) in the first and second years of study. In the similar fashion, when both the years were combined together the highest concentration of S was noted in accessions collected from Varkala (14.92 mg kg^{-1}) and the minimum concentration of sulfur was recorded in accessions collected from Khowai (11.54 mg kg^{-1}).

4.3.11. Potassium (K)

The highest observed value of potassium was noted in accessions collected from Nadia (55.06 mg kg^{-1} and 55.66 mg kg^{-1}) followed by North 24 Parganas (50.23 mg kg^{-1} and 50.51 mg kg^{-1}) and the lowest concentration was observed in accessions collected from Khowai (6.96 mg kg^{-1} and 6.87 mg kg^{-1}) in the first and second years of study. The trend continued, when both the years were combined together. The highest concentration of K was noted in accessions collected from Nadia (55.36 mg kg^{-1}) followed by North 24 Parganas (50.37 mg kg^{-1}) and the lowest concentration was observed in accession collected from Khowai (6.92 mg kg^{-1}).

4.3.12. Lithium (Li)

As per the data pertaining to the concentration of lithium present in the analyzed samples, it was observed that Li concentration was highest in accessions collected from Nadia (21.16 mg kg^{-1} and 21.85 mg kg^{-1}) followed by South Sikkim (19.78 mg kg^{-1} 19.28 mg kg^{-1}) and the lowest concentration was noted in accessions collected from Khowai (1.10 mg kg^{-1} and 1.04 mg kg^{-1}) in the first and second years of study. Likewise, when both the years were combined together the highest concentration of Li was noted in accessions collected from Nadia (21.83 mg kg^{-1}) followed by South Sikkim (19.53 mg kg^{-1}) and the lowest concentration was noted in accessions collected from Khowai (1.07 mg kg^{-1}).

4.3.13. Magnesium (Mg)

Magnesium concentration under present experiment was recorded maximum in accessions collected from Varkala (139.11 mg kg^{-1} and 146.56 mg kg^{-1}) followed by Nadia (138.15 mg kg^{-1} and 142.75 mg kg^{-1}) and the minimum concentration was noted in accessions collected from West Tripura (26.91 mg kg^{-1}) in the first and second years of study. Similarly, when both the years were combined together the highest concentration of Mg was noted in accession collected from Varkala (142.84 mg kg^{-1}) followed by Nadia

(140.43 mg kg^{-1}) and the minimum concentration was noted in accessions collected from West Tripura (26.91 mg kg^{-1}).

4.3.14. Manganese (Mn)

Maximum manganese concentration was noted in accessions collected from Nadia (2133.20 mg kg^{-1} and 2257.20 mg kg^{-1}) followed by Varkala (1805.55 mg kg^{-1} and 1949.56 mg kg^{-1}) and the minimum concentration was observed in Panruti (198.97 mg kg^{-1} and 207.77 mg kg^{-1}) in the first and second years of study. Similaraly, when both the years were combined together the highest concentration of Mn was noted in accessions collected from Nadia (2195.20 mg kg^{-1}) followed by Varkala (1877.56 mg kg^{-1}) and the minimum concentration was observed in Panruti (203.37 mg kg^{-1}).

4.3.15. Sodium (Na)

Highest sodium concentration was recorded in accessions collected from Nadia (88.33 mg kg^{-1} and 92.77 mg kg^{-1}) followed by North 24 Parganas (77.70 mg kg^{-1} and 74.03 mg kg^{-1}) and the lowest values was reported in accessions collected from West Tripura (42.21 mg kg^{-1} and 43.56 mg kg^{-1}) in the first and second years of study. Likewise, when both the years were combined together the highest concentration of Na was noted in accession collected from Nadia (90.55 mg kg^{-1}) followed by North 24 Parganas (75.87 mg kg^{-1}) and the lowest values was reported in accessions collected from West Tripura (42.88 mg kg^{-1})

4.3.16. Nickel (Ni)

Maximum nickel concentration was observed in accessions collected from Nadia (14.85 mg kg^{-1} and 15.04 mg kg^{-1}) followed by accessions collected from North 24 Parganas (10.74 mg kg^{-1} and 10.57 mg kg^{-1}) and the lowest concentration was recorded in accessions collected from Panruti (2.06 mg kg^{-1} and 2.34 mg kg^{-1}) in the first and second years of study. Same trend could be observed when data of both the years were combined together as the highest concentration of nickel was noted in accessions collected from Nadia (14.94 mg kg^{-1}) followed by accessions collected from North 24 Parganas (10.66 mg kg^{-1}) and the lowest concentration was recorded in accessions collected from Panruti (2.20 mg kg^{-1}).

4.3.17. Molybdenum (Mo)

Maximum molybdenum concentration was noted in accessions collected from Khowai (2.33 mg kg^{-1} and 2.11 mg kg^{-1}) followed by West Tripura (1.01 mg kg^{-1} and 1.02 mg kg^{-1}) and the minimum concentration was recorded in Panruti (0.31 mg kg^{-1} and 0.30 mg kg^{-1}) in the first and second years of study. However, when both the years were combined together the highest concentration of Mo was noted in accession collected from Khowai (2.22 mg kg^{-1}) followed by West Tripura (1.02 mg kg^{-1}) and the minimum concentration was recorded in Panruti (0.31 mg kg^{-1}).

4.3.18. Rubidium (Rb)

The highest observed value of rubidium was noted in accessions collected from South Sikkim (17.69 mg; 18.15 mg) followed by Nadia (14.83 mg; 15.00 mg) and the lowest concentration were recorded in Panruit (1.14 mg; 1.20 mg) in the first and second years of study. However, when both the years were combined together the highest concentration of Rb was noted in accession collected from South Sikkim (17.92 mg) followed by Nadia (14.92 mg) and the lowest concentration was recorded in Panruit (1.17 mg).

4.3.19. Tillium (Ti)

The element tillium was observed maximum in accessions collected from Nadia (355.86 mg kg^{-1} and 358.62 mg kg^{-1}) followed by North 24 Parganas (334.53 mg kg^{-1} and 347.82 mg kg^{-1}) and the minimum concentration was observed in Panruti (18.36 mg kg^{-1} and 18.24 mg kg^{-1}) in the first and second years of study. Likewise, when both the years were combined together the highest concentration of Ti was noted in accessions collected from Nadia (357.14 mg kg^{-1}) followed by North 24 Parganas (341.17 mg kg^{-1}) and the minimum concentration was observed in Panruti (18.50 mg kg^{-1}).

4.3.20. Uranium (U)

Highest uranium concentration was recorded in accessions collected from South Sikkim (1.16 mg kg^{-1} and 1.32 mg kg^{-1}) followed by Varkala (0.69 mg kg^{-1} and 0.76 mg kg^{-1}) and the lowest concentration was observed in accession of Panruti (0.12 mg kg^{-1} and 0.14 mg kg^{-1}) in the first and second years of study. Similarly, when both the years were combined together the highest concentration of U was noted in accessions collected from South Sikkim (1.24 mg kg^{-1}) followed by Varkala (0.72 mg kg^{-1}) and the lowest concentration was observed in Panruti (0.13 mg kg^{-1}).

4.3.21. Boron (B)

Boron concentration was recorded maximum in accessions collected from Panruti (12.14 mg kg^{-1}) in the first year and West Tripura (11.99 mg kg^{-1}) in the second year of study. Whereas, The lowest concentration was noted in Khowai (10.15 mg kg^{-1}) in the first year and South Sikkim (10.37 mg kg^{-1}) in the second year. However, when both the years were combined together the highest concentration of B was noted in accession collected from Panruti (11.94 mg kg^{-1}) and the lowest concentration was noted in North 24 Parganas (10.40 mg kg^{-1}).

4.3.22. Zinc (Zn)

Maximum zinc concentration was noted in accession collected from South Sikkim (4.28 mg kg^{-1} and 4.47 mg kg^{-1}) followed by Varkala (3.38 mg kg^{-1} and 3.52 mg kg^{-1}) and the lowest was recorded in West Tripura (2.09 mg kg^{-1} and 2.14 mg kg^{-1}) in the first and second years of study. Likewise, when both the years were combined together the highest concentration of Zn was noted in accessions collected from South Sikkim (4.34 mg kg^{-1}) and the lowest was recorded in West Tripura (2.12 mg kg^{-1}).

4.3.23. Silicon (Si)

Silicon concentration was observed to be highest in accessions collected from Panruti (8.52 mg kg^{-1} and 8.75 mg kg^{-1}) followed by Varkala (7.68 mg kg^{-1} and 7.59 mg kg^{-1}) and the lowest concentration was noted in accessions collected from North 24 Parganas (3.92 mg kg^{-1} and 3.88 mg kg^{-1}) in the first and second years of study. Similarly, when both the years were combined together the highest concentration of Si was noted in accessions collected from Panruti (8.63 mg kg^{-1}) followed by Varkala (7.63 mg kg^{-1}) and the lowest concentration was noted in accessions collected from North 24 Parganas (3.90 mg kg^{-1}).

4.3.24. Xenon (Xe)

Xenon concentration was recorded maximum in accessions collected from Khowai (1696.81 mg kg^{-1} and 1832. 86 mg kg^{-1}) followed by West Tripura (1449.45 mg kg^{-1} and 1461.92 mg kg^{-1}) and the lowest concentration was noted in North 24 Parganas (916.12 mg kg^{-1} and 960.86 mg kg^{-1}) in the first and second years of study. Likewise, when both the years were combined together the highest concentration of Si was noted in accessions collected from Khowai (1764.83 mg kg^{-1}) followed by West Tripura (1455.69 mg kg^{-1}) and the lowest concentration was noted in North 24 Parganas (938.49 mg kg^{-1}).

4.4. Multi-elemental profiling of jackfruit accessions

The elemental composition analysis of different jackfruit accessions using ICPMS has been illustrated below. A total of 24 elements was analyzed during the experimentation (Tables 4.16, 4.17, 4.18, 4.19, 4.20 & 4.21).

4.4.1. Barium (Ba)

Element barium was observed maximum in the accessions collected from South Sikkim (1.50 mg kg^{-1} and 1.52 mg kg^{-1}) followed by West Tripura (1.16 mg kg^{-1} and 1.25 mg kg^{-1}) in the first and second years of study. Least concentration of Ba was noted in accessions collected from Nadia (0.34 mg kg^{-1} and 0.36 mg kg^{-1}) in the first and second years of study. Similarly, when both the years were combined together the maximum Ba was observed in South Sikkim (1.51 mg) followed by West Tripura (1.20 mg) and the minimum (0.35 mg) was noted in accessions collected from Nadia.

4.4.2. Aluminium (Al)

Highest Al concentration was noted in accessions collected from South Sikkim (3.82 mg kg^{-1}) in the first year and North 24 Parganas (3.31 mg kg^{-1}) in the second year of study followed by North 24 Parganas (3.34 mg kg^{-1} and 3.33 mg kg^{-1}) in the first year and South Sikkim (3.29 mg kg^{-1}) in the second year of study. However, when both the years were combined together the accessions collected from South Sikkim (3.61 mg kg^{-1}) showed the highest concentration of Al followed by North 24 Parganas (3.33 mg kg^{-1}) and the lowest (1.71 mg kg^{-1}) concentration was noted in accessions collected from Khowai.

4.4.3. Calcium (Ca)

Calcium concentration was recorded maximum in accessions collected from North 24 Parganas (1.89 mg kg^{-1} and 2.26 mg kg^{-1}) followed by accessions collected from Panruti (1.80 mg kg^{-1} and 2.10 mg kg^{-1}) and the minimum Ca was noted in accessions collected from South Sikkim (1.33 mg kg^{-1} and 1.20 mg kg^{-1}) in the first and second years of study. Similarly, when both the years were combined together the highest concentration of Ca was noted in accessions collected from North 24 Parganas (2.07 mg kg^{-1}) followed by accessions collected from Panruti (1.95 mg kg^{-1}) and the lowest (1.27 mg kg^{-1}) concentration was observed in accessions collected from South Sikkim.

4.4.4. Cobalt (Co)

Highest cobalt concentration was recorded in the accessions collected from West Tripura (0.06 mg kg^{-1}) in the first year and from accessions of Khowai (0.07 mg kg^{-1}) in the second year of study. Whereas, the lowest was observed in accessions collected from Nadia and Varkala (0.03 mg kg^{-1}) in the first year and Nadia (0.008 mg kg^{-1}) in the second year of study. However, the accessions collected from Khowai (0.06 mg kg^{-1}) showed highest concentration Co and the lowest was noted in Varkala (0.02 mg kg^{-1}) when both the years were combined together.

4.4.5. Chromium (Cr)

Highest chromium concentration was noted in accessions collected from Nadia (19.98 mg kg^{-1}) in first year and West Tripura (21.57 mg kg^{-1}) in the second year of study followed by accessions collected from West Tripura (19.30 mg kg^{-1}) in first year and Khowai (17.13 mg kg^{-1}) in the second year of study. Whereas, the least chromium concentration was recorded in accessions collected from South Sikkim (7.98 mg kg^{-1} and 6.88 mg kg^{-1}) in the firs and second years of study. However, when both the years were combined together the highest chromium concentration was noted in accessions collected from West Tripura (20.43 mg kg^{-1}) followed by Nadia (17.39 mg kg^{-1}) and the lowest (7.34 mg kg^{-1}) concentration was noted in South Sikkim.

4.4.6. Cesium (Cs)

The highest concentration of cesium was recorded in accessions collected from South Sikkim (0.021 mg kg^{-1} and 0.067 mg kg^{-1}) in the first year and second years of study. Whereas, the lowest cesium concentration was recorded in accessions collected from North 24 Parganas (0.007 mg kg^{-1}) in the first year and Nadia (0.012 mg kg^{-1}) in the second year of study. Similarly, when both the years were combined together the highest cesium concentration was recorded in South Sikkim (0.044 mg kg^{-1}) and the lowest (0.007 mg kg^{-1}) concentration were noted in North 24 Parganas.

4.4.7. Copper (Cu)

Copper concentration was observed to be highest in the accessions collected from West Tripura (1.74 mg kg^{-1}) in the first year and Panruti (3.35 mg kg^{-1}) in the second year of study. Lowest concentration was in accessions collected from South Sikkim (0.85 mg kg^{-1}) in first year and in the accessions of Nadia (1.03 mg kg^{-1}) in the second year of study. On an average, maximum Cu was noted in accessions of Panruti (2.44 mg kg^{-1}) and the minimum was observed in accessions collected from Nadia (0.99 mg kg^{-1}) when both the years were combined together.

4.4.8. Iron (Fe)

The highest value of Iron was observed in accessions collected from North 24 Parganas (16.04 mg kg^{-1} and 15.17 mg kg^{-1}) followed by accession collected from West Tripura (14.58 mg kg^{-1} and 15.22 mg kg^{-1}) and the minimum concentration was present in accessions of South Sikkim (9.91 mg kg^{-1} and 10.11 mg kg^{-1}) in the first and second year of study. Similarly, when both the years were combined together the accessions collected from North 24 Parganas (15.60 mg kg^{-1}) was noted with the highest concentration of Fe followed by accessions of West Tripura (14.90 mg kg^{-1}) and the lowest (10.01 mg kg^{-1}) concentration was noted in accessions of South Sikkim.

4.4.9. Gallium (Ga)

Gallium concentration under present investigation was recorded maximum in accessions collected from Khowai (0.31 mg kg^{-1} and 0.33 mg kg^{-1}) followed by West Tripura (0.28 mg kg^{-1} and 0.32 mg kg^{-1}) and the lowest was found in accessions collected from South Sikkim (0.17 mg kg^{-1}; 0.17 mg kg^{-1}) in the first and second years of study. The trend was maintained when both the years were combined together as Ga concentration was recorded maximum in accessions collected from Khowai (0.32 mg kg^{-1}) followed by West Tripura (00.30 mg kg^{-1}) and the lowest (0.17 mg kg^{-1}) concentration was observed in accessions collected from South Sikkim.

4.4.10. Sulfur (S)

Sulfur concentration under present experiment was recorded maximum in accessions collected from Varkala (2.56 mg kg^{-1}) in the first year and in the accessions of Nadia (2.95 mg kg^{-1}) in the second year of study and the minimum concentration of sulfur was recorded in accessions collected from West Tripura (1.18 mg kg^{-1}) in the first year and in the accessions of Panruti (1.38 mg kg^{-1}) in the second year of study. On an average, the highest concentration of S was noted in Nadia (2.75 mg kg^{-1}) and the lowest (1.28 mg kg^{-1}) concentration of sulfur was recorded in Panruti.

4.4.11. Potassium (K)

The highest observed value of potassium was noted in accessions collected from Panruti (74.96 mg kg^{-1} and 70.62 mg kg^{-1}) and the lowest concentration was observed in accessions collected from Varkala (53.67 mg kg^{-1}) in the first and second years of study. Similarly, when both the years were combined together the maximum concentration was noted in Panruti (72.80 mg kg^{-1}) and the minimum (53.67 mg kg^{-1}) concentration was observed in accessions collected from Varkala.

4.4.12. Lithium (Li)

It was observed that Li concentration was highest in accession collected from North 24 Parganas (0.21 mg kg^{-1}) in the first year and West Tripura (0.095 mg kg^{-1}) in the second year of study. Whereas, the lowest concentration was noted in accessions collected from Varkala (0.041 mg kg^{-1}) in the first year and Panruti (0.05 mg kg^{-1}) in the second year of study. When both the years were combined together the highest concentration was found in West Tripura (0.25 mg kg^{-1}) and the lowest (0.05 mg kg^{-1}) concentration was noted in accessions collected from Panruti.

4.4.13. Magnesium (Mg)

Magnesium concentration under present experiment was recorded maximum in accessions collected from Panruti (9.99 mg kg^{-1} and 12.57 mg kg^{-1}) followed by Khowai (9.07 mg kg^{-1} and 10.35 mg kg^{-1}) and the minimum concentration were noted in accessions collected from South Sikkim (6.61 mg kg^{-1} and 6.97 mg kg^{-1}) in the first and second years of study. Likewise, when both the years were combined together the highest concentration of Mg was noted in Panruti (11.28 mg kg^{-1}) followed by Khowai (9.71 mg kg^{-1}) and the lowest (6.79 mg kg^{-1}) concentration was noted in South Sikkim.

4.4.14. Manganese (Mn)

Maximum manganese concentration was noted in accessions collected from Khowai (4.33 mg kg^{-1} and 4.39 mg kg^{-1}) followed by West Tripura (3.91 mg kg^{-1} and 3.77 mg kg^{-1}) in the first and second years of study. Whereas, the minimum concentration was observed in the accessions of South Sikkim (1.44 mg kg^{-1}) in the first year and Nadia (1.63 mg kg^{-1}) in the second year of study. On an average, the accessions collected from Khowai (4.36 mg kg^{-1}) followed by West Tripura (3.84 mg kg^{-1}) had the maximum concentration and the minimum concentration was observed in Nadia (11.62 mg kg^{-1}) when both the years were combined together.

4.4.15. Sodium (Na)

Highest sodium concentration was recorded in accession collected from South Sikkim (3.03 mg kg^{-1} and 3.28 mg kg^{-1}) followed by Panruti (3.17 mg kg^{-1} and 3.11 mg kg^{-1}) in the first and second years of study. Whereas, the lowest values were reported in accessions collected from North 24 Parganas (2.11 mg kg^{-1}) in the first year and West Tripura (1.46 mg kg^{-1}) in the second year of study. However, when both the years were combined together the accession collected from South Sikkim (3.20 mg kg^{-1}) showed the highest concentration of Na followed by Panruti (3.14 mg kg^{-1}) and the lowest values was reported in accessions collected from West Tripura (1.87 mg kg^{-1}).

4.4.16. Nickel (Ni)

Nickel concentration was maximum in accessions collected from Panruti (1.52 mg kg^{-1}; 1.52 mg kg^{-1}) in the first and second year of study and the lowest concentration was recorded in accessions collected from Varkala (1.06 mg kg^{-1}) in the first year and Nadia (1.07 mg kg^{-1}) in the second year of study. When both the years were combined together accessions collected from Panruti (1.52 mg kg^{-1}) recorded as the highest concentration of Ni and the lowest concentration was found in Varkala (1.08 mg kg^{-1}).

4.4.17. Molybdenum (Mo)

Maximum molybdenum concentration was noted in the accessions collected from Panruti (0.063 mg kg^{-1}) in the first year and Khowai (0.59 mg kg^{-1}) in the second year. Whereas, the minimum concentration was recorded in Varkala (0.029 mg kg^{-1}) in the first year and South Sikkim (0.057 mg kg^{-1}) in the second year of study. On an average, the accessions collected from Panruti (0.32 mg kg^{-1}) recorded as the highest concentration of Mo and the lowest concentration was recorded in South Sikkim (0.04 mg kg^{-1}) when both the years were combined together.

4.4.18. Rubidium (Rb)

Panruti accessions showed the highest concentration of rubidium (7.39 mg kg^{-1} and 7.61 mg kg^{-1}) followed by West Tripura (7.09 mg kg^{-1} and 6.76 mg kg^{-1}) and the lowest concentration was recorded in North 24 Parganas (1.54 mg kg^{-1} and 1.44 mg kg^{-1}) in the first and second years of study. Likewise, when both the years were combined together the highest concentration of Rb was noted in Panruti (7.50 mg kg^{-1}) followed by West Tripura (6.92 mg kg^{-1}) and the lowest concentration was recorded in North 24 Parganas (1.49 mg kg^{-1})

4.4.19. Tillium (Ti)

The element tillium was observed maximum in accessions collected from Panruti (3.63 mg kg^{-1} and 3.48 mg kg^{-1}) in the first and second years of study. Whereas, the minimum concentration was observed in Nadia (0.70 mg kg^{-1}) in the first year and West Tripura (1.05 mg kg^{-1}) in the second year of study. When both the years were combined together on an average the highest concentration of Ti was noted in Panruti (3.55 mg kg^{-1}) and the minimum concentration was observed in Nadia (0.92 mg kg^{-1}).

4.4.20. Uranium (U)

Highest uranium concentration was recorded in accessions collected from Panruti (0.11 mg kg^{-1} and 0.057 mg kg^{-1}) in the first and second years of study. Whereas, the lowest concentration was observed in South Sikkim (0.007 mg kg^{-1}) in the first year and Nadia (0.035 mg kg^{-1}) in the second year of study. Likewise, when both the years were combined together the highest concentration of U was noted in Panruti (0.040 mg kg^{-1}) and the lowest concentration was observed in South Sikkim (0.02 mg kg^{-1}).

4.4.21. Boron (B)

Boron concentration was recorded maximum in accessions collected from Varkala (1.97 mg kg^{-1}) in the first year and North 24 Parganas (1.73 mg kg^{-1}) in the second year of study. Whereas, the lowest concentration was noted in West Tripura (0.93 mg kg^{-1}) in the first year and in Panruti (1.28 mg kg^{-1}) in the second year of study. Similarly, when both the years were combined together the highest concentration of B was noted in Varkala (1.79 mg kg^{-1}) and the lowest concentration was noted in West Tripura (1.19 mg kg^{-1}).

4.4.22. Zinc (Zn)

Maximum zinc concentration was noted in accession collected from South Sikkim (0.63 mg kg^{-1} and 0.64 mg kg^{-1}) and the lowest was recorded in Varkala (0.43 mg kg^{-1} and 0.44 mg kg^{-1}) in the first and second years of study. Similarly, the highest zinc concentration was noted in South Sikkim (0.64 mg kg^{-1}) and the lowest was recorded in Varkala (0.44 mg kg^{-1}) when both the years were combined together.

4.4.23. Silicon (Si)

Silicon concentration was observed to be highest in accessions collected from West Tripura during (1.42 mg kg^{-1}) the first year and Panruti (1.44 mg kg^{-1}) in the second year of study. Whereas, the accessions collected from Nadia (1.15 mg kg^{-1} and 1.13 mg kg^{-1}) observed lowest concentration of silicon in the first and second years of study. However, the accessions collected from Panruiti (1.36 mg kg^{-1}) recorded highest concentration of Si and the lowest concentration was noted in accessions collected from Nadia (1.14 mg kg^{-1}) when both the years were combined together.

4.4.24. Xenon (Xe)

Xenon concentration was recorded maximum in accessions collected from North 24 Parganas (290. 17 mg kg^{-1}) in the first year and Varkala (238.67 mg kg^{-1}) in the second year of study. Whereas, the lowest concentration was noted in West Tripura (57.25 mg kg^{-1}) in the first year and Panruti (61.96 mg kg^{-1}) in the second year of study. However, the accessions collected from Varkala (251.32 mg kg^{-1}) observed the highest concentration of Xe and the lowest concentration was noted in West Tripura (59.64 mg) when both the years were combined together.

4.5. Multivariate Analysis

4.5.1. Principal Component Analysis (PCA) of Multi-elemental profile of Soil

Principal Component Analysis (PCA) of soil had revealed that the first principal component (PC1) of soil samples covered 45.8%, 39.8% and 44.5% of the variables and the second component (PC2) covered 10.9%, 9.91% and 10.6% of the variables of first, second and combined data of both the years of study respectively (Fig. 4.1, 4.2 & 4.3).

PCA has revealed that the all the soil samples from Nadia, North 24 Parganas and South Sikkim can be distinguished with high amount of Zn, U, Cs, Rb, Ba, Li, Cr, K, Ca, Al and Co and moderate values of B, Ga, Mg, Fe, Ni, Mn and Cr. The samples collected from Panruti can be distinguished with high amount of Si and Xe. The samples collected from West Tripura, Khowai and Varkala were grouped with low values of all parameters.

4.5.2. Linear Discriminant analysis (LDA) of Multi-elemental Characteristics of Soil

According to the LDA of soil ionome revealed that samples collected from South India were grouped together, i.e. samples collected from Panruti and Varkala as both the soil type were of lateritic soils, alluvial soils of North 24 Parganas and Nadia from West Bengal were grouped together and samples collected from Sikkim and Tripura (South Sikkim, West Tripura and Khowai) were grouped as they belonged to mountainous and sub-mountainous group of soils (Fig. 4.4, 4.5 & 4.6).

4.5.3. Principal Component Analysis (PCA) of Physico-Chemical Characteristics

Principal component analysis (PCA) was performed on the physico-chemical characters of 70 accessions collected from different jackfruit growing regions of India.

The first principal component (PC1) covered 45.8%, 47% and 47.6% of the variables and the second component (PC2) covered 18.2%, 17.2% and 18.2 % of the variables for the first, second and combined data of both the years respectively (Fig. 1A, 1B and 1C). PCA differentiated the jack fruit accessions into major groups with interlinking relations. It also revealed that all accessions from Panruti could be distinguished with high amount of TSS, total sugar, fruit length and fruit weight and moderate values of number of flake, flake weight, pulp weight, seed weight and fruit width followed by accessions from Varkala, Nadia and Khowai with all moderate values of the prementioned parameters. The accessions collected from West Tripura, North 24 Parganas and South Sikkim were grouped with low values for all parameters during both the years of study (Fig. 4.7, 4.8 & 4.9).

4.5.4. Linear Discriminant Analysis (LDA) of Physico-Chemical Characteristics

Based on the linear discriminant analysis (LDA) of physico-chemical characters of jackfruit we could distinguish accessions collected from the Panruti as a separate entity with most of the positive parameters. Further, accessions of West Tripura, Nadia, Khowai, Varkala, North 24 Parganas and South Sikkim had overlapping physico-chemical characters. Among these, accessions of West Tripura, Nadia, Khowai and Varkala had very close relationship. In addition, accessions from North 24 Parganas and South Sikkim had highly overlapping characteristics (Fig. 4.10, 4.11 & 4.12).

From LDA it could be inferred that based on the physical-chemical characteristics the accessions could be linked to the geographical location at which they are growing. This parameter could be applied specially for accessions from Panruti. Further, the results revealed that, even though, the geographical location Varkala is closer to Panruti than other locations, there was no overlapping characteristics. On the contrast, accessions of Varkala had a closer relationship with Nadia and then with Khowai.

4.5.5. Principal Component Analysis (PCA) of Multi-elemental Profile of Fruit

Principal component analysis (PCA) was performed on the fruits of 70 accessions collected from different jackfruit growing regions of India. Among the 24 different multi-elements analyzed in 70 different accessions, the first principal component (PC1) covered 27.7%, 21% and 25.2% of the variables and the second component (PC2) covered 17.1%, 16% and 14.7% of variables for the first year, second year and combined data of both the year of study respectively (Fig. 4.13, 4.14 & 4.15).

In the present experiment, the data obtained from multi-elemental profiling of different jackfruit accessions revealed that fruit samples from Panruti and some accessions from West Tripura and South Sikkim had a high amount of Zn, K, Rb, Mn, Mg, Na, Ti, Al, Fe, Si, Ni, Ca, Fe and Ga. Some accessions collected from North 24 Parganas contained high amounts of Li, Mo, U, Co and Cs in the first principal component analysis. It was also revealed that the accessions collected from North 24 Parganas and Nadia could be distinguished together with the high amount of Xe, S and B in the second component analysis. Some accessions collected from Varkala, South Sikkim and Khowai could be distinguished with all low values during first year.

In the second year of study PCA revealed that all the accessions collected from Panruti distinguished itself with high amount of Ti, Al, Na, Si, Ni, Mg, K and Zn. The accessions collected from West Tripura and Khowai also could be distinguished together with high amount of Cr, Ba, Mo, Ga, Co, Ca, Cu, Fe, Mn, Li and Ca in first PC and some accessions from Khowai and West Tripura could be distinguished with high amount of S and B in second PC. The accessions collected from Varkala and South Sikkim can distinguished with all low values.

Similarly, when data of both the yearswere combined, PCA had revealed that the all accessions from Panruti can be distinguished with high amount of Ni, Zn. Si, Cu, Mg, K, Rb, Ti and Al. The accessions collected from West Tripura and some accessions from Khowai can be distinguished with high amount of Cr, Mo, Ca, Ga and Mn. The accessions collected from North 24 Parganas, Nadia and accessions from Khowai were distinguishable with high amount of S and Xe. The accessions collected from Varkala and South Sikkim can be isolated with all lower values during combined year of study.

4.5.6. Linear discriminant analysis of Multi-elemental Characteristics of Fruit

Based on the linear discriminant analysis (LDA) of the fruit ionome of jackfruit, it's geographical linkage based separation of the accessions were visible even at 95% confidence level as all the location accessions could be distinguished from each other. Only accessions of West Bengal (North 24 Parganas and Nadia) had overlapping characteristics (Fig. 4.16, 4.17 & 4.18).

4.5.7. Correlation of Soil and Fruit ionome

The correlation analysis between soil ionome and fruit ionome had revealed that among 24 elements only Mo (0.396**) and Si (0.316**) had a significant positive correlation between its content in fruit and soil. On the other hand, soil and fruit contents of Al (-372**), Mn (-366**) and Xe (-370**) had a significant negative correlation.

Other elements in the jackfruit from different regions and its content in fruit do not correlate well with soil.

The results obtain during the course of experimentation as reported in the chapter-4 have been discussed in the present section. Geographical influence on morpho-physiological characters and ionome profile of the crops and products in general and jackfruits in particular has been discussed here.

5.1. Morphological Characters

Experimental data pertaining to the fruit weight revealed that the weight varied from 1.00 (SDTJ 61) to 17.30 kg (PANJ 48) in the first year, 0.92 kg (SDTJ 61) to 16.45 kg (PANJ 48) in the second year and 1.00 kg (SDTJ 61) to 16.87 kg (PANJ 48) when the data of both years combined together (Tables 4.1, 4.2 & 4.3). Previously, Wangchu *et al.,* (2013) analyzed forty four genotypes of superior jackfruit from three districts of West Bengal and reported fruit weight was in the range of 1.6 to 16.47 kg and Reddy *et al.,* (2004) on jackfruit clones of south Karnataka reported that the range of fruit weight was at 7 to 20 kg. In addition, Jagadeesh *et al.,* (2010) studied variation in fruit weight and reported it was in the range 2.15 kg to 14.86 kg. Based on the previous reports it was found that the data obtained on fruit weight in the present study were similar to earlier studies. However, the variation could be seen based on the location.

The result of the experiment showed that the fruit length of different treatments was in the range of 17.30 cm (SDTJ 61) to 73.60 cm (PANJ 48) in the first year, 21.10 cm (SDTJ 61) to 75.20 (PANJ 48) in the second year and 19.91cm (PARJ 9) to 74.40 (PANJ 48) when the data of both years combined together (Tables 4.1, 4.2 & 4.3). Earlier, Hossain and Haque (1977) studied the length of fruit and it ranged from 18 to 41 cm with 31.6 cm as average length. Saji *et al.,* (2015) reported fruit length ranged from 28.68 cm to 52.66 cm. Bal, (2003) also studied wide diversity among four genotypes of jackfruit with varying fruit length ranging from 32.8 cm to 48 cm. Based on the earlier reports it was found that the data obtained on fruit length in the present study were similar to earlier studies.

The observation of the experiment revealed that the fruit width was at the range of 29.50 (SDTJ 61) cm to 86.20 cm (PANJ 47) in the first year, 39.60 cm (SDTJ 63) to 87.30 cm (PANJ 47) in the second year and 30.11 cm (NADJ 14) to 86.75 cm (PANJ 47) when the data of both years combined together (Tables 4.1, 4.2 & 4.3). Comparative results were noted in findings of Khan *et al., (*2010) who had recorded maximum fruit diameter in homestead at 165.18 cm and minimum in forest/fallow areas as 66.61 cm. Saji *et al.,* (2015) also reported fruit diameter ranged from 18.46 cm to 30.50 cm.

The data obtained for number of flakes segments per fruit of different accessions were found to be in the range of 27 (SDTJ 61) to 223 (PANJ 48) in the first year, 40 (SDTJ) to 236 (PANJ 48) in the second year and 25 (NADJ 16) to 230 (PANJ 48) when the data of both years combined together (Tables 4.1, 4.2 & 4.3). Previously, Hossain and Haque (1977) studied number of bulbs of jackfruit as varied from 30 to 185. Saji *et al.,* (2015) also reported varied number of bulbs ranging from 300 to 48.

Differences in weight of the flake in respect of the accessions were ranging from 10.3 g (SDTJ 63) to 47.22 g (PANJ 47) in the first year and 9.52 g (SDTJ 63) to 47.52 g (PANJ 47) in the second year and 9.91 g (SDTJ 63) to 47.29 g (PANJ 47) when the data of both years combined together (Tables 4.1, 4.2 & 4.3). Similar results were obtained by, Wangchu *et al.,* in 2013 who studied forty four superior jackfruit genotypes and reported bulb weight was ranging from 5.73 – 74.33 g. Krishnan *et al.,* (2015) also reported that the individual bulb weight ranged from 13.20 to 48.36g.

The result obtained from the experiment revealed that the pulp weight of various accession was in the range of 6.00 g (SDTJ 63) to 38.41 g (PANJ 47) in the first year, 4.99 g (SDTJ 63) to 40.80 g (PANJ 47) in the second year and 5.50 g (SDTJ 63) to 38.79 g (PANJ 47) when the data of both years combined together (Tables 4.1, 4.2 & 4.3). However, in the previous study Reddy *et al.,* (2004) studied on jackfruit clones of south Karnataka reported that the range of pulp weight was between 21.25 to 49.25g. In addition, Krishnan *et al.,* (2015) reported individual bulb weight ranged from 13.20 to 48.36 g.

The differences in seed weight among the accessions studied was in the range of 2.7 g (SDTJ 61) to 9.07 g (PANJ 46) in the first year, 2.89 g (SDTJ 61) to 9.13 g (PANJ 46) in the second year and 2.80 g (SDTJ 61) to 9.10 g (PANJ 46) when the data of both years combined together (Tables 4.1, 4.2 & 4.3). However, variability range in seed weight was 5.5g and 5.0g in Khaja and Ghila respectively (Islam,1993). Reddy *et al.,* (2004) also recorded the seed weight range from 0.5 g to 12 g.

Hence, most of the characters studied were within the range of earlier studies. But variation could be observed based on the locational and germplasm difference.

5.2. Chemical characters

The data pertaining to the TSS of different accessions under investigation revealed that it varied in the range of 10.00^{o} Brix (KHWJ 34) to 25.404^{o} Brix (VARJ 59) in the first year 10.60^o Brix (KHWJ 34) to 27.80^o Brix (VARJ 59) in the second year and 10.70^o Brix (KHWJ 34) to 26.60^o Brix (VARJ 59) when the data of both years combined together (Tables 4.1, 4.2 & 4.3). Similarly, Wangchu *et al.,* (2013) reported the range of TSS was 20 to 28.67 ^{o}Brix. On the contraray, Jagadeesh *et al.,* (2007B) studied on inter tree variability for fruit quality in jackfruit selections of Western Ghats of India obtained highest values for TSS at 34.33 ^{o}Brix.

The observation of the experiment reported that the titratable acidity was in the range of 0.3% (PANJ 44) to 1.2% (SDTJ 68) in the first year, 0.4% (PANJ 46) to 1.2% (KHWJ 36) in the second year and 0.4% (PANJ 46) to 1.2% (SDTJ 68) when the data of both years combined together (Tables 4.1, 4.2 & 4.3). However, Wangchu *et al.,* (2013) reported the range of titratable acidity at 0.13 to 0.42%. In addition, Jagadeesh *et al.,* (2007B) studied on inter tree variability for fruit quality in jackfruit selections of Western Ghats of India and obtained highest values for titratable acidity of 0.768 %. Bal, (2003) also reported jackfruit acidity ranging from 0.28% to 0.34% .

The differences in the total sugars content among the jackfruit accessions investigated was found to be in the range of 10.14% (KHWJ 34) to 17.26 % (VARJ 59) in the first year, 10.56% (KHWJ 34) to 18.32% (VARJ 59) in the second year and 10.35% (KHWJ 34) to 17.79% (VARJ 59) when the data of both years combined together (Tables 4.1, 4.2 & 4.3). However, in the previous study, Krishnan *et al.,* (2015) reported total sugar ranged from 20.84 to 61.88 %. Maximum total sugar was found in selection KVJ-1 (61.88%) and minimum was in selection KCJ-1 (20.44%). On the contrary, Wangchu *et al.,* (2013) reported the range of total sugar was from 8.3 to 20.3 %, which ismore similar to present study. Jagadeesh *et al.,* (2007B) studied on inter tree variability for fruit quality in jackfruit selections of Western Ghats of India and obtained highest values for total sugar at 13.37%.

5.3. Ionomic Profiling of Soil and Fruit

The very purpose of analyzing soil and fruit ionome charecristics was to understand the contribution of soil ionome to the fruit ionome. It is a bygone conclusion that most of the multi elemental concentration of plants is contributed by soils. Element content in soil is greatly influenced by geographical environment and variations in the distribution of these trace elements among different geographical locations can give distinct elemental signatures in organic tissues (Sun et al*.,* 2011and Yan et al*.,* 2015). However, the uptake behavior of nutrients and other trace elements by plants are influenced by many factors especially, germplasm difference and climate. Elemental composition of fruit and vegetables depends on different factors, e.g. genetic, weather, soil, and the harvesting stage of maturity (Pramanick *et al.,* 2014). Hence, when attempting for discriminating the jackfruit based on the multi elemental concentration and linking the germplasm to the geographical location, it must be established that the ionome profile of the fruit is the contribution of various interacting factors prevailing in that location.

5.3.1. Soil ionome characteristics

The soil samples collected from Nadia contained high amounts of Ba, Al, Co, Cu, Fe, K, Mn, Na, Ni and Ti. The highest concentration of Si, Cr, S and Mg were found in samples collected from Varkala and had the lowest concentration of Cu. Soil samples from South Sikkim possessed the highest amounts of Cs, Li, Rb, U and Zn. The highest levels of Mo and the low levels of Ba, Mg and Na were found in West Tripura. The highest levels of Xe were found in accessions collected from Khowai. The highest concentration of Ca was found in samples collected from North 24 Parganas. However, the lowest concentration of Si, Xe and B was found in North 24 Parganas (Tables. 4.10, 4.11, 4.12, 4.13, 4.14 & 4,15). Gallium concentration was recorded maximum in accessions collected from Panruti and had the lowest concentration of Al, Co, Cr, Cs, Fe, Mn, Ni and Mo.

Considering the results obtained during the present experimentation, it was observed that all the samples analyzed were a good source of several macro, micro and trace elements which are present in variable concentrations in different samples of different regional variations under study. This variation in elemental composition indicated that there may be several factors which contribute to these regional variations in elemental levels. The possible cause may be that, availability of elements for uptake by the plants depends on the soil's cation exchange capacity which can vary considerably between soil types, depending on pH and mineral composition. Therefore, most of the regional differences found could be linked to underlying differences in soil types. Essential nutrients which are needed in trace and ultra trace quantities (Cu, Fe, Ni, Zn, Mn, Co, Cr and Se) are as important as macronutrients (Ca, K, Mg and Na) Cindric *et al.,* (2012). The calcium (Ca) content in soil is strongly influenced by rock composition (Kment et al., 2005; Yan *et al.,* 2015). In the present study, the maximum Calcium (Ca) content was found in soil, which may be the result of nearby rocks. The magnesium (Mn) concentrations are highest in ultrabasic and basic rocks such as serpentine and basalt, respectively, and lowest in acidic rocks such as granite (Alloway, 2013 and Yan *et al.,* 2015). However, uncovering a significant correlation between plant and soil was difficult because of distractions in topsoil from industrial wastewater irrigation, aerial deposition, and use of fertilizers and pesticides (Mench *et al.,* 1994; Ulrich *et al.,* 1999 and Yan *et al.,* 2015).

5.1.2. Fruit ionome characteristics

The element content of the jackfruit samples was investigated (Tables 4.16, 4.17, 4.18, 4.19, 4.20 & 4.21). The jackfruit accessions collected from Panruti contained high amounts of K, Mg, Cu, Rb, Ti, Ni, U and Si and low amount of Cr, S and Li. The accessions collected from Varkala contained high amounts of Xe and B. However, the concentration of Co, K, Ni and Zn were lowest in Varkala. The highest concentration of Ca, Fe and Li and the lowest concentration of Cs and Rb were found in North 24 Parganas. The accessions collected from Khowai contained the highest amount of Mn, Ga and Co and lowest amount of Al. Accessions collected from South Sikkim contained high amounts of Ba, Al, Na and Zn. However, South Sikkim possessed the lowest Ca, Ga, Mg, Mn, Mn, Mo and U content. The highest concentration of sulfur and the lowest concentration of Ba, Cs, Cu, Mn, Ti and Si were found in accessions collected from Nadia (Tables 4.16, 4.17, 4.18, 4.19, 4.20 & 4.21). However, in the previous research works, Arkroyd, *et al.,* (1996) analyzed the nutritive value of Indian food revealed that the concentration of Ca, Mg, P, K, Na and Fe were at 20.0 -37.0 mg, 27 mg, 38.0 - 41.0 mg, 191-407 mg, 2.0-41.0 mg and 0.4 -1.9 mg per 100 gram of ripe jackfruit and also similar results were found by Gunasena *et al.,* 1996; Narasimham, 1990; Soepadmo, 1992; Azad, 2000; Haq, 2006. Elemental composition of fruit and vegetables depends on different factors e.g. genetic, weather, soil, and the harvesting stage of maturity (Pramanick *et al.,* 2014).

5.1.3. Correlation of Soil and Fruit ionome

The result revealed that among 24 elements, only Al. Mn, Mo, Si and Xe had either significant positive or negative correlation between its content in fruit and soil. Other elements in the jackfruit from different regions and its content in fruit do not correlate well with soil. Hence, it may be concluded that, fruit income has been contributed by not just soil alone, but due to the interaction of germplasm, prevailing micro climate in the location and soil.

5.2. Principal component analysis of physico-chemical characteristics of soil and fruit ionome

5.2.1. Principal component analysis of soil ionome

Principal component analysis (PCA) was performed on the soil characters of 70 samples collected from different jackfruit growing regions of India. The first principal component of covered 45.8%, 39.8% and 44.5% of variables and the second component covered 10.9%, 9.91% and 10.6% of variables for the first, second and combined year of study respectively. PCA has revealed that the all samples from Nadia, North 24 Parganas and South Sikkim can be distinguished with high amount of Zn, U, Cs, Rb, Ba, Li, Cr, K, Ca, Al and Co and moderate values of B, Ga, Mg, Fe, Ni, Mn and Cr. The samples collected from Panruti can be distinguished with high amount of Si and Xe. The accessions collected from West Tripura, Khowai and Varkala were grouped with low values of all parameters (Fig. 4.1, 4.2 & 4.3). Hence, PCA of soil ionome had yielded three distinct groups, first with Nadia, North 24 Parganas and South Sikkim, a second group with West Tripura, Khowai and Varkala and a third group with Panruti.

5.2.2. Principal component analysis of Pysico-chemical charecters

The first principal component (PC1) physico-chemical characters covered 45.8%, 47% and 47.6% of the variables and the second component (PC2) physico-chemical characters covered 18.2%, 17.2% and 18.2 % of the variables in the first, second and combined data of both the years respectively. PCA of physico-chemical characters had revealed that the all accessions from Panruti could be distinguished with high amount of TSS, total sugars, fruit length and fruit weight and moderate values of number of flake, flake weight, pulp weight, seed weight and fruit width followed by accessions from Varkala, Nadia and Khowai with all moderate values. The accessions collected from West Tripura, North 24 Parganas and South Sikkim were grouped with low values for all parameters during both the year and combined year of study (Fig. 4.7, 4.8 & 4.9). Here again PCA had yielded three distinct groups *viz*. Varkala, Nadia and Khowai into one group, West Tripura, North 24 Parganas and South Sikkim into another group and Panruti into another group. When these groups were matched with the soil ionome PCA grouping, only Panruti maintained its distinctiveness.

5.2.3. Principal component analysis of Fruit ionome

The first principal component jackfruit covered 27.7 %, 21% and 25.2% of variables and the second component covered 17.1 %, 16% and 14.7% of variables for the first and second year and combined year of study, respectively. PCA has revealed that the all accessions from Panruti can be distinguished with high amount of Ni, Zn. Si, Cu, Mg, K, Rb, Ti and Al. The accessions collected from West Tripura and many accessions from Khowai could be distinguished with high amount of Cr, Mo, Ca, Ga and Mn. The accessions collected from North 24 Parganas, Nadia and some accessions from Khowai were distinguished with high amount of S and Xe. The accessions collected from Varkala and South Sikkim could be distinguished with all lower values during combined year of study (Fig. 4.13, 4.14 & 4.15).

Principal Component Analysis of fruit ionome had produced four groups *viz.* Panruti into one, West Tripura and Khowai into second, North 24 Parganas and Nadia into third and Varkala and South Sikkim into fourth group. This had revealed the relativeness of these location based accessions.

5.3. Linear discriminant analysis of physico-chemical characteristics of soil and fruit ionome

Massart, (1998) reported that Linear Discriminant Analysis computes linear combinations of the data discriminant functions via a linear combination of the original variables and it can be constructed trough a stepwise approach by selecting only the most discriminating variables and reducing the numbers of variables used as chemical descriptors. Several linear discriminant function models classified the data sets with 95% or higher accuracy and the development of a method combining elemental analysis and classification techniques that may be widely applied to the determination of the geographical origin of foods (Anderson and Smith 2005; Furia *et al.,* 2011; Tormen *et al.,* 2011). Hence, when the analysis was applied, it led to the following conclusion.

LDA of soil ionome had revealed that samples collected from South India were grouped together, i.e. samples collected from Panruti and Varkala as both the soil type were of lateritic soils. Alluvial soils of North 24 Parganas and Nadia from West Bengal were grouped together. In the same way and samples collected from Sikkim and Tripura (South Sikkim, West Tripura and Khowai) were grouped as they belonged to mountainous and sub-mountainous group of soils. Viswanath and Ukil (1943) published a soil map of India by placing thesoils in different climatic zones (Fig. 4.4, 4.5 & 4.6).

LDA of Pysico-chemical characters, it could be inferred that accessions of Panruti could be linked to the geographical location at which it was growing. Further, the results revealed that even though the geographical location Varkala is closer to Panruti than other locations, there were no overlapping characteristics. In contrast, accessions of Varkala had a closer relationship with Nadia and then with Khowai. It may be due to the jack fruit could have been introduced from one region to another. Later secondary diversification could have taken place at locations of introduction. Hence, it could be concluded that based on Physico–chemical characteristics, accessions of Panruti could be distinguished even at ninety five percent of the confidence level. Further, based on the results of PCA and LDA the accessions of Panruti specially PANJ 48 and PANJ 47 could be used as a breeding stock for yield and quality characteristics to all other accessions of North East India and Kerala (Fig. 4.10, 4.11 & 4.12).

Based on the linear discriminant analysis of the fruit ionome of jackfruit, it's geographical linkage based separation of the accessions were visible even at 95%

confidence level as all the location accessions could be distinguished from each other. Only accessions of West Bengal (North 24 Parganas and Nadia) had overlapping characteristics (Fig. 4.16, 4.17 & 4.18).

The combination of ionome and chemometrics has been widely used to trace the geographical origins of beverages (Anderson and Smith, 2002), nuts (Anderson and Smith, 2005), wine (Coetzee *et al.,* 2005; Martin *et al.,* 2012; Kruzlicova *et al.,* 2013 and Shen *et al.,* 2013), oil (Jiang *et al.,* 2014), tea (Ma *et al.,* 2016), vegetables and fruits (Bibak *et al.,* 1999; Di Giacomo *et al.,* 2007; Tormen *et al.,* 2011; Perents et al., 2013; Todea *et al.,* 2014 and Yan *et al.,* 2015) and cereals like barley (Husted *et al.,* 2004), wheat (Zhao *et al.,* 2011) and rice (Kokot and Phuong 1999; and Li *et al.,* 2012).

Similarly, in the present investigation, 24 element combination of fruit ionome had contributed for discriminating the geographical location based germplasm of jackfruit. In addition, the study had led to the identification of qualitatively better germplasm for further use in breeding programme.

The present investigation entitled **"Identification of the geographical origin of jackfruit (*Artocarpus heterophyllus* Lam.) through multielemental fingerprinting using ICPMS"** was carried out during 2016-17 and 2017-18 in plant nutrition and ionome laboratory of Department of Horticulture, Sikkim University, Gangtok, Sikkim with the objectives of collecting the fruit and soil from different jackfruit growing regions of India and profiling them for ionome concentrations as well as correlating the ionome profile of jackfruit with geographical origin.

Seventy accessions of jackfruit from seven geographic locations famous for the jack fruit production belonging to five states of India were collected for the study. Collected fruits of the accessions were subjected to physico-chemical analysis *viz.* estimation of fruit weight, fruit length, number of flakes per fruit, flake, pulp and seed weight, total soluble solids (TSS), titratable acidity, total sugars as well as multi elemental analysis. In addition, soil samples were also subjected to mutielemental analysis. The results obtained had revealed that

- Most of the Pysico-chemical characters studied were within the range of earlier studies. But variation could be observed based on the location and germplasm difference. Especially, the accessions from Panruti showed positive results in most of these characters analyzed followed by Varkala.
- Accessions of Panruti specially PANJ 48 and PANJ 47 were found to be the best accessions as far as physico-chemical characters are concerned. Hence, they could be propagated and commercially exploited. In addition they could be used as a

breeding stock for yield and quality characteristics to all other location accessions of North East India and Kerala.

- Out 24 elements, only Al. Mn, Mo, Si and Xe had either significant positive or negative correlation between its content in fruit and soil. Hence, it may be concluded that, fruit income has been contributed by not just soil alone, but due to the interaction of germplasm, prevailing micro climate in the location and soil. Hence, multielemental finger printing will be reliable.

- PCA of soil ionome and pysico-chemical characters gave ut three distinct groups accessions. Soil ionome had yielded three distinct groups, first with Nadia, North 24 Parganas and South Sikkim, a second group with West Tripura, Khowai and Varkala and a third group with Panruti. Pysico-chemical characters had yielded Varkala, Nadia and Khowai into one group, West Tripura, North 24 Parganas and South Sikkim into another group and Panruti into another group.
- When the groups of pysico-chemical characters were matched with the soil ionome PCA grouping, only Panruti maintained its distinctiveness
- Principal Component Analysis of fruit ionome had produced four groups *viz.* Panruti into one, West Tripura and Khowai into second, North 24 Parganas and Nadia into third and Varkala and South Sikkim into fourth group. This had revealed the relativeness of these location based accessions.

- Based on the LDA of physico-chemical characters, only the accessions of Panruti were distinguished even at 95% confidence level from other locations. Hence, physico-chemical characters shall form the basis for identification of Panruti jackfruits.

- LDA of soil ionome at 95% confidence level had given three groups *viz.* samples collected from Panruti and Varkala in one group, samples of North 24 Parganas and Nadia into another and samples of South Sikkim, West Tripura and Khowai into third group which augured well with the earlier classification of Indian soils.
- LDA of the fruit ionome of jackfruit, it's geographical linkage based separation of the accessions were visible even at 95% confidence level as all the location accessions could be distinguished from each other. Only accessions collected from West Bengal (North 24 Parganas and Nadia) had overlapping characteristics.

Hence, it could be concluded that the geographical location based jackfruits shall be distinguished by the multielemental fingerprinting, which is cheaper, easier than the other omics technologies like genomics, proteomics or transcriptomics as well as reliable.

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Table. 3.1. Geographical locations of Jackfruit collection

Sl.No.	Locations	States
1.	North 24 Parganas District	West Bengal
2.	Nadia District	West Bengal
3.	West District	Tripura
4.	Khowai District	Tripura
5.	Panruti	Tamil Nadu
6.	Varkala	Kerala
7.	South District	Sikkim

Table. 3.2: Location details of the sample collected

Accessions	Place of collection	Latitude	Longitude
PARJ 1	North 24 Parganas (West Bengal)	22^{O} 55.458	088^{O}32.489
PARJ 2	North 24 Parganas (West Bengal)	22^{O} 55.448	088^{O}32.476
PARJ 3	North 24 Parganas (West Bengal)	22^{O} 55.452	088^{O}32.533
PARJ 4	North 24 Parganas (West Bengal)	22^{O} 55.452	088^{O}32.533
PARJ 5	North 24 Parganas (West Bengal)	22^{O} 55.452	088^{O}32.524
PARJ 6	North 24 Parganas (West Bengal)	22^{O} 55.455	088^{O}32.522
PARJ 7	North 24 Parganas (West Bengal)	22^{O} 55.454	088^{O}32.634
PARJ 8	North 24 Parganas (West Bengal)	22^{O} 55.431	088^{O}32.622
PARJ 9	North 24 Parganas (West Bengal)	22^{O} 54.991	088^{O}33.282
PARJ 10	North 24 Parganas (West Bengal)	22^{O} 54.973	088^{O}33.284
NADJ 11	Nadia (West Bengal)	22^{O} 58.223	088^{O}31.143
NADJ 12	Nadia (West Bengal)	22^{O} 58.233	088^{O}31.095
NADJ 13	Nadia (West Bengal)	22^{O} 58.240	088^{O}31.036
NADJ 14	Nadia (West Bengal)	22^{O} 58.241	088^{O}31.027
NADJ 15	Nadia (West Bengal)	22^{O} 58.241	088^{O}31.015
NADJ 16	Nadia (West Bengal)	22^{O} 58.255	088^{O}30.905
NADJ 17	Nadia (West Bengal)	22^{O} 58.216	088^{O}31.346
NADJ 18	Nadia (West Bengal)	22^{O} 58.218	088^{O}31.333
NADJ 19	Nadia (West Bengal)	22^{O}58.223	088^{O}31.345
NADJ 20	Nadia (West Bengal)	22^{O} 58.004	088^{O}32.758
WDTJ 21	West Tripura (Tripuara)	23^{O} 52.708	091^{O}20.134
WDTJ 22	West Tripura (Tripuara)	23^{O} 52.783	091^{O}20.502
WDTJ 23	West Tripura (Tripuara)	23^{O} 52.812	091^{O}20.551
WDTJ 24	West Tripura (Tripuara)	23^{O} 52.906	091^{O}20.385
WDTJ 25	West Tripura (Tripuara)	23^{O} 52.989	091^{O}20.397
WDTJ 26	West Tripura (Tripuara)	23^{O} 54.004	091^{O}20.333
WDTJ 27	West Tripura (Tripuara)	23^{O} 52.068	091^{O}18.612
WDTJ 28	West Tripura (Tripuara)	23^{O} 52.073	091^{O}18.603
WDTJ 29	West Tripura (Tripuara)	23^{O} 51.954	091^{O}18.665
WDTJ 30	West Tripura (Tripuara)	23^{O} 51.962	091^{O}18.645
KHWJ 31	Khowai (Tripuara)	23^{O} 57.964	091^{O}35.298
KHWJ 32	Khowai (Tripuara)	23^{O} 58.271	091^{O}35.346
KHWJ 33	Khowai (Tripuara)	23^{O} 58.275	091^{O}35.366
KHWJ 34	Khowai (Tripuara)	23^{O} 58.014	091^{O}35.366
KHWJ 35	Khowai (Tripuara)	23^{O} 57.991	091^{O}35.199
KHWJ 36	Khowai (Tripuara)	23^{O} 57.293	091^{O}34.556
KHWJ 37	Khowai (Tripuara)	23^{O} 57.019	091^{O}34.191
KHWJ 38	Khowai (Tripuara)	23^{O} 57.097	091^{O}34.083
KHWJ 39	Khowai (Tripuara)	23^{O} 57.120	091^{O}33.738
KHWJ 40	Khowai (Tripuara)	23^{O} 57.952	091^{O}35.310
PANJ 41	Panruti (Tamil Nadu)	11^{O}44.684	079^{O}31.436
PANJ 42	Panruti (Tamil Nadu)	11^{O}44.689	079^{O}31.431
PANJ 43	Panruti (Tamil Nadu)	11^{O}44.690	079^{O}31.412
PANJ 44	Panruti (Tamil Nadu)	11^{O}44.692	079^{O}31.395
PANJ 45	Panruti (Tamil Nadu)	11^{O}44.689	079^{O}31.385
PANJ 46	Panruti (Tamil Nadu)	11^{O}44.665	079^{O}31.376
PANJ 47	Panruti (Tamil Nadu)	11^{O}44.676	079^{O}31.374
PANJ 48	Panruti (Tamil Nadu)	11^{O}44.692	079^{O}31.381
PANJ 49	Panruti (Tamil Nadu)	11^{O}43.792	079^{O}31.418
PARJ 50	Panruti (Tamil Nadu)	11^{O}43.788	079^{O}31.486
VARJ 51	Varkala (Kerala)	08^{O}44.589	076^{O}43.170
VARJ 52	Varkala (Kerala)	08^{O}44.580	076^{O}43.178

VARJ 53	Varkala (Kerala)	$08^{O}44.446$	$076^{O}43.185$
VARJ 54	Varkala (Kerala)	$08^{O}44.441$	$076^{O}43.132$
VARJ 55	Varkala (Kerala)	$08^{O}44.448$	$076^{O}43.065$
VARJ 56	Varkala (Kerala)	$08^{O}43.821$	$076^{O}43.644$
VARJ 57	Varkala (Kerala)	$08^{O}43.781$	$076^{O}43.667$
VARJ 58	Varkala (Kerala)	$08^{O}43.770$	$076^{O}43.778$
VARJ 59	Varkala (Kerala)	$08^{O}43.779$	$076^{O}43.773$
VARJ 60	Varkala (Kerala)	$08^{O}43.991$	$076^{O}42.776$
SDTJ 61	South Sikkim (Sikkim)	$27^{O}10.923$	$088^{O}30.793$
SDTJ 62	South Sikkim (Sikkim)	$27^{O}10.940$	$088^{O}30.851$
SDTJ 63	South Sikkim (Sikkim)	$27^{O}10.922$	$088^{O}30.833$
SDTJ 64	South Sikkim (Sikkim)	$27^{O}10.921$	$088^{O}30.990$
SDTJ 65	South Sikkim (Sikkim)	$27^{O}10.917$	$088^{O}30.910$
SDTJ 66	South Sikkim (Sikkim)	$27^{O}10.911$	$088^{O}30.759$
SDTJ 67	South Sikkim (Sikkim)	$27^{O}10.758$	$088^{O}30.746$
SDTJ 68	South Sikkim (Sikkim)	$27^{O}10.752$	$088^{O}30.746$
SDTJ 69	South Sikkim (Sikkim)	$27^{O}10.763$	$088^{O}30.732$
SDTJ 70	South Sikkim (Sikkim)	$27^{O}10.770$	$088^{O}30.706$

Table. 4.1: Physico-chemical characters of seventy accessions of jackfruit (1st Year)

Accessions	Fruit weight (Kg)	Fruit Length (cm)	Fruit Width (cm)	Number of Flake	Flake Weight (g)	Pulp Weight (g)	Seed Weight (g)	TSS (ºBrix)	Titrable Acidity (%)	Total Sugar (%)
PARJ 1	5.2±0.7	30.6±1.75	74.5±3.97	103±12.16	24.7±0.30	21.01±0.25	3.69±0.13	16.02±0.19	0.53±0.06	17.23±0.87
PARJ 2	3.6±0.4	26.1±2.78	60.1±3.38	66±8.18		12.9±1.80	8.90±0.71	4.0±0.026	20 ± 1.20	0.6±0.10	13.2±0.43
PARJ 3	3.8±0.12	22.5±0.66	61.6±3.32	59±0.[illegible]	12.7±0.66	9.81±0.39	2.9±0.17	14.8 ± 0.53	1.00±0.20	14.75±0.65
PARJ 4	5.7±0.50	38.5±0.82	71.0±2.66	73±9.54	17.9±1.57	12.00±0.16	5.9±0.26	12.2 ± 0.80	0.9±0.173	12.26±0.57
PARJ 5	4.2±0.30	33.3±1.45	66.4±0.90	64±6.56	18.8±1.57	14.61±0.57	3.69±0.19	16.2 ± 10	1.00±0.1	15.93±0.78
PARJ 6	4.8±0.43	32.4±1.56	59.4±2.96	94±10.53	15.94±1.25	10.04±0.25	5.90±0.19	18.2 ± 1.52	0.89±0.11	16.26±0.58
PARJ 7	4.3±0.40	38.9±0.87	52.1±2.10	97±3.00	16.06±1.15	12.58±0.26	3.48±0.36	18.4 ± 0.72	0.52±0.25	16.73±1.41
PARJ 8	2.0±0.20	24.1±1.26	44.4±1.31	36±5.03	12.60±1.15	8.69±0.49	3.91±0.78	12.5 ± 0.46	0.85±0.07	11.32±0.66
PARJ 9	2.3±0.40	19.5±1.82	54.8±1.47	61±4.00	11.46±0.99	8.56±0.20	2.9±0.13	14.9 ± 0.26	1.00±0.24	13.92±0.43
PARJ 10	3.3±0.30	27.3±1.35	54.3±1.21	53±3.60	13.32±0.94	9.22±0.14	4.1±0.13	16.5 ± 0.89	0.43±0.05	14.92±0.78
NADJ 11	3.3±0.10	26.3±0.87	48.5±2.46	46±6.56	21.52±1.18	16.48±0.39	5.04±0.39	20.2 ± 0.72	0.5±0.05	16.92±0.95
NADJ 12	5.3±0.44	37.3±1.14	65.2±2.05	109±11.79	24.05±2.06	19.75±0.70	4.75±0.17	16.5 ± 0.65	0.6±0.06	13.71±0.64
NADJ 13	6.3±0.42	73.1±1.90	49.2±2.36	118±7.00	28.63±0.92	21.06±0.37	7.57±0.30	16.8 ± 0.72	0.4±0.05	14.23±0.93
NADJ 14	3.7±0.57	28.4±1.07	29.5±1.28	78±30.0	22.84±0.50	19.06±0.15	3.76±0.54	20.8 ± 0.60	0.6±0.06	15.62±0.99
NADJ 15	2.1±0.17	24.1±1.11	60.0±4.33	41±2.00	21.62±0.44	18.22±0.44	3.4±0.24	19.8 ± 0.40	0.4±0.06	16.14±0.37
NADJ 16	2.9±0.21	30.2±0.26	54.6±1.93	27±5.29	20.81±0.87	17.61±0.52	3.2±0.23	25 ± 0.53	0.5±0.07	17.02±0.69
NADJ 17	2.5±1.73	28.2±2.45	54.7±2.87	46±4.36	24.67±0.91	21.70±0.54	2.9±0.29	21.9 ± 0.85	0.63±0.05	16.23±0.49
NADJ 18	5.1±1.04	37.3±2.68	60.0±2.40	146±19.0	30.26±0.37	25.78±1.33	4.48±0.18	18.4 ± 0.20	0.6±0.12	14.63±1.11
NADJ 19	3.9±0.10	35.1±1.45	62.2±1.54	81±8.00	33.92±0.71	29.80±0.67	4.12±0.24	17.2 ± 0.91	1.0±0.10	13.76±0.78
NADJ 20	1.8±0.43	25.2±0.98	51.4±3.57	50±2.65	22.02±0.09	18.73±1.59	3.29±0.25	22.5 ± 0.30	0.8±0.13	15.83±0.72
WDTJ 21	2.8±0.30	31.2±2.56	60.9±2.24	52±3.61	16.16±0.16	12.46±0.41	3.7±0.78	14.8 ± 1.71	1.02±0.13	12.24±0.30
WDTJ 22	4.0±0.56	35.8±0.95	59.6±0.78	81±8.33	29.33±0.97	24.15±0.44	5.2±0.19	12.2 ± 1.51	0.7±0.1 0	11.33±0.90
WDTJ 23	4.9±0.31	22.5±1.30	59.3±3.26	83±9.85	36.62±0.73	32.70±0.81	3.9±0.97	11.5 ± 0.55	0.9±0.06	14.05±0.42
WDTJ 24	2.1± 0.10	22.3±0.46	59.2±3.05	61±6.56	31.92±0.12	26.90±0.17	5.02±0.33	14.7 ± 1.45	0.6±0.07	10.62±0.54
WDTJ 25	2.8±0.40	36.1±1.93	69.5±1.69	101±12.77	19.2±0.82	12.50±0.38	6.7±0.46	11.5 ± 0.30	0.9±0.10	13.26±0.48
WDTJ 26	4.0±0.96	27.3±1.13	65.2±5.53	89±2.66	35.6±0.66	31.00±0.09	4.6±0.62	13.3±0.43	0.6±0.06	16.23±0.55
WDTJ 27	5.0±0.87	36.2±0.26	66.0±0.56	103±13.53	34.58±0.62	29.52±0.44	5.06±0.23	16.2±0.46	0.7±0.10	11.05±1.05
WDTJ 28	3.0±0.28	24.5±0.98	65.3±2.28	76±9.54	34.33±0.70	29.73±0.53	4.6±0.62	11.9±0.10	0.7±0.07	16.23±0.49
WDTJ 29	3.5±1.0	24.6±0.70	47.4±2.46	66±4.58	14.73±0.84	11.16±0.54	3.57±0.63	16.2±0.72	0.6±0.08	15.92±0.63
WDTJ 30	4.2±0.40	27.8±0.89	65.2±0.52	82±3.61	20±0.10	19.22±0.41	5.78±0.57	11.9±0.46	1.0±0.15	16.81±0.69
KHWJ 31	5.6±0.66	33.6±0.98	61.6±2.04	124±4.58	39±2.18	33.40±0.42	5.6±0.38	18.2±0.53	0.9±0.28	17.23±0.48
KHWJ 32	5.3±0.76	34.1±0.56	69.1±0.96	105±4.36	28.9±1.00	25.70±0.55	3.2±0.39	14.9±0.61	0.5±0.03	14.62±0.44
KHWJ 33	4.3±0.18	27.9±0.36	64.6±1.74	87±7.55	28.7±6.28	22.60±0.83	6.1±0.13	12.2±0.91	1.1±0.20	12.32±0.59
KHWJ 34	4.2±0.12	33.3±1.12	62.7±1.61	80±3.61	35.22±0.29	29.32±0.36	5.9±0.24	10.0±1.20	0.6±0.08	10.14±0.54
KHWJ 35	5.2±0.16	33.4±7.19	62.5±1.06	77±4.00	34.6±0.54	30.90±0.93	3.7±0.41	21.2±0.35	0.5±0.05	17.36±0.78

KHWJ 36	4.9±0.56	29.8±1.11	64.3±0.95	82±3.60	29.24±0.51	34.64±0.56	4.6±0.33	15.2±0.53	1.2±0.34	15.31±0.61
KHWJ 37	2.1±0.18	30±1.45	54.4±0.96	79±4.00	23.39±0.36	19.29±0.44	4.1±0.21	12.9±0.50	0.6±0.05	11.09±0.79
KHWJ 38	3.2±0.61	29.1±1.25	55.6±0.61	61±5.13	27.9±0.67	25.20±0.32	2.7±0.67	18.5±1.05	0.4±0.08	17.04±0.51
KHWJ 39	4.5±0.15	27.3±0.56	59.6±0.80	63±2.00	34.5±1.23	27.60±0.32	6.9±0.56	12.2±0.72	0.6±0.05	12.06±0.40
KHWJ 40	2.3±0.17	25.1±1.85	53.2±2.88	53±8.66	20.01±0.89	16.40±0.45	3.7±0.41	14.8±0.61	0.7±0.10	14.13±0.83
PANJ 41	7.0±0.20	48.5±4.51	72.0±1.25	203±6.08	23.23±0.42	17.44±0.46	5.79±0.33	18.5±0.55	0.4±0.09	17.23±0.41
PANJ 42	10.0±2.55	52.3±1.65	71.5±0.79	115±8.72	46.19±0.26	29.42±0.39	6.77±0.36	18.6±0.53	0.6±0.05	17.02±0.55
PANJ 43	12.0±1.08	45.9±3.03	72.4±0.76	160±4.58	36.92±0.89	30.91±0.32	6.01±0.22	16.3±0.79	0.5±0.09	16.32±1.51
PANJ 44	13.2±1.20	49.6±4.95	66.6±1.54	180±3.00	37.71±0.62	29.04±0.69	7.1±0.55	19.2±0.72	0.3±0.05	15.12±0.48
PANJ 45	7.5±0.52	50.3±1.91	73.5±2.53	130±10.44	32.9±0.90	28.60±0.51	4.3±0.23	16.8±0.52	0.5±0.07	17.16±0.34
PANJ 46	9.6±0.56	50.6±3.08	65.4±1.94	122±5.00	45.67±0.63	34.60±0.81	9.07±0.14	19.6±0.52	0.4±0.06	17.01±0.24
PANJ 47	15.2±1.73	66.3±1.02	86.2±0.30	205±9.16	47.22±0.69	38.41±5.23	7.8±0.67	19.2±0.87	0.4±0.06	16.24±0.41
PANJ 48	17.3±1.21	73.6±1.99	65.0±2.60	223±5.29	42.65±0.49	36.65±0.96	6.0±0.20	16.5±0.70	0.6±0.08	15.27±0.88
PANJ 49	8.2±0.36	47.2±2.23	66.1±0.26	121±14.64	39.92±0.86	34.02±0.29	5.9±0.19	18.9±1.34	0.7±0.11	17.06±0.43
PANJ 50	6.7±0.62	47.0±2.22	69.6±1.61	109±6.56	41.32±0.30	35.29±0.38	6.03±0.66	22.6±1.71	0.4±0.05	16.97±0.96
VARJ 51	2.1±0.11	42.1±2.41	55.7±0.66	79±12.49	34.22±0.27	28.31±0.64	6.01±0.15	19.23±1.55	0.7±0.05	16.76±0.79
VARJ 52	3.1±0.17	39.8±1.90	53.2±1.85	62±14.64	31.22±0.77	27.50±0.38	3.7±0.25	14.2±0.53	0.6±0.07	14.23±0.90
VARJ 53	2.7±0.36	36.2±1.40	43.2±0.90	57±5.29	28.00±0.92	23.97±0.10	4.03±0.21	21.04±1.65	0.6±0.07	17.11±0.56
VARJ 54	2.3±0.30	39.1±3.11	53.2±2.74	52±4.58	25.63±0.59	22.33±0.39	3.3±0.30	16.78±1.52	0.5±0.06	15.23±0.76
VARJ 55	2.2±0.20	39.5±3.12	59.0±0.95	63±6.00	23.24±0.45	19.34±0.59	3.9±0.22	20.8±1.20	0.7±0.07	16.93±0.96
VARJ 56	2.1±0.36	17.3±0.85	52.8±0.75	49±5.00	20.02±0.42	17.0±0.14	3.03±0.12	19.2±1.11	0.4±0.05	16.11±0.32
VARJ 57	3.1±0.36	46.6±2.40	54.7±0.70	80±5.50	31.23±0.16	14.96±0.35	4.12±0.10	22.2±2.30	0.5±0.06	16.76±0.79
VARJ 58	3.7±1.021	49.2±1.68	60.8±1.48	83±6.24	31.23±0.17	26.53±1.17	4.7±0.19	24.8 ± 0.72	0.6±0.08	17.03±0.37
VARJ 59	2.1±0.20	34.8±1.23	52.4±1.08	29±3.46	37.20±0.23	31.15±0.33	6.05±0.43	25.4 ± 0.71	0.6±0.07	17.26±0.96
VARJ 60	2.9±0.360	36.5±1.76	62.1±0.62	37±5.29	35.04±0.08	29.81±0.24	5.23±0.28	23.9 ± 1.30	0.6±0.05	15.33±0.63
SDTJ 61	1.0±0.20	20.5±1.09	44.2±1.08	42±3.00	11.6±0.53	8.90±0.36	2.7±0.24	19.5±0.65	1.0±0.11	14.62±0.62
SDTJ 62	2.9±0.40	24.5±1.21	74.1±0.95	69±2.00	14.2±0.77	10.5±0.42	3.7±0.53	22±1.11	0.8±0.07	13.24±0.27
SDTJ 63	1.5±0.20	28.6±0.95	41.5±1.18	52±4.58	10.3±0.41	6.0±0.19	4.3±0.20	18.8±0.91	0.9±0.06	15.26±0.89
SDTJ 64	2.5±0.46	27.8±0.36	51.4±0.82	65±5.57	16.24±0.21	12.34±0.67	3.9±0.21	19.2±1.44	0.7±0.12	14.12±0.32
SDTJ 65	1.2±0.26	25.5±0.95	52.1±0.43	31±3.05	14.06±0.46	9.46±1.23	4.6±0.33	18.5±0.65	0.6±0.05	13.62±0.65
SDTJ 66	3.1±0.47	30.6±1.65	56.2±2.16	72±5.57	16.06±0.19	11.46±0.36	4.1±0.11	23.5±0.40	0.9±0.07	16.33±0.60
SDTJ 67	3.3±0.23	31.4±2.09	43.8±0.52	81±2.645	12.23±0.19	8.2±0.67	4.03±0.15	21.9±0.46	0.5±0.06	17.12±0.67
SDTJ 68	2.9±0.55	32.4±1.44	48.2±1.76	27±1.53	13.26±0.23	9.34±0.86	3.92±0.48	19.2±0.41	1.2±0.33	17.01±0.33
SDTJ 69	2.5±0.62	34.2±0.91	54.2±2.38	61±4.59	14.04±0.97	9.96±0.95	4.08±0.16	21.4±0.20	0.7±0.05	17.06±0.52
SDTJ 70	3.0±0.36	39.0±2.08	34.9±2.25	74±3.00	15.33±1.08	11.21±1.16	4.12±0.10	13.6±1.40	0.8±0.06	15.32±0.63

Table. 4.2: Physico-chemical characters of seventy accessions of jackfruit (2nd Year)

Accessions	Fruit Weight (Kg)	Fruit Length (cm)	Fruit Width (cm)	Number of Flake	Flake Weight (g)	Pulp Weight (g)	Seed Weight (g)	TSS (ºBrix)	Titrable Acidity (%)	Total Sugar (%)
PARJ 1	4.82±0.92	32.00±1.00	75.73±1.10	112 ± 3.60	27.07±0.22	23.05±0.64	4±0.11	17.60±0.72	0.61±0.91	17.52±0.92
PARJ 2	3.76±[illegible]	[illegible]91±7.22	61.30±1.53	73 ± 7.21	13.2±0.85	8.64±0.60	4.56±0.36	21.80±0.59	0.59±1.02	14.34±1.02
PARJ 3	4.25±0.94	20.35±4.30	60.10±2.70	65 ± [illegible]	[illegible]1±0.36	9.35±0.87	2.76±0.29	15.00±0.20	0.88±0.77	15.21±0.78
PARJ 4	5.83±0.18	39.16±1.76	69.20±1.11	81 ± 2.64	18.64±0.71	13.19±1.24	5.45±0.26	16.67±1.70	0.92±0.91	12.05±0.93
PARJ 5	5.20±0.72	30.96±2.26	67.11±1.73	66 ± 6.55	18.05±0.17	9.64±0.66	4.13±0.14	18.00±1.90	0.96±0.99	15.39±0.99
PARJ 6	4.12±0.50	31.42±2,83	61.40±2.70	91 ± 2.64	15.24±0.85	14.08±0.67	5.93±0.90	19.20±0.72	0.78±0.99	17.16±1.00
PARJ 7	3.96±0.40	39.24±1.99	53.70±1.05	95 ± 4.00	18.52±1.41	9.72±0.58	4.09±0.21	12.8±1.31	0.56±0.71	16.21±0.72
PARJ 8	2.62±0.69	25.11±1.46	47.60±2.94	41 ± 3.46	13.82±0.16	9.52±0.52	4.11±0.50	15.2±0.52	0.79±1.22	11.05±1.23
PARJ 9	3.06±0.31	18.91±1.49	56.70±1.66	60 ± 3.47	12.36±0.56	9.63±1.76	2.84±0.26	17.93±.80	0.92±1.05	14.12±1.06
PARJ 10	3.81±0.42	25.03±6.43	55.30±0.79	56 ± 2.64	13.52±0.49	9.87±0.55	3.87±0.65	21.40±0.72	0.45±0.61	14.33±0.61
NADJ 11	2.56±0.51	27.40±1.15	50.30±3.45	41 ± 5.29	22.31±1.26	16.82±2.09	5.49±0.41	17.20±0.91	0.60±0.48	17.36±0.49
NADJ 12	5.62±1.17	36.10±1.41	63.70±4.78	122 ± 4,35	25.16±0.39	20.10±0.34	5.23±0.55	16.60±1.44	0.52±0.55	13.24±0.56
NADJ 13	5.98±0.70	75.30±2.61	51.20±1.15	127 ± 9.16	27.89±1.72	20.07±0.33	7.82±0.18	21.20±1.21	0.46±0.77	15.43±0.78
NADJ 14	4.13±0.39	27.10±1.22	30.72±2.47	75 ± 5.56	22.67±0.56	19.41±1.00	4.31±0.58	20.80±1.50	0.61±0.94	15.20±0.95
NADJ 15	2.37±0.32	25.30±0.8	62.50±4.78	48 ± 4.35	22.05±1.51	19.41±0.66	3.26±0.24	24.80±0.20	0.65±0.72	17.29±0.72
NADJ 16	2.71±0.58	31.40±0.86	53.70±3.23	23 ± 5.56	20.17±1.17	17.20±0.90	2.97±0.45	22.40±0.72	0.60±0.47	18.10±0.47
NADJ 17	2.58±0.47	27.92±2.20	54.60±1.63	49 ± 4.58	25.93±0.80	22.92±0.96	3.01±0.62	19.60±0.91	0.40±0.61	17.33±0.61
NADJ 18	4.82±0.56	35.70±2.58	59.20±1,11	132 ± 3.46	27.92±5.91	26.67±0.42	4.56±0.33	18.20±0.72	0.40±0.81	15.12±0.81
NADJ 19	4.10±0.42	36.50±0.88	63.90±1.07	99 ± 3.60	34.19±0.46	29.36±0.87	4.83±0.61	23.20±0.52	0.67±0.84	14.43±0.84
NADJ 20	2.05±0.26	26.10±0.43	62.47±1.00	55 ± 5.56	21.88±0.41	18.23±0.2	3.65±0.54	15.40±0.52	0.60±1.37	13.36±1.38

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WDTJ 21	3.05±0.25	33.40±1.47	61.35±1.20	56 ± 1.73	17.24±0.73	13.38±0.26	4.19±0.16	13.20±0.72	0.99±1.02	13.26±1.03
WDTJ 22	3.72±0.53	36.10±1.90	60.80±1.17	90 ± 1.50	28.56±0.91	23.2±0.72	5.36±0.70	12.60±0.36	0.82±0.53	11.53±0.54
WDTJ 23	4.13±0.42	20.00±2.62	60.70±3.24	95 ± 6.92	37.68±0.56	32.31±1.16	4.31±0.43	15.20±0.91	0.78±0.75	15.29±0.76
WDTJ 24	2.52±0.38	23.10±0.95	57.30±2.78	69 ± 21.12	32.31±0.61	27.78±1.52	5.53±1.19	11.40±0.52	0.60±0.56	11.36±0.57
WDTJ 25	3.14±0.43	35.30±2.00	58.70±2.56	110 ± 2.64	19.67±1.45	12.78±0.71	6.89±0.31	14.20±0.72	0.84±0.81	12.89±0.82
WDTJ 26	4.26±0.44	28.10±2.72	70.30±1.53	82 ± 4.93	36.72±0.78	31.66±0.68	4.73±0.35	15.80±1.24	0.95±.47	17.06±0.47
WDTJ 27	5.17±1.011	38.20±1.44	66.10±1.49	107 ± 8.54	35.36±0.64	30.03±0.60	5.33±0.66	12.70±0.11	0.70±0.61	12.33±0.62
WDTJ 28	2.99±0.90	25.10±1.17	67.20±1.58	81 ± 7.00	35.22±0.55	31.33±0.56	3.89±0.88	17.6±0.60	0.72±0.32	17.11±0.33
WDTJ 29	3.11±0.60	28.00±1.87	63.10±3.39	63 ± 4.35	15.02±1.06	11.73±0.63	3.47±0.25	11.60±0.40	0.62±0.77	15.23±0.77
WDTJ 30	4.76±0.65	28.1±1.15	50.10±2.06	85 ± 5.56	21.63±1.26	16.25±0.78	5.38±0.43	18.60±1.11	0.64±0.87	17.47±0.88
KHWJ 31	6.14±6.14	28.9±0.85	63.50±1.94	132 ± 4.35	40.36±0.70	34.47±0.46	5.89±0.52	16.20±2.42	0.60±1.49	15.33±1.50
KHWJ 32	5.73±0.76	34.80±1.50	67.30±2.42	111 ± 7.00	27.83±0.70	24.21±0.91	3.60±0.36	13.20±1.05	1.00±0.96	12.09±0.97
KHWJ 33	4.19±0.37	35.10±1.15	60.10±0.55	89 ± 10.53	28.61±0.58	21.71±0.66	6.32±0.34	11.40±0.60	0.62±0.65	11.26±0.65
KHWJ 34	3.75±0.40	29.10±1.60	65.11±2.47	75 ± 6.00	36.15±0.66	30.07±0.39	6.08±0.16	10.60±0.95	0.52±0.62	10.56±0.62
KHWJ 35	4.94±1.42	34.70±1.21	60.50±3.74	70 ± 4.58	35.09±1.017	31.48±1.05	3.61±0.45	15.80±0.34	1.10±0.62	16.37±0.62
KHWJ 36	5.33±1.15	35.10±1.15	66.30±2.08	88 ± 2.64	33.05±5.72	25.28±0.79	4.87±0.68	13.40±0.87	1.2±0.39	10.56±0.40
KHWJ 37	2.21±0.32	30.19±0.70	51.70±2.36	81 ± 3.60	24.11±0.28	20.27±0.98	3.84±0.59	19.40±1.21	0.50±0.52	16.16±0.53
KHWJ 38	3.46±0.71	30.2±0.91	53.90±3.38	66 ± 1.73	28.03±0.89	25.22±0.70	2.81±0.34	12.80±0.72	0.60±0.79	17.32±0.80
KHWJ 39	5.11±0.40	30.17±1.45	56.70±2.01	60 ± 3.60	34.16±0.77	27.63±0.35	6.51±0.71	15.20±0.72	0.73±0.44	11.65±0.44

KHWJ 40	1.95±0.27	26.30±1.15	52.10±2.74	57 ± 2.00	20.18±0.54	16.29±0.79	3.89±0.48	20.40±0.52	0.66±0.71	14.83±0.72
PANJ 41	8.36±0.67	50.63±2.12	75.10±1.95	150 ± 3.60	25.45±0.88	19.70±1.23	5.92±0.79	21.20±1.05	0.50±0.72	17.39±0.73
PANJ 42	10.41±0.73	53.10±0.79	73.20±3.10	81 ± 2.08	47.52±0.82	40.80±1.40	6.39±0.34	19.40±0.60	0.67±1.40	18.26±1.41
PANJ 43	11.94±1.34	47.00±3.60	70.10±3.26	107 ± 4.58	34.45±2.49	29.07±1.10	6.42±1.09	21.40±0.60	0.52±0.39	17.18±0.39
PANJ 44	14.39±1.34	50.10±4.53	65.50±1.90	181 ± 4.00	38.16±1.03	30.80±1.67	7.35±0.58	21.20±0.80	0.46±0.48	16.33±0.49
PANJ 45	8.29±0.61	53.20±2.88	70.50±1.15	132 ± 4.35	33.17±0.59	28.70±0.81	4.47±0.49	21.20±0.80	0.52±0.75	17.83±0.75
PANJ 46	10.27±0.74	51.09±2.19	51.51±2.29	117 ± 4.45	46.14±0.29	37.06±1.04	9.13±0.26	21.60±1.44	0.40±0.50	17.46±0.50
PANJ 47	14.76±0.23	67.40±1.01	87.30±3.23	218 ± 4.00	47.35±0.78	39.17±0.62	8.16±0.77	19.20±0.60	0.60±0.82	16.93±0.83
PANJ 48	16.45±1.64	75.20±1.08	64.90±3.29	236 ±11.35	36.43±22.32	30.15±1.26	6.46±0.84	18.20±0.72	0.58±0.58	16.47±0.50
PANJ 49	9.1±0.84	49.1±2.81	68.10±1.81	127 ± 5.56	40.08±0.47	33.57±1.56	6.18±0.64	20.40±0.78	0.70±0.55	17.87±0.56
PARJ 50	6.02±1.18	48.71±3.49	70.60±1.92	113 ± 3.00	40.21±0.68	33.86±1.33	6.33±0.71	23.80±1.80	0.50±3.38	18.10±3.38
VARJ 51	2.77±0.23	40.20±2.95	66.10±0.95	83 ± 4.35	35.39±0.61	29.13±0.64	6.23±0.64	22.40±0.87	0.60±0.79	17.91±0.79
VARJ 52	3.25±0.61	38.20±3.10	55.30±0.60	56 ± 1.73	32.13±0.41	28.37±1.49	3.46±0.42	15.80±0.20	0.60±0.65	15.32±0.65
VARJ 53	2.34±0.41	37.50±1.80	60.32±2.16	51 ± 2.64	28.14±0.23	23.62±0.35	4.52±0.60	22.90±0.95	0.61±0.58	17.33±0.58
VARJ 54	2.67±0.27	40.45±2.95	55.14±2.47	55 ± 4.50	54.67±0.68	22.24±0.68	3.92±0.69	17.20±0.72	0.63±0.86	16.26±0.87
VARJ 55	2.00±0.36	41.23±3.10	61.27±2.30	68 ± 4.35	23.01±0.91	18.87±1.46	4.07±0.27	21.40±1.31	0.65±0.54	16.43±0.54
VARJ 56	2.31±0.52	40.13±2.13	55.17±4.30	47 ± 3.00	21.67±1.47	18.42±0.54	3.23±0.20	22.80±1.38	0.50±0.55	17.73±0.56
VARJ 57	3.94±0.80	46.70±2.13	63 50±3.77	81 ± 3.60	32.08±0.95	28.81±1.49	3.88±0.80	25.60±0.60	0.60±0.43	17.31±0.44
VARJ 58	4.16±0.33	51.20±2.98	56.70±2.02	89 ± 4.58	33.10±0.59	28.80±0.9	4.27±0.26	24.33±1.52	0.50±0.73	17.81±0.73

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VARJ 59	1.82±0.28	38.97±0.95	50.1±1.01	28 ± 3.00	38.39±1.07	32.23±0.68	6.16±0.27	27.80±0.72	0.55±0.58	18.32±0.59
VARJ 60	3.12±0.64	28.60±3.43	63.16±3.07	41 ± 3.00	36.21±0.66	30.89±0.30	5.32±0.61	23.63±0.85	0.60±0.80	16.14±0.81
SDTJ 61	0.92±0.32	21.10±1.31	43.20±0.72	40 ± 4.58	12.23±0.78	9.34±0.33	2.89±0.39	12.40±0.52	1.20±0.65	15.32±0.65
SDTJ 62	2.51±0.52	22.160±1.65	70.11±1.03	57 ± 3.46	15.36±0.61	11.73±0.95	3.62±0.19	21.60±0.52	0.92±0.60	14.61±0.60
SDTJ 63	1.36±0.64	29.30±3.62	39.60±3.07	55 ± 4.50	9.52±0.42	4.99±0.32	4.53±0.51	19.20±0.52	0.80±0.61	15.33±0.62
SDTJ 64	2.21±0.17	25.30±1.17	47.30±1.15	61 ± 2.64	17.32±0.31	13.96±0.93	3.63±0.34	19.80±0.69	0.70±0.57	15.36±0.58
SDTJ 65	1.00±0.11	26.10±1.10	55.13±0.85	33 ± 3.00	15.24±0.88	10.32±0.49	4.25±0.19	18.00±0.91	0.80±0.86	12.92±0.87
SDTJ 66	2.99±0.87	33.20±1.31	57.36±2.3	67 ± 1.73	16.63±0.39	10.32±0.48	4.13±0.54	23.60±1.50	0.93±0.70	15.81±0.71
SDTJ 67	3.36±0.99	29.90±3.46	45.50±2.23	84 ± 4.58	12.36±0.59	12.50±0.51	3.93±0.33	22.20±0.72	0.53±1.28	17.37±1.29
SDTJ 68	2.16±0.27	32.50±2.52	49.11±2.81	31 ± 1.76	13.92±0.52	8.43±0.44	4.65±1.66	20.30±1.17	1.20±0.70	17.81±0.71
SDTJ 69	2.07±0.47	35.30±0.62	50.16±2.72	60 ± 4.58	14.55±0.97	8.57±3.55	4.73±0.22	20.20±0.72	0.77±0.96	16.61±0.96
SDTJ 70	2.74±0.94	37.80±4.01	52.22±2.03	71 ± 4.35	16.41±0.72	12.05±0.10	4.36±0.30	14.20±0.72	0.70±0.86	16.02±0.86

Table. 4.3: Physico-chemical characters of seventy accessions of jackfruit (1st & 2nd year combined)

Accessions	Fruit Weight (Kg)	Fruit Length (cm)	Fruit Width (cm)	Number of Flake	Flake Weight (g)	Seed Weight (g)	Pulp Weight (g)	TSS (ºBrix)	Titrable Acidity (%)	Total Sugar (%)
PARJ 1	5.01±0.27	31.57±1.36	75.12±0.87	108±6.36	25.89±1.19	3.85±0.22	22.03±1.44	16.81±1.12	0.57±0.057	17.38±0.15
PARJ 2	3.68±0.11	27.45±1.91	60.70±0.85	70±4.95	13.05±0.15	4.28±0.40	8.77±0.18	20.9±1.27	0.6±0.007	13.77±0.57
PARJ 3	4.025±0.32	21.43±1.52	60.85±1.06	62±4.24	12.41±0.30	2.83±0.10	9.58±0.33	14.9±0.14	0.94±0.085	14.98±0.23
PARJ 4	5.775±0.11	38.83±0.47	70.10±1.27	77±5.66	18.27±0.37	5.68±0.32	12.6±0.84	12.20±0.00	0.91±0.014	12.16±0.11
PARJ 5	4.7±0.71	32.15±1.68	66.75±0.49	65±1.41	18.43±0.38	3.91±0.31	12.13±3.51	16.43±0.33	0.98±0.026	15.66±0.27
PARJ 6	4.46±0.48	31.91±0.69	60.40±1.41	93±2.12	15.59±0.35	5.92±0.02	12.06±2.86	18.10±0.14	0.84±0.078	16.71±0.45
PARJ 7	4.13±0.24	39.07±0.24	52.90±1.13	96±1.41	17.29±1.23	3.79±0.43	11.15±2.02	18.80±0.57	0.54±0.028	16.47±0.26
PARJ 8	2.31±0.44	24.6±0.71	46.00±2.26	39±3.54	13.21±0.61	4.01±0.14	9.11±0.59	12.65±0.21	0.82±0.042	11.19±0.14
PARJ 9	2.68±0.54	19.21±0.42	55.75±1.34	61±0.71	11.91±0.45	2.87±0.04	9.10±0.76	15.05±0.21	0.96±0.057	14.02±0.10
PARJ 10	3.55±0.36	26.16±1.61	54.80±0.71	55±2.12	13.42±0.10	3.99±0.16	9.55±0.46	17.22±1.01	0.44±0.014	14.63±0.30
NADJ 11	2.38±0.25	26.85±1.61	49.40±1.27	44±3.54	21.92±0.39	5.27±0.32	16.65±0.24	20.80±0.85	0.55±0.071	17.14±0.22
NADJ 12	5.46±0.23	36.70±0.85	64.45±1.06	116±9.19	24.83±0.33	4.99±0.34	19.93±0.25	16.85±0.49	0.56±0.057	13.48±0.23
NADJ 13	6.14±0.23	74.20±1.56	50.20±1.41	123±6.36	28.26±0.37	7.70±0.18	20.56±0.70	16.70±0.14	0.43±0.042	14.83±0.60
NADJ 14	3.91±0.30	27.75±0.92	30.11±0.86	77±2.12	22.76±0.09	4.04±0.39	19.24±0.25	21.00±0.28	0.61±0.007	15.41±0.21
NADJ 15	2.23±0.19	24.70±0.85	61.25±1.77	45±4.95	21.84±0.22	3.33±0.10	18.82±0.84	20.30±0.71	0.53±0.177	16.72±0.58
NADJ 16	2.80±0.13	30.80±0.85	54.15±0.64	25±2.83	20.49±0.32	3.09±0.16	17.41±0.29	24.90±0.14	0.55±0.071	17.56±0.54
NADJ 17	2.53±0.05	28.06±0.20	54.65±0.07	48±2.12	25.30±0.63	2.96±0.08	22.31±0.86	22.15±0.35	0.52±0.163	16.78±0.55
NADJ 18	4.96±0.20	36.5±1.13	59.95±1.06	139±9.90	29.09±1.17	4.52±0.06	26.23±0.63	19.00±0.85	0.50±0.141	14.88±0.24
NADJ 19	4.00±0.14	35.8±0.99	63.05±1.20	90±12.73	34.06±0.13	4.48±0.50	29.58±0.31	17.70±0.71	0.84±0.233	14.10±0.34
NADJ 20	1.92±0.18	25.65±0.64	56.94±7.84	53±3.54	21.95±0.07	3.47±0.25	18.48±0.35	22.85±0.49	0.7±0.141	14.60±1.23
WDTJ 21	2.92±0.18	32.30±1.56	61.13±0.32	54±2.83	16.70±0.54	3.95±0.35	12.92±0.65	15.10±0.42	1.01±0.021	12.75±0.51
WDTJ 22	3.86±0.20	35.95±0.21	60.20±0.85	85±6.01	28.95±0.38	5.28±0.11	23.68±0.67	12.70±0.71	0.76±0.085	11.43±0.10
WDTJ 23	4.51±0.54	21.25±1.77	60.00±0.99	89±8.49	37.15±0.53	4.11±0.29	32.51±0.28	12.05±0.78	0.84±0.085	14.67±0.62
WDTJ 24	2.31±0.30	22.70± 0.57	58.25±1.34	65±5.42	32.12±0.20	5.28±0.36	27.34±0.62	14.95±0.35	0.6±0.00	10.99±0.37
WDTJ 25	4.27±1.60	35.70±0.57	64.10±7.64	106±6.36	19.44±0.23	6.80±0.13	12.64±0.20	11.45±0.07	0.87±0.040	13.08±0.19
WDTJ 26	4.13±0.18	27.70±0.57	67.75±3.61	86±4.71	36.16±0.56	4.66±0.09	31.33±0.47	13.75±0.64	1.78±1.167	16.65±0.41
WDTJ 27	5.085±0.12	37.20±1.41	66.05±0.07	105±2.83	34.97±0.39	5.20±0.19	29.78±0.36	16.00±0.28	0.7±0.00	11.69±0.64
WDTJ 28	2.99± 0.01	24.80±0.42	66.25±1.34	79±3.54	34.78±0.45	4.25±0.50	30.53±1.13	11.98±0.12	0.71±0.016	16.67±0.44
WDTJ 29	3.30±0.18	26.3±2.40	55.25±11.10	65±2.12	14.97±0.24	3.52±0.07	11.45±0.40	16.90±0.99	0.61±0.014	15.58±0.35
WDTJ 30			57.65±10.6				17.74±2.1			

Table. 4.4: Physico-chemical characters of different jackfruit geographical locations-I (1st year)

Parameters	North 24 Parganas (n = 10)		Nadia (n = 10)		West Tripura (n = 10)		Khowai (n = 10)	
	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)
Fruit weight (Kg)	2 to 5.7	3.92±1.18	1.8 to 5.3	3.58±1.55	2.1 to 5.4	1.05±3.89	2.1 to 5.6	3.89±1.05
Fruit Length (cm)	19.5 to 38.9	29.32±6.57	22.30 to 73.1	34.52±14.39	22.3 to 36.2	28.83±5.62	25.1 to 33.60	30.37±3.12
Fruit Width (cm)	44.40 to 74.50	59.86±9.07	29.50 to 65.20	53.60±1-.18	47.40 to 65.20	61.76±6.13	53.20 to 69.10	60.76±5.05
Number of Flakes	36 to 103	70.60±21.34	27 to 146	74.20±39.23	52 to 103	79.40±16.39	53 to 124	81.10±21.06
Flake Weight (g)	11.46 to 24.70	15.64±4.02	20.81 to 33.92	25.08±4.41	14.73 to 36.62	27.25±8.77	20.10 to 39.00	30.16±5.76
Seed Weight (g)	2.90 to 5.90	4.05±1.06	2.90 to 7.57	4.25±1.37	3.57 to 6.70	4.81±0.97	2.70 to 6.90	4.65±1.40
Pulp Weight (g)	8.56 to 21.01	11.54±3.87	16.48 to 29.80	20.82±4.09	11.16 to 29.73	22.93±8.42	16.40 to 34.64	24.09
TSS ºBrix	12.20 to 20.00	15.97±2.50	16.50 to 22.20	19.91±2.76	11.50 to 16.20	13.42±1.90	10.00 to 18.50	15.01±3.43
Titratable Acidity (%)	0.43 to 1.00	0.77± 2.30	0.40 to 0.80	0.60±0.18	0.60 to 2.60	0.97±0.59	0.40 to 1.20	0.71±0.27
Total Sugar (%)	11.32 to 17.23	14.65±1.96	13.71 to 17.02	15.41±1.24	11.05 to 16.81	13.77±2.40	10.14 to 17.16	14.12±2.63

Table. 4.5: Physico-chemical characters of different jackfruit geographical locations-II (1st year)

Parameters	Panruti (n = 10)		Varkala (n = 10)		South Sikkim (n = 10)	
	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)
Fruit weight (Kg)	7.00 to 17.30	10.67±3.65	2.1 to 3.7	2.59±0.55	1 to 3.33	2.39±0.85
Fruit Length (cm)	47.00 to 73.60	53.13±9.23	17.3 to 49.20	38.11±8.61	20.5 to 39.00	29.45±5.28
Fruit Width (cm)	65.00 to 86.20	70.83±6.26	43.20 to 62.10	54.71±5.34	41.50 to 74.10	50.06±10.64
Number of Flakes	109 to 223	156.80±42.99	29 to 83	59.10±18.19	27 to 74	57.41±18.68
Flake Weight (g)	23.23 to 47.22	39.37±7.26	19.08 to 35.04	28.49 ±6.35	10.30 to 16.24	13.74±1.93
Seed Weight (g)	4.30 to 9.07	6.48±1.30	3.03 to 6.05	4.41±1.06	2.60 to 4.60	3.95±0.50
Pulp Weight (g)	14.60 to 38.41	29.44±7.85	14.96 to 29.81	24.09±5.55	6.00 to 12.34	9.74±1.82
TSS °Brix	16.20 to 22.60	18.62±1.85	14.20 to 25.4	20.76±3.55	13.60 to 23.50	19.76±1`.93
Titratable Acidity (%)	0.30 to 0.70	0.48±0.12	0.40 to 0.70	0.58±0.09	0.5 to 1.20	0.81±0.20
Total Sugar (%)	15.12 to 17.19	16.54±0.78	14.23 to 17.26	16.28±1.02	13.24 to 17.12	15.37±1.46

Table. 4.6: Physico-chemical characters of different jackfruit geographical locations-I (2nd year)

Parameters	North 24 Parganas (n = 10)		Nadia (n = 10)		West Tripura (n = 10)		Khowai (n = 10)	
	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)
Fruit weight (Kg)	2.62 to 5.86	4.15±0.96	2.05 to 4.98	3.69±1.43	3.11 to 5.17	3.71±0.90	1.95 to 6.14	4.28±1.43
Fruit Length (cm)	18.91 to 39.24	29.15±6.97	26.20 to 75.30	34.88±14.85	20.00 to 38.20	29.54±6.01	26.30 to 35.10	31.50±3.16
Fruit Width (cm)	47.60 to 75.73	60.81±8.21	30.72 to 63.90	55.23±10.07	50.10 to 70.30	61.57±5.68	51.70 to 67.30	59.70±5.87
Number of Flakes	41 to 112	74.00±21.02	23 to 132	77.10±39.94	56 to 110	83.75±17.73	57 to 133	83.00±23.75
Flake Weight (g)	12.36 to 27.07	16.25±4.56	20.17 to 34.19	25.02±4.17	15.20 to 37.68	27.96±8.72	20.18 to 40.36	30.76±6.09

Seed Weight (g)	2.76 to 5.93	4.17±0.99	2.97 to 7.82	4.51±1.47	3.47 to 6.89	4.91±1.00	2.81 to 6.32	4.74±1.36
Pulp Weight (g)	8.64 to 23.05	11.67±4.37	16.82 to 29.36	21.02±4.11	11.73 to 32.31	23.05±8.65	16.29 to 27.63	25.66±5.47
TSS ºBrix	12.20 to 19.20	16.64±2.92	16.60 to 24.80	20.54±2.64	11.40 to 17.50	13.91±2.07	11.40 to 20.60	15.66±3.07
Titratable Acidity (%)	0.45 to 0.96	0.75±0.18	0.40 to 0.67	0.55±0.10	0.62 to 0.99	0.77±0.14	0.50 to 1.10	0.69±0.20
Total Sugar (%)	11.05 to 17.52	14.74±2.05	13.24 to 18.10	15.69±1.75	11.36 to 17.47	14.35±2.72	16.33 to 17.92	14.46±2.60

Table. 4.7: Physico-chemical characters of different jackfruit geographical locations-II (2nd year)

Parameters	**Panruti (n = 10)**		**Varkala (n = 10)**		**South Sikkim (n = 10)**	
	Range	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**
Fruit weight (Kg)	8.29 to 16.45	12.00±3.17	1.87 to 4.16	2.84±0.78	1.00 to 3.36	2.13±0.82
Fruit Length (cm)	47.09 to 75.20	54.55± 9.21	28.60 to 46.70	40.62±5.89	21.20 to 37.80	29.32±5.49
Fruit Width (cm)	64.90 to 87.30	72.08±6.44	50.10 to 66.13	58.68±4.97	39.60 to 70.10	50.95±8.58
Number of Flakes	81 to 236	146.26±50.26	28 to 83	59.87±19.87	31 to 84	55.87±16.94

Flake Weight (g)	25.45 to 47.52	38.27±7.51	21.67 to 38.39	33.48±9.22	9.52 to 1.32	14.35±2.141
Seed Weight (g)	4.47 to 9.13	6.68±1.28	3.23 to 6.23	4.51±1.06	2.89 to 4.73	4.07±0.57
Pulp Weight (g)	19.70 to 36.43	32.92±6.18	18.42 to 32.23	26.14±4.96	4.99 to 13.96	10.22±2.56
TSS ºBrix	18.20 to 23.80	20.68±1.56	15.80 to 27.80	22.39±3.60	12.40 to 23.60	19.15±3.49
Titratable Acidity (%)	0.4 to 0.70	0.55±0.09	0.50 to 0.65	0.58±0.05	0.70 to 1.20	0.85±0.21
Total Sugar (%)	16.33 to 18.10	17.38±0.66	15.32 to 18.32	17.06±0.96	12.92 to 17.81	15.72±1.39

Parameters	**North 24 Parganas (n = 10)**		**Nadia (n = 10)**		**West Tripura (n = 10)**		**Khowai (n = 10)**	
	Range	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**
Fruit weight (Kg)	3.68 to 5.77	4.03±1.04	2.23 to 6.14	3.64±1.49	2.31 to 5.08	3.79±0.87	2.12 to 5.86	4.22±1.32
Fruit Length (cm)	19.21 to 39.07	29.24±6.71	24.70 to 74.2	34.70±14.61	21.25 to 37.20	29.19±5.76	25.70 to 34.45	30.93±2.57
Fruit Width (cm)	46.00 to 75.12	60.34±8.61	30.11 to 65.45	54.42±9.96	55.25 to 67.75	61.66±4.18	52.65 to 64.45	60.24±5.35
Number of Flakes	39 to 108	72.60±21.05	25 to 139	76.00±39.26	54 to 106	81.90±16.84	55 to 128	82.20±22.04
Flake Weight	11.91 to 25.89	15.95±4.26	20.49 to 34.06	25.05±4.26	16.70 to 37.15	27.61±8.71	23.75 to 39.68	30.46±5.89

(g)								
Seed Weight (g)	2.83 to 5.68	4.11±1.01	2.96 to 7.70	4.39±1.41	3.52 to 6.80	4.86±0.96	2.76 to 6.71	4.70±1.37
Pulp Weight (g)	8.77 to 22.03	11.61±3.93	16.65 to 29.58	20.92±4.08	11.45 to 32.51	22.99±8.51	16.35 to 33.94	26.09±5.48
TSS Brix°	12.2 to 20.90	16.31±2.70	16.70 to 22.85	20.23±2.69	11.45 to 16.90	13.66±1.96	10.70 to 20.90	15.34±3.25
Titratable Acidity (%)	0.44 to 0.98	0.76±0.20	0.43 to 0.84	0.58±0.12	0.60 to 1.78	0.97±0.34	0.50 to 0.92	0.70±0.14
Total Sugar (%)	11.19 to 17.38	14.70±1.98	13.48 to 17.56	15.55±1.40	10.99 to 17.14	14.07±2.36	11.79 to 17.18	14.24±1.95

Table. 4.8: Physico-chemical characters of different jackfruit geographical locations-I (1st & 2nd year)

Table. 4.9: Physico-chemical characters of different jackfruit geographical locations-II (1st & 2nd year)

Parameters	**Panruti (n = 10)**		**Varkala (n = 10)**		**South Sikkim (n = 10)**	
	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)
Fruit weight (Kg)	7.68 to 16.87	11.34±3.09	1.96 to 3.93	2.71±0.64	0.96 to 3.34	2.26±0.83
Fruit Length (cm)	46.45 to 7.40	53.84±9.21	32.55 to 50.20	39.26±6.11	20.85 to 38.40	29.39±5.33
Fruit Width (cm)	64.95 to 86.75	71.46±6.08	51.75 to 62.70	56.69±4.07	40.55 to 72.1	50.51±9.13

Number of Flakes	98 to 230	151.80±45.12	29 to 86	59.60±18.93	29 to 73	56.80±17.86
Flake Weight (g)	24.34 to 47.29	38.82±7.08	20.85 to 40.15	30.99±6.42	9.91 to 16.78	14.05±2.15
Seed Weight (g)	4.39 to 7.98	6.58±1.28	3.13 to 6.11	4.46±1.05	2.8 to 4.43	4.01±0.50
Pulp Weight (g)	18.57 to 38.79	31.18±5.94	17.71 to 31.69	25.12±4.82	5.50 to 13.15	9.98±2.04
TSS Brix°	17.35 to 23.20	19.65±1.60	15.00 to 26.60	21.58±3.50	13.90 to 23.55	19.45±2.90
Titratable Acidity (%)	0.40 to 0.64	00.51±0.10	0.55 to 0.68	0.58±0.06	0.70 to 1.20	0.83±0.20
Total Sugar (%)	15.73 to 17.63	16.96±0.70	14.78 to 17.79	16.67±0.95	13.27 to 17.41	15.55±1.38

Table. 4.10: Soil ionome of different jackfruit geographical locations-I (1st year)

Elements (mg kg^{-1})	**North 24 Parganas (n = 10)**		**Nadia (n = 10)**		**West Tripura (n = 10)**		**Khowai (n = 10)**	
	Range	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**
Ba	24.51 to 55.97	34.09±9.16	24.02 to 81.40	44.78±15.57	1.21 to 14.69	8.26±4.51	4.44 to 16.06	10.47±4.09
Al	1511.26 to 4951.76	2228.75±993.27	1477.56 to 4450.57	2329.13±858.15	921.34 to 1576.80	1272.91±445.50	310.08 to 1407.65	683.42±386.39
Ca	14.73 to 59.28	29.25±14.69	15.18 to 38.21	27.23±6.95	2.54 to 7.26	4.60±1.48	3.72 to 5.89	4.51±0.66

Co	1.72 to 2.29	1.96±0.212	1.64 to 4.49	2.61±0.793	0.09 to 1.54	0.60±0.503	0.26 to 0.99	0.53±0.279
Cr	27.87 to 59.20	45.68±9.53	15.82 to 60.62	44.29±16.10	12.41 to 56.87	35.39±17.17	19.07 to 50.52	33.24±12.02
Cs	1.18 to 1.71	1.34±0.209	1.31 to 3.01	1.72±0.485	0.04 to 1.12	0.45±0.358	0.18 to 0.72	0.36±0.183
Cu	10.74 to 22.67	15.26±4.00	13.36 to 30.35	21.88±5.49	4.28 to 13.05	9.13±3.00	3.46 to 9.27	5.60±1.81
Fe	1139.92 to 1621.84	1357.50±152.29	1220.63 to 4309.28	1930.16±927.23	51.03 to 1389.94	556.91±491.12	207.83 to 2304.01	624.24±620.22
Ga	1.83 to 2.95	2.45±0.402	2.14 to 6.81	3.33±1.33	1.31 to 4.44	2.92±1.15	0.35 to 1.57	0.74±0.428
S	13.52 to 16.30	14.87±0.784	10.94 to 15.67	13.10±1.31	11.07 to 13.77	12.40±0.890	9.19 to 13.51	11.60±1.68
K	42.21 to 57.18	50.23±4.27	36.02 to 95.91	55.06±17.94	7.83 to 13.11	10.76±1.99	5.15 to 8.03	6.96±0.951
Li	14.36 to 21.56	17.73±1.85	13.87 to 38.98	21.61±7.10	0.20 to 10.59	3.06±2.56	0.33 to 4.68	1.10±1.45
Mg	99.41 to 138.50	120.08±13.13	87.37 to 242.70	138.15±45.49	11.68 to 42.84	26.24±13.00	26.07 to 124.22	48.15±40.12
Mn	126.13 to 2131.33	1014.78±699.55	1194.02 to 3165.72	2133.20±635.90	111.00 to 749.83	291.17±225.94	126.48 to 2268.78	1154.26±812.72
Na	63.62 to 95.02	77.70±9.94	75.18 to 112.01	88.33±13.59	6.80 to 52.26	42.21±12.70	38.62 to 56.94	47.84±4.90
Ni	8.48 to 15.23	10.74±2.15	8.69 to 22.76	14.85±4.36	0.63 to 8.97	4.86±2.70	2.68 to 7.88	4.95±1.80
Mo	0.24 to 0.85	0.44±0.18	0.38 to 0.96	0.74±0.24	0.05 to 3.20	1.01±0.95	1.36 to 3.02	2.33±0.60
Rb	10.14 to 15.60	11.99±1.64	11.88 to 15.60	14.83±3.48	1.27 to 17.22	6.11±4.78	2.21 to 6.37	4.00±1.54
Ti	285.43 to 401.38	334.53±37.23	223.75 to 626.67	355.66±130.35	2.12 to 72.03	37.33±24.10	22.20 to 71.05	40.53±16.45
U	0.35 to 0.62	0.48±0.09	0.30 to 1.16	0.61±0.284	0.03 to 0.46	0.24±0.129	0.14 to 0.36	0.22±0.067
B	6.42 to 12.21	10.80±1.76	10.00 to 12.50	11.39±0.70	9.39 to 13.04	11.74±1.10	3.42 to 12.29	10.15±2.90
Zn	1.57 to 3.24	2.40±0.455	2.71 to 3.81	3.10±0.502	1.43 to 2.52	2.09±0.320	1.58 to 2.48	2.12±0.265
Si	2.62 to 4.62	3.92±0.517	3.57 to 5.72	4.87±0.675	4.80 to 10.91	6.81±2.03	5.20 to 10.45	7.05±2.046
Xe	716.84 to 1139.77	916.12±139.33	1102.37 to 1740.44	1252.38±187.00	1089.67 to 1709.88	1449.45±174.94	1291.73 to 1938.34	1696.81±173.08

Table. 4.11: Soil ionome of different jackfruit geographical locations-II (1st year)

Elements ($mg\ kg^{-1}$)	**Panruti (n = 10)**		**Varkala (n = 10)**		**South Sikkim (n = 10)**	
	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)
Ba	7.34 to 11.82	9.18±1.38	5.85 to 56.47	18.05±14.38	15.77 to 67.46	37.21±17.57
Al	150.09 to 682.94	367.24±196.96	751.40 to 3304.82	1594.60±838.12	864.75 to 2296.50	1480.86±537.60
Ca	12.02 to 20.31	13.89±2.42	7.10 to 23.02	15.26±5.44	9.72 to 20.48	12.37±3.05

Co	0.197 to 0.520	0.362±0.103	0.284 to 0.930	0.562±0.211	0.736 to 1.91	1.09±0.390
Cr	12.25 to 51.77	22.77±11.24	19.73 to 78.36	57.35±20.12	19.48 to 42.42	29.75±7.42
Cs	0.03 to 0.29	0.08±0.085	0.191 to 0.694	0.415±0.208	1.518 to 4.05	2.24±0.792
Cu	4.08 to 9.14	5.76±1.76	2.67 to 9.11	5.50±1.80	6.69 to 19.11	11.98±3.93
Fe	62.60 to 778.20	192.15±243.92	507.69 to 2660.54	1462.47±755.33	558.71 to 1213.04	738.92±226.68
Ga	3.09 to 7.32	4.74±1.40	0.13 to 2.47	0.96±0.789	1.46 to 4.44	2.94±1.22
S	13.31 to 17.40	15.22±1.25	14.94 to 16.43	15.45±0.449	11.99 to 14.28	12.73±0.724
K	4.79 to 20.80	13.18±6.12	9.08 to 14.60	11.51±2.74	19.82 to 53.30	29.84±10.78
Li	1.77 to 8.13	3.85±2.07	0.38 to 8.47	3.43±2.56	14.63 to 34.35	19.78±6.57
Mg	102.67 to 129.67	113.72±7.21	89.34 to 199.75	139.11±36.45	40.11 to 89.86	52.92±14.94
Mn	123.91 to 516.43	198.97±120.27	866.11 to 2962.98	1805.55±670.08	107.48 to 2287	1040.09±728.05
Na	62.13 to 85.74	70.41±6.25	48.18 to 82.61	62.93±9.39	48.19 to 59.35	54.02±3.91
Ni	0.65 to 5.58	2.06±1.39	2.85 to 10.33	6.53 ± 2.39	2.66 to 7.06	4.81±1.28
Mo	0.01 to 2.49	0.31±0.77	0.11 to 1.26	0.55±0.36	0.09 to 1.07	0.41±0.31
Rb	0.81 to 1.96	1.14±0.34	1.44 to 3.05	2.12±0.51	10.69 to 32.53	17.69±7.18
Ti	11.40 to 35.08	18.36±8.22	19.08 to 137.02	72.14±38.01	183.36 to 386.47	265.93±86.98
U	0.07 to 0.16	0.12±0.079	0.35 to 1.18	0.69±0.290	0.80 to 1.82	1.16±0.368
B	11.48 to 12.56	12.14±0.37	10.65 to 11.87	11.38±0.40	11.25 to 12.54	11.94±0.41
Zn	2.81 to 3.63	3.26±0.283	2.96 to 4.21	3.38±0.369	3.10 to 6.51	4.20±0.946
Si	6.75 to 9.70	8.52±7.68	5.75 to 9.06	7.68±1.07	5.64 to 9.70	7.44±1.26
Xe	1093.80 to 1527.62	12.52.14	1107.98 to 1754.07	1395.00±212.66	1169.18 to 1607.41	1386.52±127.53

Table. 4.12: Soil ionome of different jackfruit geographical locations-I (2nd year)

Elements (mg kg^{-1})	**North 24 Parganas (n = 10)**		**Nadia (n = 10)**		**West Tripura (n = 10)**		**Khowai (n = 10)**	
	Range	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**
Ba	21.35 to 48.07	35.33±9.41	22.94 to 88.48	50.39±17.76	1.65 to 16.69	8.15±5.10	4.93 to 16.92	11.49±4.49
Al	1230.71 to 5003.03	2003.83±1119.82	1312.37 to 4575.19	2401.32±896.66	866.70 to 7082	1812.51±1872..51	365.45 to 1514.05	777.03±393.82
Ca	15.47 to 48.30	30.16±15.03	17.96 to 33.88	27.80±5.65	2.72 to 8.40	5.24±2.01	3.45 to 6.45	4.52±0.93

Co	1.24 to 3.38	1.93±0.60	1.56 to 3.43	2.58±0.68	0.07 to 1.77	0.59±0.53	0.24 to 0.96	0.54±0.26
Cr	28.49 to 56.98	44.80±11.77	13.81 to 63.99	45.74±17.26	17.32 to 60.39	37.18±18.69	17.32 to 57.22	35.29±13.83
Cs	0.88 to 2.29	1.71±0.37	1.12 to 4.17	2.09±0.85	0.06 to 1.09	0.46±0.35	0.05 to 0.76	0.35±0.27
Cu	9.23 to 27.05	17.04±5.74	15.13 to 36.41	23.08±6.93	4.95 to 12.79	9.70±2.74	3.30 to7.38	5.86±1.29
Fe	1014.00 to 1931.00	1480±314.52	1329.00 to 4167.00	1907.70±872.48	98.00 to 1110.00	547.80±419.79	221.00 to 2235.00	614.60±604.44
Ga	1.39 to 4.57	3.07±0.90	2.65 to 5.05	3.20±0.69	1.19 to 5.81	3.34±1.55	0.14 to 1.60	0.80±0.49
S	13.20 to 17.80	13.82±1.59	11.66 to 14.74	12.25±1.02	12.02 to 15.25	11.97±1.02	8.51 to 14.16	10.60±1.72
K	37.93 to 62.83	50.51±8.14	33.31 to 92.16	55.66± 18.27	9.32 to 14.07	11.87±1.89	4.63 to 9.07	6.87±1.38
Li	15.51 to 23.25	18.71±2.56	14.33 to 39.29	21.85±7.50	1.008 to 8.95	4.50±3.10	0.30 to 4.23	1.04±1.28
Mg	102.20 to 161.54	124.85±18.77	101.81 to 174.37	142.75±35.28	12.21 to 49.77	27.58±14.48	21.75 to 144.13	54.19±43.44
Mn	149.30 to 2380.65	1132.88±800.82	1423.12 to 3736.23	2257.20±715.48	169.23 to 834.16	329.02±252.23	184.37 to 2937.20	1307.86±933.67
Na	60.90 to 83.36	74.03±9.01	63.06 to 117.32	92.77±22.84	5.25 to 51.54	43.56±13.63	39.39 to 51.48	45.21±4.59
Ni	7.26 to 14.39	10.57±2.64	7.13 to 23.72	15.04±5.32	0.07 to 9.94	5.66±2.97	2.68 to 6.67	5.53±1.36
Mo	0.21 to 0.81	0.49±0.19	0.41 to 1.39	0.73±0.29	0.06 to 3.74	1.02±1.06	1.09 to 3.64	2.11±0.78
Rb	9.58 to 19.81	13.04±2.98	11.18 to 22.35	15.00±3.49	1.48 to 17.52	6.61±4.77	1.94 to 7.94	4.37±1.89
Ti	235.81 to 408.72	347.82±51.66	202.32 to 697.79	358.62±160.79	12.72 to 70.91	39.62±23.32	23.38 to 73.54	42.32±17.50
U	0.24 to 0.77	0.50±0.17	0.31 to 1.31	0.62±0.30	0.03 to 0.43	0.26±0.12	0.13 to 0.29	0.22±0.08
B	10.31 to 12.74	11.45±0.76	10.47 to 17.19	11.70±1.98	10.61 to 14.35	11.99±1.25	3.44 to 12.00	10.65±2.58
Zn	2.14 to 4.25	3.06±0.85	2.31 to 3.74	3.10±0.46	1.26 to 3.13	2.14±0.50	1.43 to 2.98	2.26±0.53
Si	3.00 to 5.76	3.88±0.97	3.70 to 5.17	4.42±0.64	4.19 to 9.54	6.40±1.85	4.48 to 9.98	6.69±1.82
Xe	719.85 to 1248.19	960.86±177.74	1149.92 to 2108	1345.64±309.13	1216.96 to 1528.30	1461±155.30	1347.67 to 2064.35	1832.86±195.38

Table. 4.13: Soil ionome of different jackfruit geographical locations-II (2^{nd} year)

Elements (mg kg^{-1})	**Panruti (n = 10)**		**Varkala (n = 10)**		**South Sikkim (n = 10)**	
	Range	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**
Ba	7.82 to 20.81	13.91±3.80	5.25 to 57.76	18.51±14.89	17.73 to 73.26	37.62±19.58

Al	118.64 to 791.46	370.76±216.62	802.46 to 3978.22	1722.69±1011.72	923.03 to 2399.69	1506.45±499.76
Ca	11.71 to 21.53	13.86±2.88	7.44 to 26.90	15.89±6.66	10.15 to 23.38	13.49±3.79
Co	0.22 to 0.56	0.35±0.10	0.24 to 0.91	0.55±0.20	0.72 to 1.60	1.01±0.28
Cr	14.75 to 60.37	24.31±13.26	18.72 to 77.78	55.24±17.70	18.02 to 40.26	30.01±6.98
Cs	0.03 to 0.29	0.09±0.08	0.05 to 0.76	0.35±0.27	1.13 to 4.42	2.64±0.98
Cu	3.34 to 9.91	5.91±2.27	3.80 to 8.72	5.39±1.82	7.38 to 17.83	11.93±3.69
Fe	69.00 to 818.00	191.20±242.53	582.00 to 2465.00	1457.30±684.88	499.00 to 1311.00	771.90±267.16
Ga	3.26 to 8.42	5.04±1.49	0.03 to 2.67	1.29±1.02	1.04 to 5.92	3.16±1.65
S	12.08 to 17.79	13.57±2.02	13.25 to 17.49	14.39±1.39	11.60 to 15.57	12.20±1.24
K	5.20 to 26.45	14.03±7.26	6.01 to 16.91	11.93±3.28	21.18 to 51.66	30.57±9.44
Li	1.19 to 7.34	3.49±1.87	0.45 to 7.85	3.47±2.13	14.81 to 35.19	19.28±6.74
Mg	109.37 to 137.59	121.43±9.54	100.78 to 216.95	146.56±35.71	35.62 to 76.44	53.43±13.49
Mn	104.60 to 666.80	207.77±170.61	742.63 to 3175.19	1949.56±742.63	185.23 to 2824.38	1291±951.35
Na	58.15 to 83.85	68.82±7.73	47.00 to 85.71	62.78±10.13	44.66 to 56.38	51.84±4.09
Ni	0.60 to 5.78	2.34±1.47	2.08 to 9.46	6.51±2.23	2.90 to 7.23	4.97±1.40
Mo	0.02 to 2.20	0.30±0.67	0.15 to 1.39	0.59±0.37	0.09 to 1.21	0.45±0.35
Rb	0.80 to 1.65	1.20±0.30	1.12 to 3.81	2.34±0.79	11.00 to 18.89	18.15±6.54
Ti	12.24 to 30.97	18.24±7.80	20.40 to 123.65	73.24±37.30	162.36 to 641.36	307.24±160.62
U	0.06 to 0.40	0.14±0.10	0.31 to 1.64	0.76±0.41	0.83 to 2.19	1.32±0.56
B	10.16 to 15.95	11.73±1.63	10.49 to 11.91	11.220.54	9.56 to 11.14	10.37±0.54
Zn	2.69 to 4.13	3.42±0.49	3.00 to 4.22	3.52±0.41	3.31 to 6.61	4.47±1.02
Si	7.09 to 9.93	8.75±1.13	6.16 to 9.44	7.59±1.20	5.77 to 9.72	7.37±1.26
Xe	1120.60 to 1278.36	1278.36±133.89	1110.82 to 1711.73	1359.44±225.56	1175.45 to 1601.00	1419.99±160.70

Elements (mg kg^{-1})	**North 24 Parganas (n = 10)**		**Nadia (n = 10)**		**West Tripura (n = 10)**		**Khowai (n = 10)**	
	Range	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**
Ba	25.06 to 50.2	34.74±8.41	23.48 to 84.94	47.58±16.48	1.43 to 15.69	8.21±4.75	5.77 to 15.52	10.98±4.25
Al	1501.99 to 4977.39	2116.23±1041.99	1394.97 to 4512.88	2365.23 ±864.35	725.21 to 1668.40	1142.71±277.58	345.65 to 1460.85	730.23±387.10
Ca	15.80 to 44.16	29.70±14.75	16.57 to 32.76	27.51±6.21	2.80 to 7.83	4.92±1.73	3.70 to 6.17	4.52±0.74
Co	1.51 to 2.81	1.95±0.38	1.60 to 3.96	2.60 ±0.66	0.08 to 1.65	0.59±0.51	0.23 to 0.97	0.53±0.27

Cr	28.18 to 53.25	45.24±9.76	14.82 to 61.78	45.02±16.62	13.29 to 57.63	36.29±17.91	18.20 to 54.39	34.27±12.87
Cs	1.11 to 1.79	158±0.22	1.40 to 3.59	1.97±0.64	0.05 to 1.10	0.46±0.35	0.17 to 0.80	0.38±0.19
Cu	9.88 to 24.47	16.15±4.82	14.38 to 25.58	22.48±6.07	7.87 to 12.92	9.42±2.82	3.38 to 8.27	5.73±1.49
Fe	1076.96 to 1706.09	1418.75±196.84	1276.50 to 4238.14	1918.93±897.05	74.52 to 1344.97	552.35±453.76	217.41 to 2269.51	619.42±613.45
Ga	1.62 to 3.71	2.76±0.61	2.54 to 5.93	3.27±0.99	1.25 to 4.94	3.13±1.32	0.33 to 1.35	0.77±0.44
S	13.54 to 15.66	14.95±0.86	11.30 to 15.06	13.24±1.09	11.97 to 14.26	12.73±0.77	8.85 to 13.61	11.54±1.62
K	41.34 to 57.81	50.37±5.66	36.04 to 94.03	55.36 ±17.88	8.57 to 13.59	11.32±1.90	4.89 to 7.92	6.92±1.06
Li	16.16 to 22.40	18.22±25.31	14.11 to 39.13	21.73 ±7.26	0.85 to 9.77	3.785±2.43	0.35 to 4.45	1.07±1.37
Mg	101.47 to 148.04	122.46±14.67	94.59 to 220.12	140.43±38.39	11.95 to 46.31	26.91±13.66	24.56 to 133.91	51.17±41.61
Mn	137.72 to 2142.58	1073.83±747.98	1378.87 to 3446.61	2195.20±665.68	119.33 to 792.00	310.10±238.54	155.43 to 2587.79	1231.06±868.22
Na	62.26 to 89.19	75.87±9.10	69.12 to 120.88	90.55±17.70	6.03 to 51.90	42.88±13.08	39.01 to 54.44	46.53±4.48
Ni	7.87 to 14.40	10.66±2.22	7.91 to 23.24	14.94±4.80	0.35 to 9.45	5.26±2.78	2.70 to 6.96	5.24±1.50
Mo	0.23 to 0.83	0.47±0.18	0.40 to 1.27	0.74±0.26	0.006 to 3.47	1.02±1.00	1.25 to 3.34	2.22±0.67
Rb	9.86 to 17.71	12.52±2.20	11.70 to 15.28	14.92±3.38	2.82 to 17.37	6.36±4.77	2.08 to 7.05	4.19±1.66
Ti	283.61 to 405.05	341.17±38.56	217.35 to 522.11	357.14±144.32	2.42 to 71.47	37.98±24.39	22.79 to 72.29	41.42±16.84
U	0.34 to 0.70	0.49±0.13	0.31 to 1.16	0.61±0.29	0.03 to 0.45	0.25±0.13	0.15 to 0.36	0.22±0.07
B	8.35 to 12.11	10.40±1.78	10.95 to 13.60	11.55±0.80	10.19 to 13.37	11.86±1.07	7.32 to 12.15	11.07±1.53
Zn	1.74 to 3.75	2.73±0.59	2.48 t0 3.61	3.10±0.46	1.59 to 2.83	2.12±0.38	1.51 to 2.73	2.19±0.38
Si	2.83 to 5.19	3.90±0.66	3.52 to 5.29	4.64±0.60	4.53 to 10.22	6.61±1.92	4.84 to 10.22	6.87±1.88
Xe	767.63 to 1189.14	938.49±154.79	1173.02 to 1924.43	1299.01±237.76	1156.29 to 1673.33	1455.69±149.84	1319.70 to 1922.10	1764.83±175.67

Table. 4.14: Soil ionome of different jackfruit geographical locations-I (1st & 2nd year)

Table. 4.15: Soil ionome of different jackfruit geographical locations-II (1st & 2nd year)

Elements (mg kg^{-1})	**Panruti (n = 10)**		**Varkala (n = 10)**		**South Sikkim (n = 10)**	
	Range	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**
Ba	7.58 to 19.53	13.54±3.88	5.55 to 57.11	18.88±14.62	21.95 to 67.36	37.41±18.47

Al	177.8 to 661.88	369.00 ± 205.39	776.93 to 3641.52	1658.65±919.38	893.89 to 2264.97	1493.63±513.37
Ca	12.10 to 20.92	13.87±2.61	7.27 to 24.61	15.57±5.99	9.93 to 21.93	12.93±3.36
Co	0.21 to 0.54	0.36±0.10	0.26 to 0.92	0.56±0.21	0.72 to 1.76	1.05±0.33
Cr	13.50 to 56.07	23.54±12.20	19.23 to 78.07	56.29±18.73	18.75 to 41.34	29.88±7.16
Cs	0.03 to 0.29	0.08±0.06	0.18 to 0.73	0.39±0.22	1.33 to 4.24	2.51±0.86
Cu	3.94 to 9.53	5.84±1.97	2.96 to 8.91	5.45±1.76	7.12 to 18.47	11.96±3.73
Fe	72.97 to 798.10	191.68±242.60	651.63 to 2357.32	1459.89±714.39	532.21 to 1262.02	755.41±243.43
Ga	3.18 to 7.87	4.89±1.42	0.02 to 2.57	1.12±0.89	1.39 to 5.18	3.05±1.42
S	12.69 to 17.08	14.97±1.55	14.10 to 16.70	14.92±0.78	11.90 to 14.17	13.01±0.87
K	5.19 to 23.59	13.61±6.60	6.51 to 15.46	11.72±2.91	20.50 to 52.48	30.20±10.09
Li	1.93 to 7.74	3.67±1.96	0.41 to 5.84	3.45 ±2.42	14.72 to 28.59	19.53±6.65
Mg	109.64 to124.69	117.58±5.63	95.06 to 189.40	142.84±35.45	39.35 to 81.44	53.18 ±13.64
Mn	114.27 to 591.62	203.37±144.85	916.65 to 3069.08	1877.56±702.56	146.35 to 2555.96	1165.90±837.28
Na	39.01 to 54.44	69.62 to 6.54	47.59 to 66.67	62.86±9.44	46.85 to 56.82	52.93±3.44
Ni	0.62 to 5.68	2.20 to 1.38	2.47 to 9.89	6.52±2.22	2.78 to 7.14	4.89±1.30
Mo	0.02 to 2.34	0.31±0.12	0.13 to 1.33	0.57±0.36	0.09 to 1.14	0.43±0.33
Rb	0.82 to 1.47	1.17±0.28	1.70 to 3.22	2.23±0.63	10.84 to 30.78	17.92±6.80
Ti	12.09 to 34.70	18.30±7.99	19.74 to 110.45	72.69±37.29	164.28 to 468.94	286.59±111.94
U	0.07 to 0.37	0.14±0.09	0.34 to 0.99	0.72±0.35	0.85 to 1.92	1.24±0.45
B	11.02 to 13.87	11.94±0.80	10.91 to 11.76	11.30±0.38	11.13 to 12.90	11.64±0.50
Zn	2.75 to 3.85	3.34±0.33	2.99 to 4.22	3.45±0.34	3.41 to 6.56	4.34±0.96
Si	6.92 to 10.15	8.63±1.01	5.95 to 9.25	7.63±1.06	5.86 to 9.71	7.41±1.21
Xe	1179.18 to 1732.90	1377.22±212.52	1107.20 to 1479.30	1265.25±135.57	1200.10 to 1526.99	1403.26±136.27

Elements ($mg\ kg^{-1}$)	**North 24 Parganas (n = 10)**		**Nadia (n = 10)**		**West Tripura (n = 10)**		**Khowai (n = 10)**	
	Range	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**
Ba	0.31 to 0.69	0.46±0.146	0.24 to 0.55	0.34±0.107	0.64 to 1.59	1.16±0.525	0.72 to 2.30	1.15±0.610
Al	1.54 to 4.99	3.34±1.29	1.58 to 4.21	2.75±0.81	1.03 to 4.06	2.80±1.52	1.04 to 2.95	1.71±0.56
Ca	1.04 to 2.83	1.89±0.587	0.90 to 1.95	1.42±0.410	1.10 to 2.30	1.53±0.517	1.21 to 2.25	1.54±0.370
Co	0.03 to 0.10	0.05±0.023	0.02 to 0.05	0.03±0.011	0.03 to 0.19	0.06±0.047	0.02 to 0.06	0.04±0.012

Cr	11.66 to18.91	14.78±2.87	13.43 to 25.19	19.98±4.95	10.25 to 23.28	19.30±4.31	5.01 to 29.78	15.59±8.70
Cs	0.005 to 0.009	0.007±0.001	0.005 to 0.014	0.010±0.003	0.015 to 0.090	0.029±0.022	0.006 to 0.016	0.012±0.002
Cu	0.58 to 1.98	1.12±0.450	0.49 to 2.016	0.94±0.481	0.93 to 2.91	1.74±0.688	0.31 to 1.60	0.97±0.415
Fe	9.28 to 30.18	15.17±5.94	7.60 to 16.6y1	12.25±2.95	8.29 to 31.45	14.58±6.341	8.08 to 21.32	14.39±1.103
Ga	0.13 to 0.23	0.18±0.040	0.21 to 0.35	0.27±0.05	0.10 to 0.39	0.28±0.092	0.22 to 0.53	0.31±0.097
S	2.19 to 2.68	2.44±0.207	2.27 to 2.72	2.55±0.132	1.01 to 1.43	1.18±0.155	1.03 to 2.69	2.10±0.679
K	40.32 to 90.63	58.48±13.71	49.22 to 86.98	60.82±14.12	10.16 to 91.47	59.62±22.42	50.04 to 96.84	63.61±16.07
Li	0.08 to 0.56	0.21±0.138	0.07 to 0.29	0.17±0.062	0.09 to 0.78	0.20±0.208	0.06 to 0.19	0.10±0.041
Mg	4.75 to 9.10	6.84±1.28	6.28 to 11.68	7.77±1.81	3.48 to 12.02	7.45±2.80	5.02 to 16.26	9.07±3.82
Mn	1.30 to 3.45	2.16± 0.770	0.89 to 2.93	1.62±0.60	1.38 to 6.24	3.91±1.47	2.55 to 7.53	4.33±1.34
Na	1.43 to 3.43	2.11±0.572	1.62 to 3.19	2.24±0.498	1.54 to 4.12	2.28±0.722	1.75 to 2.70	2.36±2.91
Ni	0.97 to 1.42	1.09±0.209	0.67 to 1.42	1.14±0.448	0.71 to 2.14	1.30±0.378	0.59 to 1.69	1.20±0.345
Mo	0.036 to 0.056	0.05±0.006	0.025 to 0.100	0.05±0.020	0.051 to 1.05	0.18±0.0315	0.003 to 0.076	0.04±0.022
Rb	0.74 to 3.16	1.54±0.685	1.01 to 3.98	1.84±0.915	1.92 to 9.29	7.09±2.38	2.79 to 7.78	5.73±1.433
Ti	0.46 to 1.78	0.86±0.425	0.54 to 1.24	0.70±0.213	0.34 to 2.44	0.90±0.581	0.42 to 3.07	0.90±0.581
U	0.008 to 0.019	0.011±0.003	0.006 to 0.010	0.008±0.001	0.007 to 0.065	0.016±0.017	0.007 to 0.011	0.008±0.001
B	1.57 to 1.88	1.73±0.115	1.07 to 1.58	1.27±0.340	0.60 to 1.38	0.93±0.265	0.41 to 2.21	1.58±0.626
Zn	0.36 to 0.71	0.53±0.106	0.38 to 0.74	0.54±0.115	0.39 to 0.71	0.59±0.083	0.45 to 0.76	0.59±0.069
Si	0.81 to 1.56	1.22±0.253	0.81 to 1.70	1.15±0.255	0.65 to 1.85	1.42±0.326	1.01 to 1.85	1.20±0.462
Xe	201.99 to 322.09	290.17±39.91	180.21 to 317.31	241.51±44.03	41.87 to 72.46	57.25±10.351	21.19 to 298.11	172.46±108.54

Table. 4.16: Fruit ionome of different jackfruit geographical locations-I (1st year)

Table. 4.17: Fruit ionome of different jackfruit geographical locations-II (1st year)

Elements	Panruti (n = 10)	Varkala (n = 10)	South Sikkim (n = 10)

(mg kg^-1^)						
	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)
Ba	0.25 to 0.51	0.42±0.088	0.45 to 1.04	0.66±0.220	0.80 to 1.76	1.50±0.495
Al	1.53 to 2.85	2.17±0.44	1.03 to 2.76	1.70±0.52	0.12 to 9.85	3.82±3.60
Ca	1.34 to 2.47	1.80±0.385	1.18 to 2.59	1.66±0.467	1.08 to 1.81	1.33±0.75
Co	0.03 to 0.08	0.05±0.016	0.02 to 0.04	0.03±0.007	0.02 to 0.04	0.03±0.06
Cr	5.03 to 14.47	12.41±2.85	5.94 to 9.80	7.98±1.34	6.20 to 9.63	7.98±1.50
Cs	0.006 to 0.059	0.019±0.015	0.008 to 0.046	0.022±0.013	0.006 to 0.051	0.021±0.013
Cu	0.85 to 2.04	1.53±0.406	0.87 to 1.82	1.14±0.292	0.52 to 1.64	0.85±0.353
Fe	13.39 to 16.82	14.39±1.103	12.80 to 15.90	14.20±0.986	7.21 to 14.25	9.91±2.549
Ga	0.12 to 0.34	0.23±0.069	0.15 to 0.36	0.25±0.074	0.10 to 0.28	0.17±0.054
S	0.91 to 1.70	1.22±0.251	2.36 to 2.71	2.56±0.131	0.84 to 1.71	1.22±0.278
K	59.24 to 74.96	74.96±12.36	47.08 to 67.71	53.77±7.06	32.54 to 89.81	60.43±16.74
Li	0.03 to 0.09	0.05±0.020	0.05 to 0.10	0.07±0.014	0.06 to 0.16	0.10±0.027
Mg	5.60 to 13.26	9.99±2.75	5.93 to 7.91	7.13±0.689	4.55 to 8.76	6.61±1.19
Mn	1.39 to 6.81	3.64±1.65	1.30 to 2.91	2.04±0.629	1.06 to 2.04	1.44±0.352
Na	2.54 to 3.55	3.17±0.291	2.30 to 2.94	2.57±0.230	2.58 to 4.58	3.28±0.571
Ni	1.18 to 1.99	1.52±0.243	0.74 to 1.55	1.06±0.225	0.77 to 2.27	1.25±0.425
Mo	0.046 to 0.092	0.063±0.014	0.004 to 0.062	0.029±0.016	0.017 to 0.048	0.033±0.011
Rb	1.41 to 12.45	7.39±3.28	2.14 to 8.79	4.51±2.27	1.53 to 7.22	3.45±1.77
Ti	2.11 to 5.70	3.63±1.10	0.75 to 2.07	1.48±0.396	0.62 to 3.02	1.76±0.73
U	0.007 to 0.015	0.011±0.002	0.007 to 0.009	0.008±0.001	0.006 to 0.010	0.007±0.001
B	1.01 to 1.58	1.19±0.442	1.80 to 2.11	1.97±0.097	1.08 to 1.80	1.46±0.207
Zn	0.43 to 0.69	0.60±0.069	0.35 to 0.53	0.43±0.055	0.47 to 0.92	0.63±0.139
Si	0.75 to 1.73	1.27±0.246	0.78 to 1.50	1.20±0.218	0.63 to 1.78	1.28±0.312
Xe	47.78 to 73.39	58.96±6.80	242 to 284.90	263.98±17.91	29.55 to 90.88	66.13±16.83

Elements (mg kg^{-1})	North 24 Parganas (n = 10)		Nadia (n = 10)		West Tripura (n = 10)		Khowai (n = 10)	
	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)
Ba	0.202 to 0.891	0.514±0.255	0.259 to 0.571	0.352±0.114	0.530 to 2.62	1.25±0.625	0.665 to 2.77	1.21±0.673
Al	1.22 to 5.84	3.31±1.51	1.56 to 4.23	2.71±0.788	1.29 to 6.05	2.99±1.44	1.00 to 2.97	1.71±0.585
Ca	1.26 to 3.47	2.26±0.83	0.91 to 2.68	1.68±0.576	1.26 to 2.57	1.82±0.562	1.42 to 2.63	2.12±0.450
Co	0.08 to 0.015	0.011±0.003	0.004 to 0.014	0.008±0.003	0.015 to 0.039	0.021±0.008	0.012 to 0.478	0.079±0.144
Cr	12.65 to 14.77	13.90±0.596	13.80 to 15.66	14.80±0.702	13.31 to 25.52	21.57±5.045	2.98 to 26.60	17.13±10.21

Cs	0.007 to 0.015	0.016±0.020	0.006 to 0.26	0.012±0.005	0.008 to 0.034	0.023±0.008	0.010 to 0.033	0.021±0.008
Cu	0.73 to 3.68	1.29±0.88	0.65 to 1.78	1.03±0.37	0.81 to 2.79	1.36±0.73	0.66 to 2.85	1.51±0.63
Fe	11.20 to 32.25	16.04±6.86	11.10 to 17.39	12.24±1.89	11.11 to 31.28	15.22±6.03	8.08 to 24.94	14.53±5.17
Ga	0.16 to 0.30	0.21±0.044	0.20 to 0.37	0.27±0.055	0.27 to 0.39	0.32±0.043	0.25 to 0.53	0.33±0.082
S	1.31 to 2.74	2.09±0.43	2.67 to 3.18	2.95±0.18	1.12 to 2.00	1.64±0.33	1.17 to 3.30	2.26±0.67
K	37.85 to 85.93	56.49±14.15	44.94 to 79.20	64.50±12.69	15.27 to 90.50	57.10±22.39	51.18 to 90.82	62.74±13.43
Li	0.04 to 0.10	0.068±0.020	0.04 to 0.14	0.092±0.030	0.04 to 0.16	0.095±0.032	0.03 to 0.17	0.094±0.045
Mg	6.77 to 21.16	11.18±4.22	5.81 to 12.13	8.65±2.03	3.66 to 13.09	7.62±3.04	6.04 to 15.90	10.35±3.75
Mn	1.07 to 3.99	2.27±1.05	0.99 to 2.37	1.63±0.58	1.56 to 6.75	3.77±1.63	3.15 to 6.73	4.39±1.11
Na	1.46 to 3.69	2.01±0.67	1.18 to 1.89	1.55±0.25	1.03 to 1.84	1.46±0.27	1.00 to 3.51	1.79±0.77
Ni	0.81 to 1.24	1.15±0.172	0.43 to 1.54	1.07±0.314	0.78 to 2.09	1.28±0.387	1.07 to 1.23	1.15±0.264
Mo	0.072 to 0.183	0.136±0.044	0.097 to0.153	0.130±0.020	0.102 to 2.56	0.449±0.762	0.100 to 3.959	0.595±1.19
Rb	0.47 to 2.83	1.44±0.77	0.84 to 3.57	1.75±0.86	1.96 to 10.84	6.76±2.42	3.07 to 8.54	5.90±1.85
Ti	0.94 to 4.09	2.17±1.14	0.42 to 2.21	1.13±0.51	0.72 to 1.53	1.05±0.29	0.58 to 3.65	1.55±1.00
U	0.004 to 0.088	0.040±0.032	0.007 to 0.093	0.035±0.037	0.013 to 0.095	0.037±0.030	0.006 to 0.083	0.045±0.032
B	1.22 to 2.56	1.73±0.57	1.10 to 2.16	1.60±0.35	0.26 to 2.26	1.46±0.80	0.39 to 2.99	1.31±0.90
Zn	0.310 to 0.759	0.526±0.147	0.165 to 0.794	0.473±0.226	0.203 to 0.733	0.484±0.177	0.366 to 0.794	0.542±0.090
Si	1.01 to 1.44	1.15±0.12	1.05 to 1.27	1.13±0.05	1.13 to 1.21	1.16±0.023	1.08 to 1.61	1.18±0.16
Xe	1.73.12 to 257.56	212.22±26.14	202.78 to 251.80	223.95±17.67	37.94 to 88.81	62.03±17.50	39.55 to 251.28	181.01±94.63

Table. 4.18: Fruit ionome of different jackfruit geographical locations-I (2nd year)

Table. 4.19: Fruit ionome of different jackfruit geographical locations-II (2nd year)

Elements (mg kg^{-1})	Panruti (n = 10)		Varkala (n = 10)		South Sikkim (n = 10)	
	Range	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**
Ba	0.224 to 0.672	0.458±0.134	0.434 to 0.937	0.688±0.240	1.005 to 2.022	1.52±0.376
Al	1.04 to 4.04	2.31±1.05	1.01 to 3.45	2.07±0.81	0.12 to 9.61	3.29±2.98
Ca	1.53 to 2.91	2.10±0.450	1.02 to 2.61	1.73±0.579	0.92 to 1.64	1.20±0.244
Co	0.005 to 0.027	0.012±0.006	0.003 to 0.013	0.008±0.004	0.006 to 0.013	0.009±0.003
Cr	2.76 to 13.73	12.03±3.28	2.76 to 13.10	8.32±3.42	3.79 to 10.13	6.88±2.17
Cs	0.005 to 0.090	0.029±0.025	0.012 to 0.169	0.057±0.054	0.016 to 0.138	0.067±0.044
Cu	1.44 to 9.20	3.35±2.40	0.73 to 2.09	1.62±0.71	1.06 to 3.05	1.73±0.70
Fe	11.24±17.94	13.47±2.40	10.65 to 11.41	11.00±0.24	1.00 to 12.84	10.11±3.28
Ga	0.12 to 0.30	0.23±0.062	0.16 to 0.32	0.24±0.060	0.12 to 0.24	0.17±0.040
S	1.10 to 1.81	1.38±0.27	1.59 to 3.63	2.59±0.62	0.98 to 1.93	1.42±0.37
K	57.85 to 89.28	70.62±10.75	35.70 to 69.36	53.57±9.73	31.47 to 85.51	58.55±17.91
Li	0.08 to 0.18	0.109±0.027	0.02 to 0.07	0.041±0.015	0.02 to 0.08	0.045±0.017
Mg	4.32 to 25.79	12.57±5.64	4.91 to 9.25	7.42±1.42	4.06 to 9.57	6.97±2.05
Mn	1.19 to 6.77	3.58±1.76	0.77 to 2.99	1.87±0.66	1.14 to 3.21	1.91±0.71
Na	2.28 to 3.70	3.11±0.54	2.23 to 2.50	2.38±0.08	2.41 to 4.25	3.12±0.63
Ni	1.09 to 1.93	1.52±0.264	1.00 to 1.19	1.10±0.049	1.10 to 1.19	1.13±0.026
Mo	0.032 to 0.127	0.076±0.042	0.031 to 0.143	0.073±0.041	0.015 to 0.102	0.057±0.037
Rb	2.15 to 12.80	7.61±3.26	2.55 to 6.41	4.27±1.49	1.30 to 6.40	4.44±2.38
Ti	2.34 to 5.35	3.48±0.89	0.79 to 2.33	1.38±0.45	0.95 to 3.72	1.98±0.72
U	0.012 to 0.085	0.057±0.029	0.010 to 0.98	0.048±0.028	0.008 to 0.090	0.037±0.034
B	1.11 to 1.53	1.28±0.13	1.04 to 2.47	1.60±0.47	1.03 to 1.72	1.46±0.25
Zn	0.437 to 0.740	0.571±0.090	0.288 to 0.597	0.440±0.096	0.379 to 0.927	0.644±0.194
Si	1.25 to 1.81	1.44±0.17	1.11 to 1.38	1.21±0.092	1.17 to 1.80	1.21±0.12
Xe	26.07 to 80.24	61.96±16.47	210.86 to 261.83	238.67±20.07	25.73 to 98.44	72.58±22.88

Elements (mg kg^{-1})	North 24 Parganas (n = 10)		Nadia (n = 10)		West Tripura (n = 10)		Khowai (n = 10)	
	Range	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	**Mean (± SD)**
Ba	0.24 to 0.73	0.49±0.19	0.26 to 0.55	0.36±0.11	0.59 to 2.47	1.20±0.57	0.68 to 2.54	1.18±0.63
Al	1.36 to 4.68	3.33±1.36	1.57 to 4.22	2.75±0.80	1.16 to 5.99	2.89±1.47	1.11 to 2.96	1.71±0.56

Ca	1.34 to 3.10	2.07±0.69	1.15 to 2.44	1.55±0.42	1.09 to 2.38	1.67±0.50	1.3 to 2.33	1.83±0.31
Co	0.02 to 0.06	0.03±0.01	0.01 to 0.03	0.03±0.01	0.03 to 0.1	0.04±0.02	0.02 to 0.26	0.06±0.05
Cr	12.16 to 16.39	14.34±1.43	14.08 to 22.33	17.39±2.42	11.78 to 24.39	20.43±4.33	3.99 to 27.72	16.35±8.70
Cs	0.01 to 0.04	0.01±0.001	0.01 to 0.02	0.01±0.001	0.01 to 0.05	0.03±0.001	0.01 to 0.002	0.02±0.001
Cu	0.65 to 2.43	1.20±0.52	0.57 to 1.22	0.99±0.32	0.87 to 2.62	1.45±0.58	0.66 to 2.23	1.24±0.48
Fe	10.56 to 18.92	15.60±6.02	9.35 to 17.00	12.25±2.02	10.64 to 31.36	14.90±5.79	8.26 to 21.35	14.51±4.35
Ga	0.14 to 0.25	0.20±0.04	0.2 to 0.35	0.27±0.05	0.22 to 0.39	0.30 ±0.05	0.22 to 0.53	0.32 ±0.09
S	2.01 to 2.71	2.26±0.26	2.53 to 2.91	2.75±0.14	1.09 to 1.67	1.41±0.21	1.10 to 2.92	2.18±0.63
K	39.09 to 88.28	57.49±13.29	47.08 to 81.48	62.66±11.07	12.72 to 90.98	58.36±22.20	49.35 to 86.06	57.36±13.44
Li	0.11 to 0.46	0.21±0.12	0.11 to 0.20	0.15±0.02	0.09 to 0.75	0.25±0.21	0.04 to 0.18	0.10±0.04
Mg	5.76 to 13.39	9.01±2.24	6.06 to 11.90	8.21±1.79	3.57 to 12.05	7.54±2.87	6.20 to 15.90	9.71±3.70
Mn	1.22 to 3.72	2.21±0.89	0.96 to 2.65	1.62±0.57	1.47 to 6.5	3.84±1.54	3.44 to 7.13	4.36±1.20
Na	1.59 to 3.56	2.06±0.59	1.64 to 2.14	1.90±0.20	1.57 to 2.58	1.87±0.30	1.37 to 2.70	2.08±0.43
Ni	1.04 to 1.47	1.12±0.18	0.68 to 1.69	1.11±0.32	0.75 to 2.12	1.29±0.37	1.14 to 1.90	1.18±0.19
Mo	0.05 to 0.12	0.09±0.02	0.07 to 0.11	0.09±0.01	0.09 to 1.31	0.31±0.39	0.05 to 2.00	0.32±0.60
Rb	0.60 to 2.76	1.49±0.65	0.92 to 3.77	1.79±0.85	1.94 to 9.96	6.92±2.14	2.93 to 7.99	5.81±1.54
Ti	0.93 to 2.03	1.52±0.52	0.61 to 1.40	0.92±0.26	0.69 to 1.99	0.97±0.38	0.50 to 3.36	1.36±0.93
U	0.01 to 0.05	0.03±0.02	0.01 to 0.05	0.03±0.02	0.01 to 0.05	0.03±0.02	0.01 to 0.05	0.03±0.02
B	1.40 to 2.14	1.73±0.31	0.85 to 1.76	1.44±0.27	0.46 to 2.16	1.19±0.50	0.97 to 2.22	1.44±0.40
Zn	0.34 to 0.73	0.53±0.12	0.31 to 0.77	0.51±0.14	0.37 to 0.72	0.54±0.12	0.41 to 0.78	0.55±0.10
Si	1.03 to 1.38	1.20±0.15	0.97 to 1.41	1.14±0.13	0.90 to 1.49	1.29±0.17	0.56 to 1.54	1.19±0.27
Xe	187.56 to 283.23	251.20±27.57	195.70 to 266.88	232.73±25.11	39.91 to 80.47	59.64±13.46	33.61 to 272.62	176.73±97.86

Table. 4.20: Fruit ionome of different jackfruit geographical locations-I (1st & 2nd year)

Table. 4.21: Fruit ionome of different jackfruit geographical locations-II (1st & 2nd year)

Element s (mg kg^{-1})	Panruti (n = 10)		Varkala (n = 10)		South Sikkim (n = 10)	
	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)

Ba	0.24 to 0.60	0.44±0.11	0.45 to 1.05	0.68±0.23	0.83 to 2.25	1.51±0.43
Al	1.28 to 3.20	2.24±0.721	1.33 to 3.12	1.89±0.576	0.67 to 4.73	3.61±3.71
Ca	1.44 to 2.63	1.95±0.47	1.18 to 2.56	1.69±0.47	1.00 to 1.71	1.27±0.23
Co	0.02 to 0.05	0.04±0.001	0.01 to 0.03	0.02±0.001	0.01 to 0.02	0.02±0.001
Cr	3.89 to 14.14	12.22±2.86	4.34 to11.29	8.15±2.12	5.21 to 9.76	7.34±1.64
Cs	0.01 to 0.06	0.03±0.02	0.01 to 0.08	0.040±0.03	0.2 to 0.09	0.044±0.02
Cu	1.15 to 5.40	2.44±1.22	0.80 to 1.70	1.38±0.37	0.88 to 1.79	1.29±0.30
Fe	12.77 to 17.38	13.93±1.44	11.85 to 13.66	12.60±0.51	4.79 to 12.57	10.01±2.08
Ga	0.12 to 0.32	0.23 ±0.07	0.16 to 0.33	0.24 ±0.06	0.11 to 0.25	0.17 ±0.05
S	1.00 to 1.57	1.28±0.24	2.05 to 2.91	2.58±0.33	0.94 to 1.58	1.32±0.22
K	60.12 to 93.17	72.80±11.21	42.46 to 64.78	53.67±6.95	32.00 to 87.66	59.49±17.12
Li	0.04 to 0.06	0.05±0.01	0.04 to 0.08	0.06±0.01	0.07 to 0.14	0.11±0.02
Mg	4.96 to 16.25	11.28±3.24	5.42 to 8.09	7.27±0.92	4.56 to 9.17	6.79±1.42
Mn	1.29 to 6.79	3.61±1.63	1.44 to 2.69	1.95±0.52	1.14 to 2.63	1.67±0.48
Na	2.48 to 3.54	3.14±0.39	2.34 to 2.72	2.47±0.13	2.51 to 4.41	3.07±0.57
Ni	1.29 to 1.88	1.52±0.25	0.93 to 1.14	1.08±0.12	0.95 to 1.69	1.19±0.21
Mo	0.04 to 0.09	0.07±0.02	0.02 to 0.09	0.05±0.02	0.02 to 0.07	0.04±0.02
Rb	1.78 to 11.72	7.50±3.22	2.46 to 7.60	4.39±1.83	1.47 to 7.26	3.95±1.94
Ti	2.47 to 5.53	3.55±0.97	0.87 to 2.20	1.43±0.39	1.30 to 3.37	1.87±0.71
U	0.01 to 0.05	0.04±0.02	0.01 to 0.05	0.03±0.02	0.01 to 0.05	0.02±0.02
B	0.63 to 1.45	1.23±0.23	1.51 to 2.25	1.79±0.25	1.19 to 1.75	1.46±0.18
Zn	0.47 to 0.69	0.58±0.07	0.41 to 0.53	0.43±0.06	0.42 to 0.88	0.64±0.14
Si	1.03 to 1.61	1.36±0.17	0.95 to 1.43	1.21±0.13	0.94 to 1.36	1.30±0.17
Xe	36.93 to 76.82	60.47±10.82	229.62 to 273.37	251.32±18.45	27.64 to 91.39	69.35±18.75

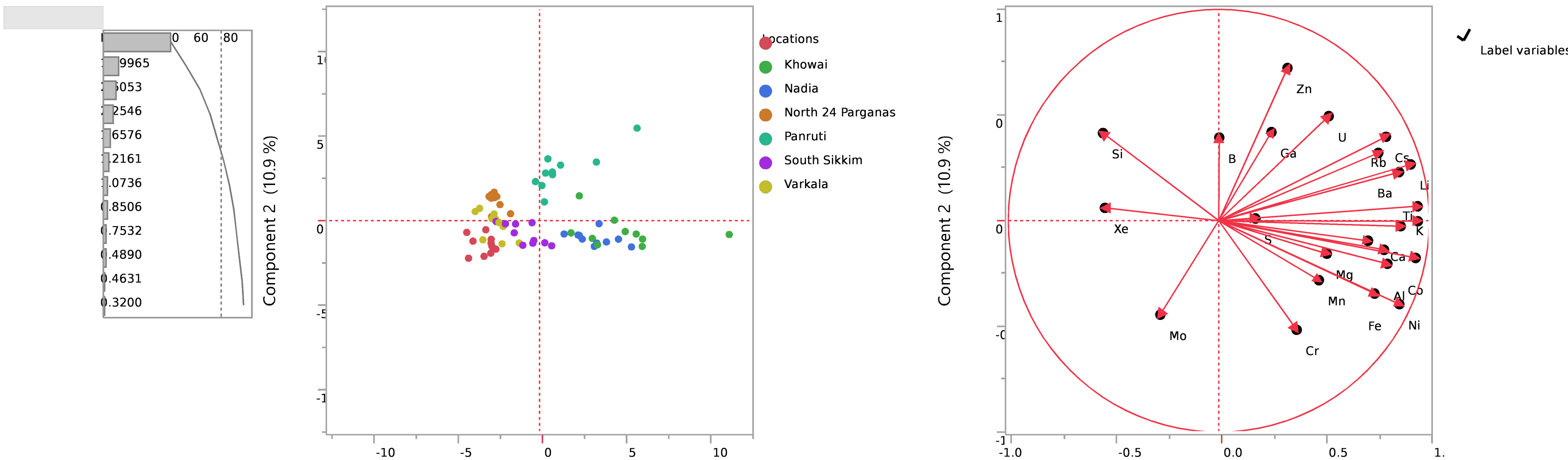

Fig.4.1: Principal component analysis (PCA) of soil ionome of jackfruit geographical locations (first year).

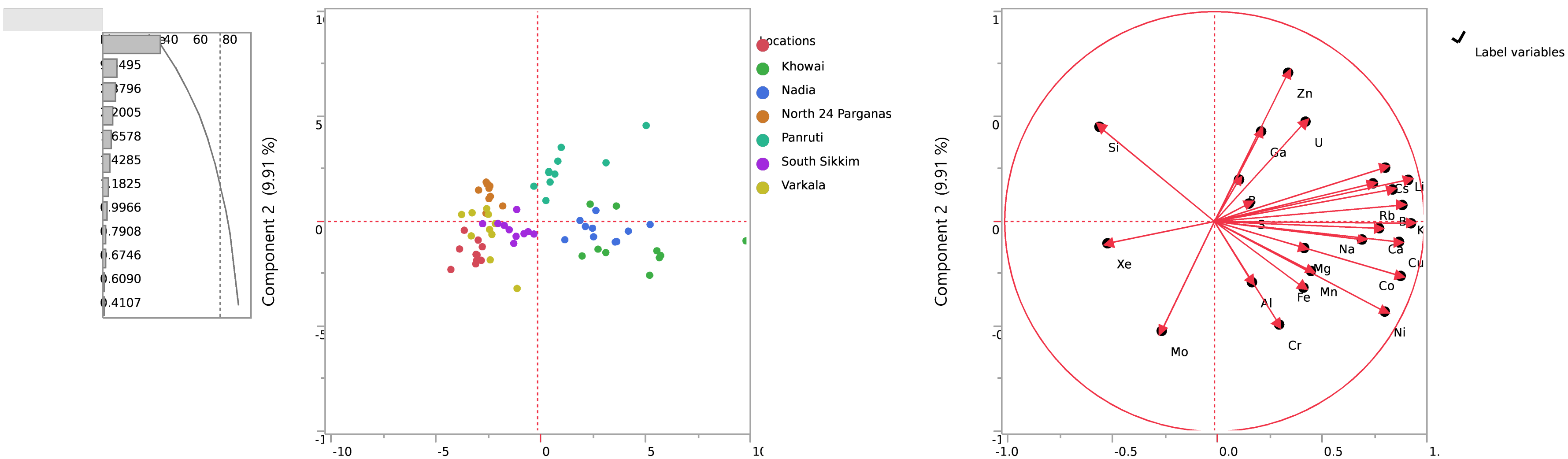

Fig.4.2: Principal component analysis (PCA) of soil ionome of jackfruit geographical locations (second year).

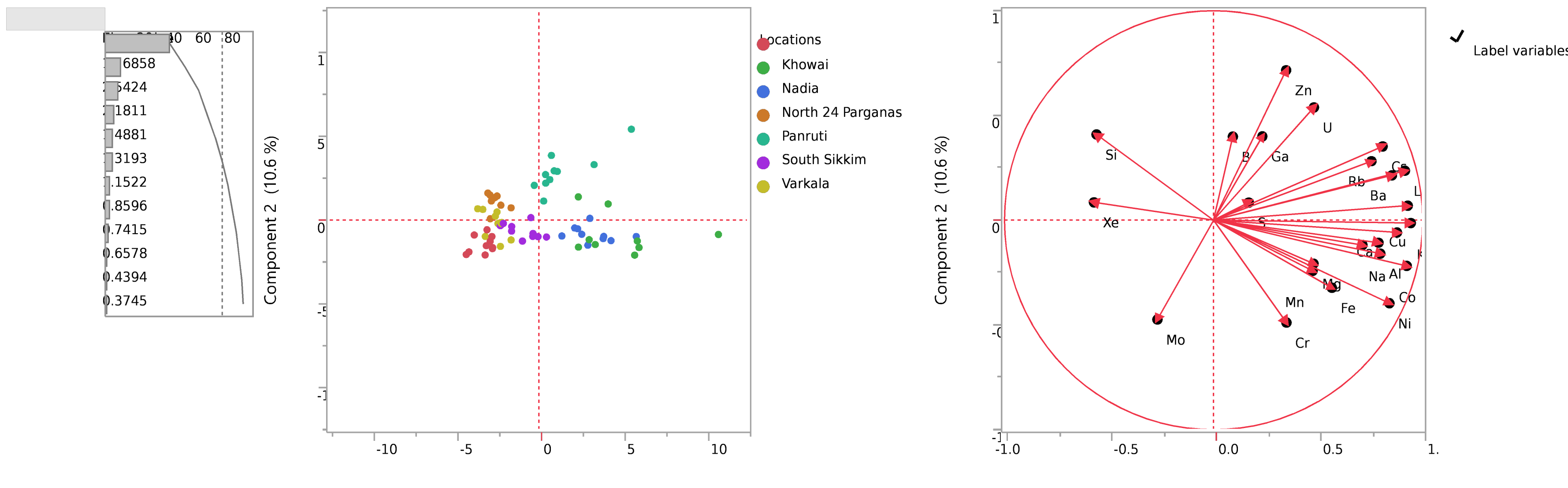

Fig. 4.3: Principal component analysis (PCA) of soil ionome of jackfruit geographical locations (first & second year combined).

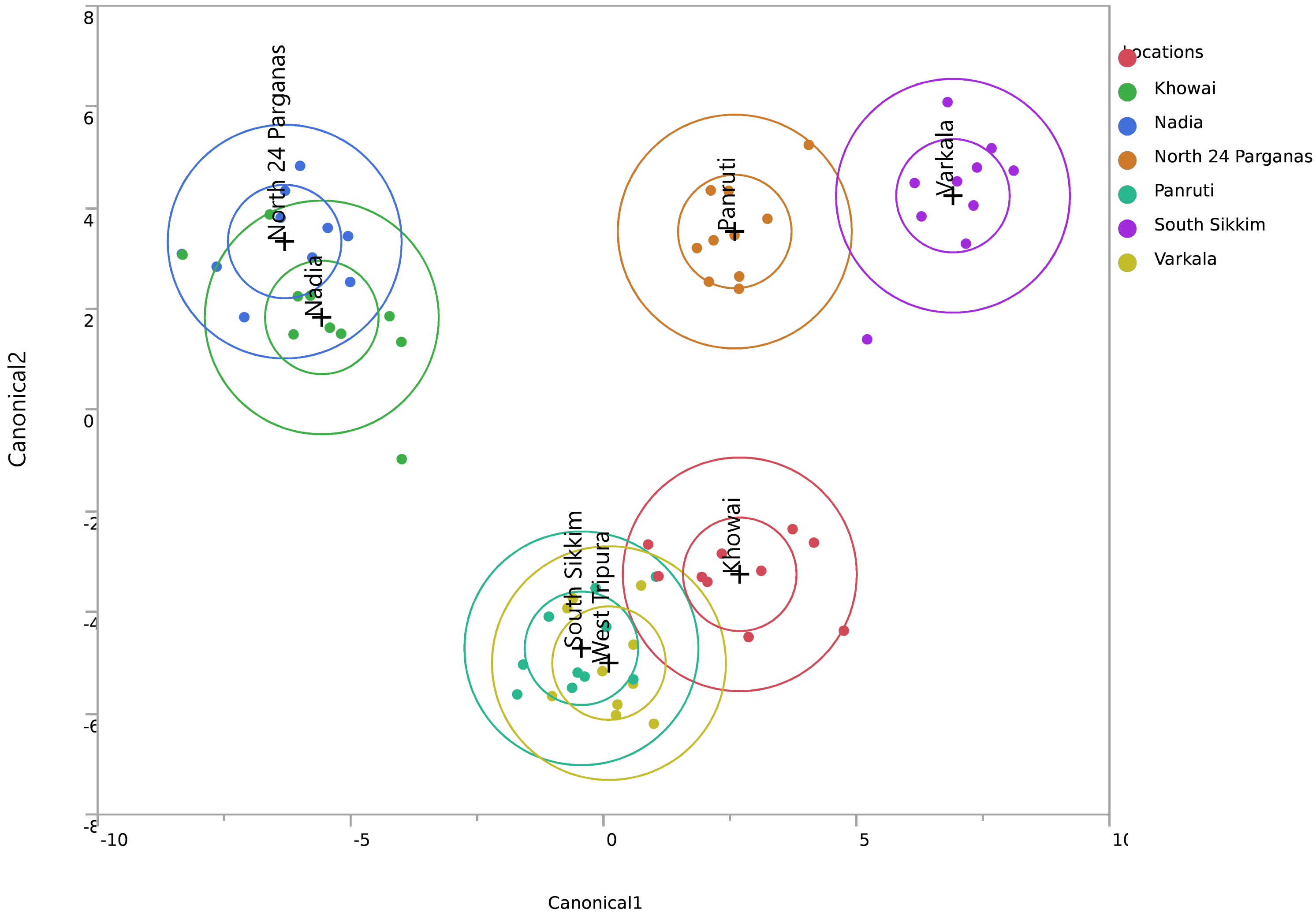

Fig. 4.4: Linear discriminant analysis (LDA) of soil ionome of jackfruit geographical locations (first year).

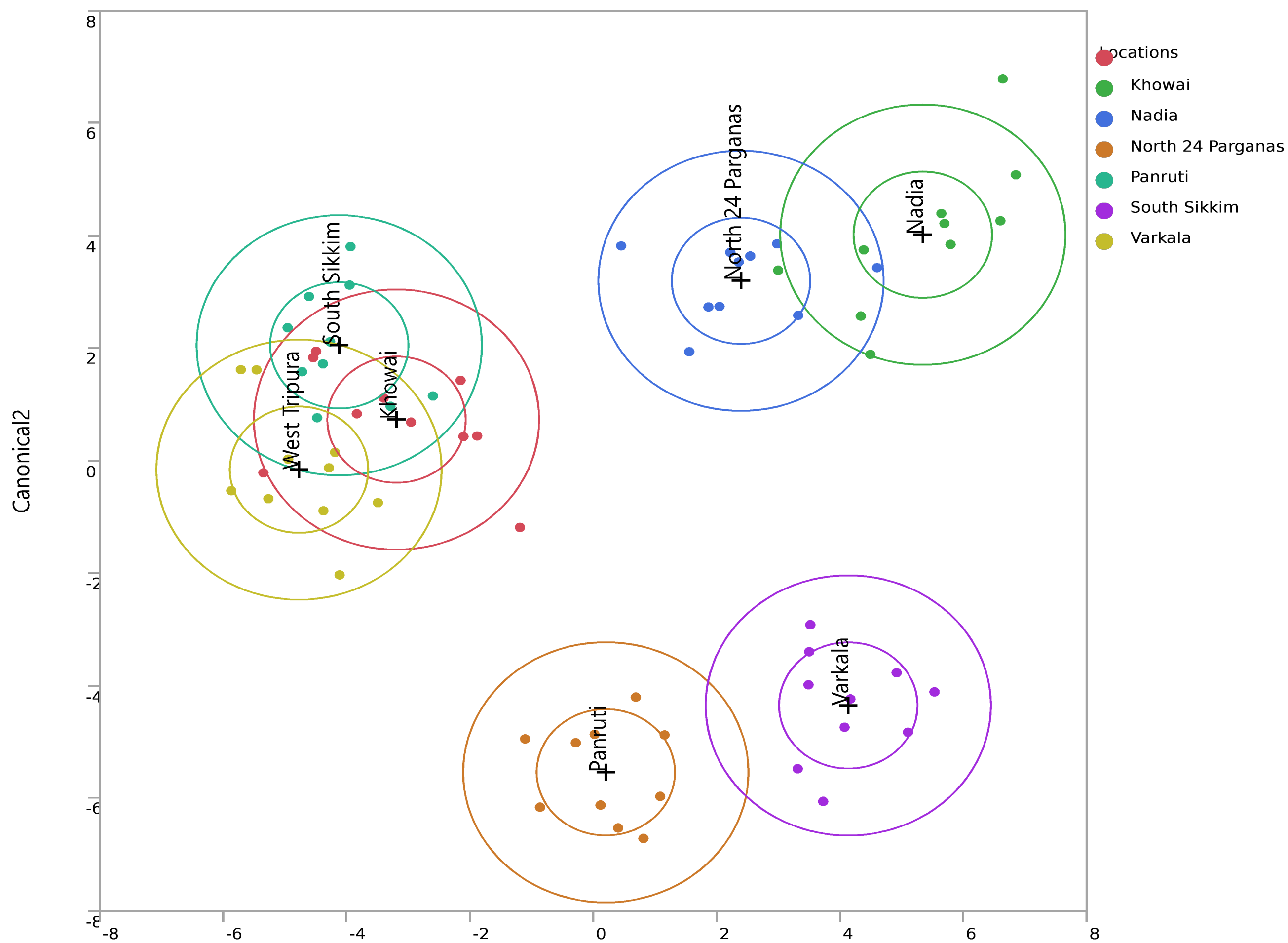

Fig. 4.5: Linear discriminant analysis (LDA) of soil ionome of jackfruit geographical locations (second year).

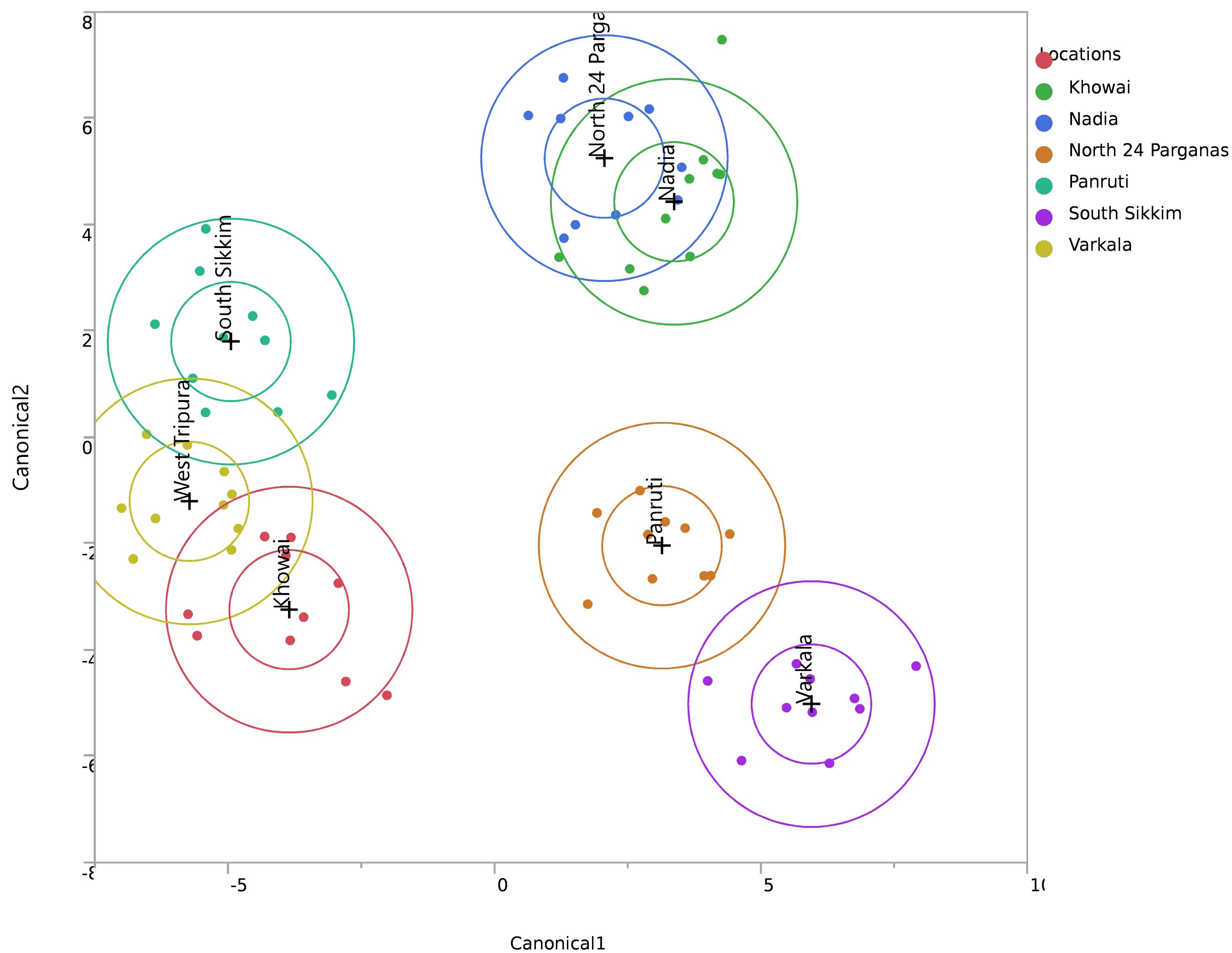

Fig. 4.6: Linear discriminant analysis (LDA) of soil ionome of jackfruit geographical locations (first & second year combined).

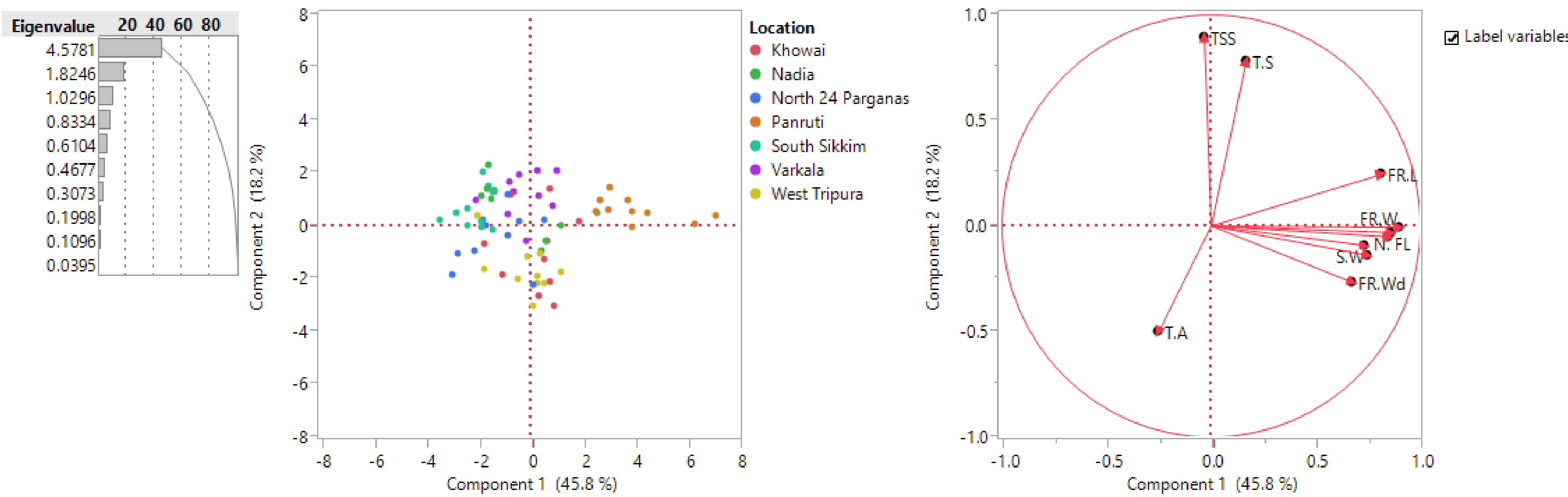

Fig.4.7: Principal component analysis (PCA) of physico-chemical characters of jackfruit geographical locations (first year).

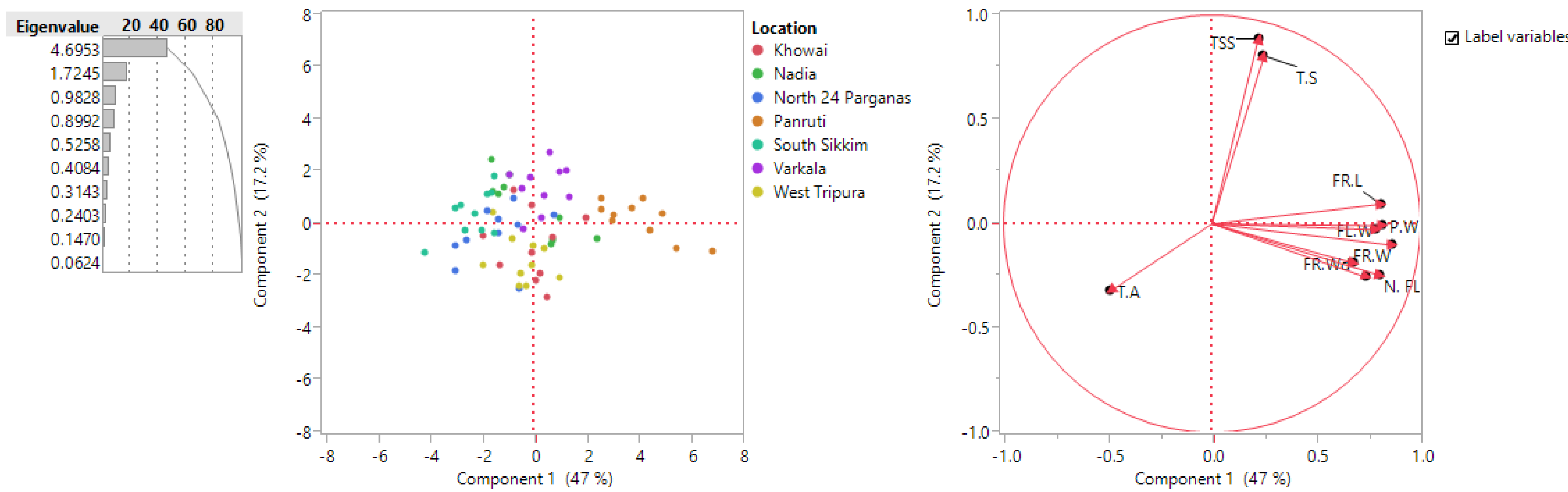

Fig. 4.8: Principal component analysis (PCA) of physico-chemical characters of jackfruit geographical locations (second year).

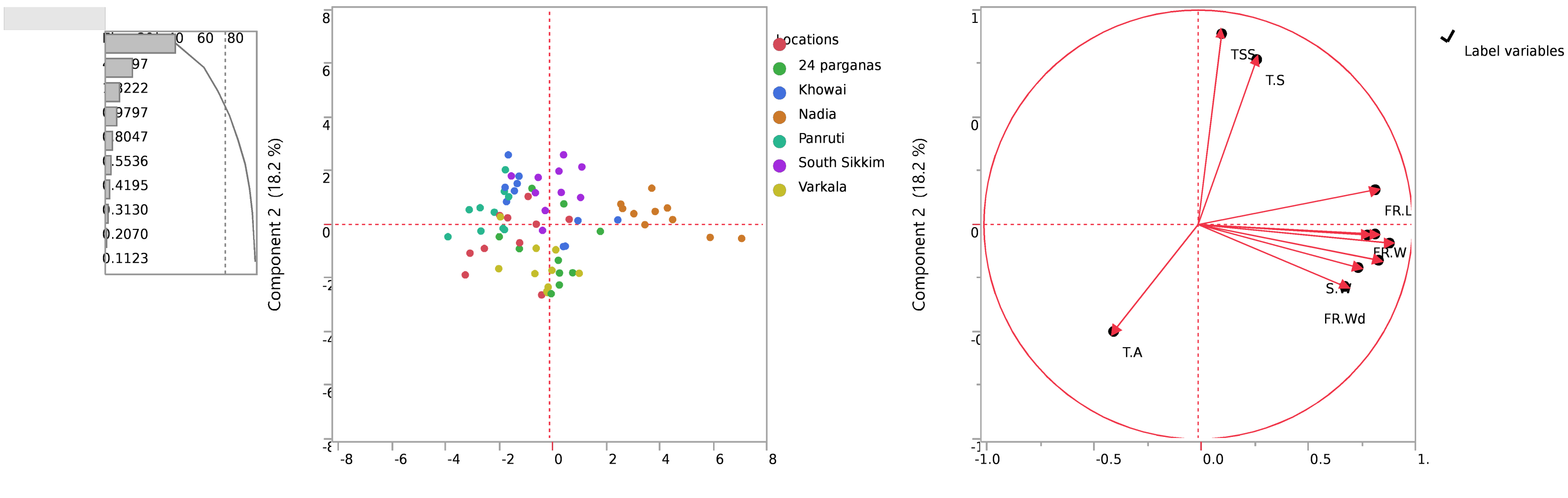

Fig. 4.9: Principal component analysis (PCA) of physico-chemical characters of jackfruit geographical locations (first & second year combined)

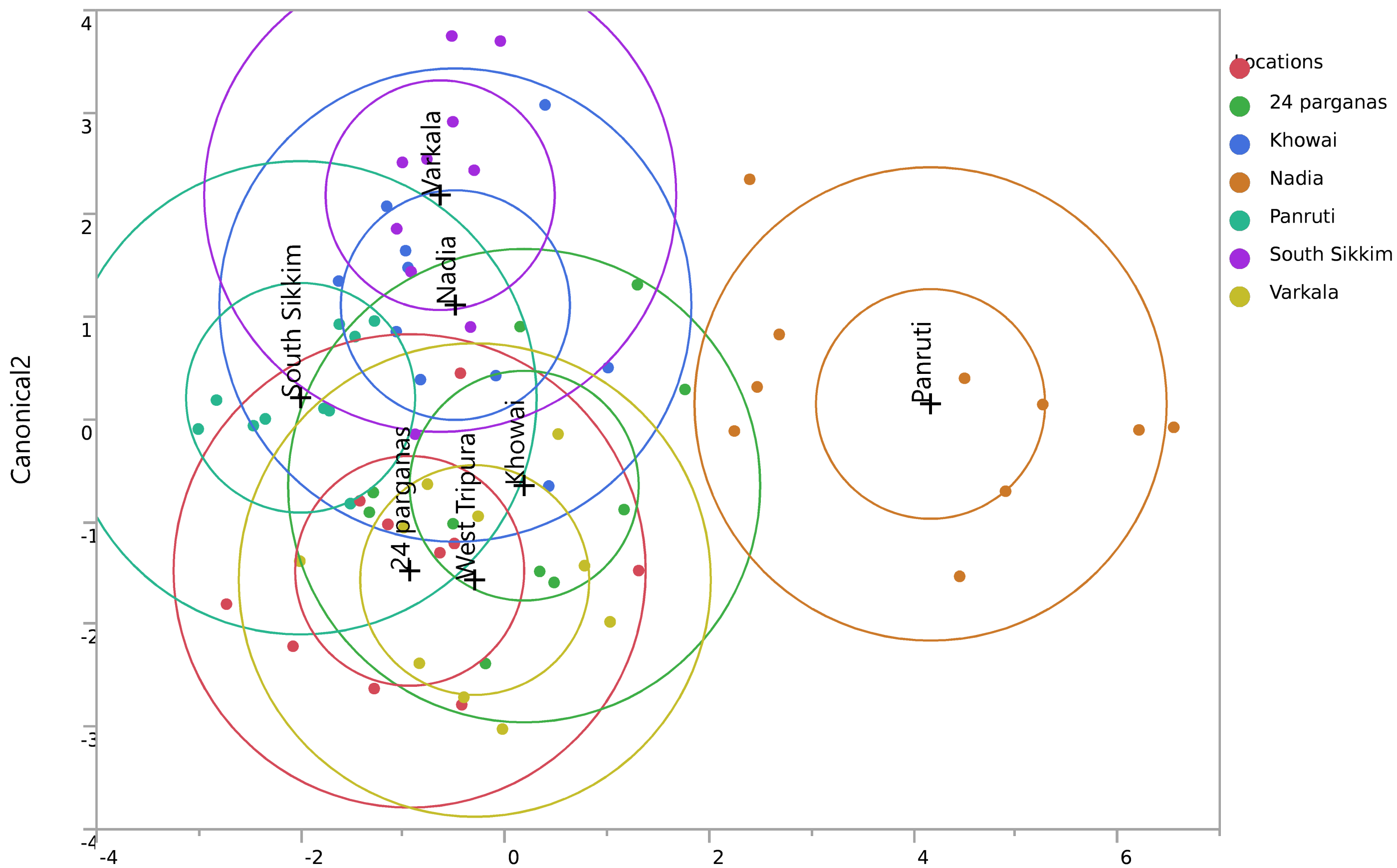

Fig. 4.10: Linear discriminant analysis (LDA) of physico-chemical characteristics of jackfruit geographical locations (first year).

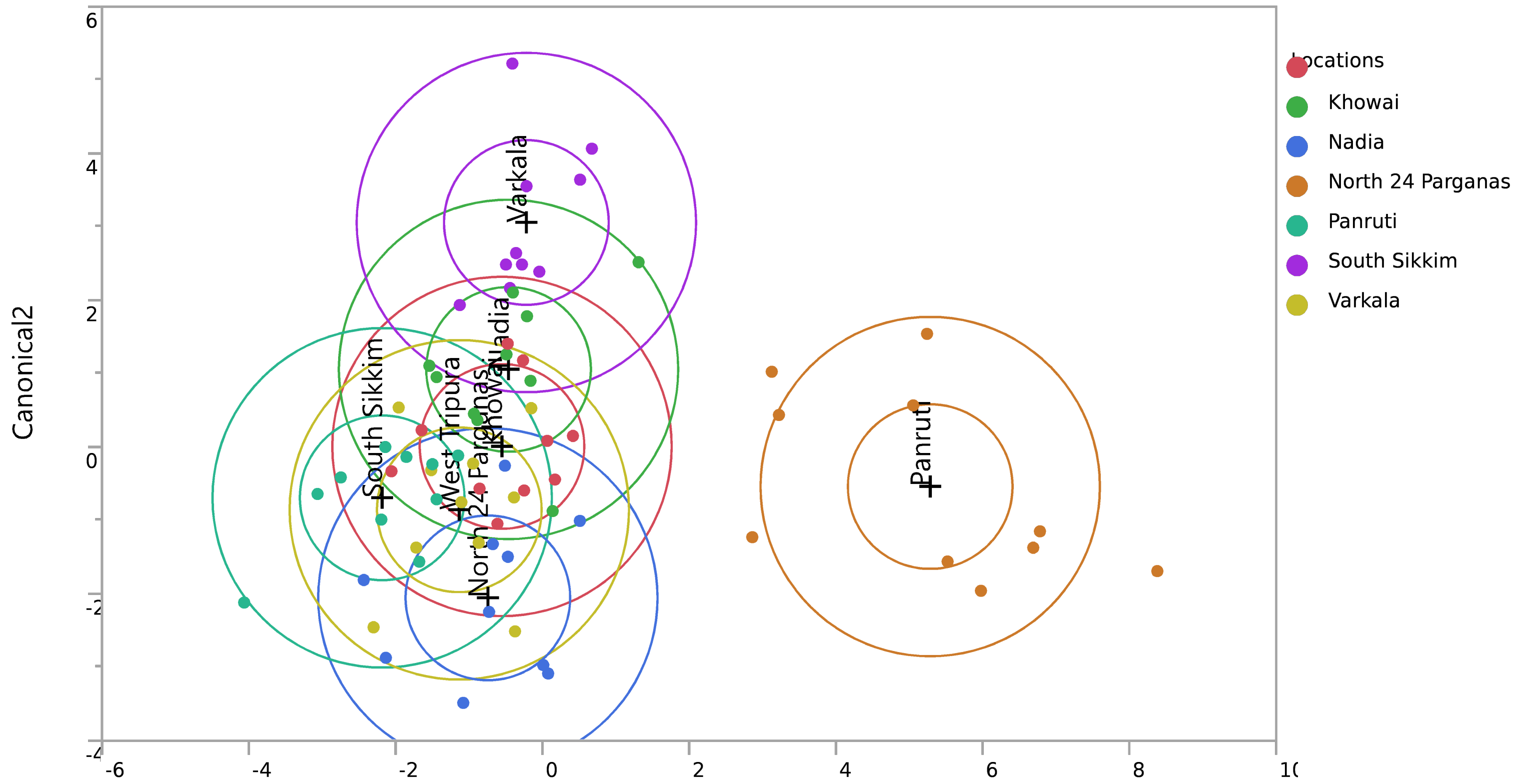

Fig. 4.11: Linear discriminant analysis (LDA) of physico-chemical characteristics of jackfruit geographical locations (second year).

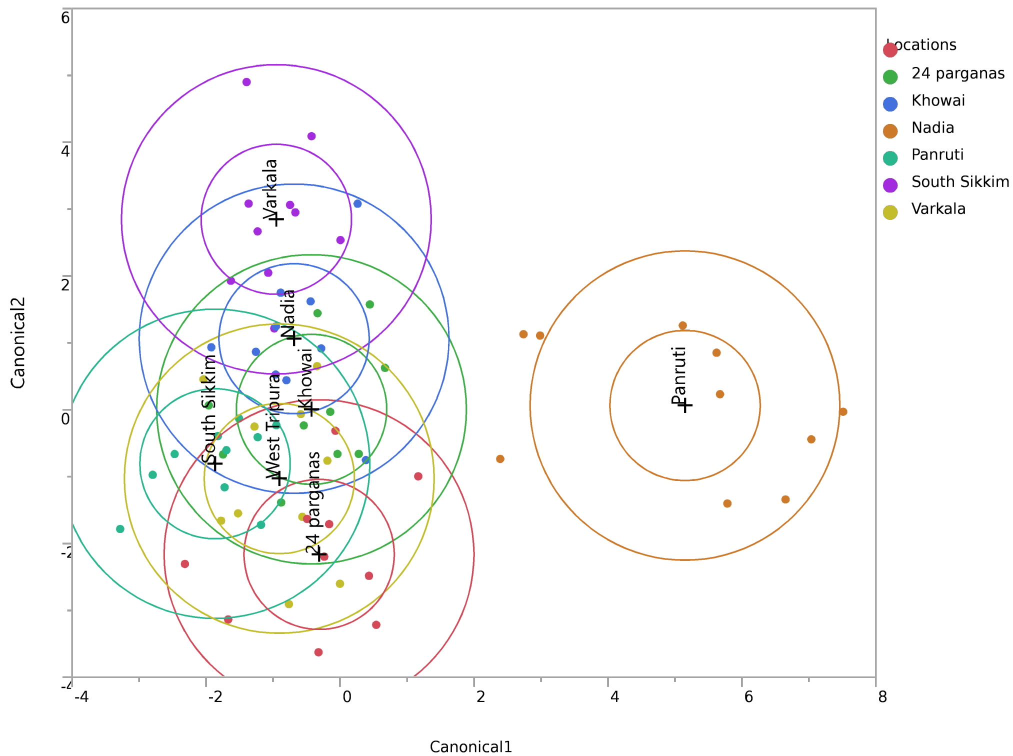

Fig. 4.12: Linear discriminant analysis (LDA) of physico-chemical characteristics of jackfruit geographical locations (first & second year combined).

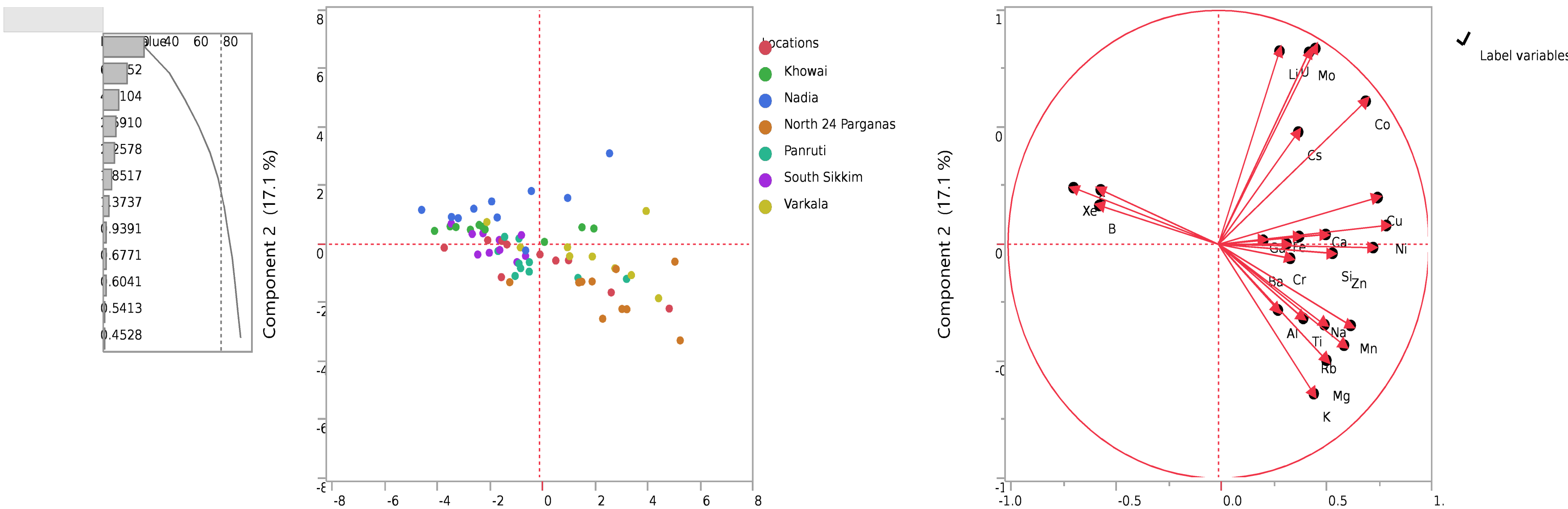

Fig. 4.13: Principal component analysis (PCA) of fruit ionome of jackfruit geographical locations (first year).

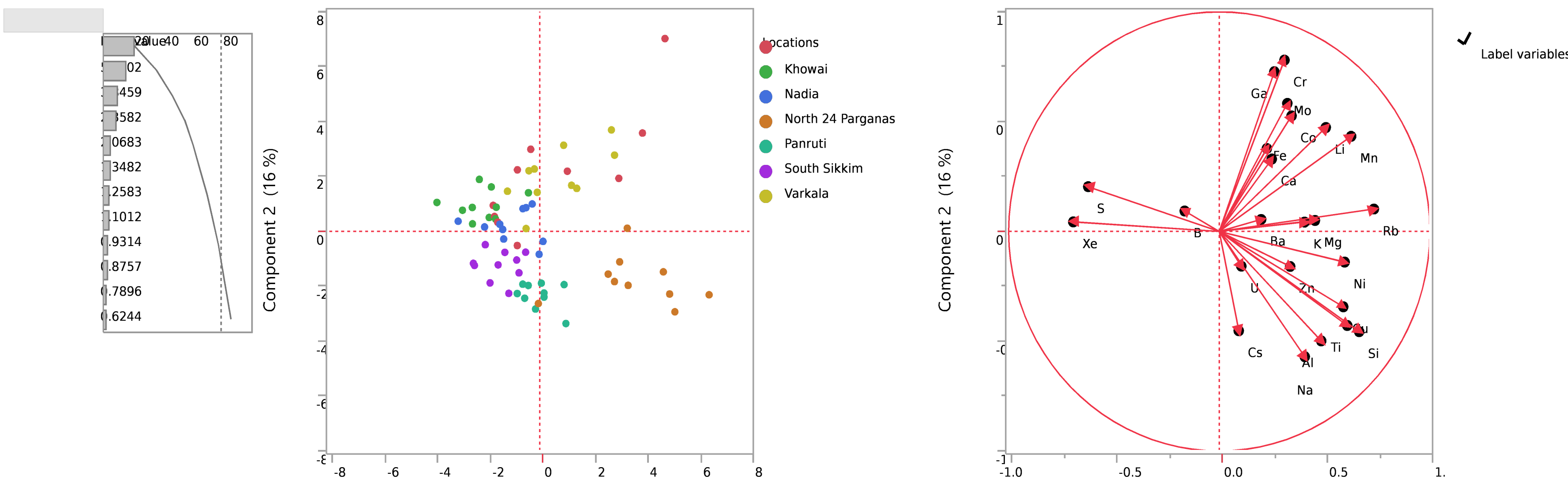

Fig. 4.14: Principal component analysis (PCA) of fruit ionome of jackfruit geographical locations (second year).

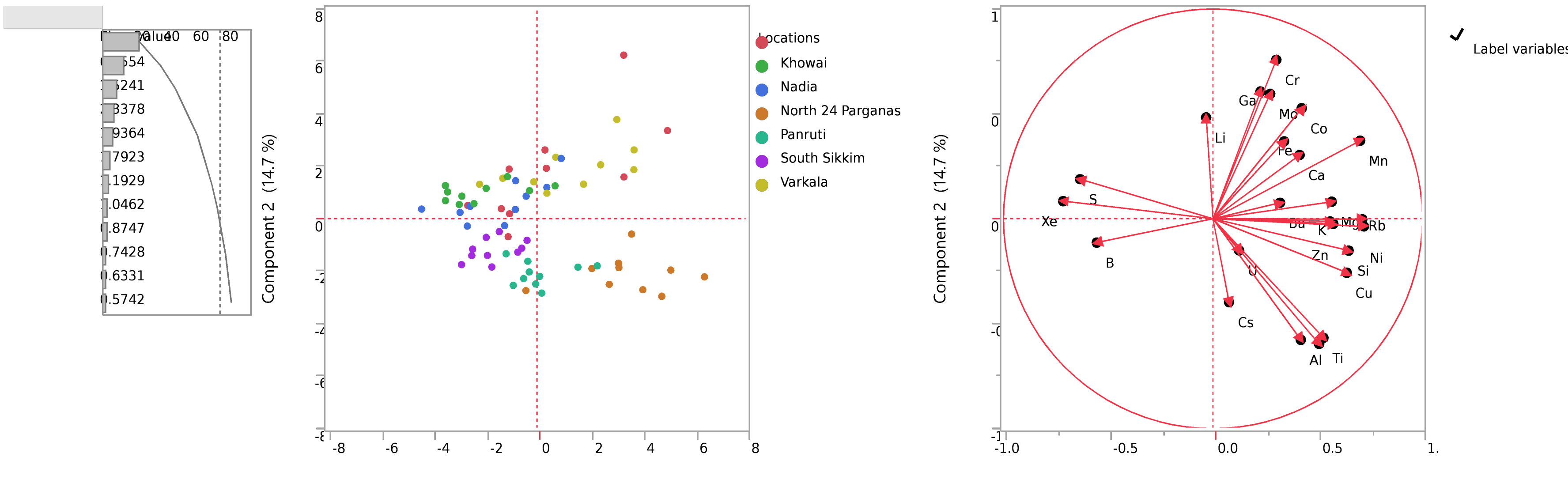

Fig. 4.15: Principal component analysis (PCA) of fruit ionome of jackfruit geographical locations (first & second year combined).

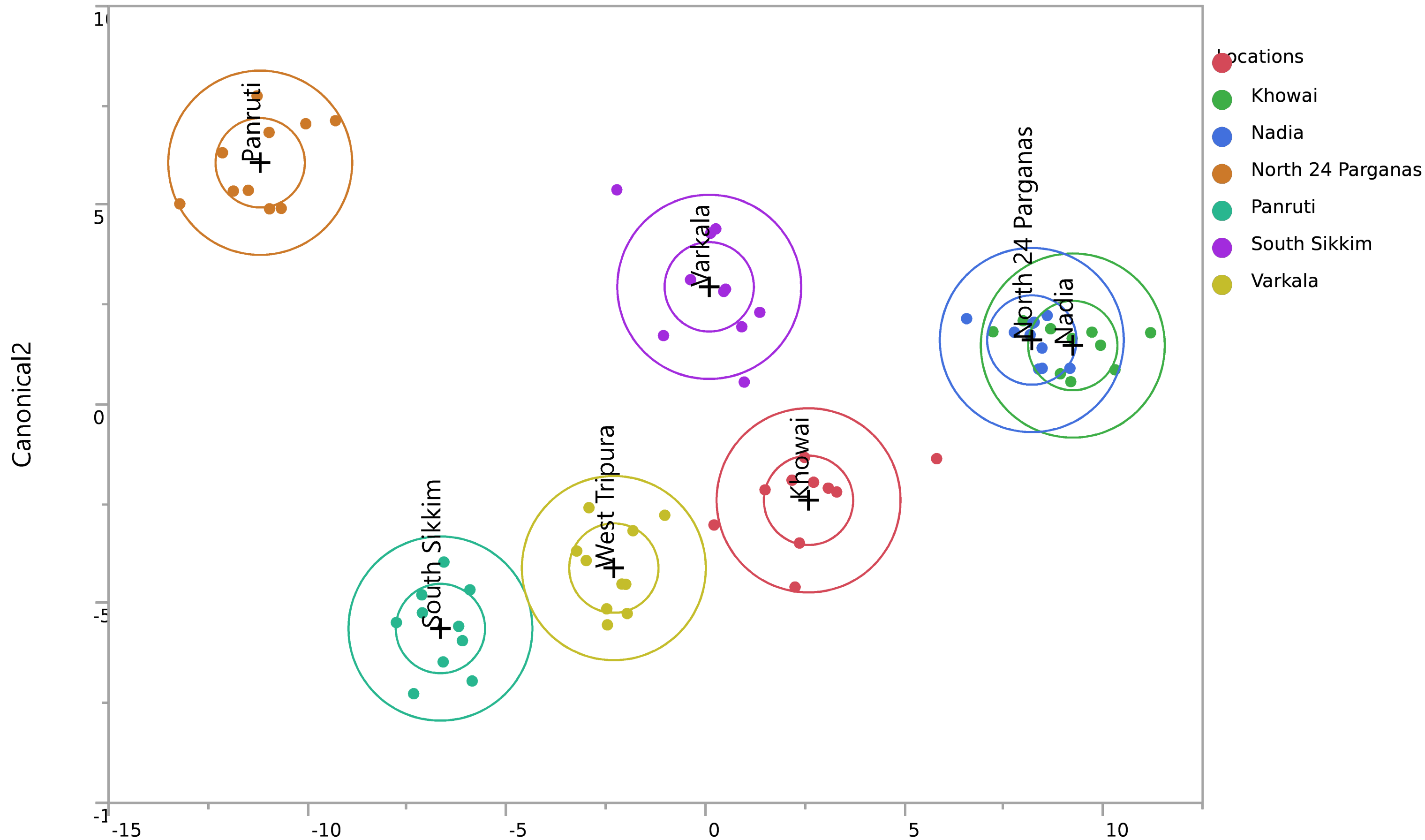

Fig. 4.16: Linear discriminant analysis (LDA) of fruit ionome of jackfruit geographical locations (first year).

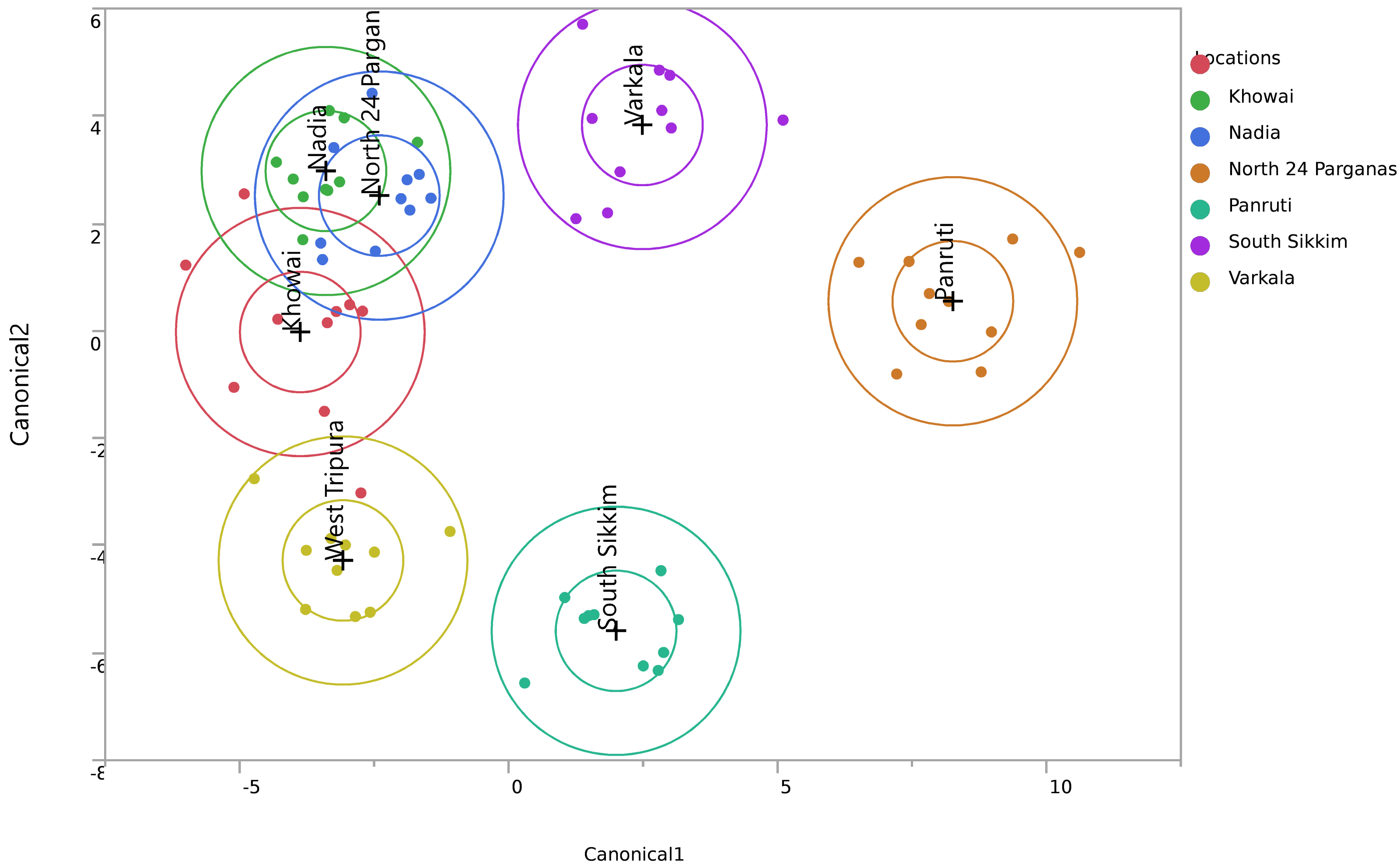

Fig.4.17: Linear discriminant analysis (LDA) of fruit ionome of jackfruit geographical locations (second year).

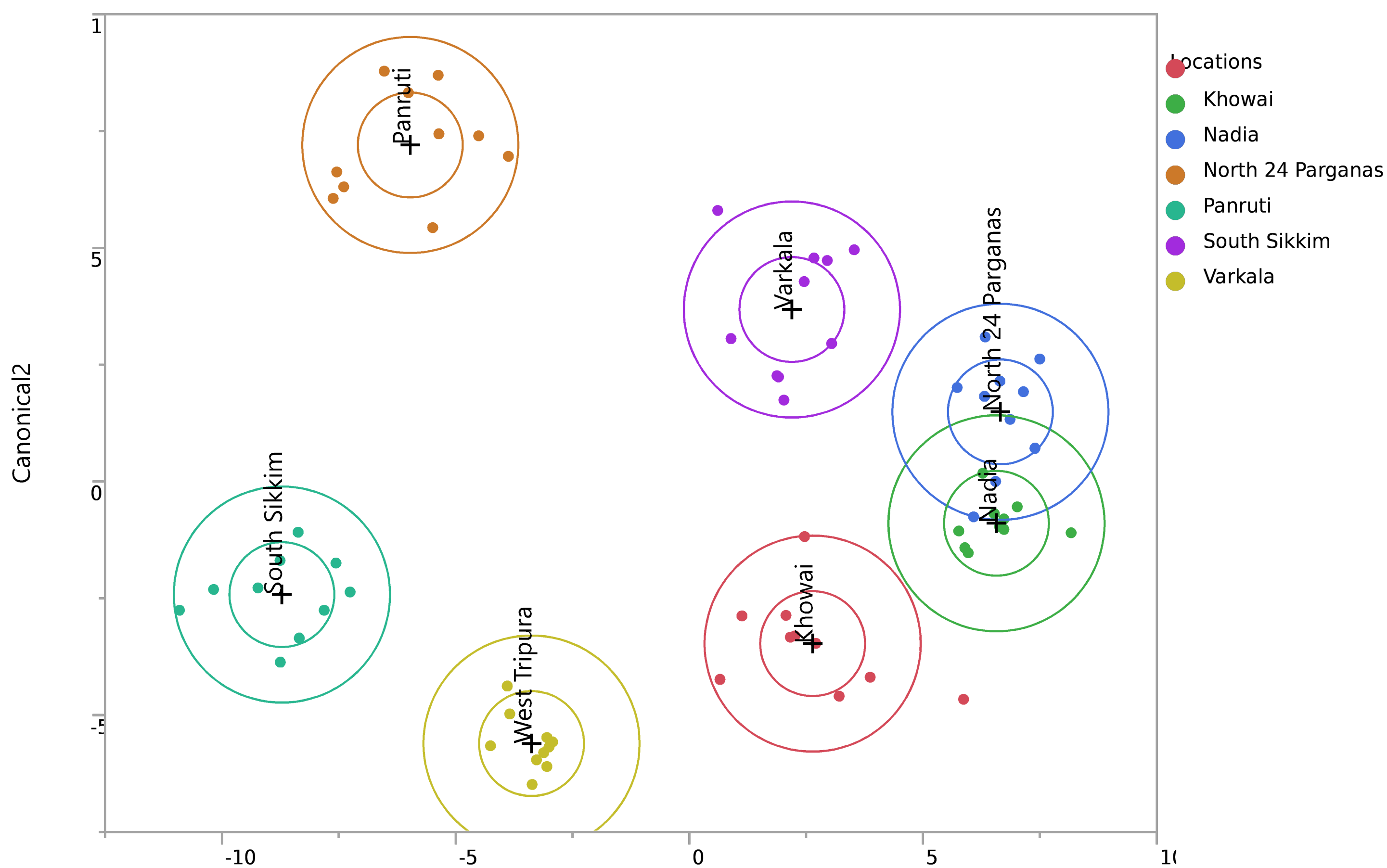

Fig. 4.18: Linear discriminant analysis (LDA) of fruit ionome of jackfruit geographical locations (first & second year combined).


PAR 1


PARJ 2


PARJ 3


PARJ 4


PARJ 5


PARJ 6


PARJ 7


PARJ 8


PARJ 9


PARJ 10

Plate.1. Different accessions of Jackfruit collected from various geographical locations

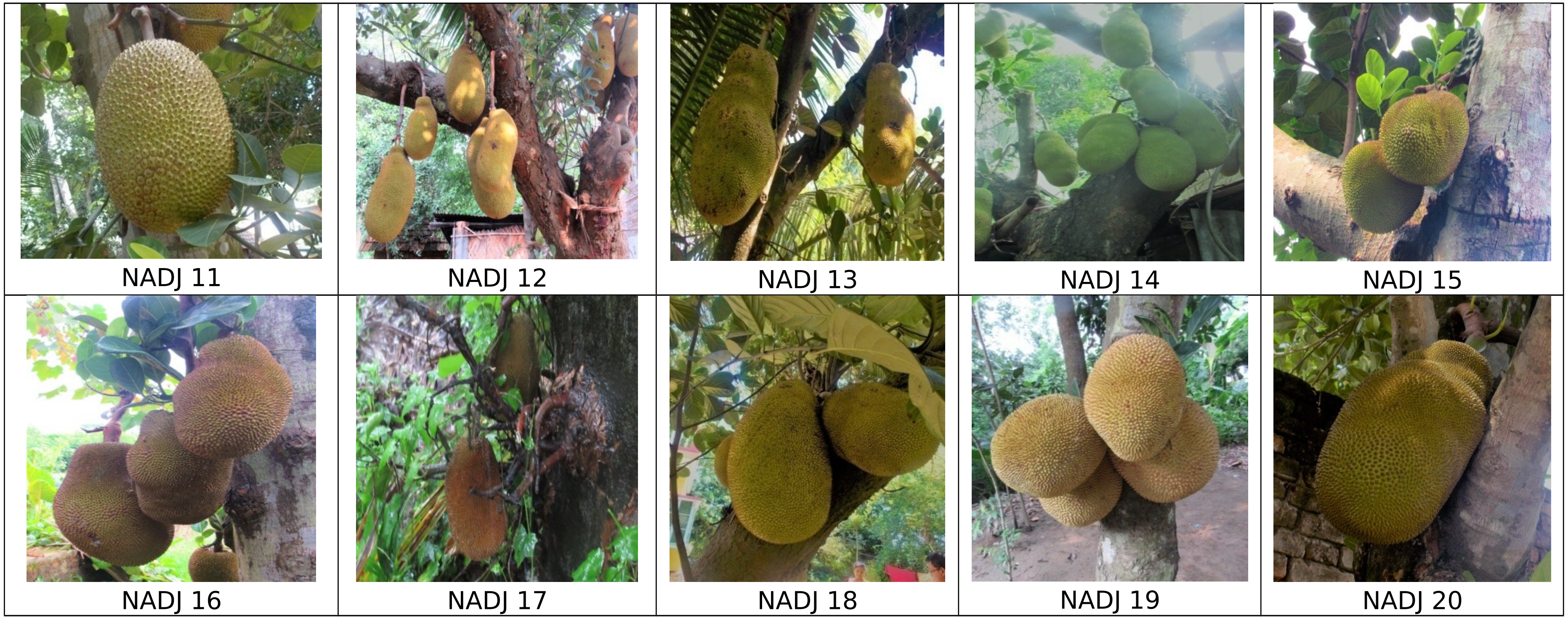

Plate.1. Different accessions of Jackfruit collected from various geographical locations

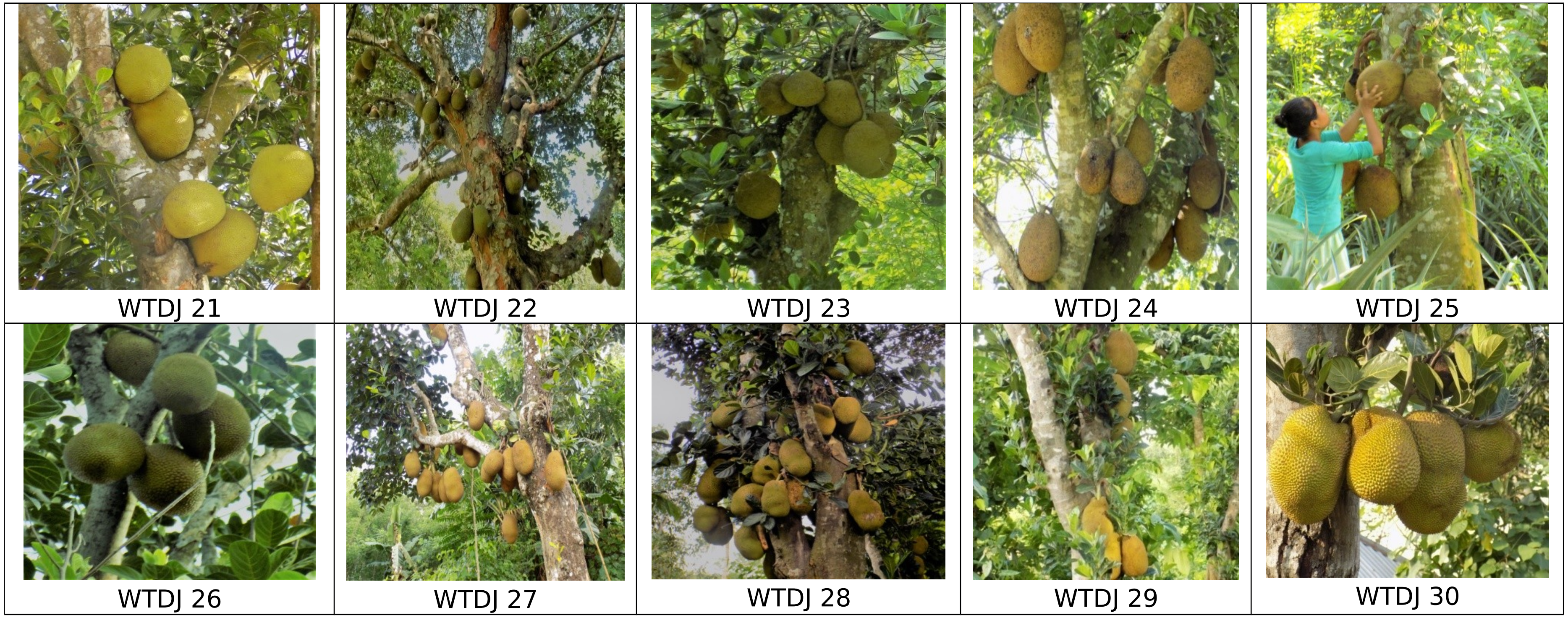

Plate.1. Different accessions of Jackfruit collected from various geographical locations

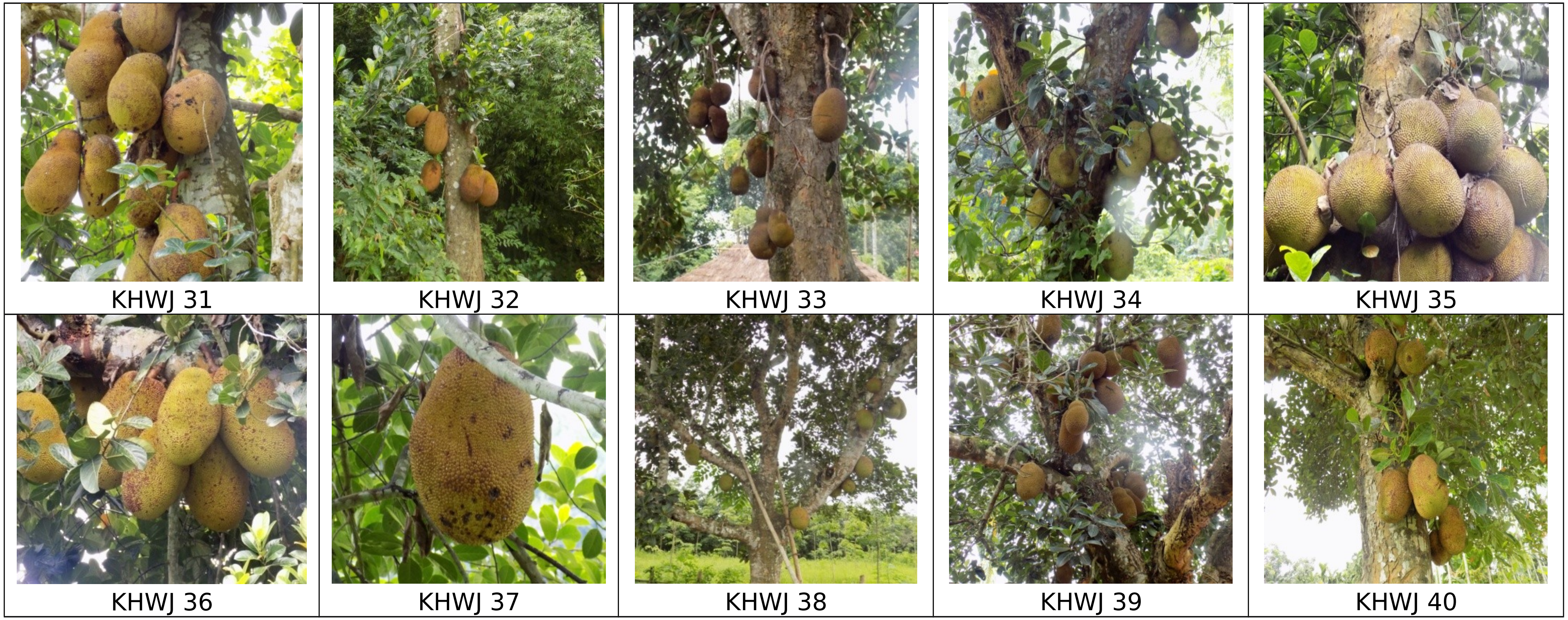

Plate.1. Different accessions of Jackfruit collected from various geographical locations

 PANJ 41	 PANJ 42	 PANJ 43	 PANJ 44	 PANJ 45
 PANJ 46	 PANJ 47	 PANJ 48	 PANJ 49	 PANJ 50

Plate.1. Different accessions of Jackfruit collected from various geographical locations

				
VARJ 51	VARJ 52	VARJ 53	VARJ 54	VARJ 55
				
VARJ 56	VARJ 57	VARJ 58	VARJ 59	VARJ 60

Plate.1. Different accessions of Jackfruit collected from various geographical locations

 SDTJ 61	 SDTJ 62	 SDTJ 63	 SDTJ 64	 SDTJ 65
 SDTJ 66	 STDJ 67	 STDJ 68	 SDTJ 69	 SDTJ 70

Plate.1. Different accessions of Jackfruit collected from various geographical locations