

**EFFECT OF NUTRIENT SOURCES ON SOIL PROPERTIES
AND PRODUCTIVITY OF KIWIFRUIT
(*Actinidia deliciosa* cv. ALLISON)**

Thesis

by

**ASHOK KUMAR
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submitted to



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This is to certify that the thesis entitled “**Effect of nutrient sources on soil properties and productivity of kiwifruit (*Actinidia deliciosa* cv. Allison)**” submitted in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY** in the discipline of **SOIL SCIENCE** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) – 173 230 is a bonafide research work carried out by **Mr. Ashok Kumar (F-2017-17-D)** son of Sh. Bhim Sain under my supervision. No part of this thesis has been submitted for any other degree or diploma.

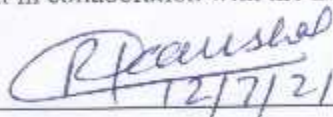
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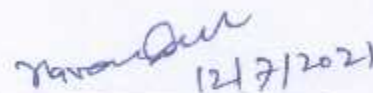
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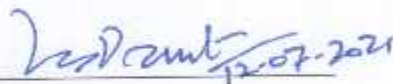
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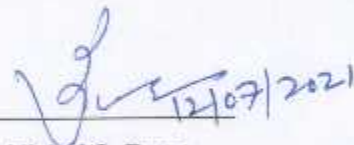


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LIST OF ABBREVIATIONS USED

Abbreviation	Meaning
%	Per cent
/	Per
@	At the rate of
µg	Microgram
°C	Degree Celsius
ANOVA	Analysis of variance
B:C	Benefit cost ratio
CD	Critical difference
CFBS	Chemical Fertilizer Based System
CFU	Colony Forming Units
Cm	Centimeter
CO ₂	Carbon dioxide
Df	degree of freedom
dS m ⁻¹	Deci Siemens per meter
EC	Electrical conductivity
<i>et al.</i>	<i>et alia</i> (and others)
etc.	<i>et cetera</i> (and other similar things)
FYM	Farm Yard Manure
G	Gram
<i>GJ</i>	<i>Ghana Jeevaamrit</i>
HP	Himachal Pradesh
Ha	Hectare (10,000 m ²)
<i>i.e.</i>	<i>id est</i> (that is)
<i>JM</i>	<i>Jeevaamrit</i>
Kg	Kilogram
K	Potassium
L	Liter
M	Meter
m ²	Meter square
Mg	Milligram
ml	Milliliter
mm	Millimeter

MOP	Muriate of Potash
Msl	Mean Sea Level
MSS	Mean Sum of Square
MT	Metric tones
N	Nitrogen
NS	Non-significant
°B	Degree brix
OC	Organic carbon
OFBS	Organic Farming Based System
P	Phosphorus
Pp	Particular page
Ppm	Parts per million
PM	Poultry manure
Psi	Pounds per square inch
pH	<i>Puissance de Hydrogen</i> (Power of hydrogen)
RBD	Randomized Block Design
RD	Recommended dose
RDN	Recommended dose of nitrogen
RH	Relative humidity
SE (d)	Standard error of difference
SE (m)	Standard error of mean
SPNFS	Subash Palekar's Natural Farming System
SS	Sum of square
SSP	Single super phosphate
TSS	Total soluble solids
VC	Vermicompost
viz.	<i>Videlicet</i> (namely)

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Chapter-1

INTRODUCTION

Kiwifruit or Chinese gooseberry (*Actinidia deliciosa* Chev.) has originated in China, but commercially exploited in New Zealand. Its fruits are rusty brown with hairy surface, oblong in shape, light green flesh and soft and small seeds. The fruit is delicate and flavors like strawberry and gooseberry (Ferguson, 1984). A total of 4.3 million tons of kiwifruit were produced worldwide during 2018 and China (2.1 m tons) alone accounts for 50% of total production (Anonymous, 2019). In India, its commercial cultivation is being carried out in mid-hills of Himachal Pradesh, Uttarakhand, Jammu & Kashmir, Sikkim, Nagaland, Mizoram and Arunachal Pradesh over an area of 4000 ha with production of 12000 MT (Anonymous, 2018). Arunachal Pradesh is the leading producer with about 57% share and Himachal Pradesh contributes only 3.2% of kiwifruit production. It occupied an area of 123 ha in Himachal Pradesh during 2015 with annual production of 344 MT (Anonymous, 2016).

Himachal Pradesh is the first state to demonstrate kiwifruit commercial cultivation. As apple has revolutionized the economy of the growers in high-hills, kiwifruit is coming up on the same line to the farmers in mid and low hills and replacing low value stone fruits due to added advantage with production and post-harvest properties. Kiwifruits are rich source of ascorbic acid (Ferguson and Huang, 2007), flavonoids (Atkinson and Macrae, 2007), polyphenols (Sheng *et al.*, 2005) and are best known nutritious fruit amongst berries and has refreshing and delicate flavor, rich source of vitamin C, minerals like K, Ca, P and high medicinal value (Ferguson and Eiseman, 1983).

Kiwifruit vines requires 700-800 chilling hours below 7°C besides appropriate amount of manure and fertilizers for optimum vegetative growth and quality fruit production. A basal dose of 20-30 kg FYM along with 500 g of NPK fertilizer mixer containing 15% N should be applied every year under Indian conditions up to 5 years of age of the plant (Rathore, 1991). After 5 years, 40 kg FYM along with 800 g of N, 600 g P₂O₅ and 800 g K₂O per plant is recommended each year (Kumar *et al.*, 1995). Full dose of P and K along with FYM should be applied in December-January and half dose of N should be applied one month before flowering and remaining half dose one month after fruit set. The adequate macro and micro-nutrient management keep the vine healthy and productive (Sale, 1981). Macronutrients are applied on

yearly basis while other elements are supplied on requirement basis or as exhibited by soil and plant analysis or deficiency symptoms. Slightly acidic (pH 5-6.5), well-drained deep sandy loam soils rich in organic matter are ideal for cultivation of kiwifruit.

Kiwifruit has been cultivated under conventional farming practices (Briones *et al.*, 2011), that utilize large amounts of chemical fertilizers, herbicides, fungicides, pesticides, plant growth regulators under both fertigation (Granelli *et al.*, 1994) and soil application (Marsh *et al.*, 1993) to achieve maximize production. The detrimental effects like soil acidification and decrease in nutrient availability has also been reported by many researchers all over the world (Kibblewhite *et al.*, 2008). In contrast, great attention is also being paid to organic production as an alternative form of agriculture to obtain high quality food in an environment friendly manner. Organic fruit production technology has gained impetus in the recent years both in terms of consumer demand and as a genuine desire of many fruit orchardists to sustain crop production and soil health. Additionally, microbial population under conventional farming system rarely exceeds 10^4 to 10^5 cfu g⁻¹ of soil under Indian conditions because of poor organic carbon status (Subba Rao, 1999). However, ample population in the range of 10^8 to 10^9 cfu g⁻¹ were recorded by Jekinson and Ladd (1981) under organic farming. The decline in precious biodiversity of microorganisms has created awareness to save the existing soil microflora, owing to its usefulness to sustain soil fertility/productivity. Therefore, the foremost emphasis of present agricultural community is to find out an alternative sustainable farming system which is ecologically sound and economically and socially acceptable (Pathak and Ram, 2004). The organic and biological sources of nutrients are environment friendly, non-bulky renewable source of energy and low-cost agro-inputs. Therefore, development of such system in which equally higher level of production using organic and natural sources are desirable for good quality produce without any detrimental effects on the environment.

Instead, another alternative viz. Zero-Budget Natural Farming (ZBNF) is a type of farming created by Mr. Subhash Palekar and which has been practiced in several states in our country. The phrase 'Zero Budget' means without using any credit and without spending money to purchase agri-inputs. On the other hand, 'Natural farming' means farming with *Nature* and *without* chemicals. Palekar has identified four aspects that are integral to ZBNF (1) *beejamrit* or microbial coating of seeds using cow dung and urine based formulations; (2) *jeevaamrit*, which is a mixture of fresh cow dung, cow urine, jaggery, pulse flour, water and soil to multiply soil microbes; (3) *Acchadana*-Mulching, or covering the soil surface with a layer of organic material to avoid evaporation losses and to contribute to soil humus formation; and (4)

waaphasa, or soil aeration through a favorable microclimate in the soil. The specialists of ZBNF explain that ‘Zero budget’ does not exactly mean that costs are ‘zero’, but rather suggests that the need for outside funding is zero, and costs incurred can be balanced by a diversified source of income which comes via farm diversification rather than dependence on monoculture (APZBNF, 2018). Palekar has challenged some resistance because of the usage of the terms ‘zero budget’ as many questioned the correctness of the term, as some expenses are involved. So, recently he changed the name of ZBNF to Subhash Palekar’s Natural Farming System (SPNFS). In Himachal Pradesh the SPNFS activities were first initiated at Chaudhary Sarwan Kumar HP Krishi Vishvavidyalaya, Palampur during National Workshop which was held on 27-30 April, 2016 under the Chairmanship of His Excellency, The Governor of HP, Acharya DevVrat and Padam Shri Subhash Palekar ji was the key speaker of the workshop. The main aim of the programme was to develop and standardize the technologies for the cultivation of different crops under SPNFS system.

In modern agriculture, farmers heavily rely on inorganic inputs such as fertilizers and pesticides, these not only contaminate groundwater, reduce soil fertility but also contribute to biodiversity loss in farmlands (Aktar *et al.*, 2009; Singh, 2000). The concept of integrated nutrient supply involving combined use of organic and chemical fertilizer has been developed for many crops in our state. Consequently, today’s horticulture production system demands balanced application of nutrients to sustain production level. The availability and escalating prices of chemical fertilizer and pesticides inputs poses the problems which lead to their indiscriminate use. The integrated nutrient management through chemicals, biological and organic manures has been reported worldwide to sustain production level without deterioration of soil health (Aulakh *et al.*, 2012).

The meager information is available about the response of kiwifruit to organic and inorganic sources of nutrients. Keeping this in view, the present investigations consisting of three systems i.e. Chemical Fertilizer Based System (CFBS), Organic Farming Based System (OFBS) and Subash Palekar’s Natural Farming Systems (SPNFS) were evaluated for both production, quality of kiwifruits and their effects on soil properties with the following two major objectives:

1. To study the effect of application of different nutrient sources on plant growth, yield and quality of kiwifruit.
2. To study the effect of various organic and inorganic inputs on physical, chemical and biological properties of soil.

Chapter-2

REVIEW OF LITERATURE

Organic farming is being increasingly promoted worldwide as a sustainable alternative to conventional farming. Some countries, such as Germany and France, subsidize their farmers to convert to organic farming in order to become more sustainable. In 2018, 71.5 million hectares were under organic agricultural management worldwide, of which most organic agricultural land is in Oceania (36 m ha), followed by Europe (15.6 m ha), Latin America (8 m ha), Asia (6.5 m ha), North America (3.3 m ha) and Africa (2.0 m ha) (Schlatter *et al.*, 2020). In Asia, there were 1.3 million organic producers, most of which were in India. The leading countries by area are China (3.1 m ha) and India (over 1.9 m ha).

Organic production technology has gained impetus in recent years both in an increase consumer demand and a sincere desire of orchardists to sustain crop production and soil health. Besides, organic produce fetches higher price than traditional commodity and thereby motivating producers to grow fruit crops organically (Schader, 2009). Natural soil fertility and nutrient sources such as manures, organic amendments, liquid formulations such as *jeevaamrit* can change nutrient management strategies. The alternative crop management systems are being promoted on the basis that they are more environmentally benign and specifically enhance soil and crop quality relative to conventional practices. Organic production systems may be a way to ensure the production sustainability, conservation of natural resources for current and upcoming generations.

Natural Farming on the other hand, is contemplated by its protagonist as one of the most potential crop cultivation methods to drastically cut down production costs by reducing dependence on market for purchase of critical inputs. Natural farming in India has been campaigned by Shri Subhash Palekar who has resulted its widespread adoption at varying levels in many states, hence called Subhash Palekar's Natural Farming System (Khadse *et al.*, 2017; Mishra, 2018; Niyogi, 2018; Government of India, 2019). Considering it as an agroecologically varied farming practice, it brings congregations of ecological and community benefits, although, there are two school of thoughts opposing each other on the usefulness of its practices.

Soil nutrient cycling changes as organic fertility sources are used and hence, organic matter content increases. Thus, fertilization plans will need alteration over time as the soil

changes. This can be in the form of farm yard manures, vermicompost, poultry manure, and other locally made liquid formulations and concentrated solid organic manures.

The relevant literature in India and abroad on the use of different organic sources namely; farm yard manure, vermicompost, poultry manure, *Jeevaamrit* and *Ghana Jeevaamrit* in relation to plant growth, yield, fruit quality and soil characteristics has been reviewed under the following subheads:

2.1. Effect of application of different nutrient sources on plant growth and yield

2.2. Effect of application of different nutrient sources on fruit quality

2.3. Changes in soil physical properties as affected by different farming systems

2.4. Changes in soil chemical properties as affected by different farming systems

2.5. Changes in soil biological properties as affected by different farming systems

2.6. Economic returns under different farming systems

Nutrient requirements and hence fertilizer plans change as newly planted orchards are developed viz. at planting; during growth of young vines and the establishment of a full fruiting canopy; and when vines are mature and carry heavy fruit loads. Application of manure or compost at planting supplies nutrients for the young plants and also improves soil structure, water holding capacity. Even mature orchards require a good supply of organic matter in the soil to withstand high yields and to achieve good fruit quality.

The kiwifruit plants need a long growing season (at least 240 frost-free days), which will not be hampered by late winter, or early autumn freezes. For high yield and quality fruits, it requires 700-800 chilling hours below 7°C to break its dormancy period. High temperature (>35° C) accompanied by high insulation, low humidity, sunscald and heat stress are the main problems in its cultivation (Mishra and Shukla, 2014).

2.1. EFFECT OF APPLICATION OF DIFFERENT NUTRIENT SOURCES ON PLANT GROWTH AND YIELD

2.1.1. Chemical Fertilizer Based System

Fertilization, as said earlier, mostly N fertilizer applied two or more times per year. Young plants that grow vigorously by heavy use of N and water in September and October are very prone to winter frost damage. For full-bearing vines, use of one pound of N (i.e. 2.2 pounds of urea) per plant is recommended in USA (Beutal, 1990). In India, 800 g of N, 600 g of P₂O₅ and 800 g of K₂O is recommended for kiwifruit cultivation of mature vines. Zinc and iron

fertilizers are occasionally needed by plants where deficiency symptoms appear or pH needs to be lowered by sulfur applied to the soil or acid in the irrigation water.

Chemical fertilizers act as kingpin to get higher crop productivity, but high doses are associated with lessening soil properties and crop yields over time period (Hepperly *et al.*, 2009). However, the chemical fertilizer increases the plant growth and vigor, hence meets the food security of the world, but the plants grown under this system does not develop good plant characters viz. good root and shoot system, nutritional characters and also will not mature properly (Chandini *et al.*, 2019). In young vines, large proportion of the minerals taken up from the soil is immobilized in the dry matter and mineral content of the permanent structures, the trunk, the leaders, the branches, and the structural roots, enhances during the first 6-8 years after planting (Xiloyannis *et al.*, 1996). Initially, vines produce few fruits and there is no need for large amounts of nutrients especially potassium, as 75% of the K is taken up during vine establishment gets accumulated in deciduous parts (Buwalda and Smith, 1987). The same is true for magnesium (Mg), and although large amounts of calcium (Ca) are taken up by young plants. Only the soil N content needs to be watched (Marangoni *et al.*, 2003). Young kiwifruit vines often show symptoms of iron (Fe) deficiency or iron chlorosis in regions that are high in calcium. In contrast, mature kiwifruit vines take up considerably more nutrients from the soil. Actually, the minerals in the fruit are lost from the orchard system while leaf litter and pruning are not normally removed from the orchard and eventually recycled to the soil. Leaf litter and pruning parts have a high C:N ratio and due to slow decomposition rate, microorganisms responsible may temporarily immobilize N in soils containing little organic matter (Xiloyannis *et al.*, 1996; Marangoni *et al.*, 2003). Senescent leaves decompose more rapidly than pruning chunks and the N derived from their mineralization will be available subsequently depending on soil temperature and humidity.

In 1950, fertilizers comprised only a small percentage of the total nutrients needed for grain production, most of the supply being provided by the “natural fertility” of the soil and added manures, but these days more than 70% of grain yield depend on chemical fertilizers. Low soil fertility is one of the most vital constraints in improving the agricultural production (Ayoub, 1999). The excessive indiscriminate use of inorganic fertilizers not only deteriorated soil health but also resulted in many health problems and unrecoverable environmental pollution. However, the combined use of organic manures with inorganic fertilizers has not only increased production of quality fruits by providing essential nutrients to the plant but also improved the soil health (Patel and Naik, 2010).

Hasey *et al.* (1997) compared organic farming system with conventional system in

kiwifruit and observed that some of the nutrients like leaf N in organic system were consistently lower than those from the conventional system but were not deficient in nitrogen. Higher sodium and chloride concentrations in leaves were observed over the three-year period in organic system but not at phytotoxic levels. Leaf zinc (Zn) levels were adequate and increased over time in both the systems. Organically grown fruits were firmer than conventionally grown fruits at harvest and four months after harvest. Application of N significantly improved the Nagpur mandarin yield with increasing N rates as compared to FYM alone (Huchche *et al.*, 1998).

Finally, sustained crop productivity depends on constant renewal when the supply of nutrients becomes a limitation to plant growth and development. Application of chemical fertilizers is essential for enhancing crop yields and sustaining soil fertility (Yadav *et al.*, 2000). However, inappropriate or excessive fertilizer application does not assure continuously increasing yields, might result in low nutrient use efficiency and can originate environmental problems in agro-ecosystems (Tilman *et al.*, 2011).

2.1.2. Organic Farming Based System

To decrease/eliminate the adverse effects of synthetic fertilizers on soil, human health and environment, nowadays a new agricultural practice has been developed called as organic agriculture, sustainable agriculture or ecological agriculture (Keeney and Follet, 1991) which are mainly cost-effective based on locally available products.

Dadhwal *et al.* (2011) conducted a study on the organic farming for resource conservation and soil health in the Himalayan region and provided an insight into real organic farming situation in the Indian Himalayan States. Organically managed farms observed low productivity and reduced yields but there was an overall improvement in the soil quality parameters. Low productivity in organic farming highlights the need for current international and national research activities. Jannoura *et al.* (2014) revealed that organic fertilizer application improved nodule dry weight, photosynthetic rates, N₂ fixation and N accumulation and concentration in several legume crops. Generally, differences in crop yield between organic and conventional systems were larger for short vegetation period crops like potatoes than for long vegetation period crops such as cereals. Newton (1995) observed a lower yield for wheat, barley, oats and potatoes on organic farms than on conventional farms. However, different crops respond in different ways to organic fertilizers (Kell, 1992).

The increase or decrease in yields with the conversion to organic is not a universal phenomenon, but depends on how crops have been produced conventionally, as well as other factors such as soils, climatic conditions, etc. For instance, Birzer and Badgery (2006) observed that farmers who produced conventionally noted a decline in yields, however after the fourth-year yields showed improvements; whereas farmers who already used organic methods did not see a drop in yields. Similarly, several works in developing countries presented that where small farmers have little access to agrochemicals, the conversion from conventional to organic usually represented an increase in yield from 15 percent (Bray *et al.*, 2002) to 67 percent in Guatemala (Damiani, 2002).

The effect of FYM, VC and PM on growth and yield of different crops have been reviewed under the following subheads:

2.1.2.1. Farm yard manure (FYM)

Farmyard manure has been the main source of organic matter since ancient time and is considered an ideal organic manure for all crops. It is prepared by heaping fresh cow dung and allowed to rot and then put to use after complete decomposition. The FYM be used for all agricultural and horticultural crops as it contains most of the nutrients essential for healthy crop production. Additionally, it also improves the soil structure, water holding capacity and resolves drainage problem of soil. Furthermore, it helps in upholding the ideal soil temperature for soil microorganism.

On an average, a well rotten FYM contains 0.5 to 1.5 per cent N, 0.5 to 0.9 per cent P, 0.5 to 1.4 per cent K and traces of other essential nutrients. However, the nutrient supplying capacity of FYM is highly dependent upon its source and quality. The nutrients become slowly available to plants subsequently few weeks of FYM application to the soil.

Musmade *et al.* (2010) carried out a study on integrated nutrient management in acid lime and recommended the combined application of neem cake and FYM along with the inorganic fertilizers. They observed significant increase in the growth characteristics viz., stem girth, canopy height and diameter.

Fawzi *et al.* (2010) conducted a study on 12-year-old pear orchard to study the effects of FYM, compost and bio-fertilizers showed that significant increase in vegetative growth, leaf mineral content, pigment content as well as physical and chemical properties of fruit has been observed. Ghosh (2015) revealed that among different organic manures, cow dung manure recorded maximum number of fruits as compared to neem cake and vermicompost in sweet orange.

2.1.2.2. Vermicompost (VC)

Vermicomposting is a technique of exploitation of earthworms to breakdown organic materials (Harris *et al.*, 1990). Basically, this is a low-cost technology that mainly uses earthworms in the processing or treatment of organic wastes (Hand *et al.*, 1988). Specific species of earthworms quickly consume organic material residues and fragment them into much smaller particles by passing them through their gizzard and obtain their nourishment from microorganisms that grow upon these materials. Simultaneously, they further promote microbial activity since the fecal material or ‘casts’ that they produce is much more fragmented and microbially active than what they consume (Edwards and Bohlen, 1996). During the process, essential nutrients like N, P, K, Ca etc. are released through microbial action and converted into much more soluble forms that are easily available to plants than those in the parent compounds.

Vermicompost, produced in the process of vermicomposting, contains earthworm casts, undigested organic matter, eggs (cocoons) and young earthworms. It also contains microorganisms ejected from the gut of earthworms, which are useful in decomposition of organic matter in the soil. The composition of VC is variable depending on the source of material and type of earth worm used. VC is rich in micro- and macro plant nutrients which are in available forms like nitrate (NO_3^-) (Atiyeh *et al.*, 2000), phosphate (PO_4^{3-}), sulfate (SO_4^{2-}), potassium (K^+) etc. and aids in plant growth promotion that increases crop productivity (Singh and Suthar, 2012; Ahirwar and Hussain, 2015). On an average, VC contains 2.5 to 3.5 per cent N, 1.5 to 2.0 per cent P and 2.0 to 3.0 per cent K and many micro-nutrients like Cu, Fe, Mn, B and Mo in addition to growth regulators. It contains 3-4 times higher N, P, K, Fe and Mn than the FYM. It also contains enzymes like phosphatases, invertase and chitinase and growth regulators viz. IAA and GA and auxins and antibiotics. Application of VC improves plant growth, yield and quality of the produce due to better availability of plant growth regulators and humic acid which are produced by enhanced activity of microbes (Aracon *et al.*, 2006).

Vermicompost application enhanced the N, P, Ca and Mg content and higher Zn content in lettuce leaves (Morselli *et al.*, 2004). Sinha *et al.* (2005) suggested up to 70 % substitution of chemical fertilizers and complete substitution of FYM with VC application resulted in 5 MT per ha per year in *Morus alba*. Maximum fruit yield in grapes (Venkatesh *et al.*, 2000), papaya (Shivaputra *et al.*, 2004) and strawberry (Aracon *et al.*, 2006) was obtained with VC application.

Arancon *et al.* (2004) carried out a research trial to establish the influence of VC on strawberries and observed that VC significantly increased the leaf area and shoot biomass of the plant when incorporated into the top 10 cm soil @ 5-10 t ha⁻¹. The significant increase in plant height was also recorded in guava plants with VC at 5 kg per plant (Ram *et al.*, 2005). Korwar *et al.* (2006) observed increase in fruit weight in *aonla* with the application of VC @ 15 kg per plant. Significant increase in plant height was observed in cassava plant with the addition of VC (Padmavathiamma *et al.*, 2008). Maximum shoot extension growth was obtained in plum with the application of 20 kg VC per tree which was due to high nutrient availability (Archana, 2008).

Murmu *et al.* (2013) found that VC provides not only major elements and trace elements that are necessary for the plant but also plant growth regulators and humic acid, which facilitate plant growth. Ghosh *et al.* (2014) investigated that different organic manures and VC @ 20 kg tree⁻¹ resulted maximum plant growth and quality with FYM @ 40 kg tree⁻¹. Beneficial effect in increasing fruit yield of ber and available soil P content was observed by Kundu *et al.* (2015) with the combined application of 50% VC and 50% neem cake. They further observed that combination of 50% FYM and 50% VC resulted in higher leaf N and K content. Whereas, sole application of FYM was found to be most useful in enhancing the fruit quality of ber.

Kumar *et al.* (2015) conducted an experiment on growth and quality parameters of strawberry to evaluate the effect of organic manure (FYM, vermicompost and press mud) and biofertilizers (*Azotobacter*, PSB and *Azospirillum*) and result revealed that the combination of VC and PSB showed highest plant height (23.6 cm), leaves plant⁻¹ (12.7).

2.1.2.3. Poultry Manure (PM)

Poultry Manure is used as a nutrient source and soil amendment. The droppings of chicken have been found to be considered as a store house of nutrients. Fresh PM contains twice as much N and 3-4 times more P as in FYM. Dry form of PM contains more quantities of N and P than the fresh form therefore, aged PM is more preferable.

Application of chicken manure to grape fruit trees in Israel, resulted in significantly higher yields, improved fruit color, reduced rind thickness and increased juice per centage but decreased citric acid and ascorbic acid contents (Bar-Akiva *et al.*, 1968). PM contains 69 per cent of its N as uric acid, 30 per cent as more stable organic form and less than 1 per cent as mineral N. The beneficial effect is due to the presence of N in the form of uric acid, which changes quickly into ammoniacal form, thus making it readily available to the plants.

According to Garg *et al.* (1971), PM contain growth promoting hormones that produce better root growth than chemical fertilizers. Akande and Adediran (2004) observed significantly higher tomato and dry matter yield as well as uptake of N, P, K, Ca and Mg with the application of PM @ 5 t ha⁻¹.

Nowshheen *et al.* (2006) studied the effect of integrated nutrient management in strawberry and observed that combined application of PM, *Azotobacter*, wood ash, phosphorus solubilizing bacteria and oil cake recorded the highest values of plant height and plant spread. Khunte *et al.* (2014) recorded maximum fruit yield in plants treated with PM and cycocel in strawberry cv. Chandler.

Sharma *et al.* (2016) noticed that maximum amount of N (1.78%) and P content (0.28%) in leaves after fruit harvest was recorded from the trees receiving 50% N as PM + 50% N as urea amplified with *Azotobacter* while, the amount of N content in leaves was found minimum (1.56%) in control. Furthermore, guava trees had maximum yield of 42.9 kg tree⁻¹ under treatment of 50% N through PM + 50% N through urea augmented with *Azotobacter* while the lowest yield (18.9 kg tree⁻¹) was obtained under control. This increase in yield might be due to contribution of PM and *Azotobacter* on more C:N ratio and more uptake of nutrients that may result to better metabolic activities which finally lead to high protein and carbohydrate synthesis. Narayan *et al.* (2016) recorded significantly higher fruit yield of peach with a combination of FYM @ 30 kg + VC @ 10 kg + PM @ 2.5 kg + neem cake @ 3 kg per tree.

Three years pooled data of an experiment conducted by Marathe *et al.* (2017) showed that the highest P, K and Fe contents in the leaves of pomegranate were supplied by PM. Maximum fruit yield was obtained with the application of PM followed by FYM.

2.1.3. Subash Palekar's Natural Farming System

Jeevaamrit (JA) is a fermented microbial culture prepared from locally available natural resources like *desi* cow dung, cow urine, pulse flour, water, jaggery and soil. JA is applied to the soils or plants at different stages of their growth. It acts as a catalytic agent, promoting microorganism and earthworm activity in the soil (Palekar, 2006). Aerobic and anaerobic bacteria present in the cow dung and urine multiply after eating organic ingredients (like pulse flour) during fermentation process of two days. A handful of undisturbed nearby bund soil is also added that act as an inoculate of native species of microbes and organisms. The conventional chemical farming practices kill both useful and harmful life forms indiscriminately result in the malfunctioning of food chain.

Jeevaamrit as foliar sprays were proved quite effective in enhancing the productivity of different crops and controlling various plant pathogens (Chadha *et al.*, 2012). Pawar *et al.* (2013) observed that application of FYM @ 5 t ha⁻¹ + VC @ 2.5 t ha⁻¹ + *Jeevaamrit* two times application (30 and 45 days after sowing) to *kharif* sweet corn recorded significantly higher sweet corn cob as well as green fodder yield. Microbial count of bacteria, fungi and virus was significantly increased with the application of FYM @ 5 t ha⁻¹ + VC @ 2.5 t ha⁻¹ + *Jeevaamrit* two times (30 and 45 days after sowing) which was found at par with FYM @ 5 t ha⁻¹ + VC @ 2.5 t ha⁻¹ as compared with rest of the treatments.

Shwetha (2008) in soybean and Kumar *et al.* (2011) in black gram reported higher pods per plant, number of seed per pod and test weight with the use of *beejamrut*, *jeevaamrit* and *panchgavya* as organic source of nutrient.

Higher yield of capsicum was recorded with *jeevaamrit* (32, 40, 52, 121, 100, 86 and 50 q ha⁻¹ at 60, 70, 80, 90, 100, 110 and 120 days after transplanting, respectively) while, lower number of plants were observed in without *jeevaamrit* (27, 33, 39, 104, 84, 77, 42 q ha⁻¹ at 60, 70, 80, 90, 100, 110 and 120 days after transplanting, respectively) application (Boraiah *et al.*, 2017).

According to Patel *et al.* (2018), foliar spray of *panchgavya* @ 4 % + soil application of *jeevaamrit* @ 500 l ha⁻¹ recorded significantly higher pod yield (1563 kg ha⁻¹) of *kharif* groundnut (*Arachis hypogaea* L.) than rest of the treatments being at par with treatments viz. application of 100% RDN through FYM i.e. control and *Panchgavya* @ 2% foliar spray + *jeevaamrit* @ 500 l ha⁻¹ as soil application to the crop.

2.2. EFFECT OF APPLICATION OF DIFFERENT NUTRIENT SOURCES ON FRUIT QUALITY

Fruit quality is mainly judged by appearance comprising color, size and secondly by texture, total soluble solids (TSS) content and/or titratable acidity, sugars, etc. These parameters may supply important information to the consumers in recognizing a more nutritional fruit (Drogoudi *et al.*, 2008).

The effect of chemical fertilizers, FYM, VC, PM and liquid organic manures on fruit quality of different crops have been reviewed under the following subheads:

2.2.1. Chemical Fertilizer Based System

According to Abha *et al.* (1997), titratable acid content of Perlette increased by different levels of N applications. According to Okamoto *et al.*, (2003), total soluble solids (TSS) in grape berries may reduce with high level of N application. Application of N significantly reduced the TSS in accordance with the previous studies (Okamoto *et al.*, 1991; Hirano *et al.*, 2002).

In contrast, Ergenoglu *et al.* (1988) and Peacock *et al.* (1989) reported that increasing N doses had slight effect on acidity. Huchche *et al.* (1998) observed that there was no adverse effect of chemical N on physico-chemical properties of fruits. Furthermore, storage of fruits at 20-28°C, 50-70% RH for 12 days and at 5–6°C, 85–90% RH for 80 days revealed that there was no adverse effect of chemical N fertilizer supplemented with P, K and FYM on weight loss and decay (%) in Nagpur mandarin. In another study, Amiri and Fallahi (2007) who aimed to investigate the effects of various macro and micronutrients on grape quality reported that acidity of grape juice was not affected by nutritional matters.

Sharma (2016) recorded that the acidity of apple ‘Royal Delicious’ under cold desert condition of HP was found maximum while TSS, reducing and total sugars were recorded lowest with spray of 0.5% urea. The best treatment in terms of fruit set, yield and quality parameters of apple comprised of boric acid (0.1%) + urea (0.5%) followed by boric acid at 0.1% concentration alone.

The TSS of apricot fruits were recorded highest under urea 100% + lime @ 708 g tree⁻¹ treatment in a study conducted at Nauni, Solan, HP by Mohit *et al.* (2017). According to them, the results may possibly be attributed to more efficient N absorption which consequently resulted into more luxuriant vegetative growth at the cost of translocation of metabolites to the developing fruits. A noticeable increase in titratable acidity was also recorded with N application, which might be due to more synthesis of amino acids, proteins and other metabolites and their subsequent translocation to the fruits. Fruit weight of the apricot fruits were also significantly improved by application of calcium nitrate at the rate of 100 per cent.

2.2.2. Organic Farming Based System

Organic farming practices affect nutritional quality of fresh produce by providing a high contribution of exogenic organic matter and nutrients for a long period in contrast to conventional farming systems where highly concentrated nutrients are directly available to the roots in a shorter time period. The cultural practices may result in different plant composition

and nutritional quality, which further influence storage performance of the products. These differences in fertility affect the allocation of secondary plant metabolites such as ascorbic acid and phenolic compounds (Ceglie *et al.*, 2016).

All fruits produced organically had significantly higher TSS and lower titratable acidity in comparison to the conventionally produced fruits (Turemis, 2002 and Cayuela *et al.*, 1997). Organically grown strawberries had significantly higher TSS (7.1%) and lower titratable acidity content (0.93%) in comparison to the conventionally grown strawberries that had 6.6% TSS and 0.99% titratable acidity, respectively.

Application of animal manure improved bell pepper fruit taste by enhancing the percentage of TSS and decreased the percentage of titratable acidity in bell pepper fruit (Abu-Zahra *et al.*, 2013).

The effect of FYM, VC and PM on fruit quality have been reviewed in the following subheads:

2.2.2.1. Farm yard manure

Ravishankar and Karunakaran (2008) found that the application of FYM (20 kg plant⁻¹ year⁻¹) resulted in maximum TSS, ascorbic acid and total sugars in papaya. Trivedi *et al.* (2012) recorded the maximum fruit yield with application of VC followed by FYM in guava. Ghosh *et al.* (2012) studied integrated nutrient management in pomegranate and reported highest yield, fruit weight, TSS, reducing sugar and vitamin C content with FYM @ 20 kg along with N: P: K (400:100:300 g year⁻¹).

Sharma *et al.* (2013) reported maximum fruit length, fruit breadth and fruit weight in guava plants applied with 25 per cent of N through FYM + 75 per cent of N through inorganic fertilizers. Kumar *et al.* (2019) noticed maximum TSS, TSS/acid ratio, total sugars, reducing sugars and minimum titratable acidity in apricot (*Prunus armeniaca*) with the application of 50 per cent N (through calcium nitrate) + 50 per cent N (through urea) + *Azotobacter* + PSB + FYM under mid hill conditions of HP.

2.2.2.2. Vermicompost

Geetha and Nair (2000) reported that sole application of VC recorded significant increase in bunch weight, number of hands/bunches, number of fingers per bunch and fruit weight in banana. Patil *et al.* (2005) recorded maximum TSS in mango 'Amrapali' with application VC along with FYM. Highest ascorbic acid content with the VC application has been recorded in *amla* (Korwar *et al.*, 2006).

According to Ramamurthy (2006), application of VC recorded significantly higher TSS content in Nagpur mandarin (*Citrus reticulata*). The amendments such as VC significantly improved chemical fruit quality parameters such as L-ascorbic, glucose and fructose in guava (Zaller, 2007).

Naik and Babu (2007) noticed significant increase in leaf N (1.4%), P (0.46%) and K (1.17%) content in guava with the application of VC @ 15 kg per plant. Singh *et al.* (2008) reported that VC application at 5 to 10 t ha⁻¹ increased TSS and juice content in strawberry due to regulated nutrient supply to the plants. Highest TSS content was also recorded by Ray *et al.* (2008) with the VC application @ 10 kg per plant in papaya. The treatments combination of VC and PSB significantly affected the TSS (10.75 °B), titratable acidity (0.82%) and vitamin C (57.2 mg/100g fruit) content.

The importance of VC in improving growth of fruit crops such as mango, sapota, guava and banana is well recognized by several workers (Athani *et al.*, 2009) and attributed to release of higher amount of nutrients as well as growth stimulating substances excreted by earthworms in their casts.

Kirad *et al.* (2010) reported that TSS and vitamin A contents in papaya were significantly increased with sole application of VC @ 15 kg per tree. Singh *et al.* (2010) reported that strawberry fruits harvested from plants receiving VC had significantly better TSS, ascorbic acid and had lower acidity than those harvested from plants receiving inorganic fertilizers only. Ghosh *et al.* (2014) investigated that VC applied @ 20 kg tree⁻¹ resulted in maximum plant growth in sweet orange.

Kumar *et al.* (2017) reported that the application of 100% NPK+10 kg VC plant⁻¹ along with biofertilizer inoculation significantly increased fruit set (59.4%), fruit tree⁻¹ (97), fruit weight (236 g), TSS (12°Brix), fruit yield (22.9 kg tree⁻¹), leaf N (2.95%), P (0.52%) and K (1.54%). They concluded that the higher growth attributes might have increased interception, absorption of radiant energy which in turn increased overall growth, fruiting and leaf nutrient status.

2.2.2.3. Poultry Manure

Huang *et al.* (1995) found that PM improved the fruit quality of satsuma mandarin and gave better results than pig manure in China. Mustaffa *et al.* (2003) demonstrated that organic manure applications *i.e.* distillery sludge @ 2.5 kg + VC @ 1 kg + neem cake @ 1 kg + PM @

2 kg plant⁻¹ significantly increased the bunch weight, number of hands, total number of fingers, finger length and girth besides enhancing fruit quality parameters in *karpuravalli* banana.

In an experiment conducted by Hassan *et al.* (2015) on effect of organic and bio-fertilization on yield and quality of olives, they concluded that PM + bio-fertilizer (@ 2 liters tree⁻¹) was the best treatment to increase flowering density, sex expression and pollen grains germination followed by improved fruit set and fruit quality.

The maximum K content in guava fruit (0.97%) was recorded in treatment that received 75% N as PM + 25% as urea along with *Azotobacter* (Sharma *et al.*, 2016). They further noticed the highest increase in total, reducing and non-reducing sugars (8.68, 4.90 and 3.59%, respectively), from guava fruits harvested from trees receiving 75% N through PM + 25% N through urea augmented with *Azotobacter* as compared to control (7.10, 4.24 and 2.72%, respectively). The authors further observed maximum fruit Mg (0.71%) content, maximum fruit length (8.5 cm) and fruit diameter (8.0 cm) with the treatment comprising 50% N through PM + 50% through urea augmented with *Azotobacter*.

2.2.3. Subash Palekar's Natural Farming System

Bhat *et al.* (2017) studied the effect of different organic formulations with different doses viz., FYM, VC, cow urine, vermiwash, nutrisol and noted a significant effect on post-harvest quality of fruits of litchi. Further they reported that application of FYM @ 100 kg per tree + VC @ 50 kg per tree + 10% cow urine per tree + 10% vermiwash per tree + nutrisol 2.5 ml per liter resulted in maximum fruit set, fruit retention, fruit yield, minimum fruit cracking and fruit drop in litchi.

Brar *et al.* (2020) concluded that the treatment comprising of 90 per cent of RDN applied through PM and VC (50:50 basis) + plant growth promoting rhizobacteria + folk liquid manures (*Panchagavya*, *Jeevaamrit*, *Amritpani*) @ 5% concentration) recorded significantly highest (4.61%) total N, P (0.60%) and K (4.0%) content in capsicum fruit.

In a study conducted by Solanki *et al.* (2020), on the effect of integrated nutrient management on fruit quality of peach (*Prunus persica*) in HP, they observed the minimum fruit length (57.2 mm) was observed in peach trees treated with four applications of *Jeevaamrit*, which was statistically at par with 75% recommended dose of fertilizers (RDF) + neem cake @ 2.5 kg per tree, 75% RDF + *Jeevaamrit*, 50% RDF + *Jeevaamrit* and 25% RDF + wild apricot cake 1.25 kg + neem cake 1.25 kg + VC 15 kg + *Jeevaamrit* and maximum fruit length (64.1 mm) was recorded in trees treated with 75% RDF + VC 15 kg per tree. Other fruit

parameters like fruit breadth (56.4 mm), fruit weight (96.3 g), fruit volume (97.9 cc) was also followed the same trend in the study. Similarly, the lowest TSS content (10.9 °B) was found in treatment 25% RDF + wild apricot cake @ 1.25 kg + neem cake @ 1.25 kg + VC @ 15 kg + *Jeevaamrit* and lowest titratable acidity (0.50%) was exhibited by the fruits received four application of *jeevaamrit*. Finally, they concluded that treatment comprising 75% RDF + VC 15 kg per tree was found to be the most effective combination of organic and inorganic fertilizers for peach under mid-hill conditions of HP.

In another experiment conducted by Maher *et al.* (2020) on effect of different soilless substrates and *jeevaamrit* on fruiting behavior of strawberry ‘Chandler’ in HP. They noticed highest TSS (11.15°B) in berries grown under perlite (75%) + cocopeat (25%) + *jeevaamrit* @ 5 per cent treatment which was statistically different from all other treatments. The positive effect could be attributed to better nutrient availability of the growing media.

2.3. CHANGES IN SOIL PHYSICAL PROPERTIES AS AFFECTED BY DIFFERENT FARMING SYSTEMS

2.3.1. Chemical Fertilizer Based System

Application of chemical fertilizers might affect soil physical properties like aggregate stability, porosity, water holding capacity, infiltration rate, hydraulic conductivity and bulk density, directly or indirectly due to improvement in soil organic matter and soil organic carbon content (Haynes and Naidu, 1998). Also, additions of fertilizers further liable for dispersion/flocculation of clay particles and thus, affects the soil aggregation stability. The soil organic matter components such as humic molecules and polysaccharides increased aggregate stability by binding mineral particles into aggregates and reduced their susceptibility to erosion by wind or water (Tisdall and Oades, 1982). In turn, formation of stable aggregates enhances physical protection of soil organic matter against microbial decomposition (Six *et al.*, 1998).

The effects of chemical fertilizers on soil are great and irreversible (Sonmez and Sonmez, 2007). An excessive use of chemical fertilizers can lead to soil acidification and formation of soil crust thereby reducing organic matter content, humus content, beneficial organisms, stunted plant growth. The soil acidity reduces phosphate intake by crops, increases the toxic ion concentration in the soil and inhibits crop growth (Cooke, 1982). Sandy soils are much more affected by soil acidification than clayey soils as the later has a capability to buffer the effects of excess chemical fertilization. Fertilizer application without the using soil testing

recommendation can lead to implications such as soil degradation, nutrient imbalance, destruction of soil structure, increasing bulk density.

A continuous dependence or application on chemical fertilizers may result in drop of organic matter content, higher soil acidity, degradation of soil physical properties and increased rate of erosion due to instability of soil aggregates (Adeoluwa and Adeogun, 2010; Olowoake and Adeoye, 2010). Bandyopadhyay *et al.* (2010) reported that conjunctive use of recommended dose of fertilizer and FYM resulted in significant decrease of bulk density of soils under soybean cultivation.

Massah and Azadegan (2016) concluded that an excessive use of chemical fertilizers every year causes formation and concentration of mineral salts of fertilizers leading to formation of compact layer and higher bulk density, high penetration resistance which in return decreases plants-absorbable nutrients.

2.3.2. Organic Farming Based System

Studies conducted in the last three decades have shown that physical fractionation methods which partition SOM based on size and degree of physical protection with aggregates and formation of organo-mineral complexes provide a useful tool for the study of functions and turnover of SOM in soil (Benbi and Senapati, 2010 and Benbi *et al.*, 2012).

Rahman *et al.* (2011) conducted a trial on the soil properties and kiwifruit quality in *Actinidia deliciosa* ‘Hayward’ and *Actinidia chinensis* ‘Hort16A’. They reported highest soil bulk density, water-holding capacity, gravitational drainage, and hygroscopic moisture in ‘Hayward’ in both biological as well as conventional management systems.

Khachi *et al.* (2015) studied the comparative efficacy of bio-organic nutrients on cropping behavior of kiwifruit using FYM, VC, biofertilizers, green manure and vermiwash. Among various treatments, the combination of FYM @ 15 kg per vine, green manure, VC @ 15 kg per vine, bio-fertilizers @ 50 g per vine and vermi-wash @ 2 kg per vine significantly improved the cropping behavior. The same treatment also resulted in higher amounts of leaf nutrients which might have contributed to better productivity and nutrient profile for sustainable kiwifruit production.

2.3.2.1. Farm yard manure

Prasad and Sinha (1980) revealed that organic inputs like FYM increase water holding capacity of soil. Bhatia and Shukla (1982) also reported that continuous application of FYM

for five years improved the physical condition of eroded alluvial soil resulting in the higher crop yield.

Chauhan *et al.* (1984) concluded that intermittent application of FYM improve the soil tilth and water infiltration. They found that citrus orchards receiving only FYM for a continuous period of several years were found to be in declining condition with poor yield in Haryana.

Shinde (1997) studied the effect of FYM and VC soil properties and reported that application of 100 per cent recommended dose through FYM and VC decreased the bulk density and increased the pore space and volume of soil over control at MPKV, Rahuri (Maharashtra). Singh *et al.* (2000) reported that application of FYM significantly brought down the bulk density of both surface and sub surface soil in comparison with the control.

2.3.2.2. Vermicompost

Application of VC reduced the bulk density, increase the water holding capacity by 366%, maximum organic C and higher pore space (Kannan *et al.*, 2005) in soil. Naik and Babu (2007) reported that as SOC has increased bulk density, decrease electrical conductivity beside maintaining the soil pH to near neutral through the VC application in guava.

The use of VC leads to total improvement in the physical (soil porosity and water holding capacity), chemical (pH and essential plant nutrients) and biological (beneficial soil microorganisms) quality of soil than the conventional compost (Suhane, 2007).

VC increases soil structural stability consequently reducing the susceptibility of soil erosion as reported by Tejada *et al.* (2009) who applied beet vinasse, VC and compost in soil vulnerable to erosion. Also, VC application increases aggregate stability in all aggregate size fractions by diminishing large aggregate formation in soil. Sari and Angin (2016) suggested that organic matter application may have caused changes in the exchange complex that resulted in breakdown of larger fractions of aggregates.

Sudhakar *et al.* (2002) reported that earthworm casts were considered to be responsible for better soil structure and improved the soil physical properties like infiltration, water retention and resistance to erosion.

Application of VC reduced soil bulk density in comparison to FYM and chemical fertilizer due to increasing concentration of organic matter which in turn decreases bulk density (Uz *et al.*, 2016).

2.3.2.3. Poultry Manure

Aluko and Oyedele (2005) observed that PM incorporation had no significant effect on soil bulk density and soil porosity of Nigerian Alfisols. Furthermore, improvement in soil moisture linked with PM is attributable to mulching effect of organic matter and improved moisture retention and water acceptance as a result of improved soil structure and macro porosity.

Adesodun *et al.* (2005) noticed that application of PM to soil increased soil organic matter, N and P and aggregate stability. The improvement in soil physical properties is due to the increase in soil organic matter content.

High negative correlation coefficients were recorded between PM and bulk density of soil (-0.99) while high positive correlation (+0.99) was recorded between PM and soil total porosity, and between PM and soil moisture content (Ojeniyi *et al.*, 2013).

2.3.3. Subash Palekar Natural Farming system

Shaikh and Ganchande (2013) reported that the application of organic inputs like FYM, *Beejamrit* and *Jeevaamrit* significantly improved the physicochemical properties of the soil which resulted in an increase of soil fertility for sustainable development.

Laharia *et al.* (2013) informed lower bulk density and significantly increased hydraulic conductivity, mean weight diameter and available water capacity with application of 100% recommended dose of nitrogen through vermicompost + *Jeevaamrit* (30 and 45 DAS) in soil after harvest of soybean as compared to other treatments.

2.4. CHANGES IN SOIL CHEMICAL PROPERTIES AS AFFECTED BY DIFFERENT FARMING SYSTEMS

2.4.1 Chemical Fertilizers Based System

Fertilizers are usually applied to soil for obtaining good crop yields which further meet the increasing demand of food. As reported by Hati *et al.* (2007) the application of inorganic fertilizers results in more soil organic matter buildup and organic activity due to increased plant biomass production and organic matter returns to soil in the form of decaying roots, litter and crop residues.

Many experiments have been conducted on the relationship between fertilization and soil pH (Zhang *et al.*, 2009). Some studies demonstrated that with different fertilizer treatments, the soil pH decreased to a certain extent (Wang *et al.*, 2010).

According to Dong *et al.* (2012), the soil pH tended to drop in different treatments with time and the decline rate in the NPK and OM treatments were relatively lower than control (no fertilizer), but producing higher pH values in the NPK and OM treatments than in the control, which suggested that chemical fertilizer and organic manure could alleviate soil acidification to some extent. It has also been reported that the application of alkaline fertilizer (e.g. calcium magnesium phosphate fertilizer) would return some alkaline substance to soils and thus increase the soil pH (Wu *et al.*, 2008).

Since a too high or too low pH of soil is harmful to the crop growth, it might be a practicable measure to create the proper range of soil pH through fertilizer use. Vidyavathi *et al.* (2011) reported that continuous chemical nutrient management practices greatly lower the fertility of soil. The results from the study conducted by Brar *et al.* (2015) that soil pH was significantly reduced to 7.25 with 150% NPK application compared to 50% NPK treatment. Furthermore, no significant reduction in pH was observed with increase in fertilizer rate from 50% NPK to 100% NPK application.

As per Benbi and Brar (2009) reported that use of urea fertilizer and build-up of organic matter might have resulted in decrease in soil pH which has positive impacts on availability of nutrients such as P, Zn, Fe and Mn. Han *et al.* (2016) conducted an experiment on yellow poplar (*Liriodendron tulipifera* Lin.) and noticed that soil N content increased by 17% with organic manure treatment while soil N content was similar to that of the control group after NPK fertilizer treatment.

2.4.2. Organic Farming Based System

Reddy and Reddy (1998) conducted an experiment at Rajendra Nagar (Andhra Pradesh) and reported that use of organic manures would not only improved soil health but also helped to sustain crop productivity of maize-soybean cropping sequence. Addition of soil organic matter increases soil organic carbon content, which is an important indicator of soil quality and crop productivity (Lal, 2003).

Kaur *et al.* (2005) compared the use of chemical fertilizer and combined application of chemical fertilizer and organic manure in sorghum (*Pennisetum glaucum*) and wheat (*Triticum*

aestivum) rotation and found that organic manure increased the soil organic carbon, N, P and K, thus highlighting its importance in tropical farmland, which lacks organic matter.

Rao *et al.* (2013) observed that the dynamics of various soil fertility parameters viz., soil organic carbon, available N, P and K and found built up of these parameters to a substantial extent with the use of organic manures to maize and sunflower crops, while the application of fertilizer only could only maintain the soil fertility status with neither considerable replenishment nor deterioration. Furthermore, the balance sheet of soil available N, P and K, the highest positive balance of soil available N was found associated with neem leaf manure, and that of P associated with PM while that of K was with VC.

The results of the study conducted by Han *et al.* (2016) shown that organic manure treatment increased soil pH, but chemical NPK fertilizer treatments decreased soil pH (Whalen *et al.*, 2000; Liu *et al.*, 2010a). The decrease of soil pH by NPK fertilizer may be explained by leaching of basic cations, such as K, Ca and Mg from the soil.

The application of organic manure could improve soil acidity by increasing the soil organic matter, improving the soil structure and enhancing the soil base saturation percentage, which is in accordance with Zhang *et al.* (2009) and Li *et al.* (2010). Moreover, studies showed that the soil pH in control was lower than the initial value, which indicated that the acid deposition could have a great influence on the soil acidification in this trial region (Liu *et al.*, 2010b).

The effect of different types of organic inputs have been reviewed under the following subheads:

2.4.2.1 Farm yard manure

Singh *et al.* (1980) reported that continuous applications of FYM to the soil in the semi-arid region of Haryana have resulted in lowering of soil pH and increased organic carbon content, cation exchange capacity and exchangeable cations. Renuka (1998) reported that low soil EC (0.15 d S m^{-1}) was obtained with the combined application of FYM and neem cake than with the application of inorganic fertilizers.

Mahajan *et al.* (1989) noted that application of FYM reduced EC of soil from 9.2 to 1.93 per cent, exchangeable sodium from 23.4 to 4.8 per cent. In contrast, Patil (1993) conducted an incubation study and reported that the application of FYM resulted into significant increase in EC, organic carbon and it was found to be most effective in building up the soil organic matter.

Shinde and Gawade (1992) conducted an incubation laboratory experiment for a period of 60 days to study the effect of FYM application @ 20 t ha⁻¹ on chemical properties of soil and reported increase in pH, EC, available N and exchangeable K. The availability of Fe, Cu and Zn was significantly higher in FYM treatments as compared to all commercial manures except processed city waste (Prakash *et al.*, 2002).

Bonde *et al.* (2004) conducted cotton + soybean intercropping system trial at MKV, Parbhani (Maharashtra) and reported that application of FYM @ 5 t ha⁻¹ recorded higher values for N, P and K availability in soil as compared to control. The initial pH of 6.6 was increased significantly to 7.6 in the soil which received FYM @ 4 t ha⁻¹ (Balaguruvaith *et al.*, 2005).

Ghuman and Sur (2006) observed a significant decrease in soil pH and EC with the application of FYM. Narwal *et al.* (2010) reported that increasing level of FYM from 0 to 45 Mg/ha increased the fraction of both Zn and Cu in surface (0-15 cm) and subsurface (15-30 cm) soil layers.

Aulakh *et al.* (2010) reported significant improvement in water stable aggregation and proportion of macro aggregates, SOC content, labile C and N fractions such as water-soluble C, particulate and light fraction organic matter, potentially mineralizable N and microbial biomass with the application of 10 t FYM ha⁻¹ along with recommended rate of NP to soybean crop.

Rahman *et al.* (2011) conducted a trial on the soil properties and kiwifruit quality in *Actinidia deliciosa* 'Hayward' and *A. chinensis* 'Hort16A' and reported that variations in soil properties for pH, N, P, K, Ca, Mg, Na and Al were linked to management practices whereas, EC, OM, Fe, Mn, Zn, Cu and B were linked to the cultural practices. The Ca/Mg ratio of the orchards was more than 7:1, and the Mg/K ratio was less than 2:1, suggesting the application of dolomitic limestone over high-Ca containing liming materials.

2.4.2.2. Vermicompost

Vermicompost protects the environment and soil health. The soil pH is neutralized by buffering action and thereby, mineral and trace elements are made available more easily to the crops. The increase in yield of crops by the application of VC may be attributed to the higher nutrient content, humus forming microbes, N fixers and micronutrients. Certain metabolites produced by earthworms may be responsible for stimulating the plant growth. Water holding capacity and aeration of soil can be increased by regular application of VC to the soil.

A field experiment was conducted to study the effect of VC on soil properties and showed that the pH of the soil in combination with lime and worms remained near neutral because of earthworm activities (Springett, 1983).

VC extract increased the pH level of an acid soil by reducing aluminum toxicity and relatively high proportion of humic substance in VC which might have formed the stable complexes to cause the increase in soil pH (Alter and Mitchell, 1992). Bhawalkar (1995) reported that application of VC showed marked improvement in the soil productivity within year. VC applied plot had 37 per cent more N, 65 per cent more P_2O_5 , 10 per cent more K_2O , 50 per cent less EC and 46 per cent less chlorides over the chemical fertilizer applied plot.

Similarly, VC has been demonstrated to act as valuable soil amendments that offer a balanced nutritional release pattern to plants, providing nutrients such as available N, soluble K, exchangeable Ca, Mg, and P that can be taken up readily by plants (Edwards, 1998) besides being a source of several micronutrients.

Hapse (1993) noticed that application of VC increased the SOC content of the soil by 0.27 per cent as compared to application of chemical fertilizers alone. Srikanth *et al.* (2000) observed slight decrease in soil pH and EC with the application of VC. This may be due to the production of organic acids during the course of decomposition of organic amendments.

Slight increase in soil pH has been observed by Verma and Bharadwaj (2005) with the application of VC in apple. Hebbara *et al.* (2006) revealed that organic carbon content ranged from 0.64 to 0.78 per cent in VC applied treatments in sapota orchard.

Similarly, Gathela *et al.* (2007) noticed that plots which received VC @ 10 t ha⁻¹ significantly improve the organic carbon and cation exchange capacity. Naik and Babu (2007) reported that available N, P and K contents of soil were significantly higher with the application of VC to guava plants. EC increases with VC application (Gutiérrez-Miceli *et al.*, 2007). It helps to prevent toxicity due to saline water and somewhat enhances plant growth. According to Azarmi *et al.* (2008) addition of VC @ 15 t/ha significantly increased the contents of total organic carbon, N, P and K compared with control plots.

Sinha *et al.* (2010) showed that content of K increased from 62.5 to 800 kg ha⁻¹ when grapes were fertilized with VC @ 5 t ha⁻¹. Ravishankar *et al.* (2010) concluded that soil analysis after 3 years of experiment showed a significant effect on the status of available K and P contents of the soil when papaya plants were fertilized with VC @ 13.5 kg/plant. Tabasum *et al.* (2010) reported that significant increase in organic carbon 5.2 g kg⁻¹ was recorded after VC application.

As per the findings of Demir (2019) application of 5% of VC treatments yielded greater organic matter contents in soils of Ankara, Turkey as compared with control treatments without VC. The highest organic matter content of 2.19% was observed in 5% VC- treatment of the full irrigation level treatment and the lowest organic matter content of 0.19% was obtained from the control treatment (without VC).

2.4.2.3. Poultry Manure

Das *et al.* (1991) observed the reduction trend of pH in case of low organic matter status soil, treated with higher dose of either PM or pig manure. According to Huang *et al.*, (1995) PM has a better C:N ratio compared to FYM and has high concentration of P (1.21%) which might increase the availability of the native soil P to the plants and resulted in improved the fruit eating quality.

The fertility status of the soil is expected to benefit from PM application since the manure is known to improve SOM and macro-nutrient status and micro nutrient qualities of the soil (Adeniyi and Ojeniyi, 2003; Akande and Adediran, 2004). The correct application of PM in agricultural land is a viable way to recycle the nutrients such as N, P and K in manure (Kaiser *et al.*, 2009). However, pollution and nuisance problems can occur when manure is applied under unfavorable environmental conditions for utilization of the manure-borne nutrients. Further, the continued productivity, profitability and sustainability of the poultry industry will depend on the formulation of best management practices to mitigate environmental consequences associated with air and water quality parameters. These practices should develop a cost-effective innovative technology that provide an alternative to poultry wastes in land applications (Szogi and Vanotti, 2009).

A build-up of N in soil with different N sources and levels combined with bio-fertilizers increases the P, Ca and Mg (Gogoi *et al.*, 2004) thereby found an increased available nutrient in soil after fruit harvest due to the application of *Azotobacter* and PM. The evidences that PM increases the organic carbon, available N, P, K, Ca and Mg in soil are reported by Albregts and Howard (1981).

The study conducted by Sharma *et al.* (2016) showed that the soil available N was maximum (271 kg ha⁻¹) with the treatment comprising 50% N through PM + 50% N as urea augmented with *Azotobacter* while, the lowest available N (231 kg ha⁻¹) was recorded under control plots. Similarly, the results on available P in soil after fruit harvest showed that with the application of 50% N in the form of PM + 50% of N as urea augmented with *Azotobacter*

recorded maximum P (19.9 kg ha^{-1}) and the lowest (13.1 kg ha^{-1}) was recorded under control. Similar results on maximum soil available Ca ($7.1 \text{ m eq per } 100 \text{ g soil}$) and Mg ($2.8 \text{ m eq per } 100 \text{ g soil}$) were recorded with the application of 50% N through PM + 50% N as urea augmented with *Azotobacter*. PM significantly improved nutrient status such as increases in organic C, available P, exchangeable cations, and ECEC of soils under soybean (Soremi *et al.*, 2017).

2.4.3. Subash Palekar's Natural Farming System

Yadav and Mowade (2004) suggested to adopt organic farming which completely exclude synthetic fertilizers as cultivation of land with the use of organic fertilizers keep the soil fertile. Organic fertilizers like FYM, VC, beneficial microbes and liquid organic inputs (formulations) in the form of *Panchagavya*, *Dasagavya*, *Beejamruth*, *Jeevaamrit*, *Amritpani* and *Sanjivak* which add nutrients into the soil for increased sustainable crop production.

Jeevamrit when applied in acidic soil increases soil pH and in alkaline soil it decreases soil pH, thus creating favorable condition for availability of maximum nutrients to plants. This condition increases the crop yield and cuts down an entire expense of chemical fertilizer (Kulkarni and Gargelwar, 2019).

Significantly higher available nitrogen (442 kg ha^{-1}) was recorded under treatment having 90% recommended dose of N through with PGPR and also liquid organic inputs (*panchagavya*, *jeevamrut* and *amritpani*) @ 5% followed by treatment receiving 80% RDN along with PGPR and organic liquids @ 5% and significantly higher value of N that 100% recommended dose of nutrients alone (Brar *et al.*, 2020).

2.5. CHANGES IN SOIL BIOLOGICAL PROPERTIES AS AFFECTED BY DIFFERENT FARMING SYSTEMS

2.5.1 Chemical Fertilizers Based System

High level of N application in the form of ammonia fertilizers like urea, DAP increased the toxicity of ammonia to the bacterial population. In chemical fertilizer treatment, urea inhibits the activity of many of the soil flora and fauna, including nitrifying bacteria and earthworms. Moreover, higher concentration of exchangeable and soluble Al^{3+} ion under the chemical fertilizer treatment might have created a deleterious impact of soil acidity on microorganisms, which in turn reduced the microbial population under the chemical fertilizer treatment (Brady and Weil, 2002).

Use of high dose of chemical fertilizers, restricts the activities of nitrogen fixing and nitrogen transforming microbes, phosphate solubilizing organisms. Nitrogen supplying fertilizers upon hydrolysis also produce ammonium, decrease soil pH and affecting activities of those microbes. However, inorganic fertilizers also facilitate high root biomass and easily decomposable rhizodeposition that support population of fungi, actinomycetes, and *r*-strategists population; oppositely with low biomass, minimal substrate flux of complex and insoluble organic substances facilitates slow growth of the *K*-strategists population of microbes (Cycon *et al.*, 2013). According to Han *et al.* (2016), NPK fertilizer treatment acidified the soil because the urea that was used by the plants as NH_4^+ first and then the H^+ was released into soil, which thereby decreased the soil pH (Magdof *et al.*, 1997). This process reduces most of the activities of bacteria and actinomycetes in the soil (Kaur *et al.*, 2005).

Fertilizer application to soil influences its microbial diversity through direct effects on the soil nutrient content and soil microbial communities which are sensitive to fertilization and their responses to manure in soils have been well calculated over the past several years (Fu *et al.*, 2017).

2.5.2. Organic Farming Based System

Hickisch and Muller (1990) studied the effect of various fertilizer regimes on soil organisms, CO_2 output, soil structure and carbon content in a long-term field experiment and found that FYM with fertilizer increased the number of bacteria and fungi as compared to control. Soil quality is highly sensitive to land management practices such as horticultural production (Springett *et al.*, 1994). Soil organic matter serves as a substrate for microorganisms that foster soil enzyme activities. A number of studies have advocated the use of enzyme activity as an index of soil quality and microbial activity (Alef and Nannipieri, 1995 and Melero *et al.*, 2006). According to Lal (1998), soil quality refers to a soil's ability to sustain productivity in terms of agricultural production.

Higher microbial pool sizes and greater microbial activity rates in organic versus conventional farm soils have also been reported by Mader *et al.* (1999) in a 14-year long-term comparison studies. They also reported a significantly greater soil microbial biomass C and enzyme activity in biodynamic and organically farmed soils compared with conventional farms using mineral fertilizers.

Santhy *et al.* (2002) conducted a long-term field experiment with finger millet-maize-cowpea cropping system in Tamil Nadu, India to assess the microbial population in a soil due

to various treatments and found that the bacterial and fungal population were higher in treatment where 100% NPK + FYM was applied as compared to 150% NPK application alone. They further observed that actinomycetal population did not vary significantly due to various treatments.

Jain *et al.* (2003) found that FYM application along with chemical fertilizer was much superior in maintaining the soil biological health as compared to chemical fertilizers alone. Sriramachandrashekhara and Ravichandaran (2003) observed that combine application of FYM and inorganic fertilizers recorded maximum activity of enzymes compared to inorganic fertilizers alone.

According to Richards *et al.* (2007) organic and other types of biological farming often increase the abundance and diversity of soil biota to facilitate uptake of nutrients by plants, maintaining soil fertility, controlling pathogens and pests and to support various ecosystem functions (water, nutrient retention and nitrogen fixation etc.). Ramesh and Rao (2009) also reported that soil health could be sustained with organic nutrition due to diversification of soil biota.

A field experiment was conducted by Deshpande and Murumkar (2007) during winter 2005-06 at Zonal Agricultural Research Station, Solapur (Maharashtra) to assess the effect of organics and tillage on microbial population. The results indicated that, at flowering stage mean population of total bacteria, total fungi, beneficial fungi, azotobacter and actinomycetes was highest in the treatment of conventional tillage with 100 per cent N through organics.

Using the activities of soil hydrolytic enzymes is a common approach for estimating soil quality (Gil-Sotres *et al.*, 2005). All enzymatic activities increased with increases in the application rates of the compost up to a threefold application rate but there was no significant difference between the threefold and the fourfold application rate (Chang *et al.*, 2007). This result indicates that no further increases take place in the enzyme activities examined when the soil organic matter content reaches a certain level.

The addition of organic amendments activates microorganisms to produce enzymes related to the nutrients cycles and the added material may contain intracellular and extracellular enzymes. The change in enzyme activities as a result of organic matter application and decomposition depends on the balance between nutrient energy supplied and demand (Burns *et al.*, 2013). Soil enzyme activities (Dehydrogenase, Cellulase and Xylanase) together with microbial biomass and clay content could predict differences in soil organic carbon between organic and conventionally managed fields, suggesting the need for using several indicators together for characterizing the organic and conventionally managed rice-wheat systems (Benbi

et al., 2018). Further, according to them organic production systems were characterized by higher microbial biomass carbon mineralizable C, enzyme activities and population of bacteria, fungi and actinomycetes in soil than the conventional system of management. The organic fertilizer treatments enhanced the abundance and diversity of bacteria and the relative abundances of various micro-organisms like *Nitrospira*, *Pseudomonas*, *Arthrobacter* and *Bacillus* in the rhizosphere soil as reported by Wu *et al.* (2020).

2.5.2.1. Farm yard manure

Soil enzyme activities are believed to indicate the extent of specific process and also act as an indicator of soil fertility. Dehydrogenases, a group of lignases involved in lignin degradation are primarily intracellular oxidative enzymes that transfer hydride groups from a substrate to an acceptor such as NAD^+ (Burns *et al.*, 2013). They play a key role in decomposition process, particularly for bacteria, which are the eventual consumers and decomposers of aromatic compounds (Burns *et al.*, 2013), a fact substantiated by the significant relationship between DHA activity and bacterial population. Apparently, DHA that showed great response to organic matter input may be used to figure out the effect of organic agriculture on microbial metabolism rates and biochemical activity of soils (Alef and Nannipieri, 1995).

Dehydrogenases (DHA) are often measured because they are constitutive and found only in living systems. DHA activity can be measured by various dyes for e.g. triphenyl tetrazolium chloride, which is colorless in the oxidized state but red in the reduced state (Paul and Clark, 1989). Phosphatase activity has been found to be a good indicator of the organic matter (Hattori, 1988). The term phosphatase has been used to describe a broad group of enzymes that catalyze the hydrolysis of both esters and anhydrides of orthophosphoric acid (Schmidt and Laskowski, 1961). Sharma *et al.* (1983) studied effect of continuous application of fertilizer, FYM and lime on microbial population of soil and reported that bacteria, actinomycetes, *azotobacter*, cellulose decomposers increased in soil treated with FYM application alone or in combination with fertilizers and lime.

Martens *et al.* (1992) reported that the enzyme activities in organic matter amended soil increased an average of two-fold to four-fold compared with unamended soil. They also observed that the addition of organic matter maintained high levels of phosphatase activity in soil during a long-term study. Soil DHA activity reflects the total range of oxidative activity of soil microflora and used as an indicator of microbial activity (Masciandaro *et al.*, 1994). The DHA of compost-treated soils was significantly higher than that of the chemically fertilized-

treated soil. Giuaquiani *et al.* (1994) reported that phosphatase activity increased when compost was added at rates up to 90 Mg ha⁻¹ and that the activity continued to show a linear increase with compost rates up to 270 Mg ha⁻¹ in a field experiment. Application of compost in addition to the incorporation of stable enzymes contained in the compost resulted in increase in soil organic matter content (Díaz-Marcote and Polo, 1995), favors the formation of complexes with free enzymes and, therefore, the soil enzyme activities rise.

Manna *et al.* (1996) reported that application of FYM @ 4 t ha⁻¹ significantly increased the microbial biomass in soybean-wheat cropping system. Among the organic sources, performance of FYM in stimulation of fungal growth was of higher order which was mainly attributed to dead food material available from FYM. Addition of organic matter significantly improved the *Azotobacter*, actinomycete population in soil (Tompe and More, 1996).

Simek *et al.* (1999) studied the effect of organic and inorganic fertilizers on soil microbial community size, activities of enzymes and found that dehydrogenase activity was lower in soils that had received the largest content of inorganic fertilizers alone as compared to the combined application of organic and inorganic fertilized soils. Marinari *et al.* (2000) reported that a higher level of DHA was observed in soil treated with VC and manure compost compared with soil treated with mineral fertilizer.

Manna and Ganguli (2001) observed low activity of phosphatase in the inorganic fertilizer applied treatments and also in control than combine application of FYM and N fertilizers. Santhy *et al.* (2002) found that phosphatase enzyme was higher in the treatment where 100% NPK + FYM was applied than the 150% NPK and control treatments while conducting a long-term fertilizer experiment to assess the microbial population and enzymatic activities in Tamil Nadu. Sriramachandrashekhara (2002) studied the effect of different levels of fertilizers on DHA activity under a maize-cowpea crop rotation and found that application of FYM along with recommended dose of fertilizers registered the highest DHA activity as compared to inorganic fertilizers alone and control. Dodor and Tabatabai (2003) found that higher phosphatase activity in soil resulted from higher organic C contents in the soils.

Parham *et al.* (2003) conducted long term experiment over 10 years and reported that cattle manure application promoted the growth of bacteria but not fungi when compared with the fungi control soils. In an experiment conducted by Chang *et al.* (2007), there was a significant linear correlation between soil organic matter content and phosphatase activity of the soils ($r = 0.993^{**}$ and $r = 0.964^{**}$ for acid and alkaline phosphatases, respectively). Ravishankar and Karunakaran (2008) found that different organic manure treatments gave significantly higher microbial population of bacteria, fungi and *Actinomycetes* coupled with

and enzymatic activities in soil. The application of FYM @ 20 kg/plant was found to be the best for improving soil quality.

Datt *et al.* (2013) reported that the biomass carbon content was highest under organic treatment followed by integrated nutrient management. The biomass carbon content decreased from 176 $\mu\text{g Cg}^{-1}$ in treatment receiving 10 t FYM + nitrogen fixer A+ phosphate solubilizer and chopped crop residues to 98 $\mu\text{g Cg}^{-1}$ in the control. The highest biomass carbon in organic treatments may be attributed to the fact that the build-up of organic carbon was more which might harbor more microbial population and ultimately resulted in the higher biomass carbon.

2.5.2.2. Vermicompost

Application of VC as organic N sources had significantly varied in their resultant microbial build-up of the soil. The highest bacterial population (393×10^4 cfu g^{-1} soil) was associated with the application of 100% N as VC, which was 5 times higher (68×10^4 cfu g^{-1} soil) than the plots treated with 100% urea (Kannan *et al.*, 2005). The fungal population was also maximum (71×10^4 cfu g^{-1}) in the former treatment over 26×10^4 cfu g^{-1} soil in urea treated plots.

The application of VC @ 10 tons ha^{-1} resulted in increased biomass and DHA (Arancon *et al.*, 2006). Ram and Pathak (2007) showed that maximum bacterial count 5.1×10^6 cfu g^{-1} soil and yeast and mould count 6.3×10^3 cfu g^{-1} soil was recorded from the rhizosphere of tree treated with VC @ 5 kg tree^{-1} . Tajeda and Gonzalez (2008) reported that soil DHA was significantly improved in plots with VC over the control plots.

Ziauddin (2009) reported that VC application significantly improved the total number of bacteria, bacterial spores and fungi in banana rhizosphere. Tejada *et al.* (2009) found that VC increased soil microbial biomass and respiration by 59.1% and 69% respectively compared to control soil. Dehydrogenase, Urease, β glucosidase, phosphatase and aryl sulfatase activities in soil was also significantly enthused with VC application compared to control. Kundu *et al.* (2015) observed that sole use of VC and neem cake was found to be effective in improving the soil nutrient status and soil microbial population as compared to other treatments.

2.5.3. Subash Palekar Natural Farming System

During preparation of *jeevamrit* a handful of soil (collected from the same field to which it should be added) serve as an initial inoculum of bacteria, fungi, actinomycetes, N-fixers and P-solubilizers. Hence, the higher beneficial microorganisms found in these organic

formulations are in conformity with Papen *et al.* (2002). Sreenivasa *et al.* (2010) who have also reported the presence of naturally occurring beneficial microorganisms predominantly bacteria, yeast, actinomycetes and certain fungi in organic liquid manures. Hence, these formulations would serve a long way in supplementing many of the biofertilizers and biocontrol agents used in crop production in the rural areas.

Yadav and Mowade (2004) observed that application of different organic liquid manures (formulations) in the form of *Panchagavya*, *Dasagavya*, *Beejamruth*, *Jeevaamrit*, *Amritpani* and *Sanjivak* results in quick build-up of soil fertility through greater activity of soil microflora and fauna. This increase might be due to cumulative effect of liquid organic inputs in increasing organic carbon content of soil which acted as carbon and energy source for microbes and in quick buildup of heterotrophic microflora and fauna. Similar results were obtained by Shwetha (2008), who reported the nutrient management through organics in soybean-wheat cropping system and found that the application of organic manures supplemented with fermented organics resulted in the significant improvement of soil microbial population and enzymatic activity.

Significant difference observed in P-solubilizers due to the application of *jeevaamrit*. Higher P-solubilizers were observed with *jeevaamrit* (27.9, 31.5 at 60 DAT and 26.7, 30.4 $\times 10^3$ cfu g⁻¹ at harvest during *kharif* and summer, respectively) and lower was recorded in without *jeevaamrit* (25.4, 29.7 at 60 DAT and 24.1, 28.4 $\times 10^3$ cfu g⁻¹ at harvest during *kharif* and summer, respectively) (Boraiah *et al.*, 2017).

As per the findings of Brar *et al.* (2020), the maximum microbial count (146.67 $\times 10^5$ cfu g⁻¹ soil), maximum dehydrogenase activity (4.79 mg TPF h⁻¹ g⁻¹ soil), maximum phosphatase activity (29.39 μ mole PNP h⁻¹ g⁻¹ soil) and highest microbial biomass-C (58.37 μ g g⁻¹ soil) were recorded in treatment receiving PGPR along with 90% RDN through bulky organic inputs (VC and PM) along with liquid organic (*panchagavya*, *jeevaamrit* and *amritpani*) inputs in capsicum (*Capsicum annuum* L.) in Western Himalayas of India.

2.6. DIFFERENCE IN ECONOMIC RETURNS UNDER DIFFERENT FARMING SYSTEMS

Farming distress is often viewed as a short-term phenomenon in which farmers look for support from various quarters on account of being unable to get a gainful return due to low price realization, increasing cost of inputs, frequent occurrence of natural calamities, etc.

Besides, substantial increase in input costs has led to a decline in crop income over the years (Mishra, 2008).

Ray and Yadav (1996) studied the combined effect of application of organic manures and chemical fertilizers on growth and productivity of banana and inferred that the maximum benefit to cost ratio was observed with the application of FYM (25%), green manuring and 75 per cent RDF which was performed with 25 per cent FYM, 50 per cent neem cake and 75 per cent inorganic fertilizers.

Kumar (2003) recorded the highest net returns and B:C ratio in treatment 25% of N as FYM and 75% N as inorganic in banana cv. Rajapuri. Main reasons for higher profitability of organic systems are (a) higher market prices and premiums: even with less yields and higher production costs, organic remained more profitable due to 400% higher market price (Younie 1990; IFAD, 2005); even with much higher costs and significantly lower yields, price premium made organic more profitable (McBride and Greene, 2008); higher prices for organic accounted for 40-75% of profits in Germany and Britain for arable farms, and 10-48% for dairy farms (Offermann and Nieberg, 2000); (b) lower production costs caused significant difference in net returns even without premiums (Mahoney *et al.*, 2004).

Bhalerao *et al.* (2009) found that application of 100 per cent recommended dose of NPK along with 10 kg FYM and bio fertilizer @ 25g per plant recorded the highest net returns of Rs. 74,590/- per ha and B:C ratio of 1.48:1 in banana. Yadav *et al.* (2011) reported maximum net profit and benefit cost ratio under 10 kg FYM, 100 per cent NPK and 25 g *Azotobacter* in cv. Pusa Dwarf of papaya.

Shivakumar *et al.* (2012) reported higher gross and net returns with the application of FYM equivalent to 100% RDN and maximum benefit to cost ratio (B:C) with application of press mud, equivalent to 100% RDN in papaya. Efficacy of different fertilizer treatments were worked out by computing the gross and net returns and benefit cost ratio. Application of 100% recommended dose of fertilizers along with either organic manure or FYM resulted in higher yield in terms of bunch weight yield ha⁻¹ resulting in higher gross returns. Application of 100 per cent RDF along with 40 per cent *Wellgro soil* recorded the maximum net profit with a high benefit-cost ratio.

Stice *et al.* (2014) reported that organic treatment had higher gross margin than conventional treatment. The costs of production for the organic treatment were lower than the conventional treatment and was likely due to the low cost of raw material that was used in the organic manures in papaya. Venugopal and Sheela (2014) reported that among various

treatment combinations, application of FYM and RDN recorded maximum total income, net income and benefit cost ratio in banana.

Ghosh (2015) reported that the 100% recommended dose of inorganic fertilizers gave the highest net revenue followed by 50% RDF and 50% VC and also reported the high net income in cow dung manure in sweet orange. The key purpose for the buying of organic products is the trust that these foodstuffs are healthier and harmless than the conventional products (Hemmerling *et al.*, 2015). This is how the consumers are conscious of organic and conventional products, which demonstrate that consumers' temperament to pay for organic products will upsurge in future.

Natural Farming, so called SPNF is considered to be agroecology based diversified farming system, which integrates crops, trees and livestock, allowing functional biodiversity (Rosset and Martinez-Torres, 2012) to drastically cut down production costs by replacing the chemical fertilizers and pesticides with home-grown product like *Jeevaamrit*, *Beejamritham*, *Neemastra*, etc., and adopting intercropping and mulching (Palekar 2005 and 2006). The results of the study conducted by Adamtey *et al.* (2016) showed that fluctuations in market prices and yields of produce were among the major determinants for obtaining a higher or lower (or even positive and negative) benefit: cost ratio from any agricultural production system and that when premium prices are available, organic farming systems can generate a higher benefit: cost ratio.

India challenging larger profusion towards agriculture with the higher use of artificial agrochemicals such as fertilizers and pesticides, larger mistreatment of irrigation potential and such use of high energy to boost product growth have led to the worsening of soil health as well as environment which is main anxiety issues towards food security (Yadav and Yadav 2018). India has carried 4.72 m ha under organic confirmation systems with 0.6 m ha of developed horticultural land and 4.12 m ha for wild gather accumulation in forest, as of March 2014 (Wani *et al.*, 2017). In the second year of conversion and thereafter, organic farming (with produce sold at a regular price) yielded similar profits as its conventional counterpart (Adamtey *et al.*, 2016). This contradicts the reports of Clark *et al.* (1999) and Setboonsarng *et al.* (2008) who argue that, in the absence of price premium, the returns to organic production system are lower than those to conventional production systems and corroborate the assertion of Welsh (1999) that price premiums are not always necessary for organic systems to be competitive with conventional systems. Delbridge *et al.* (2011) reported on a 4-year corn-soybean/alfafa crop rotation organic input system (without premium prices) that had a similar net return to chemical input systems, but when a premium was available for the organic produce, the organic system yielded considerably higher net returns than the conventional system.

According to study conducted by Tripathi *et al.* (2018a), in the year 2016-17, papaya was grown using both prevailing farming practices and SPNF, on 6 acres and 4.5 acres, respectively. The input cost on non-SPNF land was Rs. 70,450/- per acre and under SPNF was Rs. 46,450/- per acre only. The papaya yield of 56 tons per acre was recorded under SPNF which was almost 16 tons higher than the produce with prevailing practices, despite using a smaller area for SPNF cultivation. The net income per acre was Rs. 4,48,000/- under SPNF, against Rs. 3,20,000/- under conventional agriculture. Addition premium for improved quality and taste of the fruits was also reported along with improvement in crop longevity and storage value.

Tripathi *et al.* (2018b) reported very encouraging results stating that farmers practicing SPNF in Andhra Pradesh, India earn considerably more than the control group of conventional farmers and SPNF farmlands may be able to withstand droughts, high-speed winds and flooding better than non-SPNF plots. They also reported that the yields of five crops (paddy, groundnut, blackgram, maize and chilies) have increased by 8-32 per cent for SPNF farmers.

Highlighting the predominance of smallholder farmers (68.5 per cent marginal and 17.7 per cent small farmers) in India, The Economic Survey (2019) emphasized the importance of Zero Budget Natural Farming (ZBNF), now called SPNF, as one of the alternative farming practices for improving the farmers' income, in the backdrop of declining fertilizer response and farm income.

According to The Hindu (2019) newspaper in India, the prices of chemical fertilizers like urea increased by 69 per cent, that of DAP and potash rose by 300 and 600 per cent between 1991-92 and 2013-14. However, per hectare real value of output increased for most crops in recent years, but the rise in input cost was much higher resulting into reduced farm income (Businessline, 2019). So, shift to organic or natural system are the need of the hour to meet the food need of burgeoning human population as well as sustaining soil health.

Chapter-3

MATERIALS AND METHODS

The present investigation on “**Effect of nutrient sources on soil properties and productivity of kiwifruit (*Actinidia deliciosa* cv. Allison)**” was carried out at the experimental Kiwifruit Orchard Block, Department of Fruit Science, Dr. Yashwant Singh Parmar University of Horticulture and Forestry (UHF), Nauni, Solan (HP) during the years 2019 and 2020.

3.1. EXPERIMENTAL SITE

3.1.1. Location and climate

The experimental site is situated at an elevation of 1260 m above mean sea level (msl) with latitude of 30° 50' North and longitude of 77°11'30" East. The location of experimental field falls under sub-temperate, sub-humid and mid hills agro-climatic zone of Himachal Pradesh (Zone-II). The area receives an annual rainfall of about 1000-1300 mm and about 75 per cent of it is received during monsoon period (mid-June to mid-September). Summer is moderately hot during May-June, while winter is severe during December-January months. The meteorological data on mean monthly maximum and minimum air temperature (°C), relative humidity (%) and rainfall (mm) recorded at Meteorological Observatory of the Department of Environment Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP), during the period of study (January to September) is depicted in Figure 3.1 (Annexure - I). A total of 982.6 mm and 992.5 mm rainfall was received during the experimental period in 2019 and 2020, respectively.

3.1.2. Soil characteristics

The soils of the experimental area belong to Typic Haplustepts at sub group level according to soil taxonomy of US Department of Agriculture. Before laying out the experiment, random soil samples were collected from different spots of experimental field from 0-15 and 15-30 cm soil depths and composite samples were prepared which was analyzed for various physico-chemical and biological properties. The comprehensive information of the experimental soil on physico-chemical and biological characteristics and available nutrient status of the experimental soil along with procedures followed for their estimation are enumerated in Table 3.1.

Table 3.1: Physico-chemical and biological properties of experimental orchard soil

Properties of soil	Content		Method and instruments used
	0-15 cm	15-30cm	
A. Soil chemical properties			
1. Soil pH	6.54	6.75	1:2.5 soil water suspension (Jackson, 1973) Digital pH meter
2. Soil electrical conductivity (d S m ⁻¹)	0.128	0.107	1:2.5 soil water suspension (Jackson, 1973) Digital EC meter
3. Soil organic carbon (g kg ⁻¹)	14.1	8.4	Rapid titration method (Walkley and Black, 1934)
4. Available N (kg ha ⁻¹)	282.2	200.7	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
5. Available P ₂ O ₅ (kg ha ⁻¹)	100.8	56.0	Sodium bicarbonate extractant method (pH 8.5) & Color development by Stannous Chloride (Olsen <i>et al.</i> , 1954)
6. Available K ₂ O (kg ha ⁻¹)	302.4	246.4	Ammonium acetate (1N) extraction and determination using flame photometer (Merwin and Peech, 1950)
7. Zn (ppm)	1.28	1.02	DTPA extraction at pH 7.3 (Lindsay and Norvell, 1978) and determination using Atomic Absorption Spectrophotometer
8. Mn (ppm)	12.82	14.29	
9. Copper (ppm)	1.54	1.78	
10. Iron (ppm)	41.98	35.80	
B. Soil physical properties			
Sand %	79.3	77.2	Hydrometer method (Bouyoucos, 1962)
Silt %	3.2	5.2	
Clay %	17.4	17.5	
Soil textural class	Sandy loam	Sandy loam	
Bulk density (g cm ⁻³)	1.14	1.22	Core method (Soil cores collected from each depth were dried in an oven at 105°C for 24 hours and bulk density was calculated as the ratio of weight of soil core and internal volume of metallic core).
C. Soil biological properties:			
1. Viable bacterial count (cfu × 10 ⁵ g ⁻¹ soil)	50	45	Serial dilution technique using Nutrient Agar Media
2. Viable fungal count (cfu × 10 ³ g ⁻¹ soil)	9	6	Serial dilution technique using Potato dextrose Agar Media
3. Viable actinomycetes count (cfu × 10 ³ g ⁻¹ soil)	8	7	Serial dilution technique using Kenknight and Munaier's Media
4. Acid phosphatase activity (µg PNP g ⁻¹ hr ⁻¹)	86.5	81.3	p-nitrophenol method (Tabatabai and Bremner, 1969)
5. Dehydrogenase activity (µg TPF g ⁻¹ hr ⁻¹)	22.2	21.0	Triphenyl formazan method (Casida <i>et al.</i> , 1964)

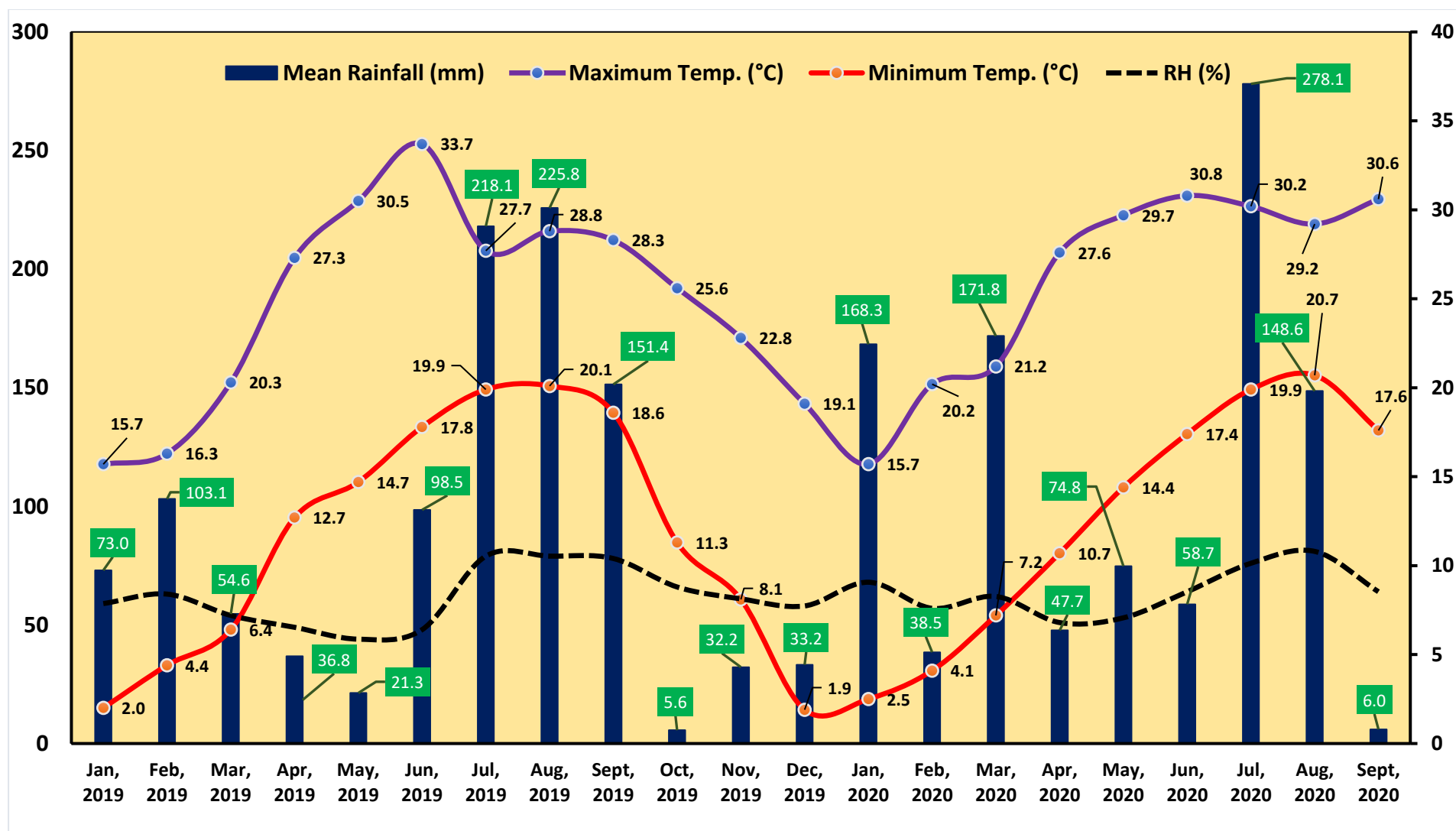


Figure 3.1. The mean monthly maximum and minimum air temperature (°C), relative humidity (%) and rainfall (mm) data during the period of experimentation (January 2019 to September 2020). Source: Weather Station, Dr. YSP, UHF, Nauni, Solan (HP.)

3.2. EXPERIMENTAL DETAILS

The experiment was carried out on 6-years old trees of kiwifruit cv. Allison. The vines with uniform vigor and size planted at a spacing of 4.0 m (row to row) × 6.0 m (plant to plant) spacing and trained on T bar system were selected for the present study. Each plant was given uniform cultural practices during the entire course of investigation to keep the plants in a good health and shape. The layout of the experiment, actual view of the experimental area and different field operations are shown in Figure 3.2, Plate 3.1 and Plate 3.2, respectively.

The experiment was laid out in a Randomized Block Design (RBD) with 8 treatments and each treatment was replicated thrice. The detail description of the different treatments and particular quantities of different sources added are given in Table 3.2.

Table 3.2: Detail description of treatments under different farming systems

Treatment No.	Treatment code	Replication (Plant #)			Farming system	Description
		R ₁	R ₂	R ₃		
T ₁	N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀	8	16	24	¹ CFBS	100% Recommended doses of N i.e. 800 g (1.74 kg Urea), P ₂ O ₅ 600 g (3.75 kg SSP) and K ₂ O 800 g (1.33 kg MOP) + 40 kg farm yard manure (FYM) applied per vine as per package of practice
T ₂	VC ₄₀₀ PM ₄₀₀ + FYM ₄₀	2	15	18	² OFBS	100% Recommended dose of nitrogen (RDN) through vermicompost (VC) + poultry manure (PM) on 50:50 basis + 40 kg FYM
T ₃	VC ₃₆₀ PM ₃₆₀ + FYM ₄₀	4	9	17	OFBS	90% RDN through VC + PM on 50:50 basis + 40 kg FYM
T ₄	VC ₃₂₀ PM ₃₂₀ + FYM ₄₀	5	11	21	OFBS	80% RDN through VC + PM on 50:50 basis + 40 kg FYM
T ₅	VC ₂₈₀ PM ₂₈₀ + FYM ₄₀	3	12	22	OFBS	70% RDN through VC + PM on 50:50 basis + 40 kg FYM
T ₆	JM ₁₅ GJ ₃ + FYM ₄₀	6	14	20	³ SPNFS	15 liters of <i>Jeevaamrit</i> (JM) + 3 kg of <i>Ghana Jeevaamrit</i> (GJ) + 40 kg FYM
T ₇	JM _{22.5} GJ ₃ + FYM ₄₀	7	13	23	SPNFS	22.5 liters JM + 3 kg GJ + 40 kg FYM
T ₈	JM ₃₀ GJ ₃ + FYM ₄₀	1	10	19	SPNFS	30 liters JM + 3 kg GJ + 40 kg FYM

¹CFBS: Chemical Fertilizer Based System

²OFBS: Organic Farming Based System

³SPNFS: Subhash Palekar's Natural Farming System

3.3. COMPOSITION AND SOURCE OF DIFFERENT NUTRIENTS USED

3.3.1. Vermicompost

Vermicompost (VC) was procured from Department of Soil Science and Water Management, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan. The nutrient contents are given in Table 3.3. The amount of VC applied to give 50% of RDN is calculated on N equivalence basis.

3.3.2. Poultry Manure

Poultry manure (PM) was procured from the local market. The nutrient contents are given in Table 3.3. The amount of PM applied to give 50% of RDN is calculated on N equivalence basis.

3.3.3. Farm Yard Manure

Farm Yard Manure (FYM) was procured from Department of Fruit Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan. The nutrient contents are given in Table 3.3.

Table 3.3: Quantity of nutrients in farmyard manure, vermicompost, poultry manure and *Ghana Jeevaamrit* during 2019 and 2020

Manure	Nutrient content (%)					
	2019			2020		
	N	P	K	N	P	K
Vermicompost	1.09	0.66	0.60	1.19	0.70	0.44
Poultry Manure	1.71	0.99	1.89	1.60	1.05	2.04
FYM	0.45	0.31	0.56	0.40	0.39	0.89
<i>Ghana Jeevaamrit</i>	1.49	0.55	1.69	1.51	0.59	1.65

3.3.4. *Jeevaamrit*

Jeevaamrit (JM) is a fermented microbial culture prepared from locally available natural resources for the purpose of being applied to the soils/plants at different stages of their growth. It acts as a catalytic agent that promotes microorganism and earthworm activity in the soil. During the 48-hour fermentation process, the aerobic and anaerobic bacteria present in the cow dung and urine multiply as they eat up organic ingredients (like pulse flour). A handful of undisturbed soil is also added to the preparation, as inoculate of native species of microbes and organisms. It also helped to prevent some of fungal and bacterial plant diseases. The method of preparation of *Jeevaamrit* is given below as suggested by Palekar (2006):

- a) 10 kg fresh *Desi* cow dung, 10 liters cow urine, 2 kg of Jaggery (*Gur*), 1 kg of pulse flour (*besan*) and 1 kg of soil from the bund of the farm were mixed thoroughly in barrel of 200 litres capacity having 180 liters of water.
- b) Drum was covered with wet gunny bags and kept in shade for 48 hours for fermentation. Stirring of the solution was done clockwise twice a day for 5-10 minutes.

The content of various elements presents in *Jeevaamrit*, as tested by Central Soil Testing Laboratory, Department of Soil Science, Punjab Agricultural University Ludhiana, Punjab, are presented in Table 3.4.

Table 3.4: The content of various elements present in *Jeevaamrit*

Element (s)	mg l ⁻¹
Nitrogen	487.2
Phosphorous	66.7
Potassium	440.5
Calcium	40.2
Magnesium	125.9
Zinc	4.76
Iron	11.1
Copper	0.65
Manganese	2.09
Chromium	1.49
Arsenic	0.06
Nickel	0.12
Boron	7.4
Sodium	76.4
Cadmium	0.01
Lead	0.38

3.3.5. *Ghana Jeevaamrit*

Ghana jeevaamrit (GJ) is a dry organic manure in powdered form. The micro-organisms present in it starts working after getting moisture when added to soil. It may protect the plants from severe hot and cold injury by strengthening the plant's power. *Ghana jeevaamrit* augments growth of plant, induce early flowering and improve quality of fruits, provides energy to tolerate adverse conditions, increases availability and absorption of nutrients etc. *Ghana jeevaamrit* was prepared by mixing of 100 kg fresh *desi* cow dung, 2 kg jaggery, 2 kg pulses flour and handful soil from the bund. All ingredients were mixed well by adding 5 liters of cow urine. The mixture was then spread on floor under shade for drying and after that it was

made in powdered form using wood hammer. The prepared powdered material was stored in plastic drum and it can be used up to six months. The nutrient contents are given in Table 3.3.

3.3.6. Chemical Fertilizers

The inorganic fertilizers namely; Urea (46% N), Single super phosphate (16% P₂O₅), Muriate of Potash (60% K₂O) were procured from local market.

3.4. TIME, METHOD AND DOSE OF DIFFERENT NUTRIENT SOURCES

The manures and fertilizers were broadcasted in the basin under the spread of trees 30 cm away from the trunk of vine and thoroughly mixed with soil. *Jeevaamrit* and *ghana jeevaamrit* were buried in soil in tree basin. The time and dose of different nutrients applied are mentioned below in Tables 3.5. The quantities of VC and PM applied on N equivalent basis are given in Table 3.6.

Table 3.5: Time and dose of nutrient application in different farming systems*

CFBS**	OFBS	SPNFS
➤ Full dose of FYM (40 kg) + SSP (3.75 kg) + MOP (1.33 kg) was applied during start of the experiment i.e. January 2019 ➤ N was applied in two equal dressings through urea (1.74 kg) i.e. first dose of 870 g was applied slightly before bud burst (i.e. February 2019) and second final dose of 870 g was applied at the flowering (last week of April 2019)	➤ FYM (40 kg) was applied to all OFBS plants at the start of the experiment ➤ After calculating the amount of VC and PM on N equivalent basis as mentioned in Table 3.3, three equal split doses of VC and PM was applied during last week of January, February and April respectively.	➤ FYM (40 kg) was applied to all SPNFS plants at the start of the experiment. ➤ Three full doses of both <i>GJ</i> (1 kg each) and <i>JM</i> (5, 7.5 and 10 kg each) was applied in the end of January, February and April, in T₆, T₇ and T₈, respectively.

*Similar treatments were applied with respective nutrients in 2020 as done in 2019 (i.e. experiment was repeated for two consecutive years).

**Recommended dose of fertilizers for kiwifruit are 800 g N, 600 g P₂O₅ and 800 g K₂O per plant per year. The amount of urea, SSP and MOP was calculated on the basis of nutrient contents contained in them. SSP contained 16% P₂O₅, MOP contained 60% K₂O and urea contained 46% N.

The calculations are done only for fulfilling recommended dose of N but these manures also contained P and K. Therefore, quantities of P and K were also added per plant through VC and PM in the year 2019 (Table 3.7) and in the year 2020 (Table 3.8), respectively are mentioned below:

Table 3.6: Quantity of vermicompost (kg) and poultry manure (kg) used in 50:50 ratio on N equivalence basis during 2019 and 2020

Treatments	Treatment code	Vermicompost (kg)*		Poultry Manure (kg)*	
		2019	2020	2019	2020
T ₂	VC ₄₀₀ PM ₄₀₀ + FYM ₄₀	36.70	33.61	23.39	25.00
T ₃	VC ₃₆₀ PM ₃₆₀ + FYM ₄₀	33.03	30.25	21.05	22.50
T ₄	VC ₃₂₀ PM ₃₂₀ + FYM ₄₀	29.36	26.89	18.71	20.00
T ₅	VC ₂₈₀ PM ₂₈₀ + FYM ₄₀	25.69	23.53	16.37	17.50

*The amount of VC (for example 36.70 kg) and PM (for example 23.39 kg) was applied in 3 equal splits (12.23 kg each of VC and 7.80 kg each of PM) in last week of January, February and April in 2019. Similar calculations were done for the year 2020.

Table 3.7: Quantity of nutrients (g) added through VC and PM per plant in 2019

Treatment Code	Vermicompost (g)			Poultry Manure (g)			Total (g)		
	N	P	K	N	P	K	N	P	K
T₂: VC₄₀₀ PM₄₀₀ + FYM₄₀	400	242	220	400	232	442	800	474	662
T₃: VC₃₆₀ PM₃₆₀ + FYM₄₀	360	218	198	360	208	398	720	426	596
T₄: VC₃₂₀ PM₃₂₀ + FYM₄₀	320	194	176	320	185	354	640	379	530
T₅: VC₂₈₀ PM₂₈₀ + FYM₄₀	280	170	154	280	162	309	560	332	464

Table 3.8: Quantity of nutrients (g) added through VC and PM per plant in 2020

Treatments	Vermicompost (g)			Poultry Manure (g)			Total (g)		
	N	P	K	N	P	K	N	P	K
T₂: VC₄₀₀ PM₄₀₀ + FYM₄₀	400	235	148	400	263	510	800	498	658
T₃: VC₃₆₀ PM₃₆₀ + FYM₄₀	360	212	133	360	236	459	720	448	592
T₄: VC₃₂₀ PM₃₂₀ + FYM₄₀	320	188	118	320	210	408	640	398	526
T₅: VC₂₈₀ PM₂₈₀ + FYM₄₀	280	165	104	280	184	357	560	348	461

Randomised layout of treatments applied in different farming systems in kiwifruit (*Actinidia deliciosa*) cv. Allison

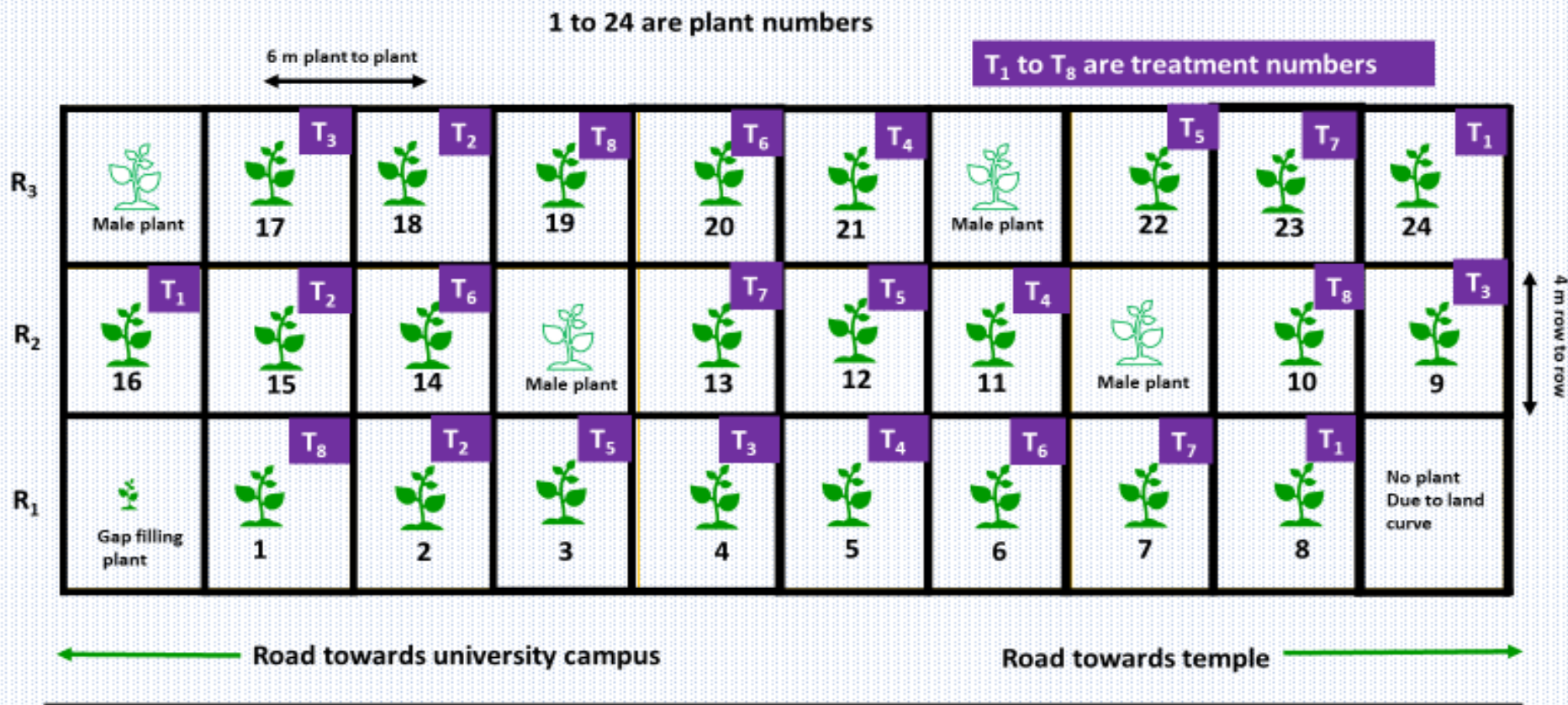


Figure 3.2. Layout of the field experiment conducted on kiwifruit depicting different treatments and replications



Plate 3.1: General view of the experimental field and display board fixed in the field showing complete details of the experiment



Plate 3.2. A. Collection of soil sample; B. Preparation of soil sample; C. Application of farmyard manure; D. Application of vermicompost and poultry manure; E. Application of chemical fertilizers; F. Preparation of *Jeevaamrit*; G. Application of *Jeevaamrit*; H. Preparation of *Ghana Jeevaamrit*.

3.5 OBSERVATIONS RECORDED:

3.5.1. Plant parameters:

3.5.1.1. Leaf area

Ten fully expanded leaves were collected randomly from each experimental tree in June and leaf area was recorded by using digital CI-202 portable laser leaf area meter (Plate 3.3) and values were expressed as average leaf area per leaf in square centimeter (cm²).



Plate 3.3: Measurement of leaf area of kiwifruit leaves using digital leaf area meter

3.5.1.2. Leaf Area Index

Leaf Area Index (LAI), which is used as a measure in hundreds of studies on forests, crops, climate and the environment, is calculated as half the area of all leaves per unit area of ground (Jonckheere *et al.*, 2004). It is measured as the one-sided leaf area (m²) per unit ground area (m²) and is unit-less. So, a plant with a LAI of 2 has an amount of leaves that can cover a given area two times. LAI is calculated for a plant or can be scaled up to give readings for a whole crop or even a region. It is one of the most important parameters to measure leaves and their activity. Leaves are an important source of carbohydrates produced during photosynthesis, which are converted to a myriad of chemicals that the plant needs. Therefore, LAI is thus an important indicator of radiation and precipitation interception, energy conversion, and water balance. Ultimately, it is a reliable parameter for plant growth. This is the reason why most

studies in agronomy and horticulture measure the results of interventions such as fertilizers and irrigation in terms of LAI, as well as yield. Since leaves are essential for photosynthesis and produce the bulk of biomass, the number of leaves (and LAI) will also influence yield.

Comparisons of LAI between different years is a good way to judge how well the crops are doing. When the fruit tree is younger, increasing LAI will boost fruit yield. However, if the canopy gets too thick and prevents light penetration to lower levels and to developing fruits, both yield quantity and quality will decrease in older fruit trees, as seen in oranges.

LAI and photosynthetic active radiation (PAR) were measured in the field using LP-80 PAR/LAI Ceptometer (Decagon Devices, Inc) (Plate 3.4.)



Plate 3.4: Measurement of leaf area index (LAI) and photosynthetic active radiation (PAR) of kiwifruit using LP-80 PAR/LAI Ceptometer

3.5.1.3. Chlorophyll index using chlorophyll meter (SPAD 502)

Chlorophyll meters are reliable alternatives to traditional tissue analysis as plant N nutritional diagnostic tools. Most widely used chlorophyll meter is the hand-held KONICA MINOLTA SPAD- (Soil Plant Analysis Development) 502 (Plate 3.5). It instantly provides an estimate of leaf N status as chlorophyll content by clamping the unplucked leafy tissue in the meter. It uses two LEDs (light emitting diodes) which emit red light with a peak wavelength of 650 nm and an infrared radiation with a peak wavelength of 940 nm. The red and infrared radiations are made to pass through the leaf. A portion of light is absorbed and the remainder is transmitted through the leaf and a silicon photodiode detector converts it into an electrical signal. The amount of light reaching the photodiode detector is inversely proportional to the amount of chlorophyll in the path of the light.

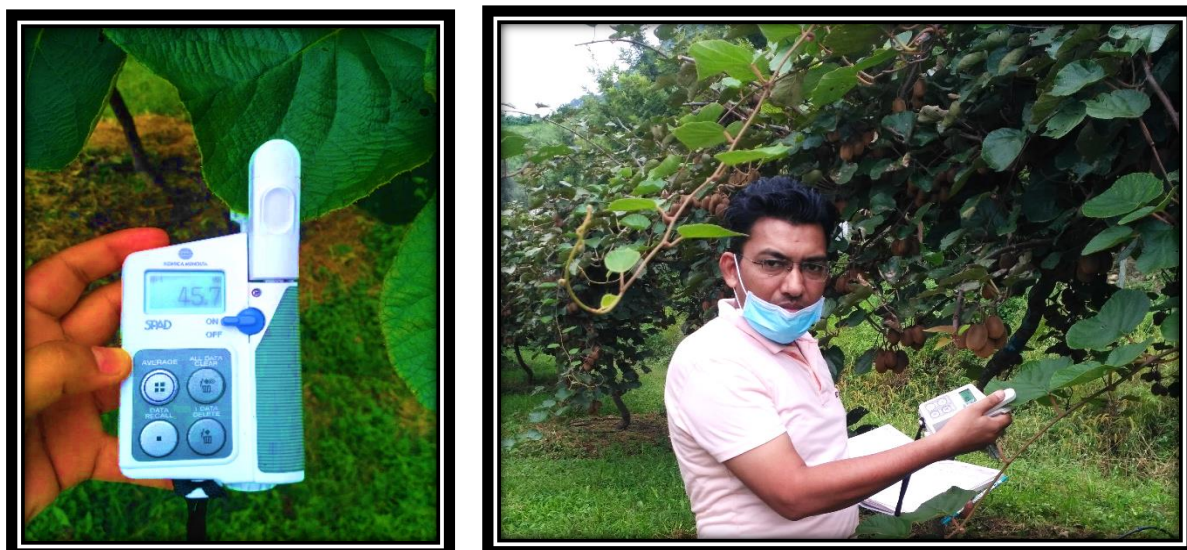


Plate 3.5: Recording of chlorophyll index values of kiwifruit leaves using Chlorophyll meter (SPAD)

The SPAD meter readings are unit less and need to be calibrated with chlorophyll or N content and leaf greenness. Measurements with SPAD meter are not only well correlated with N concentrations of leaves but also mineral N in the surface soil (Follett and Follett, 1992).

3.5.2. Fruit yield and fruit quality parameters

3.5.2.1. Total fruit and grade wise yield

The yield of fruits under different treatments was calculated on the basis of total weight of fruits harvested from the vine under each treatment and is expressed in kilogram per tree (kg/tree). On the basis of weight, the harvested fruits were classified into three grades viz., A (>70 g), B (50-70 g) and C (<50 g) grade. The yields of different grade fruit were expressed in kg/vine.

3.5.2.2. Fruit size

The size of the fruit was expressed in terms of length and diameter. The length and diameter of 20 randomly selected fruits per vine were measured at the time of harvest with the help of Digital Vernier Caliper (Aerospace, Japan) and were expressed in millimeter (Plate 3.6a, b and c). The length of the fruit was determined by measuring the length between the calyx and styler end of the fruits (Plate 3.6a). The diameter was measured in two perpendicular directions (i.e. Radial 1, shown in Plate 3.6b and Radial 2 shown in Plate 3.6c) at the center of the fruit.

3.5.2.3. Fruit weight

All fruits harvested in each treatment and replication were weighed on electronic top pan balance and average fruit weight was expressed as gram (g).



Plate 3.6a: Measurement of length of kiwifruit using digital Vernier caliper



Plate 3.6b: Measurement of diameter (Radial 1) of kiwifruit



Plate 3.6c: Measurement of diameter (Radial 2) of kiwifruit

Plate 3.6 a, b and c: Measurements of fruit parameters of kiwifruit



Plate 3.7: Measurement of total soluble solids (TSS) using ATAGO hand refractometer

3.5.2.4. Total soluble solids (TSS)

The TSS content of five randomly selected fruits per replication was determined with the help of ATAGO hand *Mera Pal* refractometer (0-53 Brix %) and averaged (Plate 3.7). The refractometer was calibrated with distilled water before use. A drop of fruit juice was placed on the prism and the value of TSS was recorded directly (AOAC, 1984). The readings were recorded for each sample and expressed as TSS percentage.

3.5.2.5. Titratable acidity

Twenty-five grams of fruit pulp collected from five randomly selected fruits per vine was thoroughly mixed in the blender, homogenized in distilled water and the volume was made upto 250 ml. The contents were then filtered through Whatman no. 1 filter paper. Out of the total volume made, 25 ml of the filtrate was taken in a separate conical flask and titrated against 0.1 N sodium hydroxide using phenolphthalein as an indicator. The appearance of a light pink colour indicated the end point (Ranganna, 1986). The total titratable acidity was calculated, in terms of citric acid ($C_6H_8O_7$: Eq. wt. 64), on the basis of one ml of 0.1 N NaOH equivalent to 0.0064 g anhydrous citric acid AOAC (1984). The results were expressed as percent titratable acidity. The remaining extract was kept for estimation of sugars.

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of NaOH} \times \text{Volume made up} \times \text{equivalent weight of acid}}{\text{Weight of fruit pulp taken} \times \text{volume of extract taken for estimation} \times 1000} \times 100$$

3.5.2.6. TSS/acid ratio

The ratio was estimated mathematically by dividing the corresponding value of total soluble solids to the titratable acid content of the fruit juice. The data so obtained was analysed and expressed as TSS/acid ratio.

3.5.2.7. Sugars

Sugar contents were estimated by the Lane and Eynon's volumetric method (Ranganna, 1986). Samples were prepared by crushing 20 g of fruit pulp was thoroughly homogenized with distilled water in an electric blender and volume was made to 100 ml in 250 ml volumetric flask and filtered through Whatman No. 4 filter paper. The filtrate was then neutralized with 1N NaOH. Twenty-five milliliter of saturated lead acetate (45%) solution was added to it and kept for 10 minutes to remove the impurities. Excess of lead acetate was removed from the sample by using a 25 ml of potassium oxalate (22%) and then filtered through Whatman No. 4

filter paper. The volume was made to 250 ml by adding distilled water. From this clear filtrate, 100 ml was separated for the estimation of total sugars and rest was used for estimation of reducing sugars.

3.5.2.8. Total sugars

Already separated 100 ml clarified solution was hydrolysed by adding 20 ml of 50 % diluted hydrochloric acid and leaving it overnight. The excess of hydrochloric acid was neutralized by saturated sodium hydroxide solution. The final volume was made to 250 ml with distilled water. The total sugars were estimated by titrating a boiling mixture of 5 ml each of Fehling A and B solutions against aliquot using methylene blue as an indicator. The end point was noted after obtaining the brick red colour and total sugars were expressed as percentage of fresh weight of fruit pulp and calculated as per formula given below (AOAC, 1984).

$$\text{Total sugar (\%)} = \frac{\text{*Factor for Fehling solution} \times \text{1st dilution} \times \text{2nd dilution}}{\text{Titer value} \times \text{Weight or Volume of sample taken (20 g)}} \times 100$$

***Factor = 0.05**

1st dilution = 250 ml/ weight of sample taken = 250/20 = 12.5

2nd dilution = 250/100 = 2.5

After simplification

$$\text{Total sugar (\%)} = \frac{0.05 \times 12.5 \times 2.5}{\text{Titer value}} \times 100 \quad \text{Total sugar (\%)} = \frac{156.25}{\text{Titer value}}$$

3.5.2.9. Reducing sugars

The remaining unhydrolyzed dealed and clarified solution obtained from total sugar estimation was titrated against boiling mixture of 5 ml each of Fehling A and Fehling B using methylene blue as an indicator (AOAC, 1984). Reducing sugars content was expressed as per cent of fresh weight of the fruit pulp.

$$\text{Reducing sugars (\%)} = \frac{\text{*Factor for Fehling solution} \times \text{Dilution}}{\text{Titre value} \times \text{Weight or Volume of samples taken}} \times 100$$

***Factor = 0.05**

Dilution = 250 ml/ weight of sample taken = 250/20 = 12.5

After simplification

$$\text{Reducing sugar (\%)} = \frac{0.05 \times 12.5}{\text{Titer value}} \times 100$$

$$\text{Reducing sugar (\%)} = \frac{62.5}{\text{Titer value}}$$

3.5.2.10. Non-reducing sugars

The quantity of non-reducing sugars was calculated by subtracting the reducing sugars content from the total sugar and multiplying the difference by standard factor 0.95 as given in AOAC (1984). The results were expressed as per cent non-reducing sugars.

$$\text{Non-reducing sugars (\%)} = (\text{Total Sugars} - \text{Reducing sugars}) \times 0.95$$

3.5.2.11. Ascorbic acid (Vitamin C)

Ascorbic acid was determined by method given in AOAC (1984), in which 5 g of fruit pulp was homogenized in 10 ml 3% metaphosphoric acid extraction solution (prepared by dissolving 15 g of metaphosphoric acid pellets in 40 ml glacial acetic acid and making the final volume to 500 ml with distilled water). The volume of the sample solution was made to 50 ml in a volumetric flask and 5 ml of clarified extract was titrated against 2, 6-dichlorophenol indophenol dye.

Standard indophenol dye solution was prepared by dissolving 50 mg of 2, 6-dichlorophenol indophenol and 42 mg of sodium bicarbonate in distilled water and the volume was made to 200 ml. Freshly prepared dye was then standardized against known concentration of ascorbic acid. The appearance of faint pink color indicated the end point, which persisted for at least 15 seconds. The volume of the dye used was recorded. Dye factor was determined by calculating mg of ascorbic acid reacting with 1 ml of dye. Titer reading for the sample was noted and the content of ascorbic acid in mg per 100 g of pulp (mg/100 g) was calculated by the following formula:

$$\text{Dye factor} = \frac{0.5}{\text{Volume of dye used}}$$

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Dye Factor} \times \text{titer value of sample} \times \text{volume made}}{\text{Weight of fruit} \times \text{volume taken for taken estimation}} \times 100$$

3.5.3. Determination of leaf nutrient status

3.5.3.1. Collection and preparation of samples

To estimate leaf nutrient status of experimental trees, mature leaves with petiole were sampled from the middle part of the current season's growth of the fruiting shoot in the mid-August every year. The leaf samples were brought directly to laboratory, thoroughly washed

first under tap water, followed by 0.1 N HCl, distilled water and finally with double distilled water. The washed samples were first air dried in the shade by spreading on clean blotting paper and final drying was accomplished in an oven at 65° C for 48 hours. The samples were then ground and were stored in butter paper bags for chemical analysis. The samples were processed for nutrient analysis as per procedure outlined by Kenworthy (1964).

3.5.3.2. Estimation of leaf nitrogen content

One gram of well ground and dried leaf samples was used for the estimation of leaf nitrogen. The samples were digested on the automatic digested system using 1 g of digestion mixture and 20 ml of concentrated sulfuric acid. The digestion mixture was prepared by mixing 480 g of K₂SO₄, 20 g of CuSO₄ 6H₂O, 3 g of HgO and 1 g of Selenium powder. The samples were boiled till light blue color appears and allowed to cool and diluted to 100 ml with distilled water. After digestion, N was estimated by Micro-Kjeldahl method (AOAC, 1984). Twenty-five milliliters of 4% Boric acid solution containing mixed indicator (Bromocresol green + methyl red) was taken in a conical flask and was placed in such a way that condenser outlet of distillation apparatus was dipped into the boric acid solution. Then 10 ml of the aliquot (digested) was taken and transferred to distillation flask of Micro-Kjeldahl distillation apparatus. After adding the aliquot, the funnel of the apparatus was washed with 2-3 ml of distilled water and 10 ml of 40% NaOH was added. Ammonia (NH₃) thus liberated was absorbed into the boric acid in conical flask. After completion of distillation, boric acid solution was titrated against standard sulfuric acid and N content was calculated on the basis of sulfuric acid solution used to neutralize the evolved ammonia and expressed in percentage on dry weight basis. The endpoint was appearance of slight red color.

3.5.3.3. Estimation of other nutrients

One gram of dried and well ground leaf samples was transferred into 250 ml conical flasks. Twenty milliliters of diacid mixture (comprising of 4 parts of nitric acid and 1 part of perchloric acid) was added to these flasks (Piper, 1966). The samples were digested on electric hot plate. The digestion was continued till 2-3 ml of clear digested material was left in the conical flasks. After complete digestion the samples were diluted to 100 ml with the help of distilled water.

Total phosphorus was estimated by Vanado-molybdo phosphoric acid method (Jackson, 1973). Five-milliliter of extract (digested sample) was taken in 25 ml of volumetric flasks. To this flask, 5 ml of vanado-molybdate reagent was added and final volume was made to 25 ml

with distilled water. The contents were mixed and allowed to develop color for half an hour. After development of yellow color, absorbance was recorded on Spectronic 20-D at 470 nm wavelength using red filter. A blank was run simultaneously to adjust the zero absorbance. The color intensity (yellow) was recorded and P content was depicted with the help of standard curve and expressed on dry weight basis.

The potassium and calcium in the plant tissue was estimated on flame photometer (Jackson, 1973). The digested samples were diluted to 100 ml with distilled water. Five milliliters of this prepared sample were diluted to 50 ml with distilled water. The samples vis-à-vis standard solutions were fed on by one to the flame photometer and readings were recorded in ppm. The final concentration of potassium was estimated by multiplying it by dilution factor. The other elements like zinc, manganese, copper and iron were determined on atomic absorption spectrophotometer by using 10 ml of 100 ml prepared sample which was further diluted to 50 ml distilled water. The macro and micro nutrients of leaf were computed on dry weight basis and expressed as percent and ppm, respectively after multiplying with dilution factor.

3.5.4. Soil characteristics

The soil samples from 0-15 and 15-30 cm depths were collected before the start of the experiment, one year after and at the end of experiment. Before the start of the experiment a composite sample of the orchard soil was collected, whereas after one year and at the end of experiment, soil samples were collected from four sides under the basin of each experimental tree with the help of screw type auger. The collected representative soil samples were dried in shade, grounded, sieved through 2 mm plastic sieve and stored in cloth bags. The samples were prepared for analysis in accordance with the procedure given by Piper (1966). The samples were analyzed for physico-chemical and microbial properties of soil by respective procedure as mentioned in the following subheads.

3.5.4.1. Soil pH

A soil suspension was prepared with distilled water keeping 1:2.5 soil to water ratio and activity of H^+ ions in soil (pH) of suspension was measured by potentiometric method (Jackson, 1973). Soil pH is a measure of hydrogen ion (H^+) activity in the soil solution defined as negative logarithm of the hydrogen ion (H^+) concentration. The soil pH is a function of the parent material, time of weathering, vegetation, climate and topography. Additionally, the season, soil

organic matter and biological activity influence soil pH. For measuring pH of soil solution, 10 gram of air-dried soil sample was taken in a 50 ml beaker and 25 ml of distilled water was added to it (Soil: water:1:1.25). The suspension was stirred for 20 to 30 minutes using magnetic stirrer. Then a digital pH meter was used to measure the pH of solution after 1 h of standing for sedimentation. The soil pH of the solution being proportional to the potential develop on the glass membrane was measured in conjunction with saturated calomel electrode as reference electrode.

3.5.4.2. Soil electrical conductivity

The soil suspension used for soil pH determination was also used to measure soluble salts after keeping them overnight to obtain a clear supernatant solution. The soluble salts in soil were measured with conductivity meter also known as salt bridge. The electrical conductivity (EC) of soil is related to the total soluble cations or anions, which determines the soil salinity. As the soil EC is a measure of soluble nutrients, it indicates nutrient availability for plants and significantly influence physical, chemical, biological properties and processes in soil. The conductivity of electric current through soil suspension is proportional to the concentration of soluble salts in it (Richards, 1954). The supernatant soil solution was used for estimation of EC by a digital conductivity meter without shaking or without disturbance. The soil EC was expressed as deci Siemens per meter (dS m^{-1}).

3.5.4.3. Bulk density (Core tube method for undisturbed soils)

The method involved sampling a soil core, from a desired depth (i.e. 0-15 and 15-30 cm soil depths), in its most natural condition, using core sampler (cylindrical metal sampler), and determining the mass of solids and water content of the soil core by weighing the wet core, during it to constant weight in an oven at 105°C , and reweighing after cooling. Wet soil core may take 24 hours or more to dry. Bulk density then calculated from the measurement of bulk volume, using the core length and diameter of the cutting edge of the sampler. The soil bulk density was estimated by the following formula:

$$\text{Bulk density (g cm}^{-3}\text{)} = \frac{\text{Weight of oven dry soil in the core (g)}}{\text{Volume of the core soil (cm}^3\text{)}}$$

3.5.4.4. Soil texture (Hydrometer method)

The hydrometer method (Bouyoucos, 1962) is based on the principle that density of a suspension at a given depth decreases as an initially homogeneous dispersed suspension settle. The rate of decreasing densities at any given depth is related to the velocities of settling particles which in turn is related to their sizes. The time required by the particles of a given size to settle can be calculated by Stoke's law. In this method 50 g of dried soil sample, passed through 2 mm sieve, was taken in 500 ml beaker. Then 50-60 ml of 6 % hydrogen peroxide (H_2O_2) was added and placed it on water bath until organic matter is oxidized. Additional lot of hydrogen peroxide was be added until frothing stops. After that content was transfer into dispersing cup with 400 ml of distilled water and 100 ml of 10% sodium hexametaphosphate (Calgon), stirred with glass rod and kept overnight. Then, the contents were quantitatively transferred to the cup of mechanical stirrer and stirred for 10 minutes. Finally, the contents were transferred to 1000 ml suspension cylinder after giving 4-5 washings with distilled water. After vigorous shaking to the cylinder carefully, the hydrometer was placed immediately to the suspension gently and first reading was recorded exactly after 40 seconds. After taking first reading, vigorous shaking was done and solution was kept un-disturbed for two hours. Second reading was recoded exactly after two hours. A blank was also run simultaneously without soil. Room temperature was recoded using thermometer and expressed in Fahrenheit. Finally, different soil fractions were estimated by the following formulae:

$$\text{Correction factor (CF)} = (\text{Actual room temperature in Fahrenheit} - 68) \times 0.2$$

$$\text{Percent silt + clay} = \{[(S - B) + CF] / \text{weight of the sample (g)}\} \times 100$$

Where S and B stands for sample and blank readings respectively taken after 40 seconds (first reading).

$$\text{Percent clay} = \{[(S - B) + CF] / \text{weight of the sample (g)}\} \times 100$$

Where S and B stands for sample and blank readings respectively taken after 2 hours (second reading).

$$\text{Percent sand} = 100 - \text{Percent silt + clay}$$

Finally, the soil textural class was determined with the help of triangle textural diagram (ISSS, 1929) as shown in Annexure – IV.

3.5.4.5. Soil organic carbon

Rapid titration method (wet digestion method) was used for organic carbon (OC) determination (Walkley and Black, 1934). In this method, 2 g of dried soil was treated with 10 ml of 1 N $K_2Cr_2O_7$ solution in a 250 ml conical flask. A 20 ml of concentrated H_2SO_4 was slowly added to the flask. After 30 minutes, about 0.5 g of NaF, 100 ml of distilled water and 10 drops of diphenyl amine indicator were added to the flask. These contents were titrated against 0.5 N ferrous ammonium sulphate (FAS) solution. The change in color from violet to bright green through blue was the end point. The value of FAS used for titration was adopted for calculating organic carbon and was expressed as percentage. In another flask, 10 ml of 1 N $K_2Cr_2O_7$ solution was titrated without soil against 0.5 N FAS solution to determine blank reading. The soil organic carbon was estimated by the following formulae:

$$1 \text{ ml on } 1 \text{ N } K_2Cr_2O_7 = 0.003 \text{ gram of organic carbon}$$

$$OC (\%) = \frac{\text{Normality of FAS} \times (\text{vol. of FAS used for blank} - \text{vol. of FAS used for sample}) \times 0.003}{\text{Weight of sample taken}} \times 100$$

In this regular method, only 76 % organic carbon gets oxidized so a correction factor of 100/76 was used in calculating OC % in the end.

$$OC \text{ in soil } (\%) = \text{Value obtained in above equation} \times 100/76$$

3.5.4.6. Soil available nitrogen

Nitrogen (N) was estimated by alkaline potassium permanganate method as given by Subbiah and Asija (1956) and expressed in $kg \text{ ha}^{-1}$. Alkaline $KMnO_4$ is a mild oxidizing agent and can extract relatively easily oxidizable fractions of organic nitrogen. Twenty grams of soil was treated with 100 ml of 0.32% $KMnO_4$ and 100 ml of 2.5 % NaOH in Kjeldahl flask and immediately fit the cork to avoid loss of ammonia. The ammonia evolved was absorbed in a conical flask having mixture of 25 ml of N/50 H_2SO_4 and 3 drops of methyl red indicator. Before boiling the soil and other reagents in Kjeldahl flask, fit the delivery tube to the conical flask having mixture of acid and indicator. About 30 ml of distillate was collected and titration of excess of N/50 H_2SO_4 was done against N/50 NaOH and color changes from pink to yellow. The amount of N/50 NaOH used in the titration was used to calculate the nitrogen in the soil sample as described below:

$$1 \text{ ml of N/50 } H_2SO_4 = 0.00028 \text{ g of N}$$

$$\% \text{ of available N} = \frac{(25 - \text{vol. of N/50 NaOH}) \times 0.00028}{\text{Weight of soil sample taken (20 g)}} \times 100$$

3.5.4.7. Soil available phosphorus

Available phosphorus refers to that fraction of this element, which can be easily absorbed from the soil by plant roots. Soil available P was determined by 0.5 N sodium bicarbonate method given by Olsen *et al.* (1954). The solubility of calcium phosphate in soil is controlled by Ca ions and pH. The 0.5 N NaHCO₃ buffered to pH 8.5 increases the bicarbonate activity in the soil and hence decreases the calcium activity. Thus, some phosphates from the surface of calcium phosphates are brought into the soil solution. Similarly, NaHCO₃ solution extracts some P from Al and Fe phosphates due to inactivation of Al and Fe. Low activity of Ca²⁺ prevents the re-precipitation of phosphates liberated as calcium phosphates. Darco G-60 absorbs the dispersed organic matter and makes the filtrate colorless. The soluble phosphates form the heteropoly complexes with molybdate ions liberated from ammonium molybdate, phosphorus being the central coordinating atom. The heteropoly complexes give a faint yellow color, which on reduction with stannous chloride gives blue color. Therefore, for analysis of available P, the soil was shaken with bicarbonate extractant for half an hour. Then the clear filtered soil extract (obtained by adding pinch of Darco G-60) was treated with ammonium molybdate, complexing agent. In the presence of stannous chloride, the soil extract gave blue color. The intensity of blue color was measured with a UV-Spectrophotometer Spectronic 20 D at 660 nm wave length. From the standard curve the amount of P present in soil was calculated and expressed in kg ha⁻¹.

3.5.4.8. Soil available potassium

Exchangeable potassium in soils represent that fraction of total potassium which is free to free to exchange with the cations of soil solutions added to the soils. Most of the available K is in exchangeable form and particularly in non-saline soils the amount of water-soluble K is too small to cause any appreciable error if it is taken as a part of the exchangeable K. The determination of available K was carried out by neutral normal ammonium acetate method (Merwin and Peech, 1950). For this, 5 g of sample soil was shaken in with 25 ml of neutral normal ammonium acetate for 10 minutes. During extraction, NH₄⁺ replace K⁺ ions adsorbed on the soil colloids. The extract was filtered and potassium in the filtrate was determine with a flame photometer and expressed in kg ha⁻¹.

3.5.4.9. Soil available micronutrients

In today's intensive agriculture, deficiencies of micronutrients, particularly, Zn, Cu, Fe and Mn, have become one of the important factors limiting crop yields. Obviously, it is

essential to know the available content of these micronutrients. Atomic absorption spectroscopy technique in which absorption of the radiation of a characteristic wavelength by the atomic vapors was used to find the concentration of that element. For estimation of four micronutrients (Zn, Cu, Fe and Mn), 10 g of air-dried soil sample was shaken for two hours with 20 ml of DTPA solution (Diethylene triamine penta acetic acid) which contains 0.005 M DTPA, 0.1 M TEA (Triethanol amine) and 0.01 M $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ (Lindsay and Norvell, 1978). During this extraction TEA gets protonated as HTEA^+ as a result of which micronutrient cations from the solid phase come into solution and are chelated by DTPA. Buffering of the extractant in slightly alkaline pH was done through Ca^{+2} and thus excludes the estimation of occluded micronutrients. After that the contents of micronutrients in the soil extract were estimated on atomic absorption spectrophotometer.

3.5.4.10. Soil viable microbial counts

Soil samples were collected from plant rhizosphere and screened through 2 mm sieve. The samples were pooled and thoroughly mixed to make a representative sample. The serial dilution and plating technique suggested by Subba Rao (1999) was employed for isolation and identification of viable bacteria, actinomycetes and fungi count. Media was prepared for desired microflora. The autoclaved and cooled (45°C) medium was poured into sterile petri plates. Then medium was allowed to solidify. The plates were kept in incubator for 24 hours and examined for any contamination. After discarding contaminated plates, sterile plates were kept only. One gram of sieved (2 mm) soil was added to 9 ml sterile water blank and shaken for 15-20 minutes. Serial dilutions 10^{-2} , 10^{-3} , 10^{-4} , 10^{-5} , 10^{-6} , 10^{-7} and 10^{-8} were prepared and 0.1 ml of aliquots of various dilutions was added over cooled and solidified medium in petri plates in Laminar Flow apparatus in order to avoid any contamination. Pour plate method was employed. Three replications for each medium were used for each sample. Plates were rotated for uniform spread of spores in the plate and allowed to solidify. After the uniform spreading the plates were inverted and incubated at 28°C for 3-5 days. The appearance of colonies on the surface of the medium in the plates were observed. After the requisite incubation period, the colony forming units (cfu) were counted and expressed as cfu per gram of dry soil.

Population count of bacteria, actinomycetes and fungi were noted using dilution plate technique by employing nutrient agar medium, Ken Knight's agar medium and potato dextrose agar medium, respectively as suggested by Rangaswamy (1966). The composition of the different media is given below:

Nutrient agar medium for bacteria

Beef extract	3.0 g
Peptone	5.0 g
NaCl	5.0 g
Agar-agar	15.0 g
Distilled water	1000 ml
pH	6.8 ± 0.2

The medium was sterilized for half an hour at 121° C at 15 psi pressure

Kenknight and Munaier's medium for actinomycetes

Monopotassium dihydrogen phosphate	0.1 g
Sodium nitrate	0.1 g
Potassium chloride	0.1 g
Magnesium sulphate	0.1 g
Dextrose	1.0 g
Agar-agar	15 g
Distilled water	1000 ml
pH	6.8 ± 0.2

Potato dextrose agar medium (PDA) for fungi

Dextrose	20.0 g
Potato extract	4.0 g*
Agar-Agar	15.0 g
Distilled water	1000 ml
pH	5.6 ± 0.2

The medium was sterilized for half an hour at 121° C at 15 psi pressure.

*4.0 g of potato extract is equivalent to 200 g of potato infusion.

3.5.4.11. Estimation of dehydrogenase activity

There are several biological soil properties that can be used as soil quality indicators, alone or in combination with other chemical or physical properties. Dehydrogenase (DHA) is one of the most acceptable and most sensitive bio-indicators relating to soil quality and fertility. It is proposed as the best indicator of the microbiological redox-systems and could be considered as good parameter of microbial oxidative activities in soil. Therefore, understanding

the role of DHA in soil environment has large potential to use as soil quality indicator (Navnage *et al.* 2018).

For all soil biological characteristics, the soil samples were collected from each plot. The DHA activity was determined by the procedure described by Tabatabai (1982) Briefly, one gram of freshly processed soil was taken in a 15 ml screw cap tube and 0.2 ml of TTC (2, 3, 5 triphenyl tetrazolium chloride) and 0.5 ml of 1% glucose were added to it. The tubes were incubated at 30°C for 24 h. After incubation, 10 ml of methanol was added to the tubes, shaken thoroughly for 1 min and kept in refrigerator for 3 hours. The amount of formazan formed from standard curve prepared from TPF (Triphenyl formazan) was in the range of 0.04 to 0.5 mg 10 ml⁻¹ The color intensity developed due to TPF was measured spectrophotometrically at 485 nm using a standard curve. The DHA activity was expressed in µg TPF produced per hour per gram of air-dried soil (µg TPF g⁻¹ hr⁻¹).

3.5.4.12. Estimation of acid phosphatase activity

The acid phosphatase activity was assayed using the standard procedure of Tabatabai and Bremner (1969). The procedure described for assay of phospho-monoesterase activities is based on the colorimetric estimation of the *p*-nitrophenol released by phosphatase activity when soil is incubated with buffered (pH 6.5) sodium *p*-nitrophenyl phosphate solution. One gram of freshly processed soil was placed in a 15-ml screw cap test tube. Then 0.2 ml of toluene, 4 ml of *p*-nitrophenyl phosphate solution prepared in acetate was added and the test tube was swirled for a few seconds to mix the contents. The samples were then incubated at 37°C for 1 hour. After incubation 1 ml of 0.5 M CaCl₂ and 4 ml of 0.5 M NaOH were added. The soil suspension was then filtered through a Whatman No. 42 filter paper. The yellow color intensity of the filtrate was measured spectrophotometrically at 420-nm wavelength using standard curves. The acid phosphatase activity was expressed as micrograms of *p*-nitrophenol released per g of soil per hour (µg PNP g⁻¹ hr⁻¹).

3.6. BENEFIT COST RATIO:

The cost of different nutrient sources used viz. FYM, VC, PM, JM, GJ and chemical fertilizers applied to respective experimental plant and expenditure incurred on all cultural operations viz. application of nutrients, incorporation into the soil, labour on preparation of JM and GJ etc. were taken into account to calculate the cost of cultivation.

The gross return was calculated by multiplying the fruit yield against each treatment with prevailing market price of kiwifruit. Economics of different treatments was worked out in terms of net return per hectare. Treatment wise benefit: cost (B:C) ratio was also calculated to ascertain the economic viability of the treatments under study. The computation details of economics for each treatment are:

$$\text{Gross return (Rs./ha)} = \text{Return from fruit yield}$$

$$\text{Net return} = \text{Gross return} - \text{Total cost of cultivation}$$

$$\text{B:C ratio} = \text{Net return (Rs./ha)} / \text{Total cost of cultivation (Rs./ha)}$$

3.7. STATISTICAL ANALYSIS:

The data generated from the experiment investigations were appropriately computed, tabulated and analyzed by applying Randomized Block Design (RBD). The statistical analysis of the data was carried out as per method described by Gomez and Gomez (1984). The level of significance was tested for different variables at 5% level of significance.

ANOVA for RBD:

Source of variation	Degree of freedom (df)	Sum of squares	Mean sum of squares (MS)	F Calculated
Treatments	(t-1)	S_t	$M_t = S_t / (t-1)$	M_t / M_e
Replication	(r-1)	S_r	$M_r = S_r / (r-1)$	M_r / M_e
Error	(r-1) (t-1)	S_e	$M_e = S_e / (r-1) (t-1)$	
Total	(rt-1)	S_T		

Where,

r = Number of replications

S_T = Total sum of squares

t = Number of treatments

M_t = Mean sum of squares due to treatments

S_t = Sum of squares due to treatments

M_r = Mean sum of squares due to replications

S_r = Sum of squares due to replications

M_e = Mean sum of squares due to error

S_e = Sum of squares due to error

The replication and treatment mean sum of square were tested against error mean squares by 'F' test at (r-1), (r-1) (t-1) and (t-1), (r-1) (t-1) degree of freedom for RBD at 5% level of significance. The calculated 'F' values were compared with the tabulated 'F' value at 5% level of significance. When calculated 'F' value was higher than tabulated, it was considered significant i.e. at least one pair differ significantly and critical difference (CD) were calculated to find out the superiority of one treatment over the others.

The standard error of mean SE (m) and CD for comparing the means of any two treatments were calculated as under:

$$CD_{0.05} = SE (d) \times t_{(0.05) \text{ value at error degree of freedom (i.e. (r-1), (t-1))}}$$

$$SE (d) \pm = \sqrt{2 M_e/r} \quad SE (m) \pm = \sqrt{M_e/r}$$

where, $CD_{0.05}$ = Critical difference at 5% level of significance, M_e = Mean sum of squares due to error, r = number of replications, $SE (d)$ is standard error of difference and $SE (m)$ is standard error of mean. Data generated from the present investigation was subjected to statistical analysis as per above methods using MS Excel.

Chapter-4

RESULTS AND DISCUSSION

The present investigation entitled “**Effect of nutrient sources on soil properties and productivity of kiwifruit (*Actinidia deliciosa* cv. Allison)**” was planned to determine the effect of different nutrient sources on the plant growth, fruit yield, quality and soil characteristics. The results obtained during the present studies are presented under following heads and subheads:

4.1 EFFECT OF APPLICATION OF DIFFERENT NUTRIENT SOURCES ON PLANT GROWTH

4.1.1 Leaf Area

The application of different sources of nutrient had significant effect on the leaf area, however, the interaction effect was non-significant in subsequent years (Table 4.1). Among different treatments, pooled data of two years (2019 and 2020) revealed that treatment T₈ (30 liters *Jeevaamrit* + 3 kg *Ghana Jeevaamrit* + 40 kg FYM per vine) under SPNFS exhibited maximum leaf area (158.1 cm²) which was significantly different from all other treatments (Figure 4.1). Among OFBS farming system, application of 50% recommended dose of nitrogen through vermicompost and 50% by poultry manure in treatment T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) recorded significantly highest leaf area (151.8 cm²). In the first year of the experiment (2019), the leaf area of chemical fertilizer treatment T₁ (FYM: 40 kg, N: 800 g, P₂O₅: 600 g, K₂O: 800 g) was at par with T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀). On the basis of pooled data, the increase in leaf area was 6.23 and 10.63% by the application of VC + PM on 50:50 basis (T₂) under OFBS and 30 liters JM + 3 kg GJ (T₈) under SPNFS, respectively over chemical fertilizer + FYM treatment (T₁). The corresponding increase in leaf area during 2019 and 2020 was 3.84, 10.70 and 8.72, 10.65%, respectively. The pooled analysis of two-years data revealed that leaf area on year basis and their interaction didn't varied significantly. The results of higher leaf area on replacement of chemical fertilizer with organic manures (VC and PM) and liquid formulations (JM and GJ) might be due to the more soil organic matter and microbial activities which might have resulted in availability of nutrients for longer period of time particularly for N that has resulted in more vegetative growth.

Table 4.1: Effect of different nutrient sources under different farming systems on leaf area in kiwifruit

Treatment code	Treatment Detail	Leaf area (cm ²)		
		2019	2020	Pooled
Chemical Fertilizer Based System (CFBS)				
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	Recommended nutrients (FYM: 40 kg, N: 800 g, P ₂ O ₅ : 600 g, K ₂ O: 800 g)	145.8	139.9	142.9
Organic Farming Based System (OFBS)				
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	100% Recommended dose of nitrogen (RDN) through vermicompost (VC) and poultry manure (PM) on 50:50 basis + 40 kg FYM	151.4	152.1	151.8
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	90% RDN through VC + PM on 50:50 basis + 40 kg FYM	140.9	140.7	140.8
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	80% RDN through VC + PM on 50:50 basis + 40 kg FYM	137.9	136.7	137.3
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	70% RDN through VC + PM on 50:50 basis + 40 kg FYM	130.9	134.7	132.8
Subhash Palekar's Natural Farming System (SPNFS)				
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	40 kg FYM + 15.0 liters of <i>Jeevaamrit</i> (JM) + 3 kg of <i>Ghana Jeevaamrit</i> (GJ)	144.9	141.2	143.1
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	40 kg FYM + 22.5 liters JM + 3 kg GJ	150.2	145.4	147.8
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	40 kg FYM + 30.0 liters JM + 3 kg GJ	161.4	154.8	158.1
Mean		145.4	143.2	144.3
CD _{0.05} =		Treatment =	9.2	8.5
		Year =	NS*	
		Year × Treatment =	NS	

*NS=non-significant

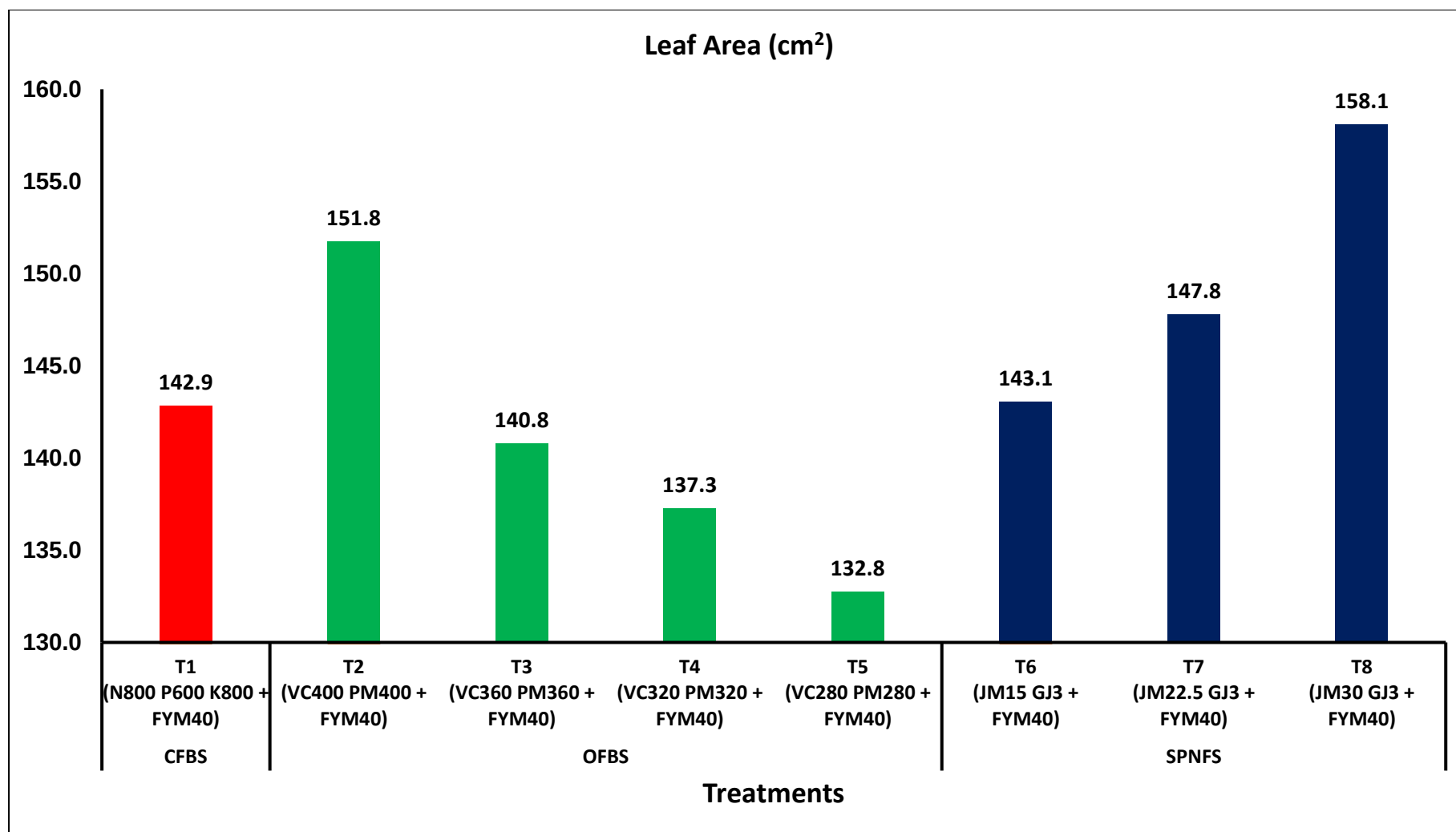


Figure 4.1: Changes in leaf area (cm²) of kiwifruit leaves with different nutrient sources under different farming systems

The data on increase in soil organic carbon (Table 4.13), nitrogen content (Table 4.14) with the application of VC and PM as well as *JM* and *GJ* in the respective treatments also confirmed the better nutrient availability, hence resulted in more leaf area. The positive correlation between leaf area and SOC ($r=0.583^*$, $p=0.05$) and between leaf area and soil available N ($r=0.715^{**}$, $p=0.01$) further support the results under present investigation. The better efficiency of organic manures might be due to the fact that it would have provided the micronutrients (Tables 4.17 and 4.18) to an optimum level. Thanunathan *et al.* (2002) also reported that application of VC @ 12.5 t ha⁻¹ registered significant increase in the growth attributes such as plant height, number of functional leaves, leaf area index and 100 seed weight as compared with rest of the manurial treatments and control. Arancon *et al.* (2004) also revealed that VC significantly increased the leaf area and shoot biomass of strawberry when incorporated into the top 10 cm soil @ 5-10 t ha⁻¹. The results are further supported by the findings of Karibasappa *et al.* (2007) and Baksh *et al.* (2008).

4.1.2 Leaf area index and chlorophyll index

Leaf area index (LAI) expresses the ratio of leaf surface (one-side only) to the ground area occupied by the crop. The assimilatory surface area of a crop stand and its increase has a direct relation to the amount of solar energy intercepted by canopy and represented the productive capacity of a crop (Verma *et al.*, 2017). Maximum LAI index (4.36) was recorded in T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS system followed by 4.35 in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS system over T₁ treatment (chemical fertilizer treatment). This higher value of LAI in liquid/organic manure treatment (T₂ and T₈) was attributed to efficient production of photosynthates that increases the size of the existing leaves (Table 4.2). The leaf area of respective treatments was also recorded maximum (Table 4.1). Similar results were obtained by Shwetha (2008) who reported significantly higher values of LAI, soybean plant height, number of branches, dry matter accumulation, seed yield with the application of organic manures in combination with fermented organics viz. *jeevaamrit*, *beejamrit*, *panchgavya* over the application of organics alone. However, lowest LAI (3.38) was recorded in vine treated with T₇ (JM_{22.5} GJ₃ + FYM₄₀) of SPNFS. The LAI values of OFBS vines followed decreasing trend from 4.35 in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) to 3.67 in T₅ (VC₂₈₀ PM₂₈₀ + FYM₄₀). Photosynthetically active radiation (PAR) is light of wavelengths 400-700 nm and is the portion of the light spectrum utilized by the plants for photosynthesis. PAR of lower canopy was recorded highest value of 642 μ mol quanta m⁻² s⁻¹ in T₂ followed by 612 μ mol quanta m⁻² s⁻¹

in T₈, although both these values are at par with chemical fertilizer treatment (T₁). PAR of upper canopy recorded highest value of 2027 μ mol quanta m⁻² s⁻¹ in T₂ followed by 2020 μ mol quanta m⁻² s⁻¹ in T₈, which were significantly higher than T₁ treatment of CFBS. Significantly increased plant height, LAI, dry matter production and number of tillers hill⁻¹ were also recorded by Ashokh *et al.* (2020). with the application of 100% N through PM in combination with foliar spray of panchagavya 3% at 30 and 45 days after transplanting followed by application of 100% N through PM + 3% *jeevaamrit* spray at 30 & 45 DAT. Similar results were also observed with the findings of Govindappa *et al.* (2009) and Sangeetha *et al.* (2010), Abdullahi *et al.* (2014). Overall results on plant growth parameters viz. leaf area, LAI and chlorophyll index showed that leaf area was recorded highest in T₈, leaf chlorophyll index values of T₈ were at par with recommended dose of fertilizers i.e. T₁. Therefore, SPNFS system was found superior with respect of leaf area than OFBS and CFBS, while it showed comparable results with respect to chlorophyll index.

The chlorophyll content is the main index showing leaf photosynthesis ability and plant health condition (Monje and Bugbee, 1992). During estimation of chlorophyll content by laboratory analysis method significant pigment losses occurs during the extraction that may lead to a high variability in the results (Shoaf and Lium, 1976). Whereas, SPAD-502 chlorophyll meter is a simple, portable diagnostic tool that measures the relative chlorophyll content of leaves (Marquard and Tipton, 1987) with substantial time saving. By measuring the leaf transmittance in two wave bands SPAD meter quantifies the relative amount of chlorophyll with a reading in arbitrary unit (SPAD-502 Chlorophyll Index) that is proportional to the leaf chlorophyll concentration (Sim *et al.*, 2015). High correlations between SPAD-502 index and chlorophyll content have been reported for several crops. Hence, in the present study SPAD meter is used for assessing chlorophyll index. A perusal of data presented in Table 4.2 revealed that different nutrient source under different farming systems exhibited a significant influence on leaf chlorophyll index. Pooled analysis results showed that all treatments (T₆, T₇ and T₈) under SPNF system recorded significantly higher chlorophyll index (ranging from 49.6 to 51.6) than OFBS treatments but they are statistically at par with the vines treated with chemical fertilizer treatment T₁ (FYM: 40 kg, N: 800 g, P₂O₅: 600 g, K₂O: 800 g) (Figure 4.2). A significant finding of the study is in congruence with the earlier study carried out by Ninan *et al.* (2013) in which they observed increased chlorophyll content in leaf tissues of rice plants treated with *Jeevaamrit*. This may be due to presence of increased population of photosynthetic bacteria in this organic formulation. The use of liquid manures (*JM* and *GJ*) with FYM have

increased N content in the leaves (Figure 4.3) and might have enhanced the Mg absorption from the soil. The chlorophyll is an essential component for photosynthesis occurs in chloroplasts a green pigment in all photosynthetic plant tissues, so more chlorophyll content in plants may be attributed to more uptake of nitrogen by the plants. Being main constituents of chlorophyll, N and Mg contents attributed to increased chlorophyll content in the leaves which is represented by SPAD chlorophyll index values. Moreover, N is the main constituent of all amino acids in protein and lipids that act as a structural compound of the chloroplast. Although percent leaf nitrogen of treatment T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS and T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS systems are comparable but chlorophyll index values are comparable only with SPNFS system that may be due to the increased photosynthetic efficiency by liquid organic manures as the later supplied adequate amount of nutrients to the plants speedily. These results were found in conformity to those of Hiremath *et al.* (2006) in paprika. SPAD values of all the treatments under OFBS were significantly lower than CFBS and SPNFS. In contrast, Nehra *et al.* (2001) reported increased chlorophyll content in wheat leaves due to the application of VC and FYM.

In general, southern side of the orchard showed higher chlorophyll index values than northern side (Table 4.2). The pooled analysis of 2-year data revealed that SPAD chlorophyll index values between years didn't varied significantly and non-significant "Treatment × Year" interaction also indicated that chlorophyll index response to treatments has not affected by climate.

4.2 EFFECT OF APPLICATION OF DIFFERENT NUTRIENT SOURCES ON YIELD AND QUALITY PARAMETERS OF KIWIFRUIT

4.2.1 Kiwifruit yield

The effect of application of different nutrient sources under different farming systems on the kiwifruit yield per vine is presented in Table 4.3. Critical examination of the data revealed that total yield per vine varied significantly among different treatments. The highest fruit yield (30.69 kg vine⁻¹) was recorded with the treatment T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) under OFBS over 29.21 kg vine⁻¹ of chemical fertilizer treatment T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) under CFBS. The T₈ treatment (JM₃₀ GJ₃ + FYM₄₀) under SPNFS recorded little lower kiwifruit yields of 28.68 kg vine⁻¹. The kiwifruit fruits of all these treatments are at par showing that replacing 100% recommended dose of nitrogen with VC and PM on 50:50 basis (T₂) and also

Table 4.2: Effect of different nutrient sources under different farming systems on chlorophyll index (SPAD reading), photosynthetically active radiation (PAR) and leaf area index (LAI) values of kiwifruit leaves

Treatment Code*	SPAD values (Chlorophyll Index)									PAR (μ mol quanta m ⁻² s ⁻¹)		LAI
	2019			2020			Pooled					
	North side	South side	Mean	North side	South side	Mean	North side	South side	Mean	Upper Canopy	Lower Canopy	
Chemical Fertilizer Based System (CFBS)												
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	50.7	51.2	50.9	51.4	51.7	51.6	51.1	51.4	51.2	1913	577	3.91
Organic Farming Based System (OFBS)												
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	47.7	49.7	48.7	47.8	50.1	48.9	47.8	49.9	48.8	2027	642	4.35
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	47.7	49.3	48.5	47.3	50.0	48.7	47.5	49.7	48.6	2019	575	4.01
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	47.4	48.9	48.1	46.4	49.4	47.9	46.9	49.1	48.0	1983	571	3.71
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	47.2	48.3	47.8	47.2	48.9	48.0	47.2	48.6	47.9	1964	532	3.67
Subhash Palekar's Natural Farming System (SPNFS)												
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	49.9	50.3	50.1	47.5	50.5	49.0	48.7	50.4	49.6	1955	574	3.99
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	50.9	51.2	51.1	51.7	52.7	52.2	51.3	52.0	51.6	1757	468	3.38
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	50.6	51.8	51.2	49.8	52.5	51.2	50.2	52.2	51.2	2020	612	4.36
Mean	49.0	50.1	49.5	48.6	50.7	49.7	48.8	50.4	49.6	1955	569	3.92
CD _{0.05} =	1.28	1.08	0.74	3.01	2.32	1.95	1.56	1.22	0.99	105	93	0.34
	Year =						NS*	0.61	NS	-	-	-
	Year × Treatment =						NS	NS	NS	-	-	-

*For details of treatment code, refer to Table 4.1.

*NS=non-significant

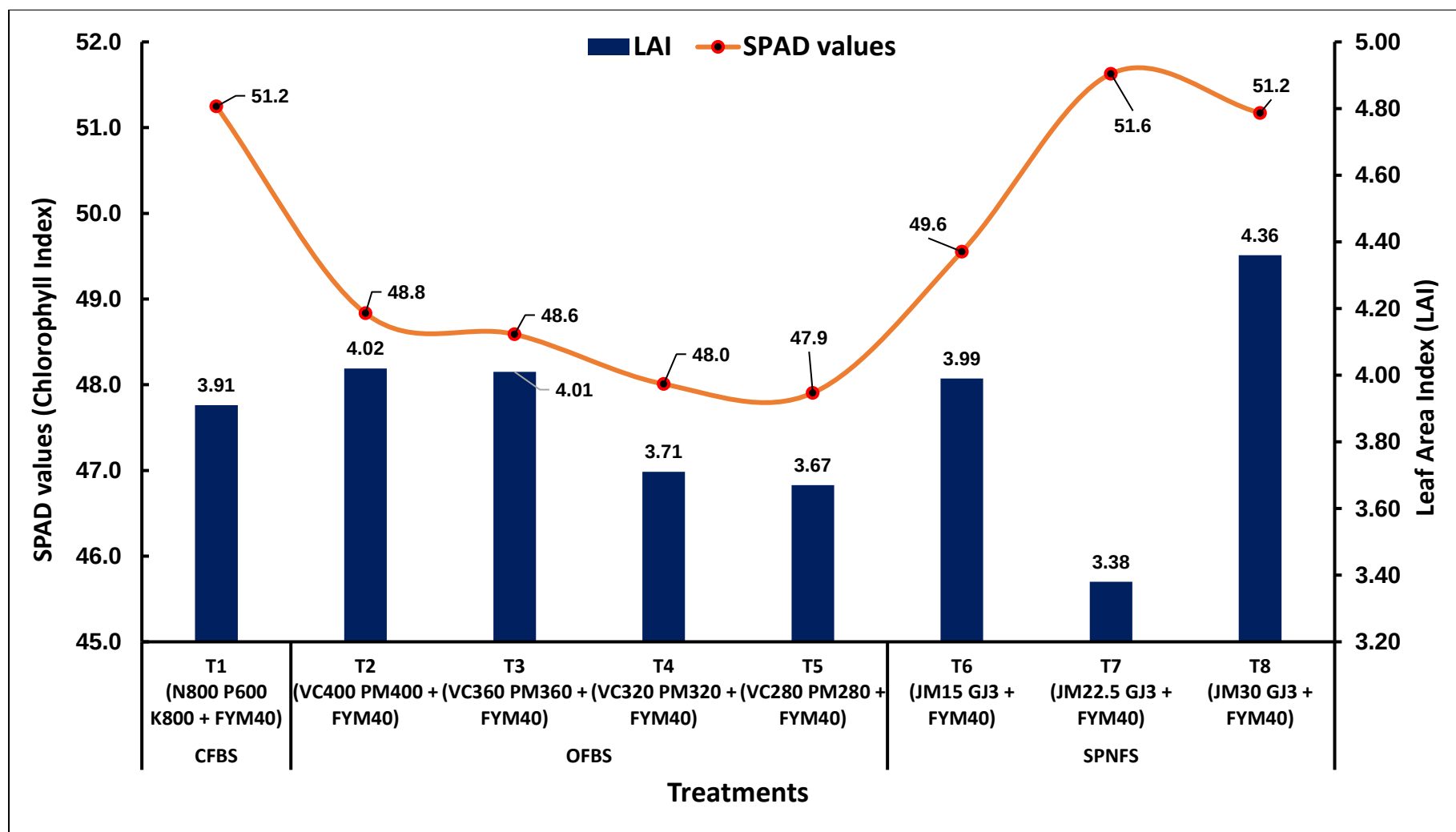


Figure 4.2: Effect of different nutrient sources on chlorophyll index (SPAD values) and LAI values of kiwifruit leaves under different farming systems

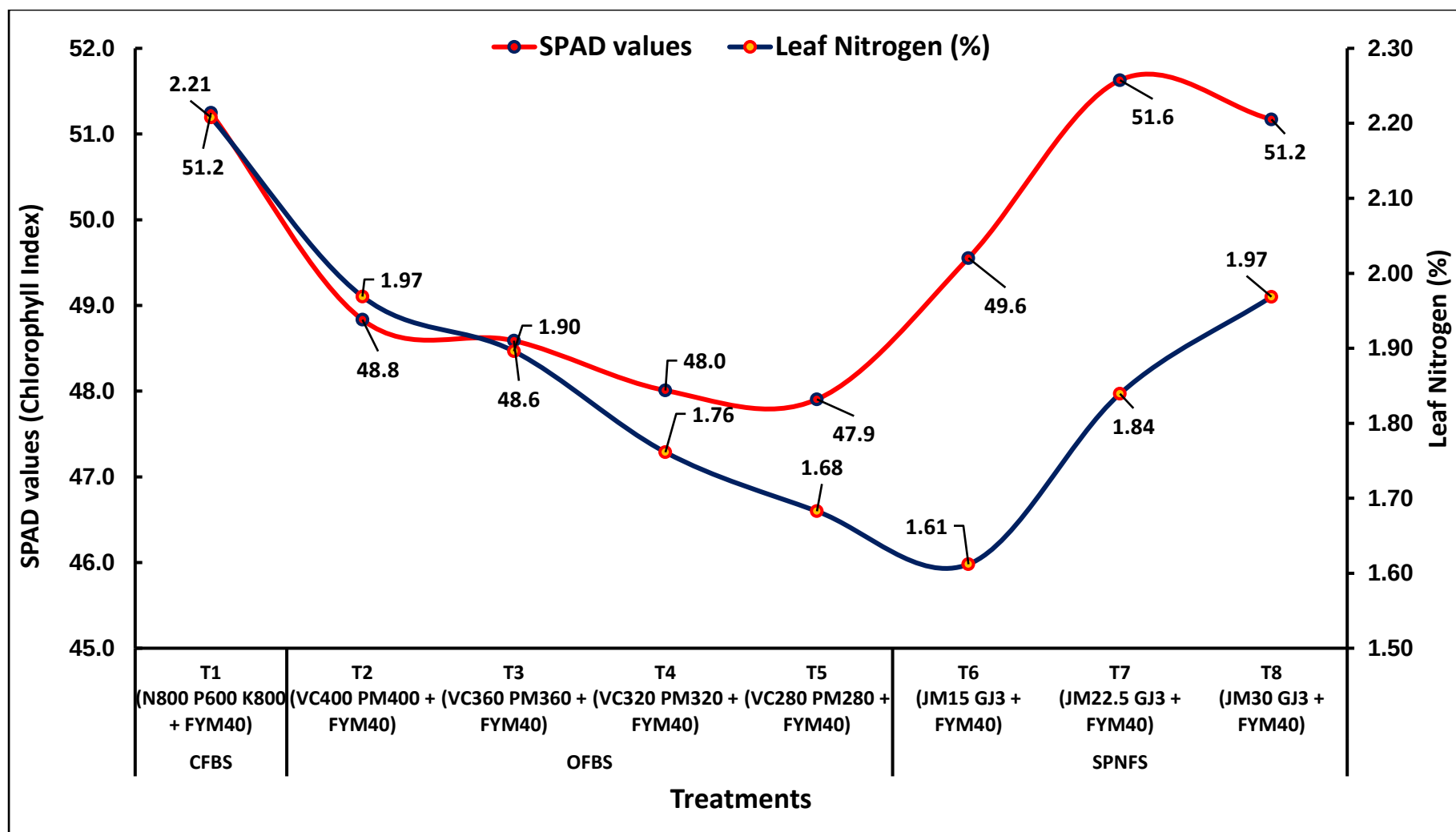


Figure 4.3: Relationship between SPAD values and leaf N content (%) in kiwifruit leaves with different nutrient sources under different farming systems.

by liquid organic manure @ 30 liters per vine (T₈) would be sufficient to meet the N need of the plant and resulted in comparable yields. The trend was same during both the years of experimentation. The respective yield values of treatments T₆ (26.13 kg vine⁻¹), T₇ (26.76 kg vine⁻¹) and T₈ (28.68 kg vine⁻¹) under SPNFS system are statistically comparable. However, decreasing trend was observed as dose of liquid manures decreases from 30 liters per vine to 22.5 and 15 liters per vine. The treatment T₂ produced highest fruit yield amongst all organic input treatments and the total fruit yield per vine of T₃, T₄ and T₅ treatments were recorded to be 25.22 kg vine⁻¹, 22.49 kg vine⁻¹ and 21.42 kg vine⁻¹, respectively. Pawar *et al.* (2013) indicated that, application of FYM 5 t ha⁻¹ + VC @ 2.5 t ha⁻¹ + *Jeevaamrit* application two times (30 and 45 DAS) to kharif sweet corn recorded significantly higher values for sweet corn cob and green fodder yield. The results are also in accordance with Gore (2009) who reported that the application of liquid organic manures i.e. *jeevaamrit* have helped in improving growth and yield.

Furthermore, several works in developing countries presented that where small farmers have little access to agrochemicals, the conversion from conventional to organic usually represented an increase in yield from 15 percent (Bray *et al.*, 2002) to 67 percent in Guatemala (Damiani, 2002). Higher yield of capsicum per hectare was recorded by Boraiah *et al.* (2017) with *jeevaamrit* application. Earlier, Shwetha (2008) in soybean and Kumar *et al.* (2011) in black gram reported higher pods per plant, number of seed per pod with the use of *beejamrut*, *jeevaamrit* and *panchgavya* as organic source of nutrient. Aniekwe and Nwokwu (2013) also recorded significantly higher number of fruits by the application of FYM and VC in watermelon. Recently, Patel *et al.* (2018) observed that foliar spray of *panchgavya* @ 4 % + soil application of *jeevaamrit* @ 500 liters ha⁻¹ recorded significantly higher pod yield (1563 kg ha⁻¹) of *kharif* groundnut (*Arachis hypogaea* L.) than rest of the treatments being at par with treatments viz. application of 100% RDN through FYM i.e. control and *Panchgavya* @ 2% foliar spray + *Jeevaamrit* @ 500 liters per ha as soil application to the crop.

In general, the kiwifruit yields were recorded higher in 2020 as compared to the year 2019 (Table 4.3). This may be due to the fact that the effect of organic nutrients on crop yield was long term and not immediate because of the slow nutrient release. So, the absence of improvements in fruit yields with organic fertilizer application in this study may be because of insufficient time to see the desirable effects. According to Gopinath *et al.* (2008), there was 23-65% reduction in grain yield of wheat under organic amendments such as composted FYM, VC and lantana compost compared with mineral fertilizer treatment during transition from chemical to organic farming. The results are in congruence with the earlier studies conducted

by Chalmers (2001). The percent increase in yield in 2020 over the year 2019 was recorded 34.3% in T₁ treatment (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) under CFBS, 37.3 to 63.1% in OFBS and 27.4 to 30.4% in SPNFS, respectively. The higher response in case of OFBS is might be due to the fact that organic manure release nutrients slowly during the first year of application. Further, the higher yield obtained with combined application of inorganic fertilizer and organic manure might be attributed to congenial physical and biological environment of soil which leads to higher and balanced nutrients uptake (Bhatt *et al.*, 2018). Secondly, the importance of VC in improving growth of fruit crops such as Mango, Sapota, Guava and Banana is well documented by many workers (Athani *et al.*, 2009) and attributed to release of higher amount of nutrients as well as growth stimulating substances excreted by earthworms in their casts. Thirdly, it might be due to comparatively low temperature in the year 2020 in the month of June (i.e. 30.8°C) as compare to 33.7°C in the respective month of the year 2019 (Figure 3.1 & Annexure-I). Furthermore, there was slightly more precipitation observed in the year 2020 (compare January to September month precipitation values) (Annexure-I) which might have resulted in better water availability. Additionally, the pooled data also confirmed that interaction effect of “Year” and “Year × Treatment” was found significant (Table 4.3). The results on comparable yields of T₁, T₂ and T₈ is might be due to better nutrient availability in T₂ and T₈ which in turn increased the flower primordial, carbohydrates and nutrients essential to promote flowering and fruit retention in plants which ultimately lead to increase in kiwifruit yield. The results of present experiment are also in line with the observations of Singh *et al.* (2012) who reported maximum fruit yield per plant of aonla with the standard doze of NPK + FYM. Tripathi *et al.* (2018a) also reported that the yields of five crops (paddy, groundnut, blackgram, maize and chillies) have increased by 8-32 per cent for SPNFS farmers.

4.2.2. Grade wise yield of kiwifruit

A perusal of data presented in (Table 4.3) and depicted in Figure 4.4 showed that different treatments of organic sources under different farming systems exhibited a significant influence on A-grade and B-grade fruits in 2019 and A, B and C-grade fruits in 2020. Pooled data of two years showed that different farming systems exhibited a significant influence on only B-grade fruits (Table 4.3).

Different nutrient sources didn't show any significant changes in A-grade fruits, however, the highest yield of A-grade fruit was found in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) recording 6.03 kg vine⁻¹ of OFBS, followed by T₈ of SPNFS, recording 5.81 kg vine⁻¹. The treatment T₁ under chemical fertilizers recorded only 4.56 kg vine⁻¹ of A-grade fruits.

Table 4.3: Effect of different nutrient sources on total and grade wise yield of kiwifruit under different farming systems

Treatment Code*	2019				2020				Pooled			
	Grade-wise yield (kg/vine)			Total yield (kg/vine)	Grade-wise yield (kg/vine)			Total yield (kg/vine)	Grade-wise yield (kg/vine)			Total yield (kg/vine)
	A	B	C		A	B	C		A	B	C	
Chemical Fertilizer Based System (CFBS)												
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	4.85	11.36	8.72	24.93	4.26	12.20	17.03	33.49	4.56	11.78	12.87	29.21
Organic Farming Based System (OFBS)												
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	5.83	11.86	8.28	25.97	6.23	13.36	15.81	35.40	6.03	12.61	12.05	30.69
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	3.64	7.54	8.02	19.20	5.41	11.90	13.93	31.24	4.52	9.72	10.97	25.21
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	2.05	6.66	8.38	17.09	4.63	10.60	12.65	27.88	3.34	8.63	10.52	22.49
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	1.51	6.26	9.02	16.79	3.40	10.49	12.16	26.05	2.46	8.38	10.59	21.42
Subhash Palekar’s Natural Farming System (SPNFS)												
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	4.14	8.08	10.46	22.68	3.63	11.95	13.99	29.57	3.89	10.02	12.23	26.13
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	4.70	9.66	9.88	24.24	4.13	13.03	14.13	31.29	4.42	11.35	12.00	27.77
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	5.84	10.04	9.35	25.23	5.78	13.30	13.05	32.13	5.81	11.67	11.20	28.68
Mean	4.07	8.93	9.01	22.01	4.68	12.11	14.09	30.88	4.38	10.52	11.55	26.45
CD _{0.05} =	0.51	1.26	NS**	2.96	0.61	1.04	2.59	1.92	NS	2.18	NS	3.19
	Year =								0.19	0.39	0.81	0.84
	Year × Treatment =								0.54	1.10	2.28	2.38

*For details of treatment code, refer to Table 4.1.

**NS=non-significant

The yield of B-grade fruits changes significantly with different organic manures (Table 4.3). The vines treated with T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) under OFBS produced maximum yield of B-grade fruits (12.61 kg vine⁻¹) followed by treatment T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) under CFBS, recording 11.78 kg vine⁻¹ and treatment T₈ (JM₃₀ GJ₃ + FYM₄₀) under SPNFS recorded 11.67 kg vine⁻¹. All of these treatments were comparable in producing B-grade kiwifruits in two years pooled data.

There was no significant change in the yield of C-grade kiwifruits with the application of different organic sources. However, the highest yield of C-grade fruits (12.87 kg vine⁻¹) was observed with T₁ treatment (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) under CFBS, followed by T₆, T₂ T₇ and T₈ recording 12.23, 12.05, 12.00 and 11.20 kg vine⁻¹, respectively which was statistically at par with each other.

The pooled data showed that climate has significant effect on grade wise yield of kiwifruit, which is clear from the significant values of ‘Year’ and ‘Year × Treatment’ interaction. The results of the experiment also showed that there is no response of substituting the RDN with either organic manures like VC and PM or by combined application of JA and GJ, with respect to yield of A-grade and C-grade of kiwifruits. Significantly lower yields of B-grade fruits were observed with the replacement of RDN with 90, 80 and 70% VC and PM on 50:50 basis (T₃, T₄ and T₅ treatments, respectively). This might be due to the reason that organic manure released nutrients slowly and replacing with low quantity would not be sufficient to meet the nutrient requirement. The decrease in nutrient content of leaves (Table 4.6) also supports the hypothesis.

The percent proportion of grade wise yield of kiwifruit is depicted in Figure 4.5. The percent proportion of A-grade fruits varied from 11.5% to 20.3% which was significantly higher (CD_{0.05} = 1.8) in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS and T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS, recording 19.6 and 20.3% over control treatment of T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) that has only 15.6% A-grade fruits.

The percent proportion of B-grade fruits didn’t vary significantly (CD_{0.05} = non-significant). The percent proportion of C-grade fruits varied from 39.1% to 49.4% which was significantly higher (CD_{0.05} = 5.1) in T₅ (VC₂₈₀ PM₂₈₀ + FYM₄₀) of OFBS than control treatment of T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀). The lowest percent proportion of C-grade fruits (39.1%) was noticed in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS and T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS vines. So, finally it is concluded that substituting organic manure would be enough to maintain the size of the fruit out of the total respective yield which can fetch higher price in the market.

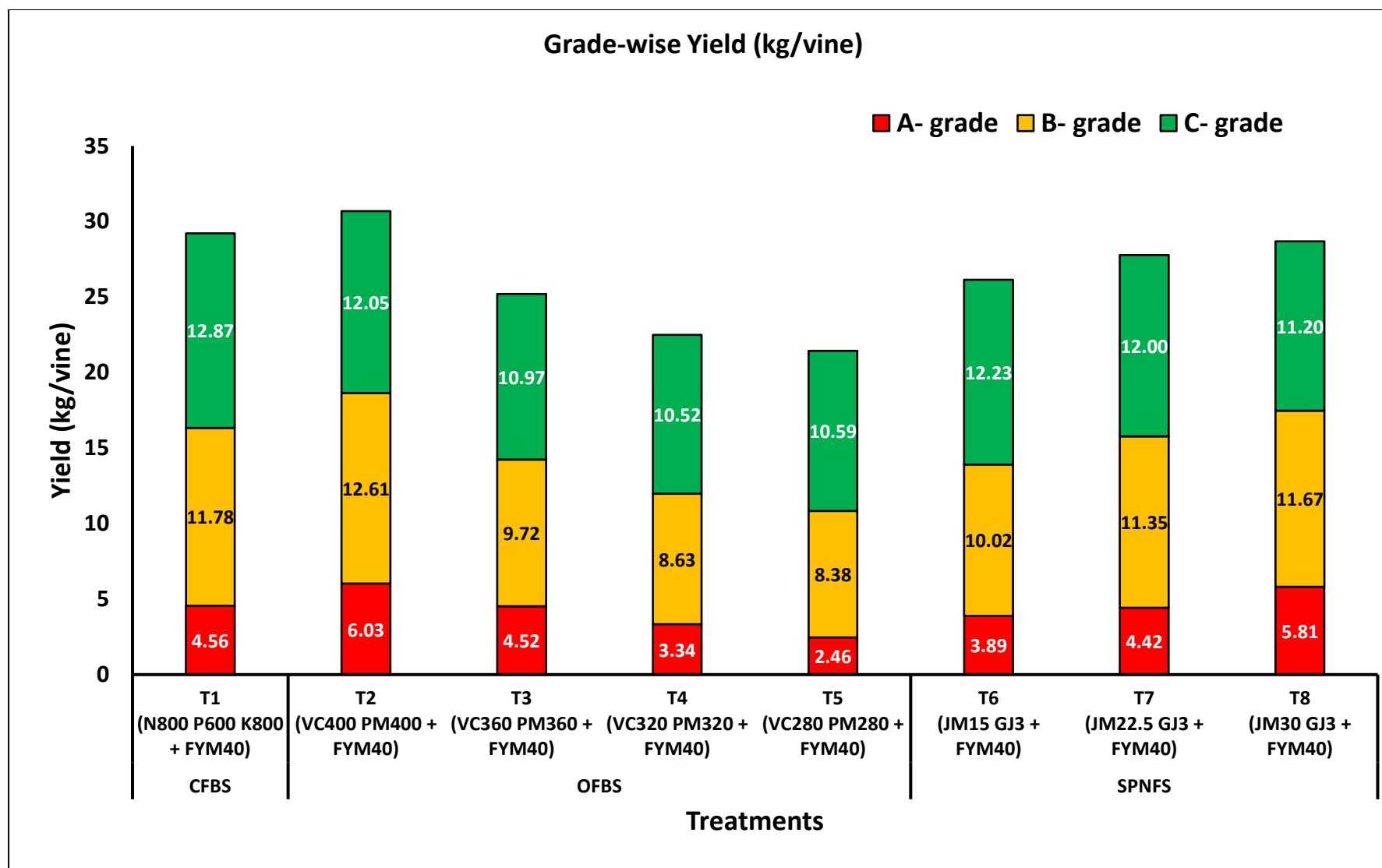


Figure 4.4: Effect of different nutrient sources on grade-wise yield of kiwifruit under different farming systems.

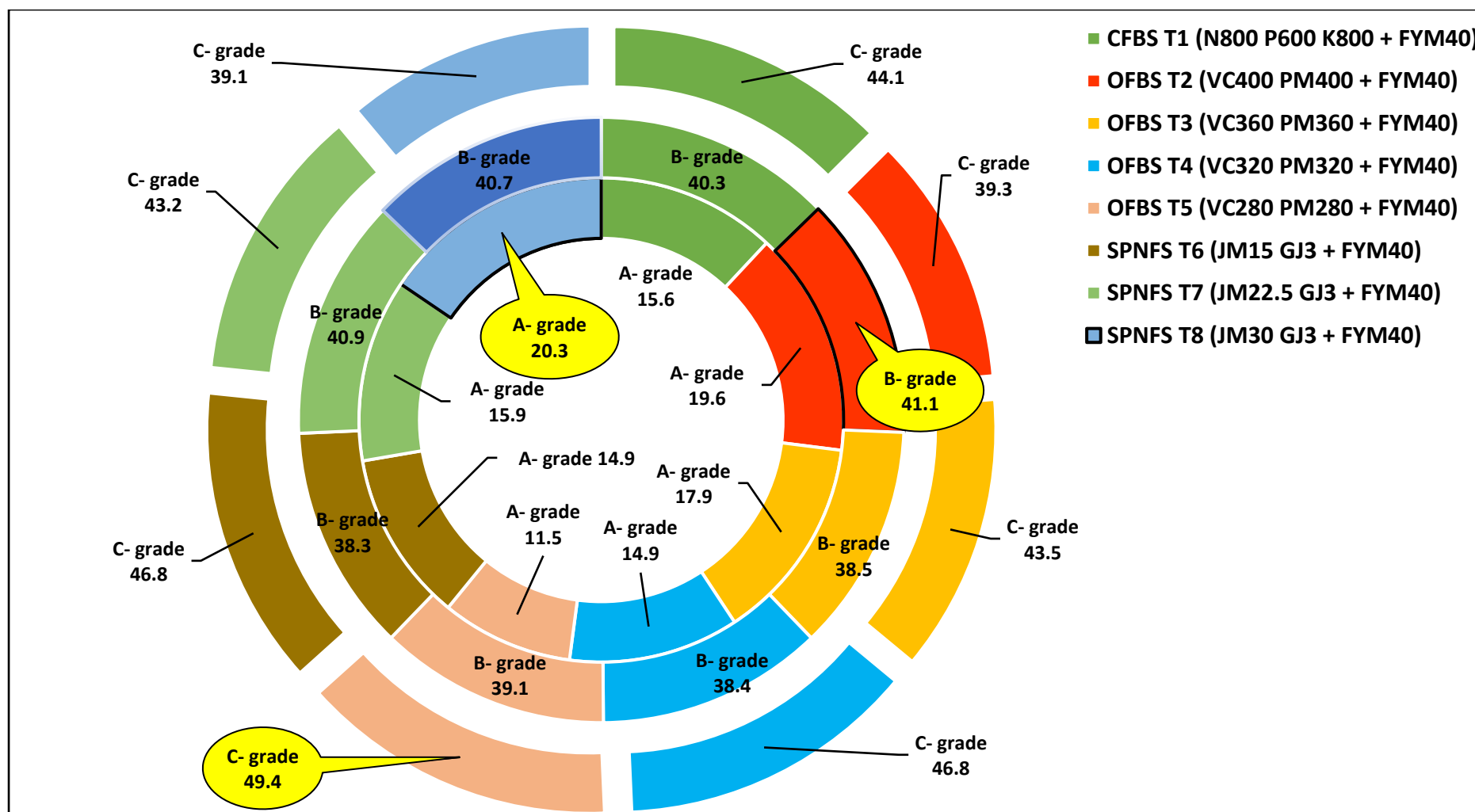


Figure 4.5: Effect of different nutrient sources on per cent proportion of grade-wise yield of kiwifruit. (A-grade>70 g, B-grade 50-70 g and C-grade<50 g)

4.2.3. Fruit size of kiwifruit

The data pertaining to the fruit length, average fruit diameter, L/D ratio after the completion of first year (2019) and second year (2020) field trial as influenced by different organic manures under different farming system had significant effect on the fruit length and average diameter (Table 4.4 and Plate 3.8). However, non-significant difference was observed in the L/D ratio of fruits after first year trial only. Among different treatments, T₁ treatment of recommended dose of nutrients under CFBS was found to be the best in terms of fruit length during both the years of experimentation. The maximum fruit length (66.7 mm) was recorded with treatment T₁ which was followed by T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS, T₇ (JM_{22.5} GJ₃ + FYM₄₀) and T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS vines, which recorded fruit length of 63.4 mm, 63.0 mm and 62.5 mm, respectively in 2019. The respective variations in the year 2020 was 64.8 mm in T₁ followed by T₂, T₈ and T₇, which recorded fruit length of 60.7 mm, 59.7 mm and 59.4 mm, respectively. The data presented in Table 4.4 also revealed that no significant changes in fruit size has been noticed among different treatments of OFBS (i.e. T₂, T₃, T₄ and T₅) and SPNFS (T₆, T₇ and T₈) during 2019. Similar trend has been noticed in 2020 except for T₅ of OFBS and T₆ of SPNFS which has significantly lower fruit size as compare to other treatments in their respective system. In general, fruit length was smaller in 2020 as compared to 2019.

The pooled data on fruit length showed the similar trends as that of individual years (Table 4.5 and Figure 4.6) with maximum fruit length of 65.8 mm was recorded in T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) under CFBS. The interaction effect of 'Year' was found to be significant but interaction of 'Year × Treatment' was non-significant. In general, among OFBS and SPNFS, the former produced more long fruits than later suggesting that continuous supply of nutrients especially nitrogen for longer period under OFBS and vermicompost may have accounted for improvement in physical fruit quality characteristics.

Average maximum kiwifruit diameter (40.9 mm) was noted in T₁ treatment (Recommended dose of chemical fertilizers + FYM₄₀), followed by T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS and T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS, recording 40.4 mm and 40.2 mm diameter of fruit, respectively (Table 4.5 and Figure 4.6). The data suggest that only 100% substitution of RDN with VC and PM and 30 liters of JM along with 3 kg of GJ are sufficient to maintain the fruit diameter. Pooled data depicts that 'Year' showed significant effect on fruit size suggesting climate has influenced the fruit size. The interaction effect of 'Year × Treatment' was found non-significant.

Table 4.4: Effect of different nutrient sources on kiwifruit size, L/D ratio and fruit weight under different farming systems

Treatment Code*	2019						2020					
	Fruit length (mm)	Radial diameter 1 (mm)	Radial diameter 2 (mm)	Average Diameter (mm)	L/D ratio	Fruit weight (g)	Fruit length (mm)	Radial diameter 1 (mm)	Radial diameter 2 (mm)	Average Diameter (mm)	L/D ratio	Fruit weight (g)
Chemical Fertilizer Based System (CFBS)												
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	66.7	43.4	40.0	41.7	1.60	69.5	64.8	42.2	38.2	40.2	1.61	66.7
Organic Farming Based System (OFBS)												
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	63.4	43.2	39.0	41.1	1.54	62.7	60.7	42.5	36.1	39.3	1.54	63.1
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	62.1	42.0	38.5	40.3	1.54	62.4	59.0	41.8	35.4	38.6	1.53	61.6
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	61.3	41.5	38.2	39.8	1.54	60.3	57.5	41.6	35.2	38.4	1.50	60.3
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	60.9	41.5	38.1	39.8	1.53	59.2	57.2	40.7	34.8	37.8	1.51	57.8
Subhash Palekar's Natural Farming System (SPNFS)												
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	60.4	39.9	37.7	38.8	1.56	53.6	56.5	41.6	35.9	38.7	1.46	54.6
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	63.0	41.0	38.1	39.5	1.59	57.3	59.4	42.6	36.2	39.4	1.51	57.7
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	62.5	42.3	39.2	40.7	1.53	63.3	59.7	43.7	36.5	40.1	1.49	59.3
Mean	62.5	41.8	38.6	40.2	1.55	61.0	59.3	42.1	36.0	39.1	1.52	60.1
CD_{0.05} =	3.31	NS**	1.03	1.44	NS	7.35	3.19	NS	NS	1.42	0.06	4.18

*For details of treatment code, refer to Table 4.1.

**NS=non-significant

Table 4.5: Effect of different nutrient sources on kiwifruit size, L/D ratio and fruit weight (Pooled data for two years 2019 and 2020) under different farming systems

Treatment Code*		Fruit size (mm)				L/D ratio	Fruit weight (g)
		Fruit length (mm)	Radial diameter 1 (mm)	Radial diameter 2 (mm)	Average fruit diameter		
Chemical Fertilizer Based System (CFBS)							
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)		65.8	42.8	39.1	40.9	1.61	68.1
Organic Farming Based System (OFBS)							
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)		62.0	42.8	37.5	40.2	1.54	62.9
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)		60.5	41.9	37.0	39.4	1.54	62.0
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)		59.4	41.6	36.7	39.1	1.52	60.3
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)		59.0	41.1	36.4	38.8	1.52	58.5
Subhash Palekar’s Natural Farming System (SPNFS)							
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)		58.4	40.7	36.8	38.7	1.51	54.1
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)		61.2	41.8	37.1	39.5	1.55	57.5
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)		61.0	43.0	37.9	40.4	1.51	61.3
Mean		60.9	42.0	37.3	39.6	1.54	60.6
CD _{0.05} =	Treatment =	2.20	NS	1.15	0.96	0.06	4.04
	Year =	1.10	NS	0.57	0.48	0.03	NS
	Year × Treatment	NS	NS	NS	NS	NS	NS

*For details of treatment code, refer to Table 4.1.

**NS=non-significant

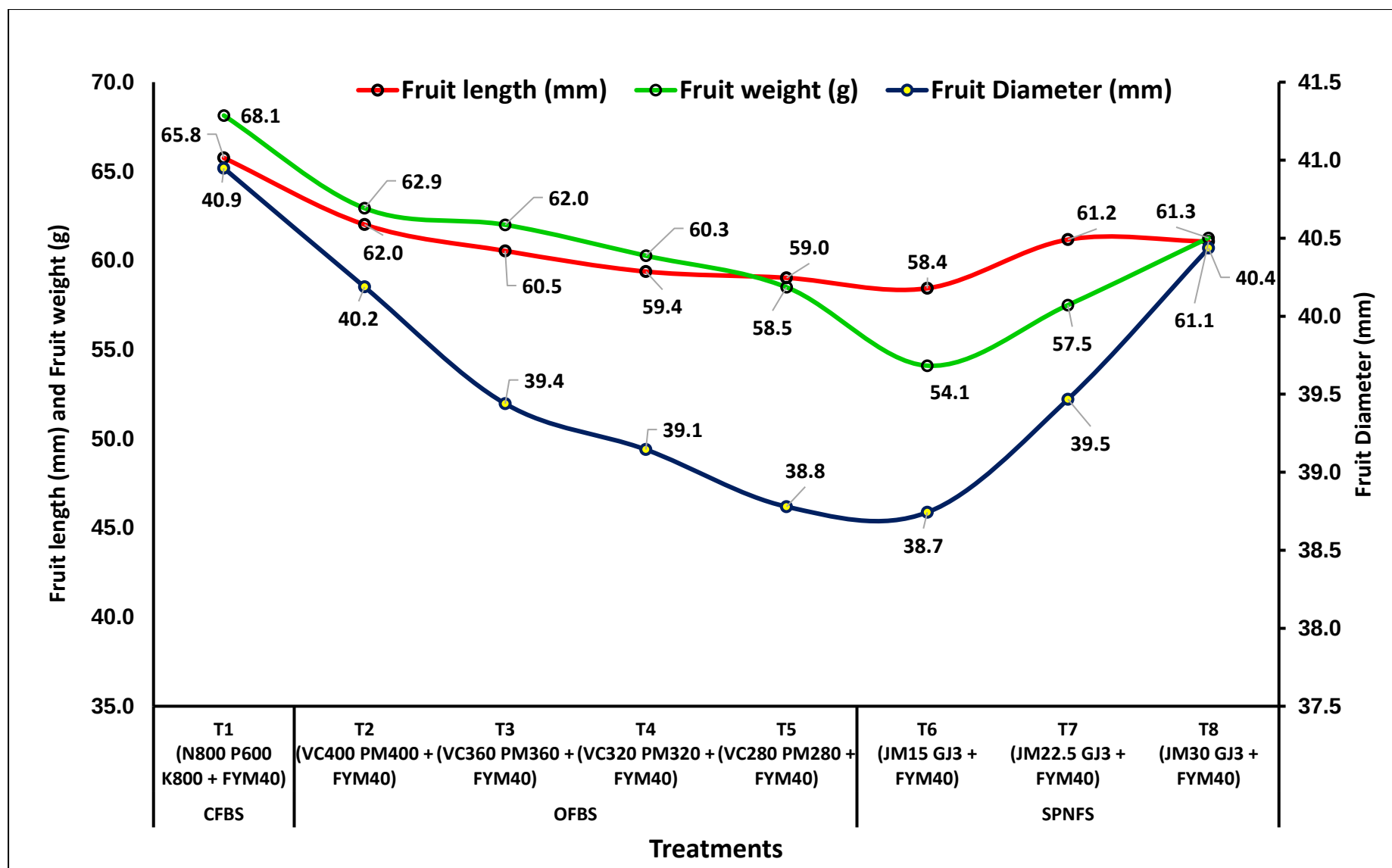
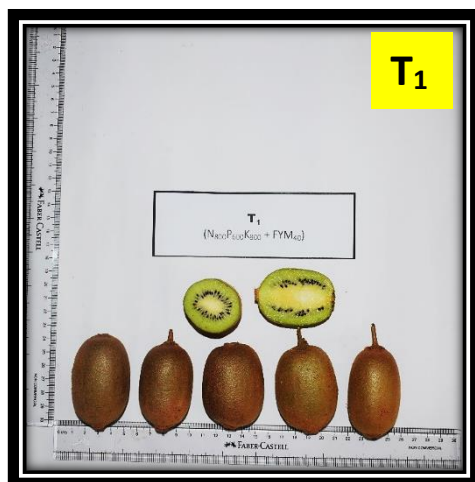
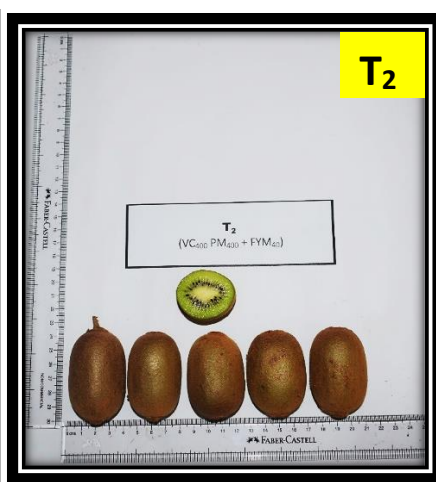


Figure 4.6: Effect of different nutrient sources on kiwifruit length (mm), diameter (mm) and weight (g) under different farming systems



CFBS



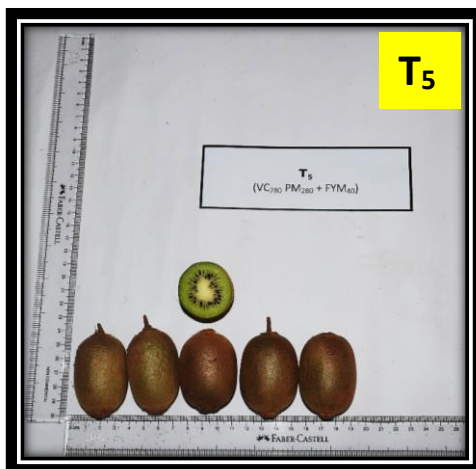
OFBS



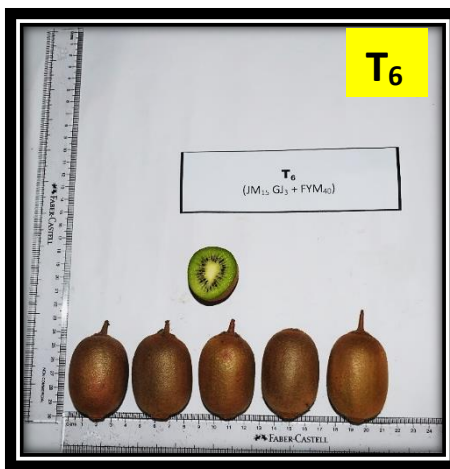
OFBS



OFBS



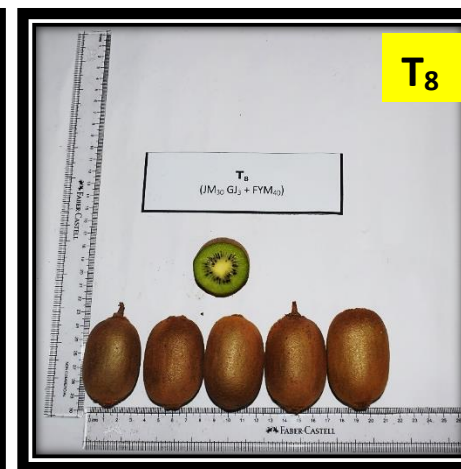
OFBS



SPNFS



SPNFS



SPNFS

Plate 3.8: Comparison among CFBS, OFBS and SPNFS systems on fruit size

The data pertaining to L/D ratio of kiwifruit revealed that application of different organic manures showed slight significance effect. However, the highest L/D ratio (1.61) was still recorded with treatment T₁ (Recommended dose of chemical fertilizer + FYM₄₀). The treatment T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS, and T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS, recorded lower L/D ratio of 1.54 and 1.51, respectively (Table 4.4).

Our results are in congruence with Abu-Zahra (2016) who also observed that fruit size is highly affected by the farming systems; the conventional agriculture resulted in the biggest fruits, in comparison to organically produced fruits. The large fruit size in the conventional farming system may be due to the good availability of soil nutrients that produced vigorous plants with higher yield and larger fruits.

4.2.4. Fruit weight of kiwifruit

Effect of application of different organic manures on the fruit weight in different farming systems are presented in Table 4.4 and Table 4.5. It is evident from the data that the fruit weight was not improved by different sources of organic manures as compared to conventional farming (i.e. T₁: N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) in both the years of experimentation. The highest fruit weight (68.1 g) average of five fruits was recorded with the treatment T₁ which was followed by T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS and T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS, recording 62.9 and 61.3 g fruit weight, respectively in pooled data. In OFBS, the treatment T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) recorded highest fruit weight of 62.9 g which was at par with T₃ (VC₃₆₀ PM₃₆₀ + FYM₄₀) and T₄ (VC₃₂₀ PM₃₂₀ + FYM₄₀) treatments. In general vines SPNFS recorded lower fruit weights than other farming systems.

The results are in close congruence with Sharma (2018) who observed higher fruit weight of 97.9 g with recommended nutrients NPK + 40 kg FYM in kiwifruit among other organic treatments of different combination of VC and PM. The higher fruit weight of kiwifruit in the CFBS may be attributed to the relative increase in availability of nutrients and better solute uptake by plants. These findings are in close conformity with Gautam *et al.* (2012) in Mango. Moreover, most researchers found only small and non-significant differences between organic and conventional systems in respect to fruit weight (Leskinen *et al.*, 2002). But in an experiment conducted on strawberry plants, they observed that the use of chemical fertilizers was found to produce the highest significant average fruit weight compared to fruits produced by using organic materials or without using any type of fertilizers (Abu-Zahra *et al.*, 2007 and Abu-Zahra and Tahboub, 2008).

Similarly, Zhang *et al.* (2020) also reported that the use of inorganic fertilizer could significantly promote growth of new shoots and stems, net photosynthetic rates, and increase the fruit yield in kiwifruit. In the same way, higher fruit yield and quality after fertilizer application have been reported in perennial fruit crops, especially on soils with nutritional limitations to plant growth by several workers like Kozera *et al.* (2013), Donno *et al.* (2013), and Guarconi and Ventura (2011) in caraway fruit, kiwifruit and pineapple respectively.

4.2.5. Leaf nutrient content of kiwifruit

The application of different nutrient sources significantly influenced kiwifruit leaf nutrient content. The highest total N (2.05%) and total Ca content (3.97%) was recorded in chemical fertilizer treatment T₁ under CFBS during 2019, whereas, total highest P content (0.32%) and total K (1.73%) content was recorded in leaves in treatment T₂ (where 100% RDN was substituted for VC and PM on 50:50 basis) under OFBS in 2019. Similar trend was observed in 2020 and the corresponding values for total N (2.37%), total Ca content (4.38%), P content (0.39%) and total K (1.87%) was recorded in leaves, respectively.

Among OFBS, T₂ treatment, where 100% RDN was applied through VC and PM on 50:50 basis, recorded highest N (1.81%), P (0.32%), K (1.73%) and Ca (3.68%) in kiwifruit leaves in 2019. The corresponding values in 2020 were 2.13, 0.38, 1.87 and 3.85%, respectively. The data clearly showed that substituting 100% RDN with VC and PM was not enough to maintain leaf N as with RDN by chemical fertilizers (T₁) in 2019, but in consecutive year the same treatment recorded comparable leaf N. Phosphorus and potash content in leaves was sufficient in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) as VC and PM have supplied adequate quantity of these in soil, especially PM that contain 0.99-1.05% P and 1.89-2.04% K (Table 3.3). Pooled data also follows the similar trend, T₂ treatment (VC₄₀₀ PM₄₀₀ + FYM₄₀) recorded highest value of N (1.97%), P (0.35%), K (1.80%) and Ca (3.77%) in kiwifruit leaves (marked in Figure 4.7).

Among SPNFS, treatment T₈ (30 liters of JM and 3 kg of GJ was applied instead of fertilizer N), recorded highest N (1.87%), P (0.32%), K (1.63%) and Ca (3.74%) in kiwifruit leaves in 2019. The corresponding values in 2020 were 2.07, 0.35, 1.78 and 4.28%, respectively. The results obviously showed that the substitution was not adequate to maintain nutrient content in leaves. However, P, K and Ca contents in leaves was at par with T₁ during 2019 and 2020. Pooled data showed that T₈ treatment (JM₃₀ GJ₃ + FYM₄₀) was highest value of N (1.97%), P (0.34%), K (1.71%) and Ca (4.01%) in kiwifruit leaves which were comparable with T₂ of OFBS (marked in Figure 4.7).

Table 4.6: Effect of different nutrient sources on N, P, K and Ca (%) content in kiwifruit leaves under different farming systems

Treatment Code*		2019				2020				Pooled			
		Nutrients (%)				Nutrients (%)				Nutrients (%)			
		N	P	K	Ca	N	P	K	Ca	N	P	K	Ca
Chemical Fertilizer Based System (CFBS)													
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)		2.05	0.30	1.68	3.97	2.37	0.35	1.78	4.38	2.21	0.32	1.73	4.18
Organic Farming Based System (OFBS)													
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)		1.81	0.32	1.73	3.68	2.13	0.39	1.87	3.85	1.97	0.35	1.80	3.77
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)		1.71	0.29	1.56	3.48	2.08	0.35	1.68	3.15	1.90	0.32	1.62	3.32
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)		1.49	0.25	1.38	2.85	2.03	0.28	1.56	2.85	1.76	0.27	1.47	2.85
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)		1.45	0.24	1.35	2.68	1.92	0.27	1.53	2.75	1.68	0.26	1.44	2.72
Subhash Palekar's Natural Farming System (SPNFS)													
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)		1.52	0.26	1.38	3.05	1.70	0.33	1.48	3.23	1.61	0.30	1.43	3.14
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)		1.74	0.29	1.46	3.47	1.94	0.34	1.60	3.64	1.84	0.32	1.53	3.56
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)		1.87	0.32	1.63	3.74	2.07	0.35	1.78	4.28	1.97	0.34	1.71	4.01
Mean		1.70	0.28	1.52	3.37	2.03	0.33	1.66	3.52	1.87	0.31	1.59	3.44
CD_{0.05} =	<i>Treatment =</i>	0.13	0.03	0.13	0.49	0.25	0.04	0.16	0.86	0.13	0.02	0.10	0.47
	<i>Year =</i>									0.07	0.01	0.05	NS**
	<i>Year × Treatment =</i>									NS	NS	NS	NS

*For details of treatment code, refer to Table 4.1.

**NS=non-significant

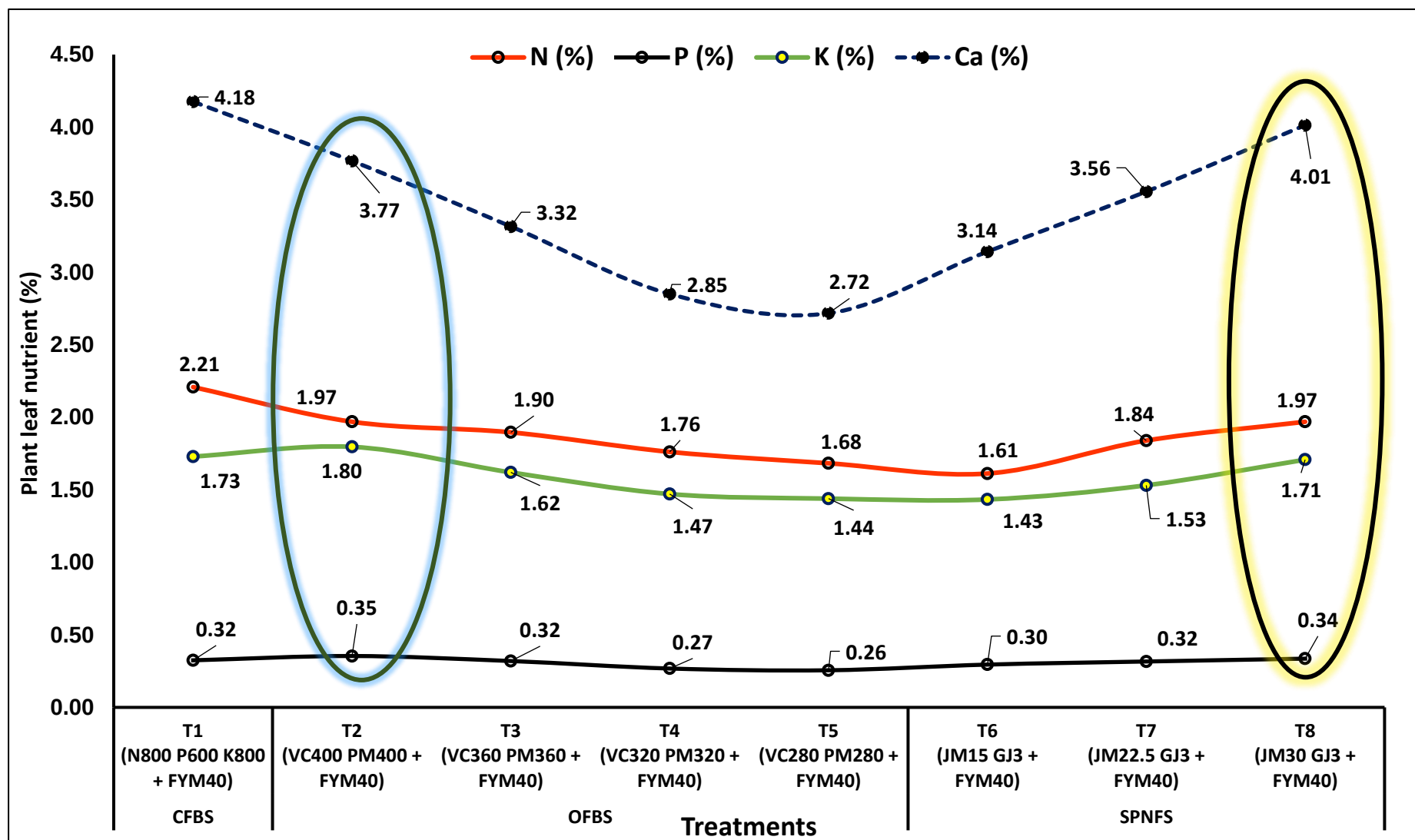


Figure 4.7: Changes in leaf N, P, K and Ca content with different nutrient sources under different farming systems

Climate exhibited small significant effect on nutrient content in leaves except calcium. The ‘Year $\times$ treatment’ interactions were not significant with respect to leaf nutrients. The increased availability of macronutrients in the leaves of kiwifruit vines with the addition of VC, PM and microbial liquid manures credited to the acceleration of microbial N-fixation, improved physical condition of soil, root development by mycelial network of mycorrhizal fungi, additional moisture retention and thus increased absorption of water and nutrients. The increase in leaf nutrient content in microbial fertilizers (*JM* and *GJ*) also suggests that these fertilizers solubilize the available nutrient pool in the soil and improves the uptake of both macro and micronutrients. The uptake of various nutrients (N, P, K, Ca, Mg, Fe, Cu, Mn and Zn) was significantly higher in pomegranate upon dual inoculation with AM fungi and *Azotobacter* (Aseri *et al.*, 2008) and in sweet orange with AM fungi + PSB (Shamseldin *et al.*, 2010) has also been reported. The higher N and P uptake was might be due to improved symbiotic nitrogen fixation as well as due to better phosphatase activity and thereby P mobilization and consequent P uptake whereas, the significantly higher amount of other nutrients viz. K, Ca, Mg, Cu, Fe, Zn and Mn might be due to the production of nutrient-solubilizing enzymes by microorganisms, besides increasing the surface area of roots thereby exploring larger soil volume. Hasey *et al.* (1997) reported that leaf N levels from the organic system were consistently lower than those from the conventional system but were not deficient in kiwifruit. Similar results were reported by Khachi *et al.* (2015) in kiwifruit.

4.2.6. Total soluble solids, titratable acidity and TSS/acid ratio

The effect of different nutrient sources under different farming systems on the total soluble solids (TSS) of fruits is presented in Table 4.7 and pooled values of TSS are represented in Figure 4.8. The data presented that different nutrient source applications has no significant effect on TSS content of kiwifruits (after 10 days of storage period from harvest) in 2019 but the effect was significant in consecutive year (2020). The maximum TSS (15.87%) was recorded with treatment T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) under OFBS, followed by 15.77% with treatment T₈ (JM₃₀ GJ₃ + FYM₄₀) under SPNFS in 2019. However, all the treatments under OFBS showed large significant enhancement in TSS values in 2020 and found better than CFBS and SPNFS. The highest value of TSS was recorded with treatment T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) followed by T₃, T₄ and T₅, recording 17.87, 17.33, 17.10 and 16.17%, respectively. Pooled data on TSS content didn’t showed any significant changes in treatments, however, ‘Year’ and ‘Year $\times$ Treatments’ effects were significant (Table 4.7).

Titrateable acidity (TA) as influenced by different nutrient sources indicated that their applications did not have any significant effect on the titrateable acid content of fruits (Table 4.7) in 2019 but showed significant fluctuations in 2020. The highest TA (1.19%) was recorded with treatment T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) under CBFS followed by 1.16% with treatment T₆ (JM₁₅ GJ₃ + FYM₄₀) under OFBS in 2019. In general, TA values were observed lower under all treatments in 2020 except SPNFS where all the treatments showed higher TA values. Pooled data didn't show any significant changes in TA content, but 'Year × Treatments' interaction showed little significant results (Table 4.7) A large dip (1.21% to 0.99%) in TA has been observed in OFBS treatments over CFBS (Figure 4.8). These results are in line with the findings of Amarante *et al.* (2008) who reported that apple (cv. Royal Gala) taken from the organic orchard had lower TA and high TSS content than conventional orchard.

Our results are in conformity with Turemis (2002) and Cayuela *et al.* (1997) who reported that all organically produced fruits had significantly higher TSS and lower TA in comparison to the conventionally produced fruits; for example, sensory attributes are important aspects of fruit quality, and the balance between sweetness and sourness are the most important determinants of overall quality of fruits (Cayuela *et al.*, 1997), for example, acceptance of the flavor quality of strawberry fruits is minimum 7% for TSS content, while the maximum is 0.8% for TA (Kader, 1999). Furthermore, organically grown strawberries had significantly higher TSS and lower TA content in comparison to the conventionally grown strawberries. Instead, addition of animal manure improved bell pepper fruit taste by increasing the percentage of TSS and the addition of animal manure decreased the percentage of TA in bell pepper fruit (Abu-Zahra *et al.* 2013). Additionally, according to Wang and Lin (2002) organic manures are hydrophilic in nature and absorb moisture and nutrients which persist for longer duration in the soil and hence improves the soil structure and indirectly augments the fruit quality. The decrease in TA might be due to the degradation of organic acids. These results are also in agreement with the findings of Kumar *et al.* (2019) in apricot under mid-hill condition of Himachal Pradesh.

The data on TSS/acid ratio showed large significant changes in 2020 with maximum TSS: acid ratio of 19.64 was observed in the treatment T₂ (100% dose of RDN was replaced with VC and PM) under OFBS. The ratios were much higher than other two systems in 2020. Pooled data didn't show significant variations in the ratio, while the 'Year' and 'Year × Treatment' interactions were significant. The results are in congruence with the results of Kumar *et al.* (2019) and Sharma (2018) in apricot and kiwifruit, respectively. Previous studies had also shown that the use of organic fertilizers, either alone or in combination with inorganic fertilizers, can increase fruit yields, quality and nutrition more than inorganic fertilizer alone.

Table 4.7: Effect of different nutrient sources on total soluble solids (TSS), titratable acidity and TSS/Acidity ratio in kiwifruits under different farming systems

Treatment Code*	2019			2020			Pooled		
	TSS (%)	Titratable Acidity (%)	TSS/Acid	TSS (%)	Titratable Acidity (%)	TSS/Acid	TSS (%)	Titratable Acidity (%)	TSS/Acid
Chemical Fertilizer Based System (CFBS)									
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	14.73	1.19	12.46	14.63	1.22	12.04	14.68	1.21	12.25
Organic Farming Based System (OFBS)									
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	15.87	1.07	14.96	17.87	0.91	19.64	16.87	0.99	17.30
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	15.53	1.09	14.30	17.33	0.93	18.68	16.43	1.01	16.49
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	15.30	1.11	13.84	17.10	0.94	18.20	16.20	1.02	16.02
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	15.10	1.11	13.68	16.17	1.00	16.11	15.63	1.06	14.89
Subhash Palekar's Natural Farming System (SPNFS)									
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	14.27	1.16	12.30	13.93	1.28	10.89	14.10	1.22	11.60
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	15.53	1.07	14.68	14.77	1.22	12.17	15.15	1.14	13.43
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	15.77	1.07	14.78	15.47	1.20	12.90	15.62	1.13	13.84
Mean	15.26	1.11	13.87	15.91	1.09	15.08	15.59	1.10	14.48
CD_{0.05} =	NS**	NS	NS	1.48	0.06	2.08	NS	NS	NS
	<i>Year</i> =						0.46	NS	0.73
	<i>Year × Treatment</i> =						1.29	0.11	2.06

* For details of treatment code, refer to Table 4.1

**NS=non-significant;

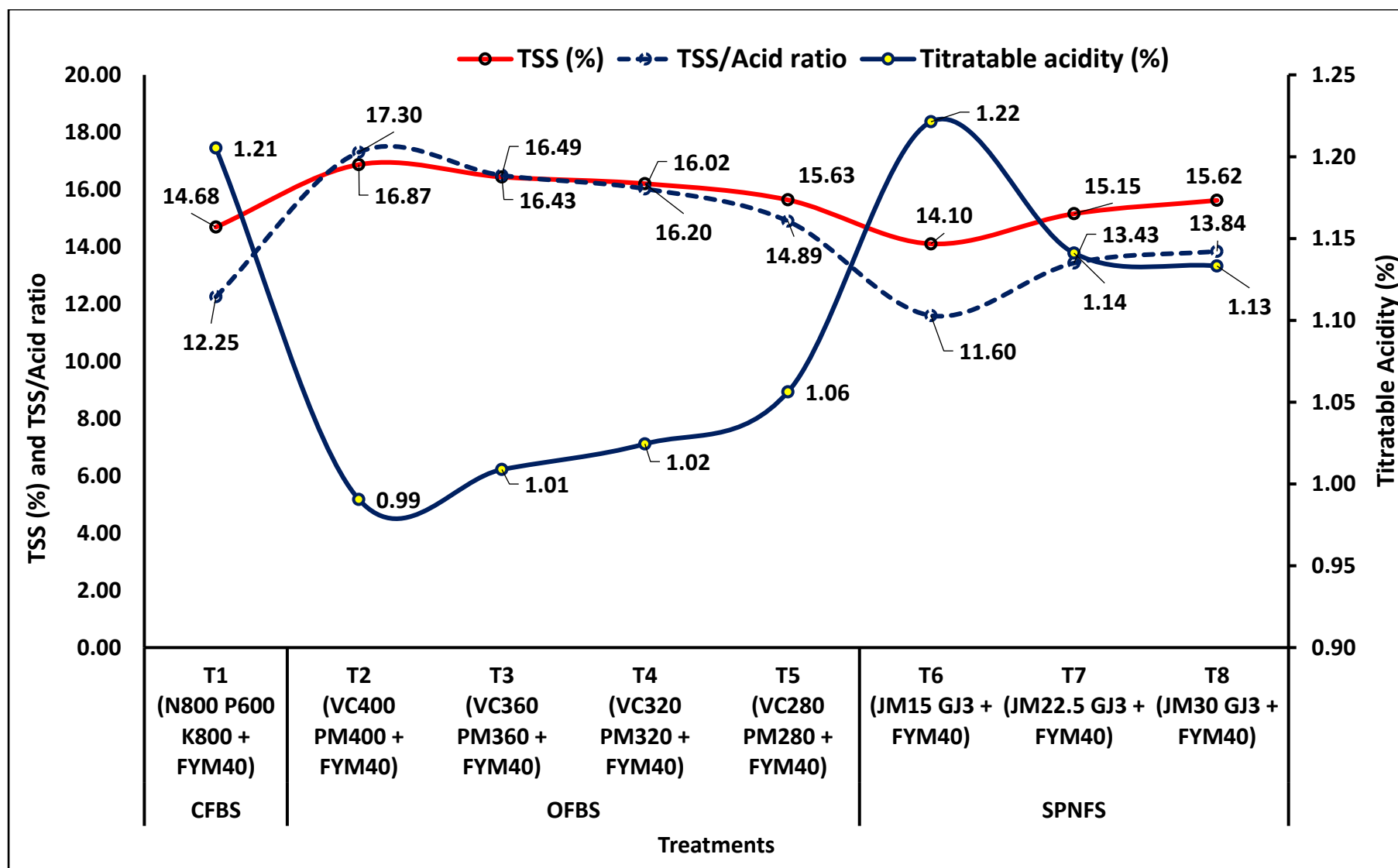


Figure 4.8: Effect of nutrient sources on TSS (%), titratable acidity (%) & TSS/Acid ratio of kiwifruit under different farming systems

This may be due to the fact that organic manures may supply multiple nutrients, improve soil physical properties, increase microbial biomass (Carey *et al.*, 2009) and stimulate enzyme activities (Chalmers, 2001). However, we concluded that organic fertilization had a positive effect on kiwifruit quality by increasing the TSS content, low TA and high TSS/acid ratio. This may be explained from the fact that organic manures enhanced the nutrient availability (Table 4.6) by enhancing the capability of better solute uptake from the rhizosphere. The findings are further supported by the results of Magdoff (1998) who reported increase in fruit quality characteristics by the application of organic manure might be due to the increase in the available N, P and K in the soil that may have a direct impact on photosynthesis and accumulation of dry matter and TSS.

4.2.7. Total sugars, reducing sugars and non-reducing sugars

The data pertaining to the outcome of different nutrient sources under different farming systems on the total sugars content are presented in Table 4.8. A perusal of the data revealed that the organic manures (VC and PM) resulted in significantly higher total sugars content as compared to vines subject to recommended fertilizers in both 2019 and 2020. The highest total sugars content (11.12%) was obtained in the fruits subject to treatment T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) under OFBS which was statistically at par with T₈ (JM₃₀ GJ₃ + FYM₄₀) under SPNFS, over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) under CFBS, recording 10.82 and 9.72 per cent total sugars, respectively in 2019. The corresponding values in 2020 are 12.41, 11.23 and 10.26 per cent respectively. In general, the content of total sugars in kiwifruits was recorded higher in 2020 than that of 2019.

The pooled data on total sugar content range from 9.42 to 11.77% and showed that only OFBS treatments T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) and T₃ (VC₃₆₀ PM₃₆₀ + FYM₄₀) were found significantly superior than T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀), recording 11.77 and 11.11% total sugars, respectively (Figure 4.9 and Table 4.8). The treatments under SPNFS didn't show any significant improvement in total sugar content than chemical fertilizers (pooled data of 2019 and 2020). Pooled data also depicted that there is little significant effect of 'Year' (CD_{0.05} = 0.15 and 'Year × Treatment' interaction (CD_{0.05} = 0.44). Ram and Rajput (2000) also reported improvement in fruit quality parameters with application of organic manures and biofertilizers. Furthermore, increased total sugars in organic treatments are may be due to gradual supply of nutrients by organic manures throughout the growth period which increases the metabolites in soil that helps in improving soil moisture availability, soil pH, organic carbon and nutrient status of the soil. Besides, the decrease in acidity of fruits may be attributed to their conversion

into sugars and their derivatives by the reactions involving reversal of glycolytic pathway or might be used in respiration or both. Similar findings were also reported by Singh and Varu (2013), Bhandari *et al.* (2018).

A reducing sugar is a type of carbohydrate or natural sugar that contains a free aldehyde or ketone group and capable of acting as a reducing agent. All monosaccharides are reducing sugars for e.g. galactose, glucose and fructose. In present study the reducing sugars of fruits in all treatments exhibited a similar tendency as that for total sugars. The data on reducing sugars content of kiwifruit revealed significant differences among the treatments of different nutrient sources under different farming systems (Table 4.8). The highest value of reducing sugars content (7.92%) were recorded in T₂ (where 100% RDN through VC and PM on 50:50 basis) which was statistically at par with T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS (7.80%) in 2019. However, in 2020, the trend of change in reducing sugars is a bit different showing T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) treatment has recorded highest reducing sugars content (8.70%) than all other treatments. Pooled data also revealed that T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) treatment was recorded the highest reducing sugars (8.31%) under OFBS and T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS, recording 7.72%, respectively over 7.08% in T₁ treatment of chemical fertilizer (Figure 4.9). Alike total sugars pooled data on reducing sugars also exhibited a slight significant effect of 'Year' ($CD_{0.05} = 0.06$) and 'Year $\times$ Treatment' interaction ($CD_{0.05} = 0.17$).

The non-reducing sugars don't have a free aldehyde or ketone, so it cannot act as a reducing agent. The content of non-reducing sugars in the study varied from (2.62 to 3.28%) in the pooled data (Table 4.8). Its value didn't observe any significant change in the year 2020, but it showed small significant effect due to application of different nutrient sources in 2019 and so in the pooled data too. The highest non-reducing sugars content (3.28 %) was recorded with T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) under OFBS and T₈ (JM₃₀ GJ₃ + FYM₄₀), recording 2.97%, respectively over 2.76% in T₁ treatment of chemical fertilizer. In general, all the treatments under OFBS recorded higher content of non-reducing sugars. Year $\times$ Treatment interaction of non-reducing sugars was non-significant. The increase in reducing and non-reducing sugars in VC and PM treated plots may be due to microbial decomposition and slow mineralization of nutrient which were made available to the plants that leads to maximum photosynthetic activity which resulted maximum accumulation and then translocation into the fruits. Furthermore, during ripening fruit experiences physical, physiological and bio-chemical changes and increase in TSS and total sugars may be attributed to the conversion of reserved starch and other insoluble carbohydrates into soluble sugars. Similar results were also observed by Zhang

Table 4.8: Effect of different nutrient sources on total sugars (%), reducing sugars (%), non-reducing sugars (%) and ascorbic acid (mg 100 g⁻¹) in kiwifruits under different farming systems

Treatment Code*	2019				2020				Pooled			
	Total Sugars (%)	Reducing Sugars (%)	Non-reducing Sugars (%)	Ascorbic acid (mg 100g ⁻¹)	Total Sugars (%)	Reducing Sugars (%)	Non-reducing Sugars (%)	Ascorbic acid (mg 100g ⁻¹)	Total Sugars (%)	Reducing Sugars (%)	Non-reducing Sugars (%)	Ascorbic acid (mg 100g ⁻¹)
Chemical Fertilizer Based System (CFBS)												
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	9.72	6.93	2.64	59.85	10.26	7.23	2.87	70.27	9.99	7.08	2.76	65.06
Organic Farming Based System (OFBS)												
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	11.12	7.92	3.04	78.07	12.41	8.70	3.53	85.03	11.77	8.31	3.28	81.55
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	10.23	7.27	2.82	71.48	11.98	8.37	3.44	80.48	11.11	7.82	3.13	75.98
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	9.97	6.95	2.87	65.91	11.23	7.73	3.33	78.31	10.60	7.34	3.10	72.11
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	9.69	6.67	2.88	61.36	10.87	7.62	3.09	74.06	10.28	7.14	2.98	67.71
Subhash Palekar's Natural Farming System (SPNFS)												
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	9.03	6.42	2.49	57.58	9.80	6.91	2.75	61.69	9.42	6.66	2.62	59.63
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	9.97	6.92	2.90	71.23	10.40	7.29	2.95	71.91	10.18	7.10	2.93	71.57
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	10.82	7.80	2.87	74.51	10.87	7.63	3.07	75.57	10.84	7.72	2.97	75.04
Mean	10.07	7.11	2.81	67.50	10.98	7.69	3.13	74.67	10.52	7.40	2.97	71.08
CD_{0.05} =	0.25	0.18	0.24	8.79	0.60	0.18	**NS	2.39	0.93	0.69	0.31	8.01
	<i>Year</i> =								0.15	0.06	0.15	2.18
	<i>Year × Treatment</i> =								0.44	0.17	NS	6.15

*For details of treatment code, refer to Table 4.1

**NS=non-significant

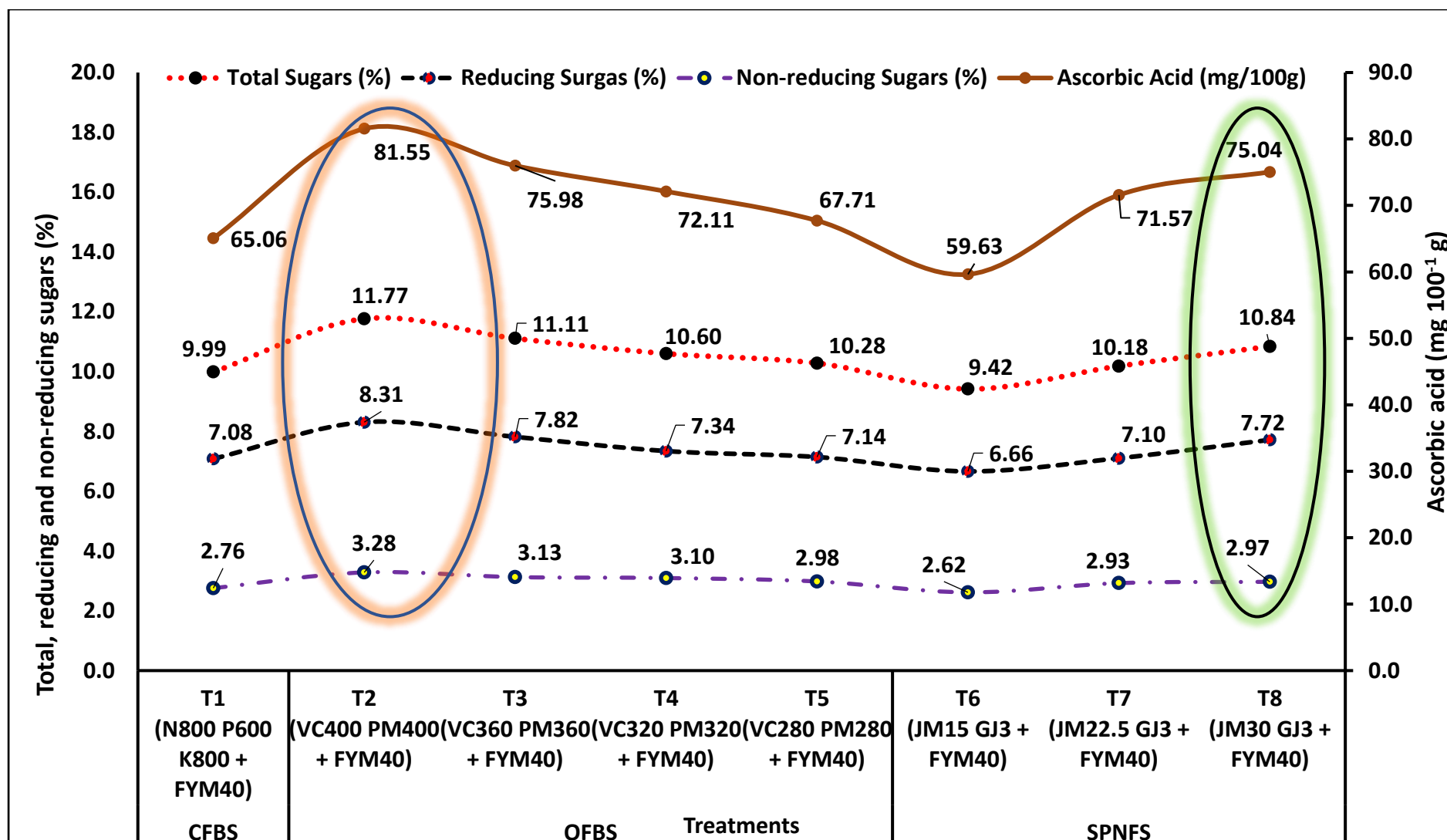


Figure 4.9: Effect of different nutrient sources on total sugars (%), reducing sugars (%), non-reducing sugars (%) and ascorbic acid (mg 100 g⁻¹) of kiwifruit under different farming systems

et al. (2020) who noted improved fruit quality by addition of organic fertilizers that deliver organic matter and a variety of nutrients (Ca^{2+} , Mg^{2+} , Zn^{2+} etc.).

4.2.8. Ascorbic Acid

The results pertaining to the outcome of different nutrient sources under different farming systems on ascorbic acid content is presented in Table 4.8. The application of different nutrient sources had significant effect on the ascorbic acid content of fruits. The highest ($78.07 \text{ mg } 100\text{g}^{-1}$) ascorbic acid content of was found in fruits subject to treatment T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$) which was statistically at par with T_8 ($\text{JM}_{30} \text{ GJ}_3 + \text{FYM}_{40}$) treatment of SPNFS, recording $74.51 \text{ mg } 100\text{g}^{-1}$ in 2019. The corresponding values in 2020 are 85.03 and $75.57 \text{ mg } 100\text{g}^{-1}$, but both values differ significantly. In general, 1.0 to 20.7% higher values of ascorbic acid content were recorded in 2020 than 2019. Major improvement has been observed in OFBS treatments than SPNFS treatments. Pooled data illustrated that there is significant improvement in ascorbic acid content in kiwifruits when grown under OFBS and SPNFS system than under CFBS, recording $81.55 \text{ mg } 100\text{g}^{-1}$ in T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$) treatment of OFBS, $75.04 \text{ mg } 100\text{g}^{-1}$ in T_8 ($\text{JM}_{30} \text{ GJ}_3 + \text{FYM}_{40}$) treatment of SPNFS over $65.06 \text{ mg } 100\text{g}^{-1}$ in treatment T_1 ($\text{N}_{800} \text{ P}_{600} \text{ K}_{800} + \text{FYM}_{40}$) of CFBS (Figure 4.8). Pooled data also exhibited significant effect of ‘Year’ ($\text{CD}_{0.05} = 0.15$ and ‘Year $\times$ Treatment’ interaction ($\text{CD}_{0.05} = 0.44$).

Comparable results were obtained by Naik and Babu (2007) in guava. The results were also in congruence with study conducted by Asami *et al.* (2003) who observed consistently higher levels of ascorbic acid in organically produced fruits than the levels in the conventionally grown ones. The highest fruit ascorbic acid content ($50.5 \text{ mg } 100 \text{ g}^{-1}$ fruit fresh weight) was obtained by the organically treated berry fruits, whereas the conventional treatment gave the lowest ascorbic acid content ($41.25 \text{ mg } 100 \text{ g}^{-1}$ g fruit fresh weight), according to Abu-Zahra *et al.* (2007). Instead, Cayuela *et al.* (1997) did not find significant difference in the ascorbic acid content between organic and conventional grown strawberry fruits.

4.3 EFFECT OF APPLICATION OF DIFFERENT NUTRIENT SOURCES ON PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES OF SOIL

4.3.1 Soil pH

The changes in soil pH values of 0-15 and 15-30 cm soil layer as influenced by different nutrient sources under different farming systems are presented in Table 4.9. The data indicate that application of different organic sources had significant effect on soil pH values of 0-15 cm

layer during each year, but didn't show any significant change in pH values of pooled data of 0-15 cm soil layer. A significant change in pH value of 15-30 cm soil layer has been recorded in pooled data. The effect of interaction i.e. Year $\times$ treatment was significant during 1st year in surface layer and non-significant in subsurface layer during both the years.

In 2019, highest soil pH value of 7.19 was recorded in 0-15 cm soil layer in treatment T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) which was significantly higher than T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) treatment of CFBS. The data shows 6.73 to 9.94 per cent improvement in soil pH values of surface soil over initial values. However, in 2020, there is significant improvement (5.1 to 5.4%) in soil pH values of surface soil layer in all treatments under SPNFS receiving different doses of *JM* and *GJ* over initial values. The highest soil pH value of 6.89 was recorded in 0-15 cm soil layer in treatments T₆ (JM₁₅ GJ₃ + FYM₄₀) which was significantly higher than T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) treatment of CFBS but at par with T₇ and T₈ treatments during 2020. However, pooled data on soil pH of surface soil layers recorded statistically non-significant changes over T₁ of CFBS (Figure 4.10).

The soil pH values of sub-surface soil (15-30 cm soil layer) in 2019 recorded significant positive improvement in soil pH values from 6.87 to 6.95 (+1.88 to +3.08%) in SPNFS treatments over 6.74 of T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) treatment of CFBS. The highest value of soil pH (15-30 cm) value of 6.95 was recorded in T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS. The data also shows improvement in soil pH values of sub-surface soil samples with the 100% replacement of RDN with VC and PM, recording 6.83 (+1.38%) values in T₂ treatment. Similar trend is observed in 2020 and improvement in soil pH values range from +2.18 to +3.22% in SPNFS treatments and from +0.55 to +1.74% in OFBS treatments over CFBS system (Table 4.9). The pooled data on soil pH of 15-30 cm soil depth showed that there is significant positive improvement in pH values that range from 6.84 (+1.56%) and 6.94 (+3.07%) in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) and T₈ (JM₃₀ GJ₃ + FYM₄₀) over T₁ treatment of CFBS (Figure 4.10). The interaction effect between 'Year $\times$ treatment' was non-significant in soil pH of sub-surface soil (15-30 cm) that confirms that climate didn't influence the soil pH of sub-surface soil layers. Variations in soil pH over time occur by the displacement of cations or by addition of sources of acidity like H⁺ and Al⁺³ ions. Chemical fertilizers are highly reactive and can result extreme pH fluctuations in the localized area. In contrast organic manures can increase the buffering capacity of soils, preventing changes in pH, because of addition of organic matter (Arden-Clarke and Hodges, 1988).

Table 4.9: Changes in soil pH (1:2.5) values at 0-15 and 15-30 cm soil depths by the application of different nutrient sources under different farming systems

Treatment Code*	Soil depth (0-15 cm)						Soil depth (15-30 cm)					
	2019	% age change over CFBS	2020	% age change over CFBS	Pooled	% age change over CFBS	2019	% age change over CFBS	2020	% age change over CFBS	Pooled	% age change over CFBS
Chemical Fertilizer Based System (CFBS)												
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	7.08	-	6.70	-	6.89	-	6.74	-	6.72	-	6.73	-
Organic Farming Based System (OFBS)												
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	7.19	+1.65	6.78	+1.19	6.99	+1.43	6.83	+1.38	6.84	+1.74	6.84	+1.56
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	7.04	-0.52	6.71	+0.20	6.88	-0.17	6.77	+0.40	6.76	+0.55	6.76	+0.47
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	6.98	-1.32	6.73	+0.42	6.85	-0.47	6.77	+0.49	6.76	+0.59	6.77	+0.54
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	6.99	-1.22	6.59	-1.59	6.79	-1.40	6.71	-0.45	6.67	-0.74	6.69	-0.59
Subhash Palekar's Natural Farming System (SPNFS)												
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	7.03	-0.61	6.89	+2.81	6.96	+1.05	6.91	+2.52	6.94	+3.22	6.93	+2.87
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	7.07	-0.09	6.88	+2.69	6.97	+1.26	6.87	+1.88	6.87	+2.18	6.87	+2.03
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	7.02	-0.85	6.87	+2.54	6.94	+0.80	6.95	+3.07	6.93	+3.07	6.94	+3.07
Mean	7.05	-0.37	6.77	+1.03	6.91	0.31	6.82	+1.16	6.81	1.33	6.82	1.24
CD_{0.05} =	0.09		0.15		NS**		0.15		0.15		0.10	
	<i>Year =</i>				<i>0.04</i>	-	<i>Year =</i>				<i>**NS</i>	
	<i>Year × Treatment =</i>				<i>0.12</i>	-	<i>Year × Treatment =</i>				<i>NS</i>	

*For details of treatment code, refer to Table 4.1

¹Initial soil pH of 0-15 and 15-30 cm soil layer was 6.54 and 6.75

**NS=non-significant

However, soil pH increased significantly in VC amended plots compared with mineral fertilizer treatment. These results are similar to earlier works of Gopinath *et al.* (2008), Meera (2006), Werner (1997), Clark *et al.* (1998) where organic systems had higher pH levels in slightly acidic soils and which clearly reveals that organic inputs can help in buffering soil pH.

4.3.2 Soil electrical conductivity

The changes in soil EC values of 0-15 cm soil layer showed significant changes as influenced by different nutrient sources under different farming systems during both the years of experimentation (Table 4.10). In general, all the treatments under OFBS, recorded higher EC values than other systems. Pooled data showed that EC values range from 0.162 to 0.171 d Sm⁻¹ in OFBS system which were statistically higher than T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) treatment (0.124 dSm⁻¹) of CFBS. All treatments under SPNFS showed lower soil EC than T₁ treatment. There was no significant effect of climate and their interaction on EC of 0-15 cm soil layer (Figure 4.10).

The EC of soil depth (15-30 cm) recorded non-significant changes among the different nutrient sources under different farming systems. Critical examination of results on EC of surface soil (0-15 cm) layer revealed that soil EC increases with the application of organic manure like VC and PM over chemical fertilizers and also with the application of decreasing doses of organic sources. Our results are similar to earlier studies that showed when animal wastes decompose, salts and ions in the soil and in its liquid phase are increased. Such changes exert an influence on soil EC, which is regulated by several soil fertility attributes, such as pH, P, K, Ca, Mg, organic matter, and by the contents of other soluble salts and organic ligands (Bronson *et al.*, 2005; Aimrun *et al.*, 2009; Peralta and Costa, 2013).

The increase in the soil EC values can be explained by the inputs of nutrients and salts contained in the wastes. In the soil system, ions in the liquid phase are in equilibrium with their levels in the solid phase. Thus, it is very reasonable that the factors governing solubilization, sorption and mineralization/immobilization processes exert a great influence on the amounts of ions governing soil EC (Carmo *et al.*, 2016). The pH changes as reported in previous section is a key factor regulating the solubility and availability of nutrients in soil. The organic matter mineralization rates are other key factors which strongly regulate the amounts of ions in the liquid phase as well as the soil EC values. Thus, EC could be an additional soil fertility index.

Table 4.10: Changes in soil EC (d S m⁻¹) values at 0-15 and 15-30 cm soil depths by the application of different nutrient sources under different farming systems

Treatment Code*	Soil depth (0-15 cm)			Soil depth (15-30 cm)		
	2019	2020	Pooled	2019	2020	Pooled
Chemical Fertilizer Based System (CFBS)						
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	0.126	0.121	0.124	0.115	0.110	0.112
Organic Farming Based System (OFBS)						
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	0.161	0.164	0.162	0.111	0.116	0.114
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	0.163	0.169	0.166	0.111	0.115	0.113
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	0.169	0.172	0.171	0.114	0.114	0.114
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	0.166	0.173	0.169	0.115	0.115	0.115
Subhash Palekar's Natural Farming System (SPNFS)						
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	0.119	0.118	0.119	0.114	0.115	0.114
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	0.118	0.118	0.118	0.114	0.114	0.114
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	0.116	0.117	0.117	0.115	0.111	0.113
Mean	0.142	0.144	0.143	0.114	0.114	0.114
CD_{0.05} =	0.013	0.022	0.012	NS*	NS	NS
	<i>Year</i> =		<i>NS**</i>	<i>Year</i> =		<i>NS</i>
	<i>Year</i> × <i>Treatment</i> =		<i>NS</i>	<i>Year</i> × <i>Treatment</i> =		<i>NS</i>

*For details of treatment code, refer to Table 4.1

¹Initial soil EC of 0-15 cm soil layer was 0.128 and 0.107 d S m⁻¹

**NS=non-significant

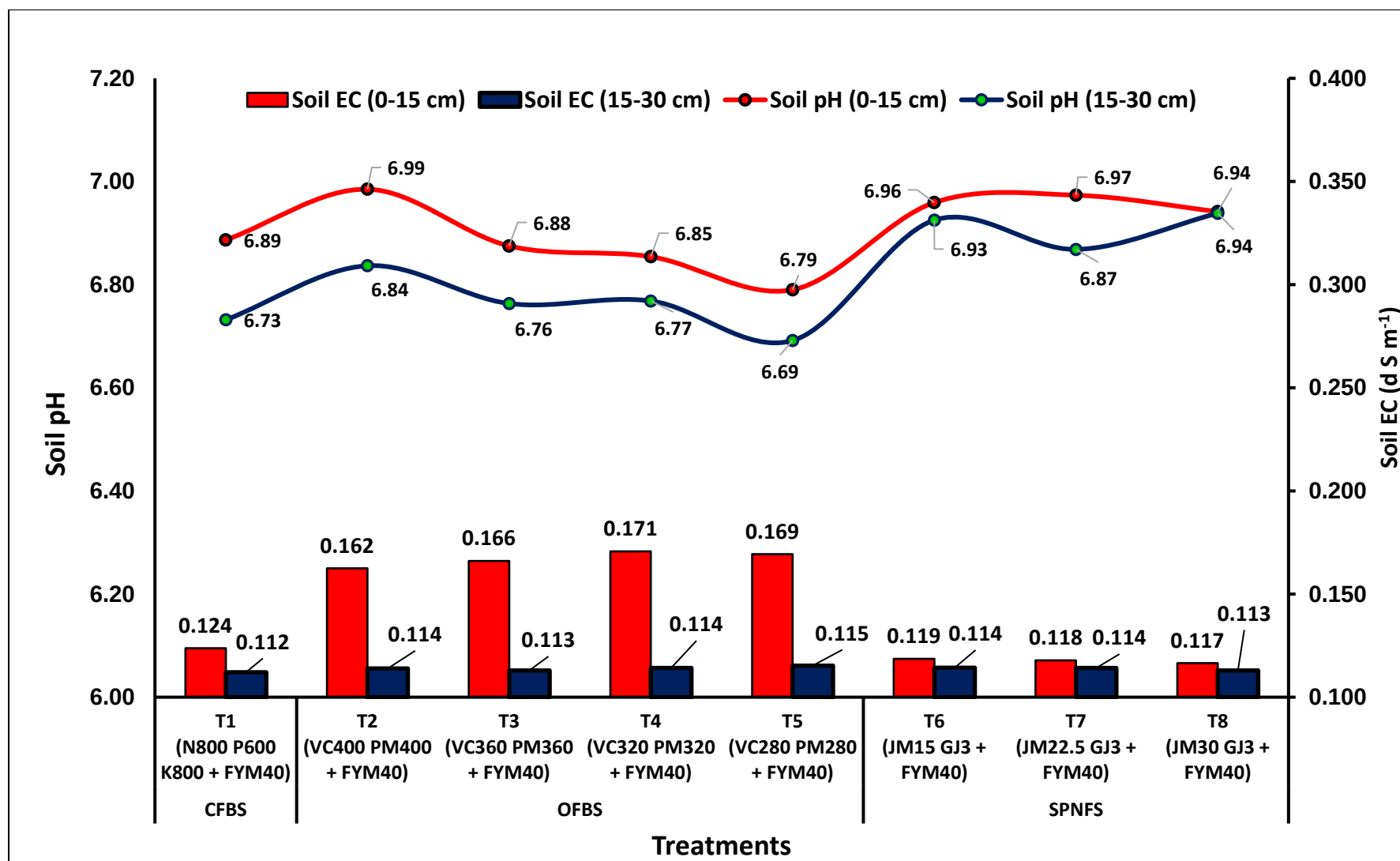


Figure 4.10: Effect of different nutrient sources on soil pH and EC values of 0-15 and 15-30 cm soil layers under different farming systems

4.3.3 Soil bulk density and particle size fraction

It is evident from the data presented in Table 4.11 that the different nutrient sources had a significant influence on the bulk density of 0-15 cm soil depth during both years of study. Pooled data revealed that lowest soil bulk density (0.927 g cm^{-3}) of 0-15 cm soil depth was recorded with T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) treatment of OFBS, which is statistically at par with other levels of OFBS treatments. Year and Year $\times$ Treatment interactions were found non-significant.

Table 4.11: Effect of different nutrient sources under different farming systems on soil bulk density (g cm^{-3}) values at 0-15 and 15-30 cm soil depths

Treatment Code*	Soil depth (0-15 cm)			Soil depth (15-30 cm)		
	2019	2020	Pooled	2019	2020	Pooled
Chemical Fertilizer Based System (CFBS)						
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	1.110	1.120	1.115	1.210	1.197	1.203
Organic Farming Based System (OFBS)						
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	0.943	0.910	0.927	1.203	1.170	1.187
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	0.950	0.950	0.950	1.200	1.193	1.197
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	0.977	0.960	0.968	1.200	1.200	1.200
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	0.980	0.980	0.980	1.213	1.193	1.203
Subhash Palekar's Natural Farming System (SPNFS)						
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	1.107	1.097	1.102	1.197	1.197	1.197
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	1.110	1.087	1.098	1.223	1.213	1.218
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	1.097	1.063	1.080	1.220	1.220	1.220
Mean	1.034	1.021	1.028	1.208	1.198	1.203
CD_{0.05} =	0.098	0.121	0.074	NS*	NS	NS
	<i>Year</i> =		NS**			NS
	<i>Year</i> $\times$ <i>Treatment</i> =		NS			NS

*For details of treatment code, refer to Table 4.1

**NS=non-significant

Soil bulk density of subsurface soil layers (15-30 cm) were not affected by application of different nutrient sources. On the whole, soil bulk density of organic treated surface soils (viz. 0-15 cm) are lower than conventional treatments (Table 4.11).

Similar results on decrease in bulk density has already been reported earlier by Mahmood *et al.* (2017) who observed that plots treated with organic manures alone showed

substantial reduction in soil bulk density followed by the plots where inorganic and organic fertilizers were applied in combination. Further our results are in congruence with the results of Gangwar *et al.* (2006) who observed reduced bulk density might be due to increased soil bio-pores and soil aeration, higher soil OC content, and better soil aggregation by the application of bulky organic manures that ultimately improved soil porosity and water holding capacity as well. Other workers like Bandyopadhyay *et al.* (2010) and Papini *et al.* (2011) also reported a negative correlation of soil bulk density of top 15 cm soil layer with the SOC contents present in it. In present study, significant negative correlations between bulk density and SOC (-0.997^{**}) of pooled data of 0-15 cm soil layer in 2019 was observed that clearly shows bulk density decreases with addition of organic manures.

Changes in particle size proportion in surface as well as subsurface soil samples drawn at the end of the experiment in 2020 as affected by addition of different nutrients are depicted in Table 4.12. Although the significant changes in particle size fractions (i. e. sand, silt and clay %) are observed in both the layers after the addition of different organic sources but the soil textural class (Sandy loam) remained the same throughout the experiment that signifies that organic materials did not affect soil texture in the short period of field study (Figure 4.11).

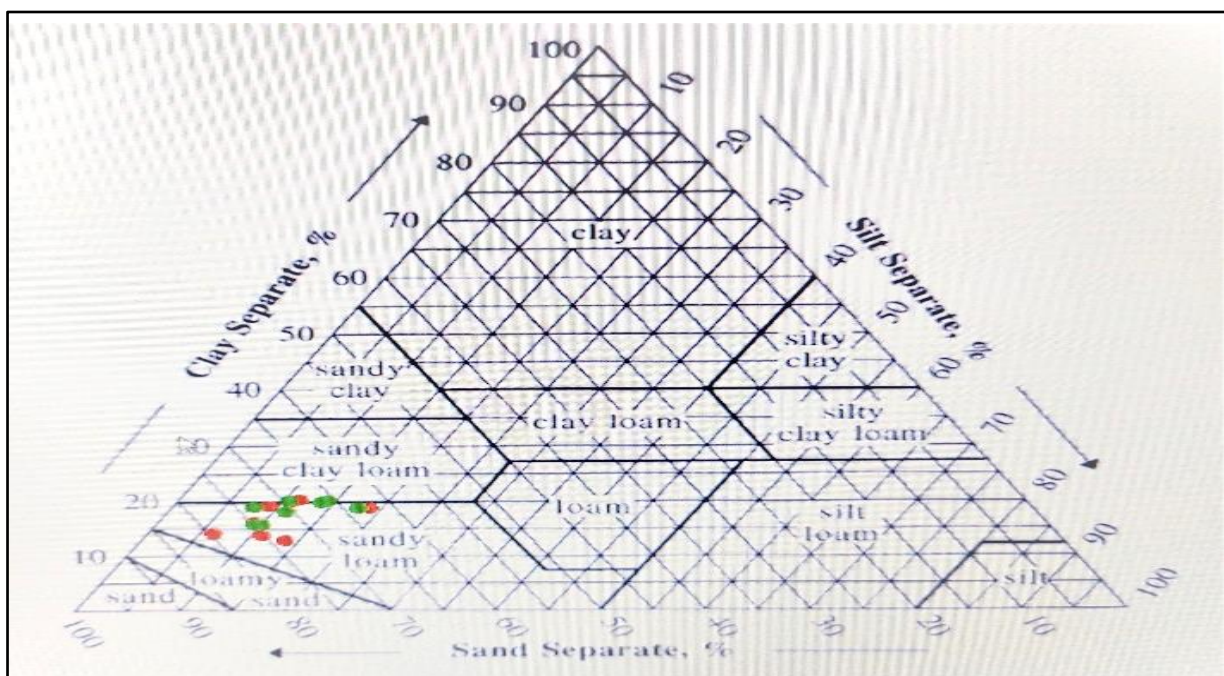


Figure 4.11. Triangular soil textural diagram at 0-15 (red circles) and 15-30 (green circles) cm soil depths

Highest sand content (80.8) was recorded in T₅ (VC₂₈₀ PM₂₈₀ + FYM₄₀) of OFBS, followed by T₃ (VC₃₆₀ PM₃₆₀ + FYM₄₀) and T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀), recording 76.4 and 75.8 % sand, respectively in 0-15 cm soil layer. The corresponding values in 15-30 cm soil layer were 75.4, 76.0 and 66.8, respectively. Similarly, highest clay content (19.7) was recorded in T₇ (JM_{22.5} GJ₃ + FYM₄₀) of SPNFS, followed by T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) and T₈ (JM₃₀ GJ₃ + FYM₄₀), recording 19.4 and 18.6% clay, respectively in 0-15 cm soil layer. The corresponding values in 15-30 cm soil layer were 18.4, 19.6 and 17.6, respectively. Highest silt content of 18.2 and 17.2 was recorded in T₆ (JM₁₅ GJ₃ + FYM₄₀) of 0-15 and 15-30 cm soil layers, respectively. There was no specific trend was observed in the variation of sand, silt and clay fractions of soil samples of 0-15 and 15-30 cm soil layers, however, soil textural class remained the same during the field study.

Table 4.12: Effect of different nutrient sources under different farming systems on particle size fractions (%) of soil

Treatment Code*	Soil depth (0-15 cm)				Soil depth (15-30 cm)			
	Sand (%)	Clay (%)	Silt (%)	Soil textural Class	Sand (%)	Clay (%)	Silt (%)	Soil textural Class
Chemical Fertilizer Based System (CFBS)								
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	70.4	19.4	10.2	Sandy loam	70.4	19.6	10.0	Sandy loam
Organic Farming Based System (OFBS)								
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	75.8	15.6	8.6	Sandy loam	66.8	19.6	13.6	Sandy loam
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	76.4	13.2	10.4	Sandy loam	76.0	15.2	8.8	Sandy loam
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	74.6	12.3	13.1	Sandy loam	67.6	19.2	13.2	Sandy loam
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	80.8	13.6	5.6	Sandy loam	75.4	15.2	9.4	Sandy loam
Subhash Palekar's Natural Farming System (SPNFS)								
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	63.6	18.2	18.2	Sandy loam	64.6	18.2	17.2	Sandy loam
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	69.4	19.7	10.9	Sandy loam	74.4	18.4	7.2	Sandy loam
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	72.8	18.6	8.6	Sandy loam	71.8	17.6	10.6	Sandy loam
Mean	73.0	16.3	10.7	Sandy loam	70.9	17.9	11.3	Sandy loam

*For details of treatment code, refer to Table 4.1

4.3.4 Soil organic carbon

It is apparent from the data presented in Table 4.13 that the different nutrient sources had significant influence on the soil organic carbon (SOC) content of the surface 0-15 cm as well as subsurface 15-30 cm soil, although the influence is less pronounced in the lower layers.

Significantly highest organic carbon content (25.83 g kg^{-1}) in 0-15 cm soil layer was recorded in T_2 ($VC_{400} PM_{400} + FYM_{40}$) under OFBS, T_8 ($JM_{30} GJ_3 + FYM_{40}$) under SPNFS, recording 22.54 g kg^{-1} over chemical fertilizer T_1 treatment recording SOC of 19.75 g kg^{-1} (Table 4.13) during 2019. The percent increase over CFBS (T_1) was +30.77 and +14.22% in T_2 and T_8 , respectively. In general, improvement in SOC of 0-15 cm soil layer with the addition of different doses of organic sources ranged from 4.98 to 30.77% in OFBS and 8.69 to 14.13% in SPNFS over conventional farming.

In 2020, there has been an increase in SOC from 32.8 to 47.1% in surface soil under all the treatments than in 2019. Significantly highest organic carbon content (36.64 g kg^{-1}) in 0-15 cm soil layer was recorded in T_2 ($VC_{400} PM_{400} + FYM_{40}$), which was followed by T_8 ($JM_{30} GJ_3 + FYM_{40}$), T_3 ($VC_{360} PM_{360} + FYM_{40}$) and T_7 ($JM_{22.5} GJ_3 + FYM_{40}$), recording 33.16, 32.50 and 31.81 g kg^{-1} which was statistically at par with each other in 2020 (Table 4.13). The percent increase over CFBS (T_1) was +39.39, +26.43, +23.92 and +21.29% in T_2 , T_8 , T_3 and T_7 , respectively. The improvement in SOC of 0-15 cm soil layer with the addition of different doses of organic sources followed the same trend as in 2019, ranging from 7.23 to 39.39% in OFBS and 12.59 to 26.43% in SPNFS over conventional farming (Table 4.13).

The pooled data on SOC of 0-15 cm soil layer showed that treatment T_2 ($VC_{400} PM_{400} + FYM_{40}$) of OFBS was found superior (significantly higher) to all other treatments just as in individual years, recording 31.23 g kg^{-1} (+35.86% higher than conventional) (Figure 4.12). In other treatments of OFBS, the increase in SOC over conventional range from 6.26-21.27%. In the same way, the increase in SOC in SPNFS range from 10.92-21.15% over conventional farming. In case of SPNFS, T_8 ($JM_{30} GJ_3 + FYM_{40}$) was recorded highest 27.85 g kg^{-1} soil organic among all treatments during both years. Furthermore, the 'Year' showed significant influence on SOC while 'Year $\times$ Treatment' interaction effect was non-significant in pooled data (Table 4.13).

Since organic manures are incorporated in to the surface soil and a major portion of the them accumulate in the top few centimeters of the soil layers, there was possibility for a relatively greater accumulation of organic carbon in 0-15 cm soil as compared to the soils of lower layer. The SOC of subsurface soil layers was recorded lower values than surface soils,

albeit the variation in different treatments was significant. Highest organic carbon content (9.31 g kg^{-1}) in 15-30 cm soil layer was recorded in T_2 ($VC_{400} PM_{400} + FYM_{40}$) of OFBS, which was at par with T_8 ($JM_{30} GJ_3 + FYM_{40}$) and T_7 ($JM_{22.5} GJ_3 + FYM_{40}$), recording 9.30 (16.21% higher than CFBS) and $9.26 (15.75\%) \text{ g kg}^{-1}$ in 2019 (Table 4.13). The corresponding SOC content in 2020 was 15.44 (29.56%), 14.45 (21.22%) and 14.05 (17.84%) g kg^{-1} over CFBS (T_1) in T_2 , T_8 and T_7 , respectively. In general, improvement in SOC of 15-30 cm soil layer with the addition of different doses of organic sources (OFBS) ranged from 3.46 to 16.42 and 3.33 to 29.56% in 2019 and 2020, respectively. Similarly, the enhancement in SOC content of 15-30 cm soil layer under SPNFS ranged from 7.17 to 16.21 and 7.89 to 21.22% in 2019 and 2020, respectively. The pooled data also followed the similar trend with highest SOC of 15-30 cm soil layer was recorded in T_2 treatment followed by T_8 and T_7 of SPNFS (Figure 4.12). The 'Year $\times$ Treatment' interaction effect on SOC in 15-30 cm was non-significant but 'Year' showed significant effect in pooled data (Table 4.13).

VC treated soils significantly influenced the organic matter content of the soils, especially, when 100% of RDN was substituted with VC and PM than control. Organic matter plays a significant role in soils because it is considered as a great resource of available nutrients. In our study SOC in surface 0-15 cm has significant positive correlations with available N ($r = 0.890^{**} p < 0.01$) and available P_2O_5 ($r = 0.687^{**} p < 0.01$) of the soils (Annexure II). Likewise, SOC in 15-30 cm has positive significant positive correlations with available N ($r = 0.733^{**} p < 0.01$) and available P_2O_5 ($r = 0.646^{**} p < 0.01$) of the soils (Annexure II). Similarly, Ouda and Mahadeen (2008) and Angelova *et al.* (2013) reported increasing SOC contents with increasing vermicompost doses. The decomposition of organic manure improves the organic matter content of the soil leading to increase in the soil organic carbon. Similar results were reported earlier by Laharia *et al.* (2013) who reported that application of 100%RDN through VC + jeevaamrit significantly increased SOC and available N, P, K content in soil after harvest of soybean as compared to control. The results of the present study are in agreement with the findings of Brar (2020), who reported application of 90% RDN by VC and PM along with liquid organic formulations i.e. *Panchagavya*, *Jeevaamrit* and *Amritpani* significantly improved soil organic carbon. Sharma *et al.* (2016) showed maximum organic carbon (0.72%) from the treatment receiving full dose of N through PM + *Azotobacter*. Similar results were earlier reported by Adesodun *et al.* (2005) who observed increase in SOC by addition of PM. The greater organic carbon under organic system than the conventional farming systems has been attributed to substantial inputs of organic matter as reported by Rai *et al.* (2014) and Singh *et al.* (2014).

Table 4.13: Effect of different nutrient sources on soil organic carbon (g kg⁻¹) values at 0-15 and 15-30 cm soil depths under different farming systems

Treatment Code*	Soil depth (0-15 cm)						Soil depth (15-30 cm)					
	2019	% age change over CFBS	2020	% age change over CFBS	Pooled	% age over change CFBS	2019	% age change over CFBS	2020	% age over change CFBS	Pooled	% age over change CFBS
Chemical Fertilizer Based System (CFBS)												
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	19.75	-	26.23	-	22.99	-	8.00	-	11.92	-	9.96	-
Organic Farming Based System (OFBS)												
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	25.83	+30.77	36.64	+39.39	31.23	+35.86	9.31	+16.42	15.44	+29.56	12.38	+24.28
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	23.46	+18.77	32.50	+23.92	27.98	+21.71	8.86	+10.75	14.23	+19.35	11.54	+15.90
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	21.97	+11.22	30.51	+16.30	26.24	+14.12	8.51	+6.42	13.02	+9.23	10.77	+8.10
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	20.73	+4.98	28.13	+7.23	24.43	+6.26	8.28	+3.46	12.32	+3.33	10.30	+3.38
Subhash Palekar's Natural Farming System (SPNFS)												
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	21.47	+8.69	29.53	+12.59	25.50	+10.92	8.57	+7.17	12.86	+7.89	10.72	+7.60
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	22.36	+13.22	31.81	+21.29	27.09	+17.82	9.26	+15.75	14.05	+17.84	11.65	+17.00
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	22.54	+14.13	33.16	+26.43	27.85	+21.15	9.30	+16.21	14.45	+21.22	11.87	+19.21
Mean	22.26	+12.72	31.07	+18.43	26.66	+15.98	8.76	+9.52	13.54	+13.55	11.15	+11.93
CD_{0.05} =	2.12	-	3.95	-	2.14	-	0.60	-	1.39	-	0.72	-
	<i>Year</i> =				<i>1.07</i>	<i>-</i>	<i>Year</i> =				<i>0.36</i>	<i>-</i>
	<i>Year</i> × <i>Treatment</i> =				<i>NS**</i>	<i>-</i>	<i>Year</i> × <i>Treatment</i> =				<i>NS</i>	<i>-</i>

Initial soil organic carbon of 0-15 and 15-30 cm soil depth was 14.1 and 8.4 g kg⁻¹, respectively

*For details of treatment code, refer to Table 4.1

**NS=non-significant

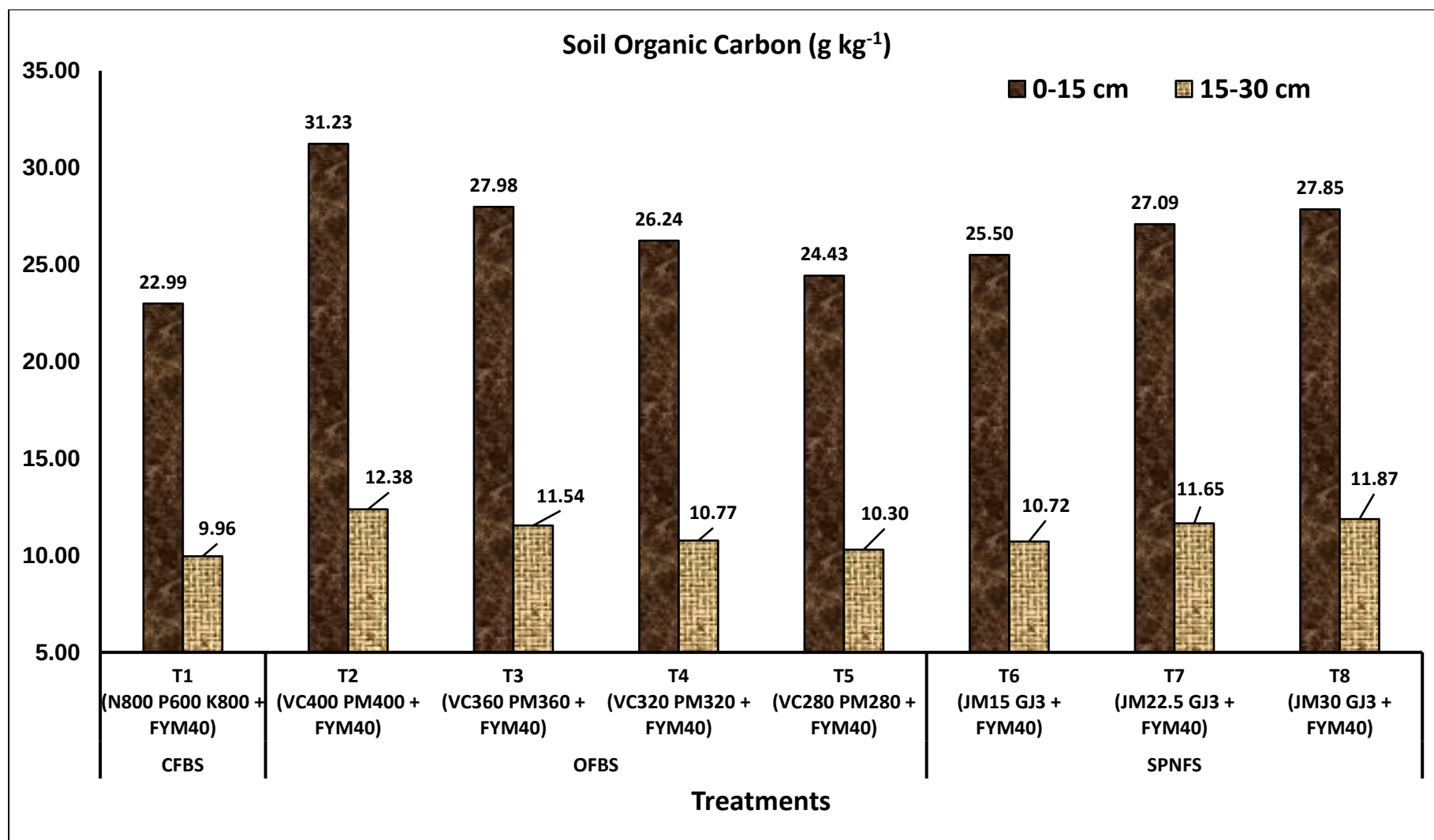


Figure 4.12: Effect of different nutrient sources on soil organic carbon (g kg^{-1}) at 0-15 and 15-30 cm soil layers under different farming systems

4.3.5 Soil available nitrogen

The data presented in Table 4.14 showed that the different nutrient sources has exhibited significant influence on the soil available nitrogen content of the surface 0-15 cm as well as subsurface 15-30 cm soil, and the effect is more distinct in 2020 compared to 2019. Significantly highest soil available nitrogen content (339 kg ha^{-1}) in 0-15 cm soil layer was recorded in T_2 ($VC_{400} PM_{400} + FYM_{40}$) of OFBS. The N content of T_3 ($VC_{360} PM_{360} + FYM_{40}$) of OFBS and T_8 ($JM_{30} GJ_3 + FYM_{40}$), recording 315.8 and 316.2 kg ha^{-1} are statistically at par with each other in 2019. The percent increase in nitrogen content over CFBS (T_1) was $+18.54$, $+10.41$ and $+10.56$ in T_2 , T_3 , and T_8 , respectively. In general, improvement in soil available nitrogen was observed only up to 90% replacement of RDN with VC and PM in OFBS and with 30 liters of *Jeevaamrit* + 3 kg of *Ghana Jeevaamrit* only. Rest of the treatments are at par with CFBS with respect to soil available nitrogen. In 2020, significantly highest soil available nitrogen amounting 392.6 kg ha^{-1} (26.7% higher than CFBS) in 0-15 cm soil layer was recorded in T_2 ($VC_{400} PM_{400} + FYM_{40}$), which was followed by T_8 ($JM_{30} GJ_3 + FYM_{40}$) and T_3 ($VC_{360} PM_{360} + FYM_{40}$), recording 367.2 (18.5% higher than CFBS) and 356.6 (15% higher than CFBS) kg ha^{-1} which was statistically at par with each other in 2020 (Table 4.14). The $\pm$ change in soil available nitrogen of 0-15 cm soil layer during 2020 with the addition of different doses of organic sources ranged from -10.24 to $+26.7\%$ in OFBS and from -7.9 to $+18.5\%$ in SPNFS over conventional farming (Table 4.14).

The pooled data on soil available nitrogen of 0-15 cm soil layer showed that treatment T_2 ($VC_{400} PM_{400} + FYM_{40}$) of OFBS was found significantly higher, recording 365.8 kg ha^{-1} ($+22.77\%$ higher than conventional) followed by T_8 ($JM_{30} GJ_3 + FYM_{40}$) and T_3 ($VC_{360} PM_{360} + FYM_{40}$), recording 341.7 ($+14.67\%$) and 336.2 ($+12.82\%$) kg ha^{-1} , respectively (Figure 4.13). The $\pm$ change in soil available nitrogen of 0-15 cm soil layer in pooled data with the addition of different doses of organic sources ranged from -7.12 to $+22.77\%$ in OFBS and from -5.25 to $+14.67\%$ in SPNFS over conventional farming (Table 4.14). Furthermore, the 'Year' and 'Year $\times$ Treatment' interaction effect was significant in pooled data representing climate has influenced the soil available nitrogen of surface soil.

Soil available N of subsurface layers are lower since organic manures were incorporated in to the surface soil and a major portion of the them accumulate in the top few centimeters of the soil layers. However, the variation in soil N under different treatments was significant. Highest available N content (222.2 kg ha^{-1}) in 15-30 cm soil layer was recorded in T_2 ($VC_{400} PM_{400} + FYM_{40}$) of OFBS, which was at par with T_3 ($VC_{360} PM_{360} + FYM_{40}$) of OFBS and T_8

(JM₃₀ GJ₃ + FYM₄₀) of SPNFS, recording 213.3 (8.26% higher than CFBS) and 210.3 (6.72%) kg ha⁻¹ in 2019 (Table 4.14). The corresponding soil nitrogen content in 2020 was 264.1 (18.04%), 248.4 (11.03%) and 261.7 (16.99%) kg ha⁻¹ over CFBS (T₁) in T₂, T₃ and T₈, respectively.

The pooled data also followed the similar trend with highest available nitrogen of 15-30 cm soil layer was recorded (243.1 kg ha⁻¹) in T₂ treatment followed by T₈ of SPNFS and T₃ of OFBS, recording 236 and 230.8 kg ha⁻¹, respectively (Figure 4.13). The ‘Year’ and ‘Year × Treatment’ interaction effects on available soil N in both soil layers were significant in pooled data (Table 4.14).

The increase in soil available N with *Jeevaamrit* application @ 30 liters per plant may be attributed to the favorable soil conditions that might have helped in mineralization of soil N leading to build up of higher available N. Similar results were obtained by Kumari *et al.* (2019) while working on effect of different organic nutrient sources on soil properties in onion in Solan, HP. Kiran *et al.* (2015) also observed significantly higher available N in soil with the application of *beejamrit* + *jeevaamrit* + VC equivalent to 100% RDN + *panchagavya* (3%) while working on the effect of nutrient management practices through organics on soil chemical property after harvest of chickpea.

VC contain nutrients in forms that are readily taken up by the plants such as nitrates, exchangeable phosphorus, and soluble potassium, calcium, and magnesium (Orozco *et al.* 1996). Increase in available N with VC or PM might be due to mineralization of N from organic manures in soil and greater multiplication of soil microbes, which could convert organically bound N to inorganic form and also augmented nitrification process. Similar findings were reported by Kumar and Prasad (2008), Rai *et al.* (2014) and Singh *et al.* (2014). Organic manures have more beneficial effects on soil quality than inorganic fertilizers thereby improving nutrient release and their availability to the plants (Birkhofer *et al.*, 2008). Sharma *et al.* (2005) also noticed enhancement in available N content of soil with the use of organics in Entisol of Himachal Pradesh. In the present study there have been a significant positive correlation of available N with SOC ($r = 0.890^{**}$ $p < 0.01$) in surface 0-15 cm and subsurface (15-30 cm) ($r = 0.733^{**}$ $p < 0.01$) soil layers which clearly showed that higher the amount of SOC higher will be the availability of nitrogen in soil. Similar results of enhancement in available nitrogen content of soil with the use of organics was earlier reported by Sharma *et al.* (2009)

Table 4.14: Effect of different nutrient sources on soil available nitrogen (kg ha⁻¹) values at 0-15 and 15-30 cm soil depths under different farming systems

Treatment Code*	Soil depth (0-15 cm)						Soil depth (15-30 cm)					
	2019	% age change over CFBS	2020	% age change over CFBS	Pooled	% age over change CFBS	2019	% age change over CFBS	2020	% age over change CFBS	Pooled	% age over change CFBS
Chemical Fertilizer Based System (CFBS)												
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	286.0	-	310.0	-	298.0	-	197.0	-	223.7	-	210.4	-
Organic Farming Based System (OFBS)												
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	339.0	+18.54	392.6	+26.67	365.8	+22.77	222.2	+12.76	264.1	+18.04	243.1	+15.57
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	315.8	+10.41	356.6	+15.04	336.2	+12.82	213.3	+8.26	248.4	+11.03	230.8	+9.73
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	296.8	+3.78	316.3	+2.06	306.6	+2.88	202.1	+2.55	237.8	+6.32	220.0	+4.56
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	275.3	-3.74	278.2	-10.24	276.8	-7.12	186.9	-5.13	219.7	-1.77	203.3	-3.34
Subhash Palekar's Natural Farming System (SPNFS)												
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	279.1	-2.41	285.6	-7.87	282.3	-5.25	171.8	-12.78	203.0	-9.24	187.4	-10.90
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	294.9	+3.11	338.9	+9.35	316.9	+6.36	185.5	-5.84	247.5	+10.62	216.5	+2.91
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	316.2	+10.56	367.2	+18.47	341.7	+14.67	210.3	+6.72	261.7	+16.99	236.0	+12.18
Mean	300.4	+5.03	330.7	+6.68	315.5	+5.89	198.6	+0.82	238.2	+6.50	218.4	+3.84
CD_{0.05} =	15.4	-	18.5	-	33.1		12.0	-	18.0	-	19.6	-
	<i>Year</i> =				5.7	-	<i>Year</i> =				5.2	-
	<i>Year</i> × <i>Treatment</i> =				16.3	-	<i>Year</i> × <i>Treatment</i> =				14.6	-

Initial soil available nitrogen of 0-15 and 15-30 cm soil layer was 282.2 and 200.7 kg ha⁻¹, respectively.

*For details of treatment code, refer to Table 4.1

4.3.6 Soil available phosphorus

An estimate of the pool of plant available P in the soil can provide an indication of the soil's ability to supply P to meet crop demands. The data presented in Table 4.15 showed that the different nutrient sources has revealed significant influence on the soil available P content of the surface 0-15 cm and subsurface 15-30 cm soil. Significantly highest soil available nitrogen content (104.1 kg ha^{-1}) in 0-15 cm soil layer was recorded in T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$) of OFBS over conventional T_1 ($\text{N}_{800} \text{ P}_{600} \text{ K}_{800} + \text{FYM}_{40}$) treatments. All the remaining treatments showed decline in available P content in surface soil during 2019, although treatments T_3 ($\text{VC}_{360} \text{ PM}_{360} + \text{FYM}_{40}$) of OFBS and T_8 ($\text{JM}_{30} \text{ GJ}_3 + \text{FYM}_{40}$), recording 97.8 and 98.1 kg ha^{-1} are statistically at par with each other. This is clear from the data that substituting 100% RDN with VC and PM on 50:50 basis has sustained the available P in soil during first year of replacement over conventional while replacing with liquid organic manures (*Jeevaamrit*) failed to maintained the same level of available P in surface soil during first year. During 2020, treatment T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$) again observed highest P content recording 105.2 kg ha^{-1} (11.9% higher than T_1) in 0-15 cm soil layer. The Treatment T_8 ($\text{JM}_{30} \text{ GJ}_3 + \text{FYM}_{40}$) of SPNFS has found effective to maintain the P content 100.7 kg ha^{-1} (+7.18% higher than T_1) in surface soil layers in 2020 and statistically at par with T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$) of OFBS.

The pooled data on soil available P of 0-15 cm soil layer showed similar trend as individual year that treatment T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$) of OFBS was found significantly highest P content recording 104.6 kg ha^{-1} (+8.9% higher than conventional). The treatment T_8 ($\text{JM}_{30} \text{ GJ}_3 + \text{FYM}_{40}$) and T_3 ($\text{VC}_{360} \text{ PM}_{360} + \text{FYM}_{40}$), recording available P content of 99.4 (+3.46%) and 98.1 (+2.05%) kg ha^{-1} , respectively which was at par with each other but significantly lower than T_2 (Table 4.15 and Figure 4.13). Furthermore, 'Year' effect was significant in pooled data representing climate has influenced the soil available P of surface soil, but 'Year $\times$ Treatment' interaction was non-significant.

In general, sub-surface soil layers (15-30 cm) contain approximately 50% of available P than surface soil layers since organic manures were incorporated in surface soil and a major percentage of the them accumulate in the top few centimeters of the soil layers. However, the variation in soil P under different treatments was significant. No treatment has observed significantly higher values than conventional farming with respect to soil available P in sub-surface soil of 2019. Highest available P content of 48.0 kg ha^{-1} (+4.2%) in 15-30 cm soil layer was recorded in T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$) of OFBS, which was at par with T_1 ($\text{N}_{800} \text{ P}_{600} \text{ K}_{800}$

+ FYM₄₀), recording 46.1 kg ha⁻¹ in 2019 (Table 4.15). In 2020, T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀), T₃ (VC₃₆₀ PM₃₆₀ + FYM₄₀), and T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS recorded 48.1, 47.1 and 47.6 kg ha⁻¹ available P content, respectively which were comparable with each other.

In pooled data no treatment has shown significant improvement in soil available P content of 15-30 cm soil layer over conventional farming. Although the highest available P in 15-30 cm soil layer was recorded in in T₂ treatment (48.0 kg ha⁻¹) followed by T₃ (VC₃₆₀ PM₃₆₀ + FYM₄₀), and T₈ (JM₃₀ GJ₃ + FYM₄₀), recording 47 and 46.1 kg ha⁻¹, respectively (Figure 4.13). The 'Year' didn't show any significance in pooled data that shows that climate didn't influence the subsurface soil P content but 'Year × Treatment' interaction effects on available P was significant in pooled data (Table 4.15).

Vermicompost (0.66-0.70% P) and poultry manure (0.99-1.05% P) contains adequate phosphorus in forms that are readily taken up by the plants that leads to high P content in Treatment T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) where VC and PM are used in place of chemical fertilizers. On the other hand, *Jeevaamrit* (66.7 mg l⁻¹) and *Ghana Jeevaamrit* (0.55-0.59%) contains small amount of P that leads to small addition and hence less available P for plants to uptake (Table 3.3). Secondly, the higher built up of available P in the organic manures treated plots might be due to release of organic acids during microbial decomposition of organic matter which might have helped in the solubility of native phosphates and consequently increasing available P pool in the soil. Thirdly, the organic anions compete with phosphate ions for the binding sites on the soil particles. The complex organic anions chelate Al⁺³, Fe⁺³ and Ca⁺² and thus decrease the phosphate precipitating power of these cations thereby increasing the phosphorus availability. These results are in close agreement with that of Patra *et al.* (2011) who reported that use of VC or PM enhances P availability. In our study SOC in soils has been reported significant positive correlations with available P₂O₅ ($r = 0.69^{**}$ $p < 0.01$ for 0-15 cm and $r = 0.66^{**}$ $p < 0.01$ for 15-30 cm) of the soils. Sharpley and Syres (1977) indicated that the physical breakdown of material and the enhancement of phosphatase activity caused greater mineralization. Present findings are in conformity with those of many earlier studies reporting increasing P contents with vermicompost treatments (Padmavathiamma *et al.*, 2008). Similarly, Garg and Bahl (2008) reported that poultry manure more readily supplies P to plants than other organic sources like FYM, green manure and crop residues. The present findings are also in line with those of Rai *et al.* (2014) and Singh *et al.* (2014) who reported increase in available P content of may be attributed to the direct addition of P as well as solubilization of native P through release of various organic acids during the decomposition of organic matter.

Table 4.15: Effect of different nutrient sources on soil available phosphorus (kg ha⁻¹) values at 0-15 and 15-30 cm soil depths under different farming systems

Treatment Code*	Soil depth (0-15 cm)						Soil depth (15-30 cm)					
	2019	% age change over CFBS	2020	% age change over CFBS	Pooled	% age over change CFBS	2019	% age change over CFBS	2020	% age over change CFBS	Pooled	% age over change CFBS
Chemical Fertilizer Based System (CFBS)												
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	98.2	-	94.0	-	96.1	-	46.1	-	44.2	-	45.1	-
Organic Farming Based System (OFBS)												
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	104.1	+6.01	105.2	+11.91	104.6	+8.90	48.0	+4.20	48.1	+8.83	48.0	+6.46
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	97.8	-0.41	98.3	+4.61	98.1	+2.05	46.9	+1.75	47.1	+6.57	47.0	+4.11
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	84.2	-14.23	90.6	-3.58	87.4	-9.05	44.7	-2.97	44.1	-0.08	44.4	-1.55
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	80.8	-17.66	87.9	-6.49	84.4	-12.19	42.3	-8.18	41.6	-5.81	42.0	-7.02
Subhash Palekar's Natural Farming System (SPNFS)												
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	85.8	-12.63	89.2	-5.11	87.5	-8.95	39.8	-13.68	43.6	-1.21	41.7	-7.57
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	92.6	-5.64	94.6	+0.59	93.6	-2.59	43.4	-5.86	45.8	+3.62	44.6	-1.22
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	98.1	-0.10	100.7	+7.18	99.4	+3.46	44.6	-3.11	47.6	+7.85	46.1	+2.25
Mean	92.7	-5.58	95.1	+1.14	93.9	-2.29	44.5	-3.48	45.3	+2.47	44.9	-0.57
CD_{0.05} =	4.8	-	6.2	-	3.8	-	2.9	-	2.8	-	3.4	-
	<i>Year =</i>				<i>1.9</i>	<i>-</i>	<i>Year =</i>				<i>NS*</i>	<i>-</i>
	<i>Year × Treatment =</i>				<i>NS**</i>	<i>-</i>	<i>Year × Treatment =</i>				<i>2.7</i>	<i>-</i>

Initial soil available phosphorus of 0-15 and 15-30 cm soil depth was 100.8 and 56.0 kg ha⁻¹, respectively

*For details of treatment code, refer to Table 4.1

**NS=non-significant

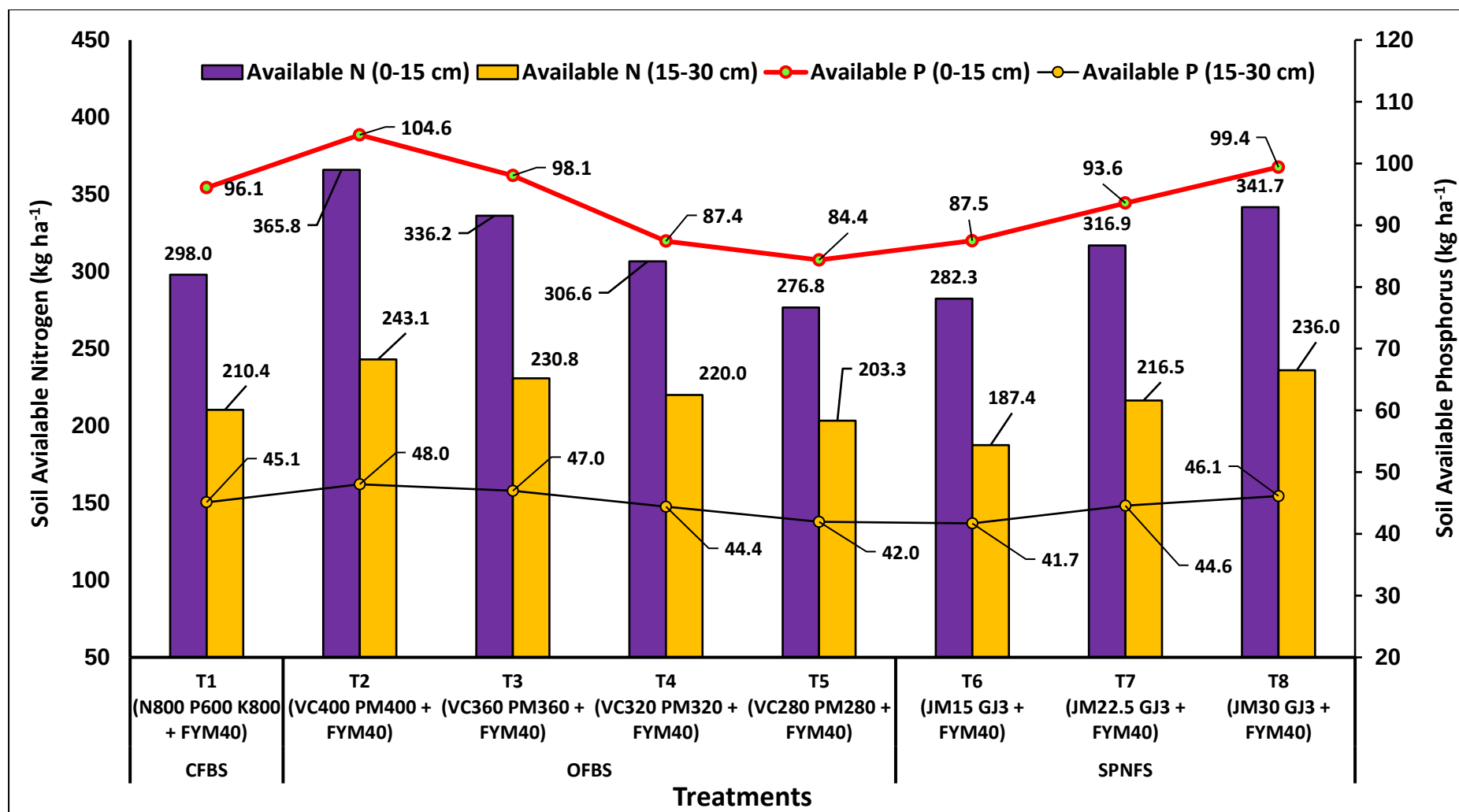


Figure 4.13: Effect of different nutrient sources on soil available N and P (kg ha^{-1}) of 0-15 and 15-30 cm soil layers under different farming systems

4.3.7 Soil available potash

The data presented in Table 4.16 showed that only organic farming-based system (OFBS) has exhibited significant improvement in the soil available K content of the surface 0-15 cm up to 90% exchange with VC and PM in 2019. Subhash Palekar Natural farming system observed no significant improvement in soil available K in surface as well as sub-surface soil, rather it showed declining trend in some of the treatments. The significantly highest soil available K content (398.7 kg ha^{-1}) in 0-15 cm soil layer was recorded in T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$) of OFBS over conventional T_1 ($\text{N}_{800} \text{ P}_{600} \text{ K}_{800} + \text{FYM}_{40}$), followed by T_3 ($\text{VC}_{360} \text{ PM}_{360} + \text{FYM}_{40}$), recording 368.6 kg ha^{-1} . All the remaining treatments showed comparable K content in surface soil during 2019. The data clearly presented that using 90% RDN through application of VC and PM on 50:50 basis has sustained the available K in soil during first year of replacement over conventional farming method while liquid organic manures (*jeevaamrit*) failed to uphold the same level of available K in surface and subsurface level during both years.

In general, during 2020 all the treatments exhibited higher K content in surface soils over 2019 but only treatment T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$) observed significantly highest K content recording 499.6 kg ha^{-1} (26% higher than T_1) in 0-15 cm soil layer. The Treatment T_8 ($\text{JM}_{30} \text{ GJ}_3 + \text{FYM}_{40}$) of SPNFS has recorded 366.9 kg ha^{-1} (-7.44% lower than T_1) in surface soil layers in 2020. The pooled data on soil available K of 0-15 cm soil layer showed similar trend as individual year that treatment T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$) of OFBS was found significantly highest K content recording 449.1 kg ha^{-1} (+26.93% higher than conventional). Remaining treatments are at par with K content (Table 4.16 and Figure 4.14). Furthermore, 'Year' and 'Year $\times$ Treatment' effects were found significant in pooled data representing climate has great influence on available K of surface soil and their interaction has further aggravated the effect.

In general, sub-surface soil layers (15-30 cm) registered lower K content over surface soil layers since organic manures were incorporated in surface soil and a major portion of them stored in the top soil layers. No treatment under SPNFS has observed significantly higher K content than conventional farming in sub-surface soil of 2019 and 2020, however, the content is either lower or comparable. In contrary, significantly highest available K content of 354.1 kg ha^{-1} (+20.54%) in 15-30 cm soil layer was recorded in T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$) of OFBS, over T_1 ($\text{N}_{800} \text{ P}_{600} \text{ K}_{800} + \text{FYM}_{40}$), recording 293.7 kg ha^{-1} in 2019 (Table 4.16). Similar to T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$), T_3 ($\text{VC}_{360} \text{ PM}_{360} + \text{FYM}_{40}$) treatment also showed significantly higher K content than conventional. In 2020, T_2 ($\text{VC}_{400} \text{ PM}_{400} + \text{FYM}_{40}$), T_3 ($\text{VC}_{360} \text{ PM}_{360} + \text{FYM}_{40}$),

and T₄ (VC₃₂₀ PM₃₂₀ + FYM₄₀) of OFBS recorded 395.4, 375.1 and 346.2 kg ha⁻¹ available K content, respectively which were noticed significantly higher than conventional T₁ treatment.

In pooled data no treatment under SPNFS has shown improvement in soil available K content of 15-30 cm soil layer over conventional farming. However, OFBS observed improvement in available K in 15-30 cm soil layer up to 80% replacement of RDN with VC and PM (i.e., up to treatment T₄) (Figure 4.14). The 'Year' showed significance effect in pooled data that shows that climate has influenced the subsurface soil P content but 'Year × Treatment' interaction effect was non-significant in pooled data (Table 4.16).

Poultry manure (1.89-2.04% K) and vermicompost (0.44-0.60% K) holds great amount of potash in forms that are readily taken up by the plants that leads to high K content in Treatment T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) where VC and PM are used in place of chemical fertilizers. On the other hand, *jeevaamrit* (0.044 %) and *ghana jeevaamrit* (1.65-1.69%) contains comparatively lower amount of K that leads to small addition (Table 3.3) and hence leads to lower uptake of K by leaves which is clearly seen in the results given in Table 4.6. Increase in available K due to organic manures application may be attributed to direct addition of K to available pool of soil K. Secondly, the beneficial effect of organic manure on available K might also be attributed to the reduction in K fixation and release of K due to interaction of organic matter with clay besides the direct K addition to the available K pool of soil. This might be due to the reason that application of organic manure secreted organic acid during process of decomposition which led to mineralization of the fixed K and increased the availability of K. Moreover, humus retains divalent cations (Ca⁺², Mg⁺²) more strongly than the monovalent cations and consequently weaker retention of K relative to Ca and Mg may increase K availability (Nagar *et al.* 2016). Since K is not strongly bound in organic matter, microbial action is not much important for the mineralization of K. Inorganic acids such as nitric acid and organic acids formed during the decomposition of organic matter help in the release of mineral bound insoluble K and application of organic matter reduces the K fixation. Balaji (1994) reported that higher levels of available K were recorded in the treatments that received either vermicompost. In our study SOC in soils has been reported significant positive correlations with available K₂O ($r = 0.758^{**}$ $p < 0.01$ for 0-15 cm and $r = 0.540^{**}$ $p < 0.05$ for 15-30 cm) of the soils. The present results got the support from the work of Rai *et al.* (2014) and Singh *et al.* (2014). These results are also in confirmation to the findings of Aziz *et al.* (2010) who reported that organic manures application significantly increases the soil available potassium content in soil.

Table 4.16: Effect of different nutrient sources on soil available potash (kg ha⁻¹) values at 0-15 and 15-30 cm soil depths under different farming systems

Treatment Code*	Soil depth (0-15 cm)						Soil depth (15-30 cm)					
	2019	% age change over CFBS	2020	% age change over CFBS	Pooled	% age over change CFBS	2019	% age change over CFBS	2020	% age over change CFBS	Pooled	% age over change CFBS
Chemical Fertilizer Based System (CFBS)												
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	311.3	-	396.4	-	353.9	-	293.7	-	323.4	-	308.6	-
Organic Farming Based System (OFBS)												
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	398.7	+28.05	499.6	+26.04	449.1	+26.93	354.1	+20.54	395.4	+22.25	374.7	+21.44
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	368.6	+18.39	443.3	+11.85	406.0	+14.73	342.7	+16.68	375.1	+15.97	358.9	+16.31
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	321.4	+3.23	385.3	-2.79	353.4	-0.14	317.9	+8.24	346.2	+7.04	332.1	+7.61
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	291.6	-6.34	337.8	-14.77	314.7	-11.06	286.2	-2.58	290.5	-10.19	288.3	-6.57
Subhash Palekar's Natural Farming System (SPNFS)												
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	305.6	-1.85	316.7	-20.10	311.1	-12.07	266.7	-9.20	281.5	-12.98	274.1	-11.18
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	325.2	+4.46	328.8	-17.05	327.0	-7.58	286.5	-2.47	296.4	-8.35	291.5	-5.55
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	342.5	+10.02	366.9	-7.44	354.7	+0.24	299.0	+1.80	324.7	+0.40	311.9	+1.07
Mean	333.1	+7.00	384.4	-3.29	358.7	+1.38	305.9	+4.13	329.2	+1.77	317.5	+2.89
CD_{0.05} =	34.6		55.1		59.8	-	24.6		17.2		14.3	-
	<i>Year</i> =				15.5	-	<i>Year</i> =				7.2	-
	<i>Year</i> × <i>Treatment</i> =				43.9	-	<i>Year</i> × <i>Treatment</i> =				NS*	-

Initial soil available potash of 0-15 and 15-30 cm soil depth was 302.4 and 246.4 kg ha⁻¹, respectively

*For details of treatment code, refer to Table 4.1

**NS=non-significant

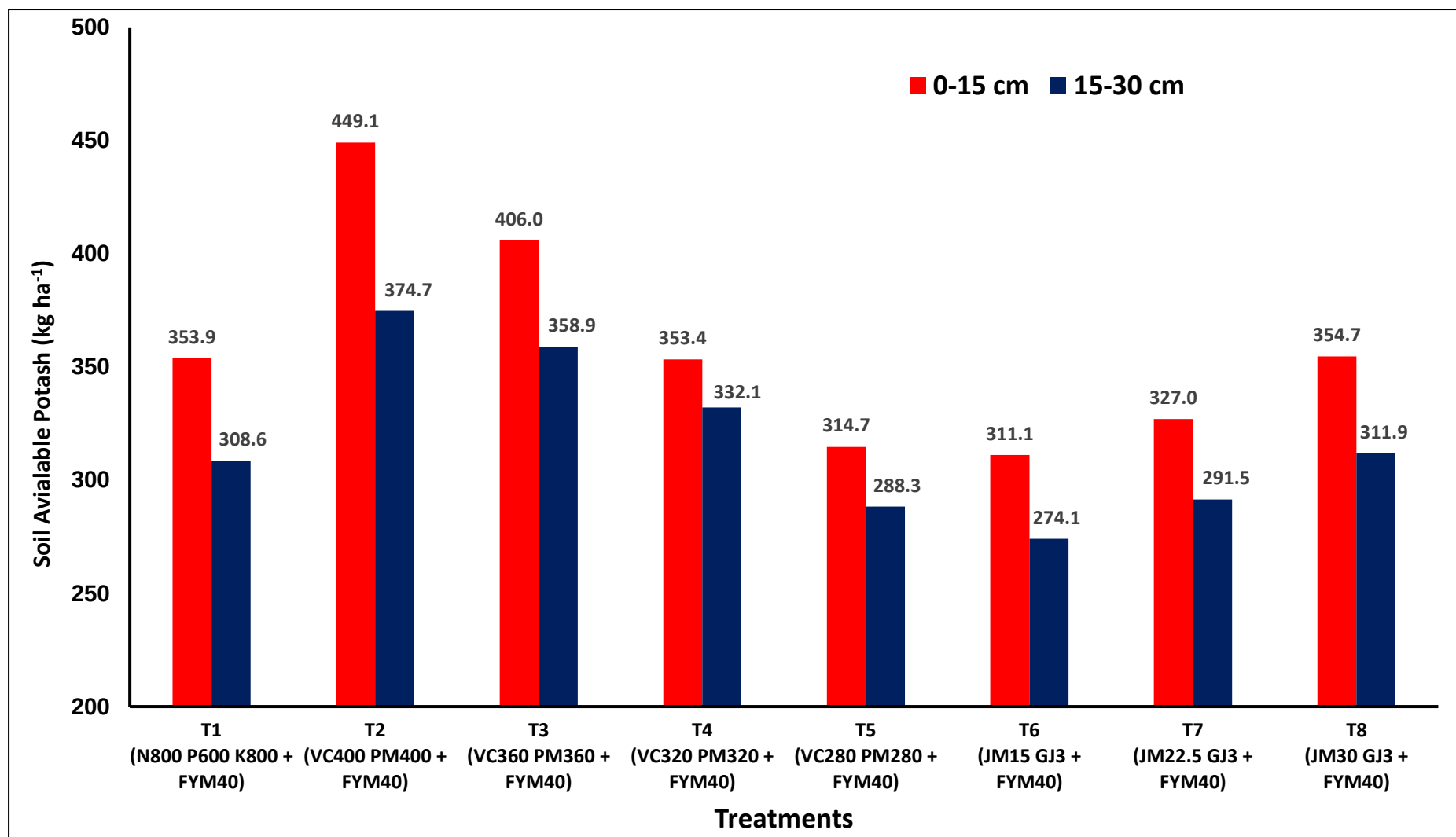


Figure 4.14: Effect of different nutrient sources on soil available K (kg ha⁻¹) of 0-15 and 15-30 cm soil layers under different farming systems.

4.3.8 Soil available micronutrients

The different nutrient sources have exhibited significant influence on the soil available micronutrient (DTPA extractable viz. Copper (Cu), Iron (Fe), Zinc (Zn), Manganese (Mn)) content of the surface (0-15 cm) as well as subsurface (15-30 cm) soils as presented in Tables 4.17 and 4.18. showed that the. Significantly highest soil available micronutrient viz. Cu, Mn and Zn content was recorded in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS in 0-15 cm soil layer recording 3.28, 14.34 and 4.06 (mg kg⁻¹) over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) recording 2.84, 12.28 and 3.59 mg kg⁻¹, respectively in 2019 (Table 4.17). The corresponding values in 2020, are 3.97, 15.50 and 4.39 (mg kg⁻¹) have recorded in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀), recording 2.89, 13.08 and 3.89 mg kg⁻¹, respectively. The Fe content of surface soil under treatment T₈ (JM₃₀ GJ₃ + FYM₄₀) was recorded significantly highest amount of 54.87 mg kg⁻¹ over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) containing 50.17 mg kg⁻¹ of Fe in 2019 (Table 4.17). The corresponding Fe content under treatment T₈ (JM₃₀ GJ₃ + FYM₄₀) has recorded significantly highest amount of 71.52 mg kg⁻¹ over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) recording 63.47 mg kg⁻¹ in 2020, followed by T₇ (JM_{22.5} GJ₃ + FYM₄₀) that contain 70.59 mg kg⁻¹. The percent increase in Cu, Mn and Zn content in T₂ treatment over CFBS (T₁) was +15.38, +16.83 and +13.08%, respectively in 2019. The equivalent increase in 2020 was +37.34, +18.46 and +12.78%. Overall, improvement in soil available micronutrients was observed only up to 100% replacement of RDN with VC and PM only except iron content.

The pooled data on soil available micronutrients also followed the same order as individual years. Significantly highest soil available DTPA extractable Cu, Mn and Zn content in 0-15 cm soil layer recording 3.63, 14.92 and 4.23 (mg kg⁻¹) was recorded in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) recording 2.87, 12.68 and 3.74 mg kg⁻¹, respectively (Figure 4.15 and 4.16). The Fe content in pooled data of surface soil under treatment T₈ (JM₃₀ GJ₃ + FYM₄₀) was recorded significantly highest amount of 63.20 mg kg⁻¹ over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) containing 56.82 mg kg⁻¹ of Fe (Figure 4.16). Furthermore, the 'Year' showed significant effect on availability of micronutrients in surface soils representing climate has influenced the later but 'Year × Treatment' interaction effect was non-significant.

Soil available micronutrients of subsurface layers have recorded lower values as compared to surface soil layers except Fe. Significantly highest soil available micronutrient like Cu, Mn and Zn content was recorded in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS in 15-30 cm soil layer recording 2.97, 11.87 and 3.12 (mg kg⁻¹) over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) recording

2.44, 10.09 and 2.87 mg kg⁻¹, respectively in 2019 (Table 4.18). The corresponding values in 2020, are 3.42, 13.94 and 3.91 (mg kg⁻¹) have recorded in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀), recording 2.74, 11.19 and 3.15 mg kg⁻¹, respectively. The Fe content of subsurface soil showed decreasing trend over conventional plots during both the years as well as in pooled data (Table 4.18). The percent increase in Cu, Mn and Zn content in subsurface soil of T₂ treatment over CFBS (T₁) was +21.52, +17.69 and +8.73%, respectively in 2019. The equivalent increase in 2020 was +25.03, +24.59 and +24.18%. Similar in surface soil, the enhancement in soil available micronutrients (except Fe) in subsurface soil in subsurface soil was observed only up to 100% replacement of RDN with VC and PM only like it was in surface soils.

The pooled data on soil available micronutrients content in subsurface soil layers also followed the same trend as individual years. Significantly highest soil available DTPA extractable Cu, Mn and Zn content in 15-30 cm soil layer recording 3.19, 12.90 and 3.52 (mg kg⁻¹) was recorded in T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) of OFBS over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) recording 2.59, 10.64 and 3.01 mg kg⁻¹, respectively (Figure 4.15 and 4.16). The Fe content in pooled data of sub-surface soil recorded decreasing trend and was recorded highest in T₁ only (Figure 4.16). Furthermore, the ‘Year’ showed significant effect on availability of micronutrients in subsurface soils representing climate has influenced the later but ‘Year × Treatment’ interaction effect was non-significant.

The results are in resemblance earlier study by Demir (2019) who reported that with increasing VC doses application to soil, micronutrient concentrations also increase. High organic matter content of vermicompost, its oxidation and degradation increase the availability of micronutrients such as Fe, Mn, Zn and Cu (Gallardo-Lara and Nogales 1987). In the present study there have been a significant positive correlation of available Cu ($r = +0.875^{**}$ $p = 0.01$), Mn ($r = +0.701^{**}$ $p = 0.01$) and Zn ($r = +0.572^*$ $p = 0.05$) with SOC in surface 0-15 cm and Cu ($r = +0.528^*$ $p = 0.05$) with SOC subsurface (15-30 cm) soil layers which clearly showed that higher the amount of SOC higher will be the availability of micronutrients. Similar findings were also reported by Antoniadis and Alloway (2003). There has been no correlation observed in SOC and Fe content in soil of surface and subsurface layers, Zn and Mn also showed no correlation with SOC in subsurface layers. According to Jordao *et al.* (2006), high concentration of extracted Mn with DTPA may be due to the dissolution of Mn precipitates (phosphate, hydroxides, and carbonates) caused by microbial activity that changes the gaseous composition. Soil organic matter significantly influences the mobility of Zn and Cu in the soil (McGrath *et al.*, 2000).

Table 4.17: Effect of different nutrient sources on DTPA extractable iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) content at 0-15 cm soil depth under different farming systems

Treatment Code*		2019				2020				Pooled			
		Nutrients (ppm)				Nutrients (ppm)				Nutrients (ppm)			
		Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn
Chemical Fertilizer Based System (CFBS)													
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)		2.84	50.17	12.28	3.59	2.89	63.47	13.08	3.89	2.87	56.82	12.68	3.74
Organic Farming Based System (OFBS)													
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)		3.28	51.35	14.34	4.06	3.97	68.20	15.50	4.39	3.63	59.78	14.92	4.23
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)		3.11	45.18	13.33	3.69	3.78	61.64	14.10	3.84	3.44	53.41	13.72	3.77
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)		2.49	42.13	11.77	3.35	3.47	61.27	12.75	3.46	2.98	51.70	12.26	3.40
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)		2.17	41.74	10.41	3.11	3.29	59.87	11.16	3.37	2.73	50.81	10.79	3.24
Subhash Palekar’s Natural Farming System (SPNFS)													
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)		2.67	50.19	10.17	3.06	2.74	67.11	10.71	3.27	2.71	58.65	10.44	3.16
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)		2.89	52.38	11.16	3.14	3.04	70.59	11.78	3.39	2.97	61.48	11.47	3.26
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)		3.12	54.87	13.51	3.23	3.34	71.52	12.85	3.64	3.23	63.20	13.18	3.44
Mean		2.82	48.50	12.12	3.40	3.31	65.46	12.74	3.65	3.07	56.98	12.43	3.53
CD _{0.05} =	Treatment =	0.40	3.47	1.09	0.38	NS**	5.35	1.14	0.31	0.46	3.04	0.76	0.23
	Year =									0.23	1.52	0.38	0.12
	Year × Treatment =									NS	NS	NS	NS

Initial values of DTPA extractable Cu, Fe, Mn and Zn were 1.54, 41.98, 12.82 and 1.28 ppm, respectively in 0-15 cm soil layer

*For details of treatment code, refer to Table 4.1

**NS=non-significant

Table 4.18: Effect of different nutrient sources on DTPA extractable iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) content at 15-30 cm soil depth under different farming systems

Treatment Code*		2019				2020				Pooled			
		Nutrients (ppm)				Nutrients (ppm)				Nutrients (ppm)			
		Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn
Chemical Fertilizer Based System (CFBS)													
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)		2.44	67.95	10.09	2.87	2.74	75.52	11.19	3.15	2.59	71.74	10.64	3.01
Organic Farming Based System (OFBS)													
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)		2.97	60.05	11.87	3.12	3.42	66.22	13.94	3.91	3.19	63.14	12.90	3.52
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)		2.68	59.66	10.11	2.65	3.03	66.09	11.92	3.20	2.86	62.88	11.02	2.92
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)		2.40	55.88	8.46	2.33	2.67	61.80	9.58	2.76	2.54	58.84	9.02	2.54
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)		2.01	53.51	7.79	2.12	2.40	57.11	8.98	2.67	2.21	55.31	8.39	2.40
Subhash Palekar's Natural Farming System (SPNFS)													
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)		1.81	57.84	6.40	2.18	2.27	66.66	7.48	2.55	2.04	62.25	6.94	2.37
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)		2.04	61.55	7.07	2.40	2.06	67.49	8.07	2.77	2.32	64.52	7.57	2.59
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)		2.30	64.39	9.91	2.53	2.71	68.87	10.70	3.04	2.51	66.63	10.30	2.79
Mean		2.33	60.11	8.96	2.53	2.73	66.22	10.23	3.01	2.53	63.16	9.60	2.77
CD_{0.05} =	<i>Treatment =</i>	0.46	3.40	2.18	0.31	0.57	3.43	2.01	0.33	0.35	2.31	1.42	0.22
	<i>Year =</i>									0.18	1.15	0.71	0.11
	<i>Year × Treatment =</i>									NS**	NS	NS	NS

Initial values of DTPA extractable Cu, Fe, Mn and Zn were 1.78, 35.80, 14.29 and 1.02 mg kg⁻¹, respectively in 15-30 cm soil layer

*For details of treatment code, refer to Table 4.1

**NS=non-significant

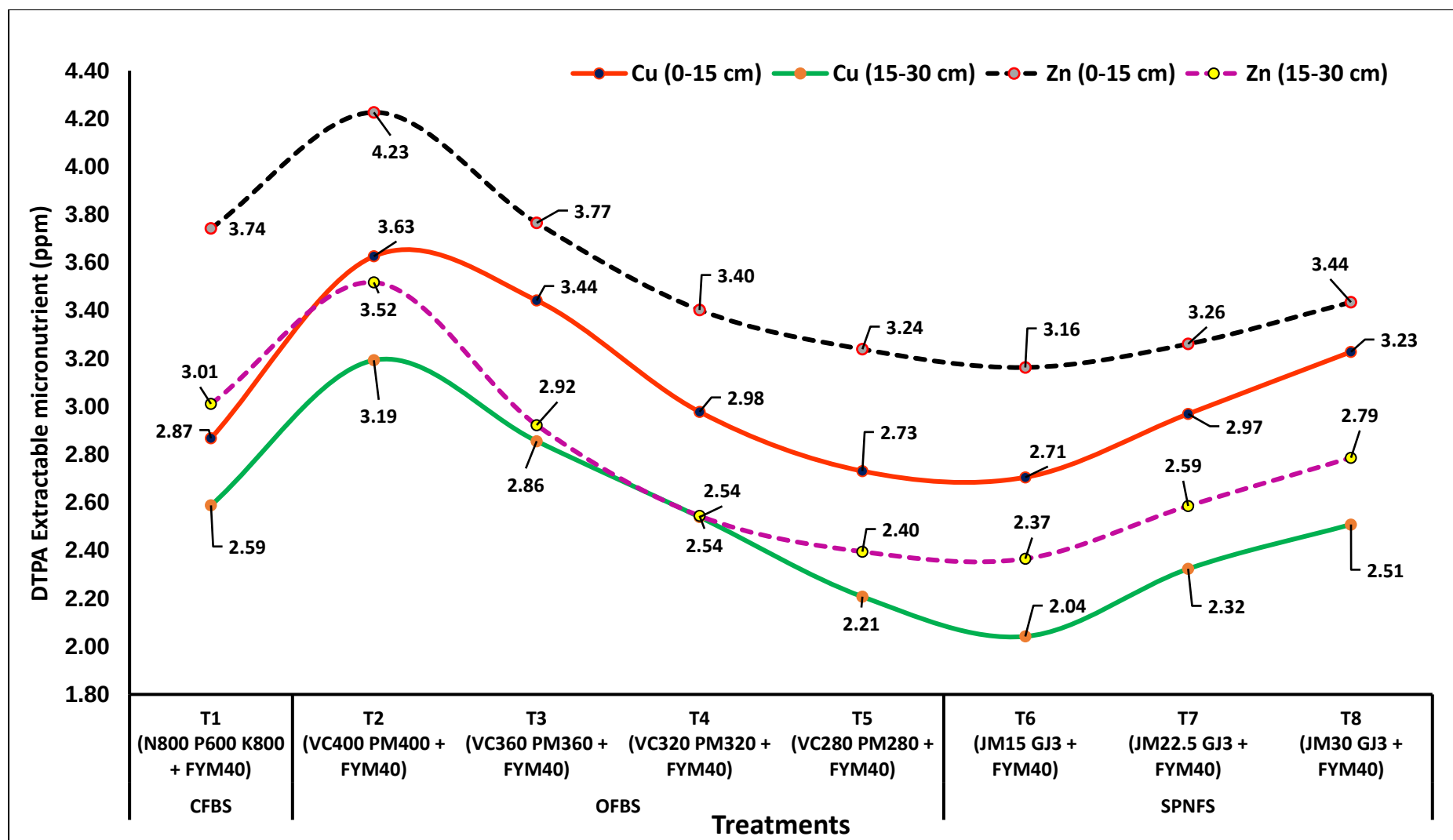


Figure 4.15: Effect of different nutrient sources on DTPA extractable Cu and Zn (mg kg^{-1}) of 0-15 and 15-30 cm soil layers under different farming systems

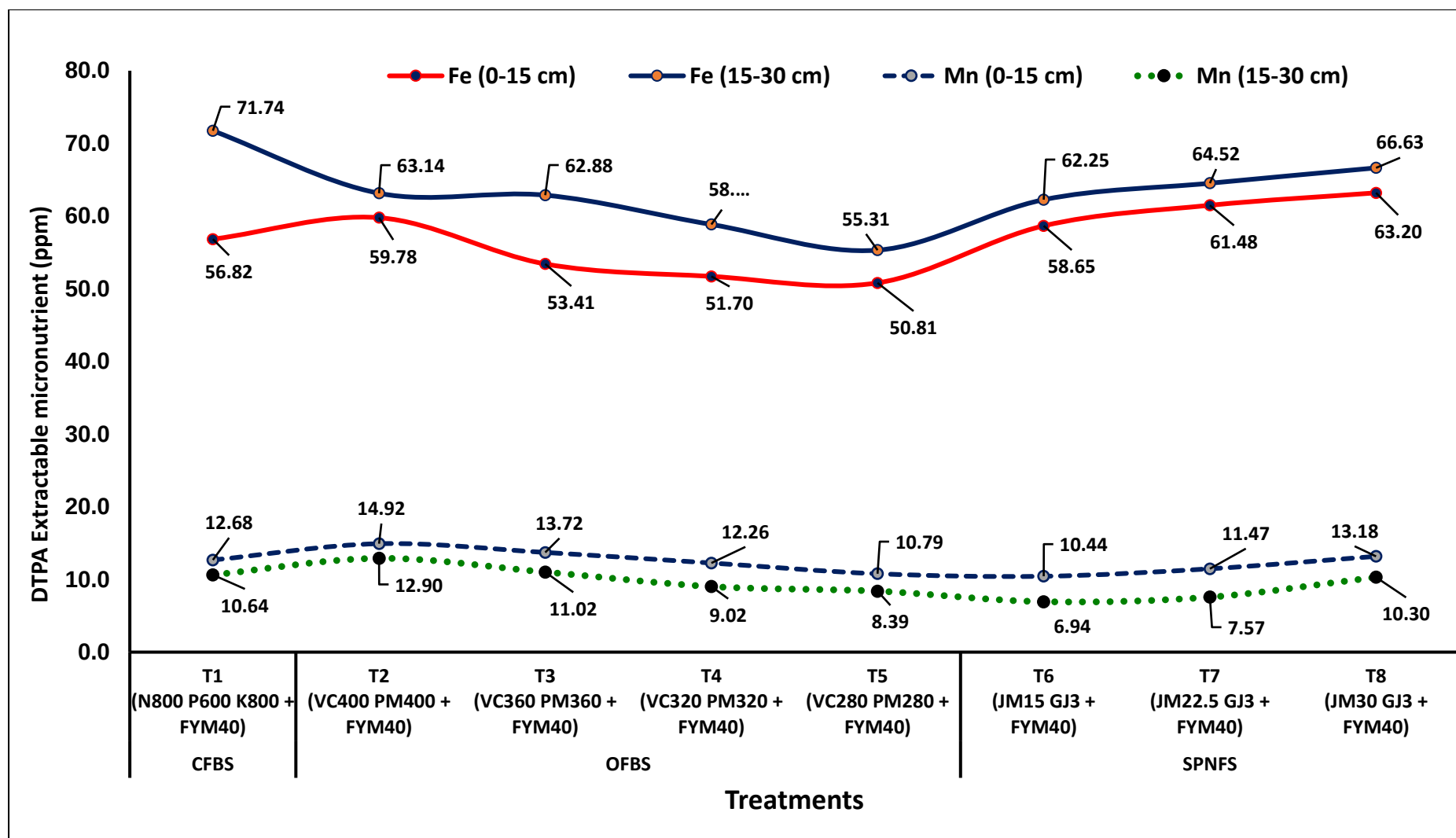


Figure 4.16: Effect of different nutrient sources on DTPA extractable Fe and Mn (mg kg^{-1}) of 0-15 and 15-30 cm soil layers under different farming systems

4.3.9 Soil microbial count

4.3.9.1 Bacterial count

The bacterial population was significantly enhanced by the application of organic nutrient sources (Plate 4). The data relating to bacterial count of 0-15 cm soil layer revealed that soil receiving 100% RDN through VC and PM on 50:50 N-equivalence basis (T_2 treatment) recorded maximum bacterial count (149×10^5 cfu g⁻¹) among OFBS plants while minimum bacterial count of 46×10^5 cfu g⁻¹ was observed with T_1 ($N_{800} P_{600} K_{800} + FYM_{40}$) in 2019. Highest bacterial count of 177×10^5 cfu g⁻¹ was recorded in T_8 ($JM_{30} GJ_3 + FYM_{40}$) under SPNFS (Table 4.19). In 2020, there has been enhancement in bacterial count that ranged from 22 to 36 % higher than recorded in 2019. The T_2 treatment under OFBS has recorded 3.03 times higher bacterial count than conventional treatment T_1 . The further increase in bacterial count has been recorded in SPNFS plants that range from 2.78 to 3.72 times higher than T_1 . The significantly highest bacterial count (223×10^5 cfu g⁻¹), was recorded in T_8 ($JM_{30} GJ_3 + FYM_{40}$) during 2020. Pooled data also showed the same order, recording 3.13 times higher bacterial count in T_2 - $VC_{400} PM_{400} + FYM_{40}$ over T_1 ($N_{800} P_{600} K_{800} + FYM_{40}$) in 0-15 soil layer. Among all treatments T_8 ($JM_{30} GJ_3 + FYM_{40}$) of SPNFS recorded significantly highest bacterial count of 200×10^5 cfu g⁻¹ which was 3.77 times higher than conventional T_1 plants (Figure 4.17). Pooled data also presented that 'Year' has significant influence on bacterial count and critical difference showed that the variation in bacterial count is contributed by the climate. The 'Year $\times$ Treatment' interaction effects are non-significant.

The pooled data pertaining to bacterial count of subsurface (15-30 cm) soil layer revealed that deeper layer observed small but significant changes in bacterial than surface layer and improvement was approximately 50% than that of surface layers (compare Table 4.19 and Table 4.20). This may be due to the fact that soil bacterial populations are generally higher at the surface soil owing to higher organic matter and availability of more nutrients which act as a source for their food for their survival by continuous addition of organic matter with minimum tillage treatments than in deeper depths. However, depth increase the compaction of soil that results in less organic matter and less nutrients which recorded the lowest microbial populations. Pooled data of subsurface soil layer recorded 113% higher bacterial count in T_2 - $VC_{400} PM_{400} + FYM_{40}$ over T_1 ($N_{800} P_{600} K_{800} + FYM_{40}$) treatment. Among all treatments T_8 ($JM_{30} GJ_3 + FYM_{40}$) of SPNFS recorded significantly highest bacterial count of 124×10^5 cfu g⁻¹ which was 130% higher than conventional T_1 plants (Figure 4.17).

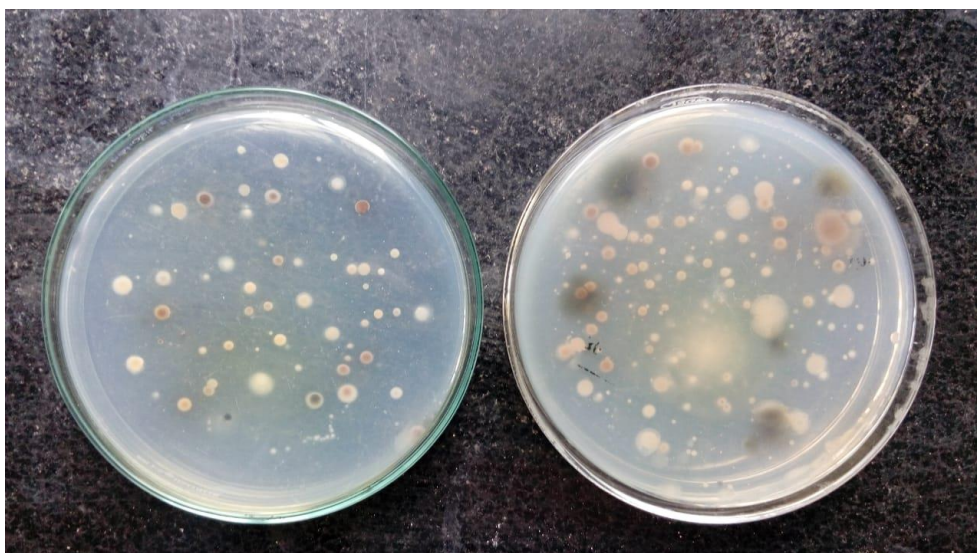
Table 4.19: Effect of different nutrient sources on viable microbial counts in 0-15 cm soil layer under different farming systems

Treatment Code*	2019			2020			Pooled		
	Bacterial (cfu × 10 ⁵ g ⁻¹ soil)	Actinomycetes (cfu × 10 ³ g ⁻¹ soil)	Fungi (cfu × 10 ³ g ⁻¹ soil)	Bacterial (cfu × 10 ⁵ g ⁻¹ soil)	Actinomycetes (cfu × 10 ³ g ⁻¹ soil)	Fungi (cfu × 10 ³ g ⁻¹ soil)	Bacterial (cfu × 10 ⁵ g ⁻¹ soil)	Actinomycetes (cfu × 10 ³ g ⁻¹ soil)	Fungi (cfu × 10 ³ g ⁻¹ soil)
Chemical Fertilizer Based System (CFBS)									
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	46	7	7	60	8	8	53	8	8
Organic Farming Based system (OFBS)									
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	149	12	17	182	13	20	166	13	19
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	127	11	14	173	13	18	150	12	16
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	114	9	13	147	9	16	131	9	15
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	105	9	12	133	10	15	119	9	14
Subhash Palekar's Natural Farming System (SPNFS)									
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	129	14	16	167	15	18	148	15	17
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	142	16	18	179	17	22	161	16	20
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	177	22	24	223	23	26	200	22	25
Mean	124	13	15	158	13	18	141	13	16
CD_{0.05} =	<i>Treatment</i>	14	4	16	3	2	10	2	0.6
	<i>Year</i> =						5	NS	1.2
	<i>Year × Treatment</i> =						**NS	NS	NS

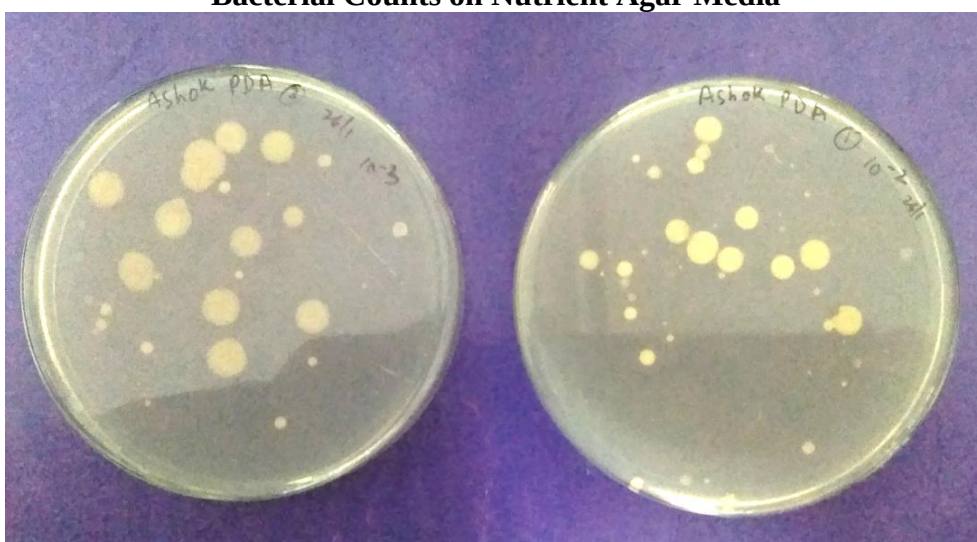
Initial values of bacterial, fungal and actinomycetes count were 50 cfu × 10⁵ g⁻¹ soil, 9 cfu × 10³ g⁻¹ soil and 8 cfu × 10³ g⁻¹ soil, respectively in 0-15 cm soil layer

*For details of treatment code, refer to Table 4.1

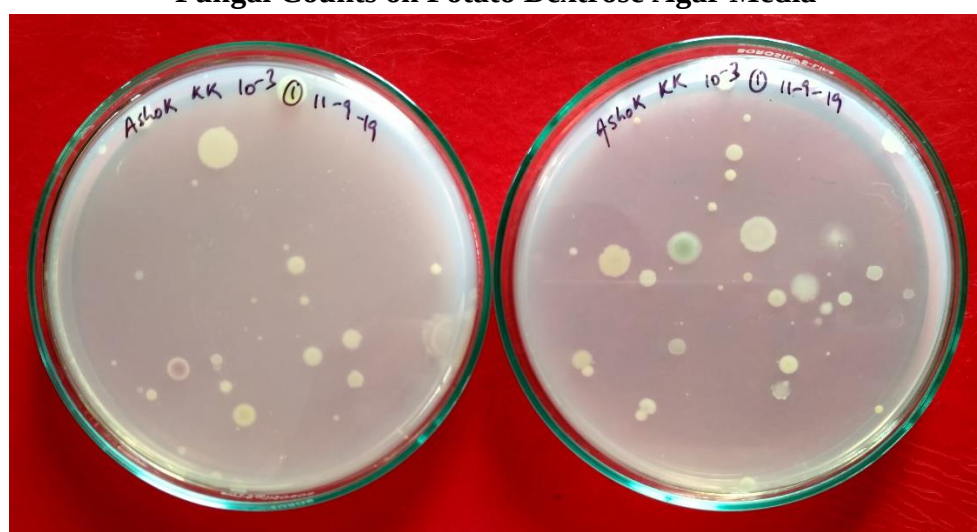
**NS=non-significant



Bacterial Counts on Nutrient Agar Media



Fungal Counts on Potato Dextrose Agar Media



Actinomycetes Counts on KenKnight and Munaier's Media
Plate 4: Viable bacterial, fungal and actinomycetes counts

Pooled data also presented the same trend as that of surface layer and ‘Year’ showed significant influence on bacterial count and but ‘Year $\times$ Treatment’ interaction effects are non-significant. Biswas *et al.* (2017) attributed the higher bacterial count due to the positive effects of manure by providing nutrients for the growth of microbes directly or indirectly by stimulating plant growth and enhancing root carbon flow. In the present study surface soil SOC ($r = 0.755^{**}$, $p=0.01$) and available N ($r = 0.567^*$, $p=0.05$) has exhibited strong correlation with bacterial count. Similar correlation with subsurface soil was recorded (i. e. $r = 0.942^{**}$ with SOC and $r = 0.687^{**}$ with soil available N), therefore, work of Biswas *et al.* (2017) support our results. Also, the organic manures show superiority in enriching the richness and diversity of soil bacteria (He *et al.*, 2008) due to enhanced soil microbial biomass and activities of organic treated soils (Islam *et al.*, 2011). Velmourougane *et al.* (2014) reported that the microbial population declined with depth and maximum activity was recorded within 0–30 cm soil depth. The use of fermented liquid manures like *jeevaamrit* and concentrated soil manure like *ghana jeevaamrit* has practically a paying suggestion because in these liquid manures, beneficial organisms survive easily and are helpful in phosphate solubilization, nitrogen fixation etc. Application of these organic liquid formulations will enhance the soil microbial activity and population to a larger extent. This in turn has a positive effect on growth and yield of crops. Our results are in congruity with the work of Boraiah *et al.* (2017) who observed significantly higher nitrogen fixers due to the application of *jeevaamrit* as it contains enormous amount of microbial load which multiply in the soil and acts as tonic to enhance microbial activity in soil (Palekar, 2006). Yadav and Mowade (2004) has suggested that the increase in bacterial count might be due to cumulative effect of liquid organic inputs in increasing SOC content of soil which acted as C and energy source for microbes and in quick buildup of heterotrophic microflora and fauna.

4.3.9.2 Fungal and actinomycetes count

During both the years, the fungal and actinomycetes populations were significantly affected by the application of different nutrient sources after harvest of crop. The data pertaining to fungal and actinomycetes count of 0-15 cm soil layer as affected by different sources under different farming systems is mentioned in Table 4.19. The data revealed that soil receiving 100% RDN through VC and PM on 50:50 N-equivalence basis (T_2 -VC₄₀₀ PM₄₀₀ + FYM₄₀) in kiwifruit, recorded maximum fungal count (17×10^3 cfu g⁻¹) among OFBS plants, while minimum (7×10^5 cfu g⁻¹) fungal count was observed with T_1 (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) in 2019. Highest fungal count of 24×10^3 cfu g⁻¹ was recorded in T_8 (JM₃₀ GJ₃ + FYM₄₀) under

SPNFS plants (Table 4.19) during 2019. Similarly, highest actinomycetes count was recorded in 22×10^3 cfu g⁻¹ in T₈ (JM₃₀ GJ₃ + FYM₄₀), in 2019 under SPNFS plants. Among OFBS plants T₂ treatment (VC₄₀₀ PM₄₀₀ + FYM₄₀) has recorded highest actinomycetes count 12×10^3 cfu g⁻¹, which was significantly higher than conventional T₁ treatment.

In 2020, there has been enhancement in fungal and actinomycetes counts that ranged from 4.5 to 18.2 and 8.3 to 28.6%, respectively than recorded in 2019. The treatment T₂ -VC₄₀₀ PM₄₀₀ + FYM₄₀ under OFBS has recorded 1.5 and 0.63 times higher fungal and actinomycetes count, respectively than conventional treatment T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀). The further increase in fungal and actinomycetes count has been recorded in SPNFS plants that range from 1.25 to 2.25 and 0.88 to 1.88 times higher than T₁. The significantly highest actinomycetes (23×10^5 cfu g⁻¹) and fungal count (26×10^5 cfu g⁻¹), was recorded in T₈ (JM₃₀ GJ₃ + FYM₄₀) during 2020.

Pooled data also followed the same order, recording 62.5% higher actinomycetes in T₂ -VC₄₀₀ PM₄₀₀ + FYM₄₀ over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) in 0-15 soil layer. The corresponding increase in fungal count was 138% over control. Overall T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS recorded significantly highest actinomycetes and fungal counts of 22 and 25×10^3 cfu g⁻¹ which was 2.00 and 3.13 times higher than conventional T₁ plants (Figure 4.17). Pooled data presented that 'Year' and 'Year × Treatment' interactions has non-significant influence on actinomycetes count while fungal count has been affected by climate. The pooled data pertaining to actinomycetes and fungal count of subsurface (15-30 cm) soil layer revealed that Treatment T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS recorded significantly highest number of actinomycetes count 16×10^3 cfu g⁻¹ (+100% higher) and fungal count 22×10^3 cfu g⁻¹ (+213% higher) over conventional T₁ plants (Figure 4.18). Pooled data of subsurface soil layer recorded 37.5% higher actinomycetes count in T₂ -VC₄₀₀ PM₄₀₀ + FYM₄₀ over T₁ (N₈₀₀ P₆₀₀ K₈₀₀ + FYM₄₀) treatment. The corresponding increase in fungal count was 100%. Pooled data showed that in both fungal and actinomycetes populations 'Year' showed significant influence in subsurface soil layers and but 'Year × Treatment' interaction effects were non-significant.

Our results are supported by the work of Chauhan (2008) who reported that higher dose of VC @ 20 kg tree⁻¹ resulted in an increased microbial population in plum rhizosphere. The increase was attributed higher amount of growth promoting substances, vitamins and enzymes which in turn increased the microbial population and resulted in higher production of root

Table 4.20: Effect of different nutrient sources on viable microbial counts in 15-30 cm soil layer under different farming systems

Treatment Code*		2019			2020			Pooled		
		Bacterial (cfu $\times 10^5$ g ⁻¹ soil)	Actinomycetes (cfu $\times 10^3$ g ⁻¹ soil)	Fungi (cfu $\times 10^3$ g ⁻¹ soil)	Bacterial (cfu $\times 10^5$ g ⁻¹ soil)	Actinomycetes (cfu $\times 10^3$ g ⁻¹ soil)	Fungi (cfu $\times 10^3$ g ⁻¹ soil)	Bacterial (cfu $\times 10^5$ g ⁻¹ soil)	Actinomycetes (cfu $\times 10^3$ g ⁻¹ soil)	Fungi (cfu $\times 10^3$ g ⁻¹ soil)
Chemical Fertilizer Based System (CFBS)										
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)		47	7	6	60	8	7	54	8	7
Organic Farming Based System (OFBS)										
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)		107	10	13	122	12	15	115	11	14
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)		85	10	11	100	12	12	92	11	12
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)		83	8	9	92	9	11	87	8	10
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)		68	8	9	81	9	11	74	9	10
Subhash Palekar's Natural Farming System (SPNFS)										
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)		75	10	14	90	14	15	83	12	15
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)		98	11	15	104	14	15	101	13	15
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)		115	15	21	133	17	23	124	16	22
Mean		85	10	12	98	12	14	91	11	13
CD_{0.05} =	<i>Treatment</i> =	15	1	3	10	2	2	9	1	2
	<i>Year</i> =							4	1	1
	<i>Year $\times$ Treatment</i> =							**NS	NS	NS

Initial values of bacterial, fungal and actinomycetes count were 45 cfu $\times 10^5$ g⁻¹ soil, 6 cfu $\times 10^3$ g⁻¹ soil and 7 cfu $\times 10^3$ g⁻¹ soil, respectively in 15-30 cm soil layer

*For details of treatment code, refer to Table 4.1

**NS=non-significant

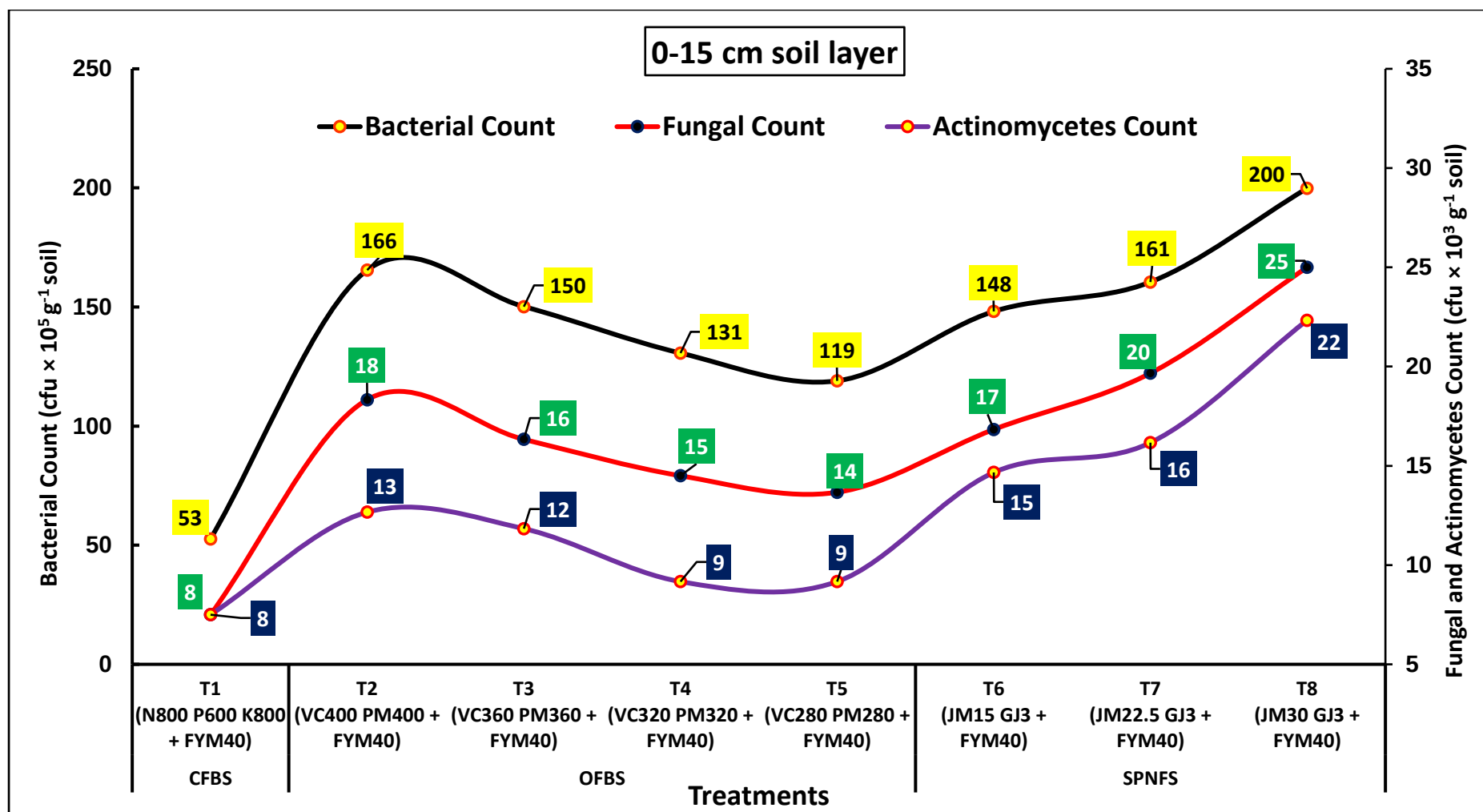


Figure 4.17: Effect of different nutrient sources on bacterial count ($\text{cfu} \times 10^5 \text{ g}^{-1} \text{ soil}$), fungal and actinomycetes count ($\text{cfu} \times 10^3 \text{ g}^{-1} \text{ soil}$) of 0-15 cm soil layer under different farming systems

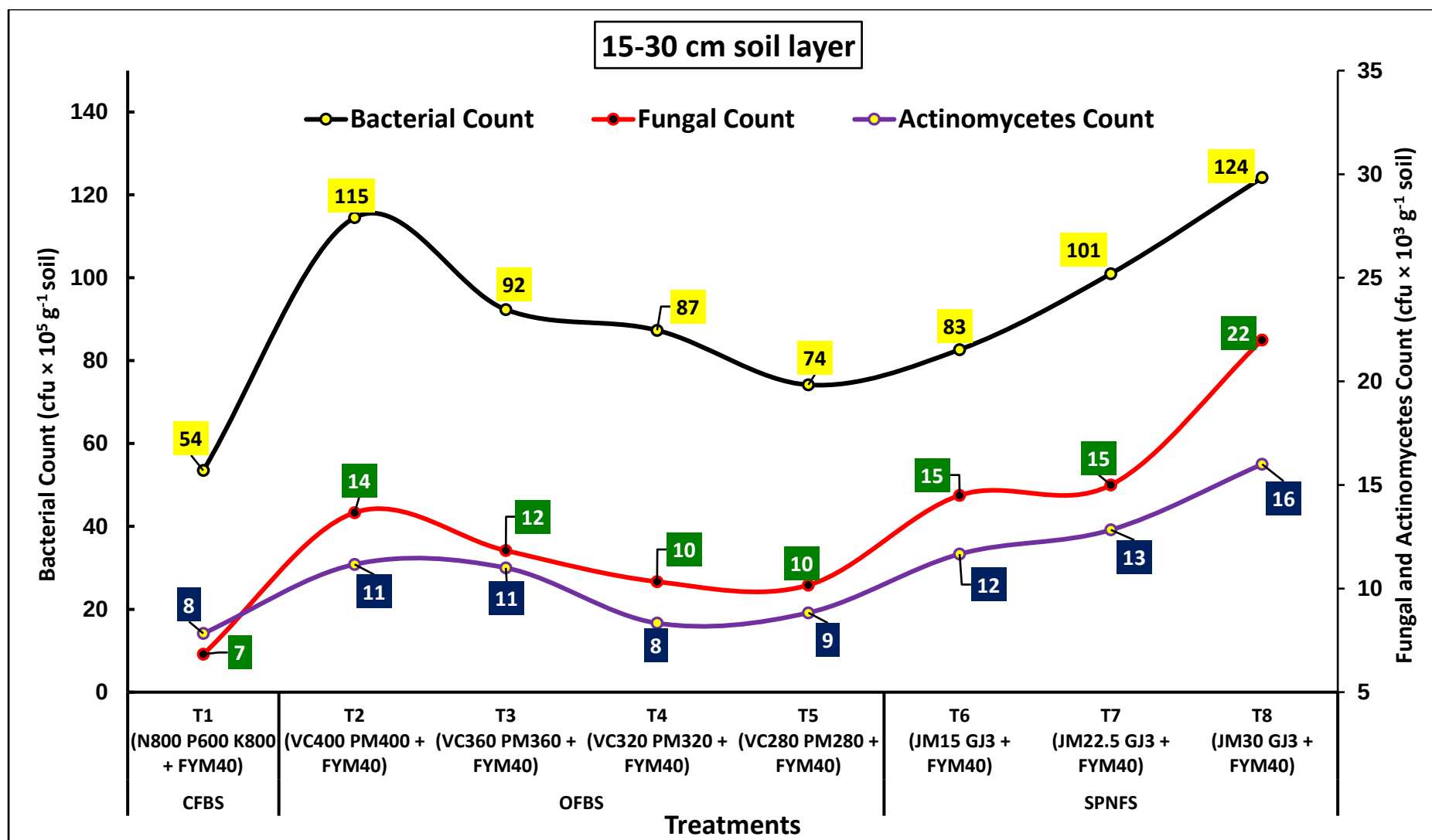


Figure 4.18: Effect of different nutrient sources on bacterial count ($\text{cfu} \times 10^5 \text{ g}^{-1} \text{ soil}$), fungal and actinomycetes count ($\text{cfu} \times 10^3 \text{ g}^{-1} \text{ soil}$) of 15-30 cm soil layer under different farming systems

exudates increasing the beneficial bacteria, fungi and *Actinomycetes* population in rhizosphere region (Masciandaro *et al.*, 1997). Ingle *et al.* (2014) also reported an increase in fungal population with addition of organics since most of these organisms are chemoheterotrophs, which require organic source of carbon as food and oxidation of organic substances provides energy, thereby increasing their population. In the present study fungal count exhibited strong correlations with SOC ($r = 0.680^{**}$, $p=0.01$) and soil available N ($r = 0.549^*$, $p=0.05$) of surface soil. Similarly, fungal populations also exhibited strong correlation SOC ($r = 0.701^{**}$, $p=0.01$) of subsurface soil. Manjunatha *et al.* (2009) also reported that the application of *jeevaamrit* to soil increased the activity of microbes by enhancing the solubilization and uptake of nutrients that ultimately yield and economics of sunflower (*Helianthus annuus* L.).

4.3.9.3 Dehydrogenase activity

Soil dehydrogenases (EC 1.1.1.) are the major representatives of the Oxidoreductase enzymes class (Gu *et al.*, 2009). Among all enzymes in the soil environment, dehydrogenases (DHA) are one of the most important indicator of overall soil microbial activity (Salazar *et al.*, 2011), because they occur intracellular in all living microbial cells (Zhao *et al.*, 2010; Yuan and Yue, 2012). DHA play a significant role in the biological oxidation of soil organic matter by transferring hydrogen from organic substrates to inorganic acceptors (Zhang *et al.*, 2010). Thus, measurement of DHA activity serves as an indicator of the microbiological redox systems and may be considered a good measure of microbial oxidative activities in soils (Casida *et al.*, 1964).

Application of different organic sources exerted a significant influence on the DHA enzyme activity. It is discernible from the pooled data given in Table 4.21 that dehydrogenase activity was recorded highest ($35.8 \mu\text{g TPF g}^{-1} \text{ hr}^{-1}$) in the treatment the T_8 ($\text{JM}_{30} \text{GJ}_3 + \text{FYM}_{40}$) of SPNFS over T_1 ($\text{N}_{800} \text{P}_{600} \text{K}_{800} + \text{FYM}_{40}$) of CFBS in the surface soil (Figure 4.19). Among OFBS plots, treatment T_2 i.e. 100% RDN through VC and PM on 50:50 N-equivalence basis recorded significantly higher dehydrogenase activity measuring $34.6 (\mu\text{g TPF g}^{-1} \text{ hr}^{-1})$ over T_1 ($\text{N}_{800} \text{P}_{600} \text{K}_{800} + \text{FYM}_{40}$) of CFBS in surface soil. It might be due to the fact that organic carbon level was recorded 21.1 (27.85 g kg^{-1}) and 35.9 (31.23 g kg^{-1}) per cent higher in the respective treatments over T_1 ($\text{N}_{800} \text{P}_{600} \text{K}_{800} + \text{FYM}_{40}$) of CFBS, which resulted in increase in dehydrogenase activity (Table 4.13).

The results revealed that the treatments where 100% RDN dose was substituted through organics or by 30 liters of *jeevaamrit* registered more dehydrogenase activity than inorganics only, because substitution of organics increased the concentration of substrate which resulted in the increase in DHA activity in soil. On the basis of pooled data, the increase in DHA activity in surface soil was 20.5 and 16.6 per cent by the application of 30 liters of *jeevaamrit* (T₈) and T₂ (VC₄₀₀ PM₄₀₀ + FYM₄₀) doses over recommended dose of chemical fertilizers and FYM (T₁), respectively. The corresponding increase in subsurface layer was 22.7 and 21.8 per cent over recommended dose of chemical fertilizers and FYM. Furthermore, the reaction followed the 1st order of reaction meaning thereby the activity of enzyme is proportional to the concentration of substrate (Mark, 1999). DHA activity in all the treatments was higher in surface soils than in subsurface soils (Table 4.21), recording highest value of DHA again in T₈ (JM₃₀ GJ₃ + FYM₄₀) of SPNFS. This might happens firstly be due to the fact that the maximum organic matter accumulation was at the surface soil (Table 4.13). Secondly, the addition of N doses solely and/partially through chemical fertilizer resulted in accumulation of nitrate in subsurface which inhibited the activity of enzyme through interfering the process of electron acceptor (Goyal *et al.*, 1992). Our results are in agreement and might be supported by the findings of Xiang *et al.* (2008), who observed that DHA was roughly 4-fold higher in surface (till to 5 cm depth), than in subsoil (90-100 cm). The 'Year × Treatment' interactions were non-significant. Strong positive correlation coefficient exists between SOC and DHA of surface ($r = 0.739^{**}$, $p = 0.01$) and subsurface ($r = 0.854^{**}$, $p = 0.01$) soil layers. Other strong correlation coefficients also exist between DHA and soil available nutrients of surface and subsurface soil layers (Annexure- II).

The results of the present study are in line with the findings of Mandal *et al.* (2007) who also recorded higher dehydrogenase activity treatment where 100% RDN had replaced with VC and PM on 50:50 N-equivalence basis. They concluded that might be due to a strong relationship between soil organic matter content which increases microbial biomass carbon and subsequently higher enzyme activities. Increase in DHA activity has also been observed by Liu *et al.* (2010a), Macci *et al.* (2012), Moharana *et al.* (2014) and Kashyap and Khokhar (2017).

4.3.9.4 Phosphatase activity

Phosphatase is the group of enzymes that catalyze the hydrolysis of both esters and anhydrides of orthophosphate anions. Major part of the soil P is organically bound and its fractions also vary from soil to soil. Data presented in Table 4.21 revealed the low phosphatase activity in conventional treatment which increased with increase in doses of organic fertilizers.

Table 4.21: Effect of different nutrient sources on dehydrogenase (DHA) and acid phosphatase (Acid-P) enzymes activities in 0-15 and 15-30 cm soil layers under different farming systems

Treatment Code*		2019				2020				Pooled			
		DHA (µg TPF g ⁻¹ hr ⁻¹)		Acid-P (µg PNP g ⁻¹ hr ⁻¹)		DHA (µg TPF g ⁻¹ hr ⁻¹)		Acid-P (µg PNP g ⁻¹ hr ⁻¹)		DHA (µg TPF g ⁻¹ hr ⁻¹)		Acid-P (µg PNP g ⁻¹ hr ⁻¹)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Chemical Fertilizer Based System (CFBS)													
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)		25.1	23.5	87.4	83.9	34.3	28.1	91.9	87.7	29.7	25.8	89.7	85.8
Organic Farming Based System (OFBS)													
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)		30.6	28.2	111.5	104.5	38.7	34.7	121.6	113.2	34.6	31.4	116.5	108.8
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)		29.4	26.3	99.3	96.8	37.5	31.8	111.2	109.3	33.5	29.0	105.2	103.1
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)		27.9	24.5	89.3	87.2	34.3	30.5	101.5	99.1	31.1	27.5	95.4	93.1
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)		26.0	22.8	80.6	78.0	33.3	28.8	92.4	82.7	29.7	25.8	86.5	80.4
Subhash Palekar's Natural Farming System (SPNFS)													
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)		23.6	21.6	90.0	88.1	30.3	26.5	103.7	94.5	27.0	24.0	96.8	91.3
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)		26.7	24.8	98.4	94.8	35.4	33.4	115.8	99.9	31.0	29.1	107.1	97.4
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)		33.2	28.7	115.4	101.5	38.3	34.6	124.1	110.1	35.8	31.7	119.8	105.8
Mean		27.8	25.1	96.5	91.8	35.2	31.1	107.8	99.6	31.5	28.1	102.1	95.7
CD _{0.05} =	Treatment =	2.9	1.6	12.5	8.7	3.7	1.6	5.3	14.7	2.3	2.0	6.5	8.2
	Year =									1.1	0.5	3.3	4.1
	Year × Treatment =									NS**	1.5	NS	NS

Initial values of dehydrogenase and acid phosphatase enzyme activities in 0-15 and 15-30 cm soil layers were 22.2 and 21.0 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$ and 86.5 and 81.3 $\mu\text{g PNP g}^{-1} \text{hr}^{-1}$, respectively.

*For details of treatment code, refer to Table 4.1

**NS=non-significant

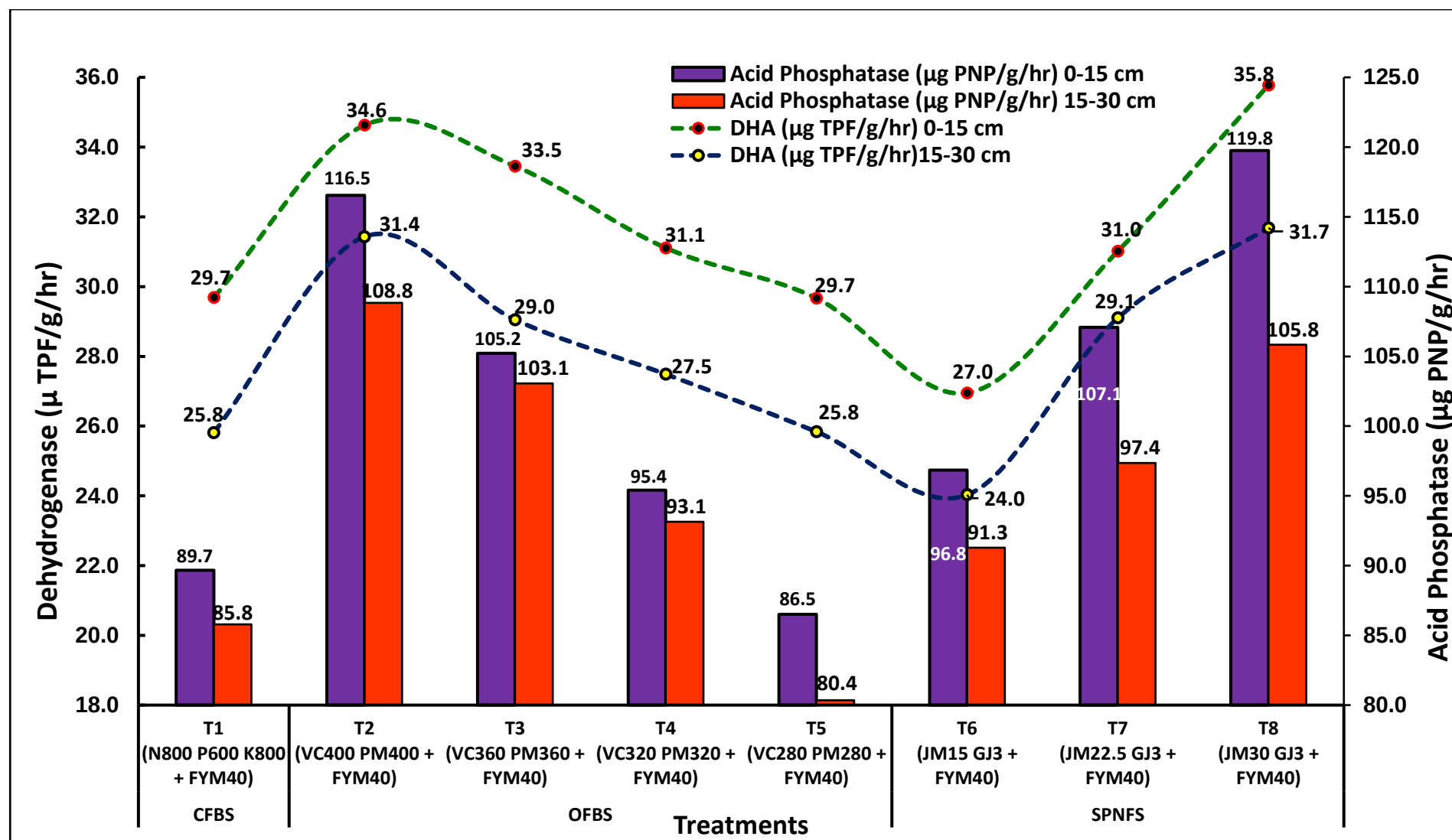


Figure 4.19: Effect of different nutrient sources on dehydrogenase ($\mu\text{g TPF g}^{-1} \text{hr}^{-1}$) and acid phosphatase ($\mu\text{g PNP g}^{-1} \text{hr}^{-1}$) enzyme activity of 0-15 and 15-30 cm soil layers. (Pooled Data of 2019 and 2020) under different farming systems.

In pooled data, the acid phosphatase activity was recorded highest ($119.8 \mu\text{g PNP g}^{-1} \text{ hr}^{-1}$) in the treatment the T_8 ($\text{JM}_{30} \text{GJ}_3 + \text{FYM}_{40}$) of SPNFS over T_1 CFBS in the surface soil (Figure 4.19). Among OFBS plots, treatment T_2 where 100% RDN applied through VC and PM on 50:50 N-equivalence basis recorded significantly higher phosphatase activity measuring $116.5 \mu\text{g PNP g}^{-1} \text{ hr}^{-1}$ over T_1 of CFBS in surface soil. The treatment T_8 of SPNFS and T_2 of OFBS were comparable in phosphatase activity in surface soil. Although, T_3 ($\text{VC}_{360} \text{PM}_{360} + \text{FYM}_{40}$) of OFBS and T_7 ($\text{JM}_{22.5} \text{GJ}_3 + \text{FYM}_{40}$) and T_6 ($\text{JM}_{15} \text{GJ}_3 + \text{FYM}_{40}$) of SPNFS, recording 105.2, 107.1 and 96.8 $\mu\text{g PNP g}^{-1} \text{ hr}^{-1}$ were significantly higher phosphatase activities in surface soil over conventional T_1 treatment ($89.7 \mu\text{g PNP g}^{-1} \text{ hr}^{-1}$). On the basis of pooled data, the increase in acid phosphatase activity in surface soil was 33.6 and 30.0 per cent by the application of 30 liters of *jeevaamrit* (T_8) and T_2 ($\text{VC}_{400} \text{PM}_{400} + \text{FYM}_{40}$) doses over recommended dose of chemical fertilizers and FYM (T_1), respectively.

The increased available P status of soil with the application of equal content organic manures might have contributed to higher phosphatase activity in surface layers. Since monoesters and diesters of phosphate act as the source of substrate for the activity of phosphatase enzyme (Beknazarov, 2002). Secondly, organic sources maintained the continuity of addition of nutrients from organic to inorganic forms, so the substrate of P i.e. monoesters and diesters are continuously available and resulted in more phosphatase activity. Thirdly, organic matter increased the availability of P due to solubilization of inorganic phosphates (Mishustin, 1971). Fourthly, organic P compounds adsorbed and/or interacted with clay mineral and sesquioxides thereby decreasing the number of sites able to fix the fertilizer P and thus keeping the more phosphate in the solution. The organic acids released during the decomposition of added manure affect both phosphate solubilization and fixation (Singh and Sarkar, 1992). Similar results were also obtained earlier by Liang *et al.* (2003) in China. The organic carbon and available P level were recorded 21.1 ($27.85 \text{ g SOC kg}^{-1}$) and 3.5 ($99.4 \text{ kg P ha}^{-1}$) and 35.9 ($31.23 \text{ g SOC kg}^{-1}$) and 8.9 ($104.6 \text{ kg P ha}^{-1}$) per cent higher in the T_8 ($\text{JM}_{30} \text{GJ}_3 + \text{FYM}_{40}$) of SPNFS and T_2 ($\text{VC}_{400} \text{PM}_{400} + \text{FYM}_{40}$) treatments over T_1 ($\text{N}_{800} \text{P}_{600} \text{K}_{800} + \text{FYM}_{40}$) of CFBS, which resulted in increase in phosphatase activity (Table 4.13 and 4.15).

Phosphatase activity in all the treatments was higher in surface soils than in subsurface soils (Table 4.21), recording highest value $108.8 \mu\text{g PNP g}^{-1} \text{ hr}^{-1}$ of phosphatase in T_2 ($\text{VC}_{400} \text{PM}_{400} + \text{FYM}_{40}$) of OFBS followed by $105.8 \mu\text{g PNP g}^{-1} \text{ hr}^{-1}$ in T_8 ($\text{JM}_{30} \text{GJ}_3 + \text{FYM}_{40}$) of SPNFS. This might happens firstly be due to the fact that the maximum organic matter accumulation was at the surface soil (Table 4.13). The 'Year $\times$ Treatment' interactions were

non-significant. Strong positive correlation coefficient exists between SOC and acid phosphatase of surface ($r = 0.86^{**}$, $p = 0.05$) and subsurface ($r = 0.92^{**}$, $p = 0.05$) soil layers. Similarly, a strong positive correlation coefficient exists between available P and acid phosphatase of surface ($r = 0.78^{**}$, $p = 0.05$) and subsurface ($r = 0.82^{**}$, $p = 0.05$) soil layers.

The results of the study are in conformity with finding of Clarholms (1993). Generally, soil enzyme activities are related to the soil organic matter content which might be improved due to inclusion of organic manure (Frankenberger and Dick, 1983). The study by Manna and Ganguly (2001) also showed that phosphatase activity can be improved by the addition of organic manures. Therefore, it can be inferred that significant increase in activity of phosphatases indicates that application of enriched VC and *jeevaamrit* enhanced build-up of microbial biomass. Application of *jeevaamrit* also resulted in higher phosphatase activity ($34.4 \mu\text{g PNP g}^{-1} \text{ hr}^{-1}$) in the experiment conducted by Gangadhar *et al.* (2020).

4.3.9.5 Relationship of bacterial population and soil enzymes with available pool of nutrients

Bacterial population was positively and significantly correlated with soil organic carbon and available N. In the present study, the correlation coefficient between SOC and bacterial population and between surface soil available N and bacterial population was 0.755^{**} ($p = 0.01$) and 0.567^{*} ($p = 0.05$), respectively. The corresponding correlation in subsurface soil layer was 0.942^{**} ($p = 0.01$) and 0.687^{**} ($p = 0.01$), respectively (Annexure-II). It might be due to the fact that increase in carbon and nitrogen had maintained the proper C:N ratio for mineralization process which resulted in increase of bacterial population. Similar increase in microbial population with organic matter addition was observed by Bedi (2004).

Bacterial population also showed the positive significant correlation with dehydrogenase and phosphatase enzyme activities because these two enzymes are considered truly to be of microbial origin (Tabatabai, 1994). Strong correlations have observed between DHA and bacterial population ($r = 0.58^{*}$; $p = 0.05$), DHA and fungal count ($r = 0.59^{*}$; $p = 0.05$), DHA and SOC ($r = 0.74^{**}$; $p = 0.01$), DHA and soil available N ($r = 0.90^{**}$; $p = 0.01$), DHA and soil available P ($r = 0.78^{**}$; $p = 0.01$) and DHA and soil available K ($r = 0.71^{**}$; $p = 0.01$) in the surface soil layer. The corresponding correlations between DHA and bacterial population ($r = 0.85^{**}$; $p = 0.01$), DHA and fungal count ($r = 0.58^{*}$; $p = 0.05$), DHA and SOC ($r = 0.85^{**}$; $p = 0.01$), DHA and soil available N ($r = 0.95^{**}$; $p = 0.01$), DHA and soil available P ($r = 0.84^{**}$; $p = 0.01$) and DHA and soil available K ($r = 0.64^{**}$; $p = 0.01$) have been observed

in subsurface layers (Annexure-II). Dehydrogenase enzyme showed positive and significant correlation with organic carbon as well as available pool of nutrients at both the depths which might be due to the fact that organic carbon is the substrate for dehydrogenase activity and proper supply of N, P and K is required for maintenance of C:N:P:K ratio for mineralization by micro-organisms since the origin of DHA is through microbial synthesis.

Phosphatase activity was positively and significantly correlated with soil available P at surface ($r = 0.56^*$; $p = 0.05$) and subsurface soil ($r = 0.67^*$; $p = 0.05$) layers. It also showed positive correlation with SOC ($r = 0.86^{**}$; $p = 0.01$), available N ($r = 0.78^{**}$; $p = 0.01$), available K ($r = 0.77^{**}$; $p = 0.01$), bacterial population ($r = 0.82^{**}$; $p = 0.01$), fungal population ($r = 0.84^{**}$; $p = 0.01$) and actinomycetes population ($r = 0.79^{**}$; $p = 0.01$) in surface layers (Annexure- II). The corresponding correlation of phosphatase with SOC ($r = 0.92^{**}$; $p = 0.01$), available N ($r = 0.82^{**}$; $p = 0.01$), available K ($r = 0.67^{**}$; $p = 0.01$), bacterial population ($r = 0.86^{**}$; $p = 0.01$), fungal population ($r = 0.65^{**}$; $p = 0.01$) and actinomycetes population ($r = 0.62^{**}$; $p = 0.05$) in subsurface layers. Orthophosphoric acid, mono- and di-esterase are the substrate for phosphatase activity, so its activity depends on the concentration of available P from the total pool of nutrients as well as microbial population. Furthermore, synthesis of phosphatase is consequently dependent on proper mineralization of nutrients viz. C, N, P and K in these layers of soils.

4.3 EFFECT OF APPLICATION OF DIFFERENT NUTRIENT SOURCES ON BENEFIT: COST RATIO

The application of different nutrient sources in different farming systems influenced the benefit: cost ratio and is presented in Table 4.22. The different treatments exhibited noteworthy differences on the cost benefit ratio. The data revealed that highest benefit: cost ratio (12.36:1) was recorded in treatment T_1 (Recommended dose of NPK + 40 kg FYM). Among SPNFS treatments, highest benefit cost ratio (12.22:1) was observed with T_8 (30 liters *JM* + 3 kg *GJ* + 40 kg FYM). But organic manure treatments have shown great decline in benefit cost ratio over chemical fertilizer treatment as well as SPNFS and recording maximum benefit: cost ratio of 4.17:1 in T_2 treatment (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM). The probable reason is that the cost and quantity of organic manures needed to meet the nutrient requirement are high which leads to low net returns and hence low benefit: cost ratio apart from various improvements in soil properties. Labor costs are also high in organic systems. The critical examination of results revealed that highest benefit cost ratio was recorded in the treatment which was treated by inorganic fertilizer with FYM. As,

inorganic fertilizers are rich source of N, P and K and the cost of cultivation is comparatively less coupled with higher yield as compared to organic sources. In our study, although gross returns are high in T₂ treatment (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) but at the same time cost of cultivation is nearly three times over chemical fertilizer treatment which leads to nearly one third of benefit cost ratio. However, the yield is less in the initial years in organic manures but subsequently, it can be compensated with yield recovery and higher market price of organic produce. Evidence from the previous studies analyzed showed that yields in well-established organic farms are most often lower than conventional, to varying degrees. Most European studies including cereals, vegetables and mixed farming systems produced somewhat lower yields (Offermann and Nieberg, 2000). But in India, there are many examples in which yield increases in organic systems. For example, Jackson (2005) found that organic cotton yields in Kutch, Gujrat were on average 2.5- 2.75 t ha⁻¹, similar to or even in excess of those obtained under non-organic systems, and much more than irrigated conventional hybrid cotton yields in other states, such as Punjab and Andhra Pradesh. The possible factors explaining these differences were low pest populations due to dry climate, the widespread use of *Desi* varieties and greater attention paid to soil fertility.

Organic agriculture specifically requires a system approach due to its complexity. Conventional and organic farms represent different systems. Thus, the usual simplified approach of comparing them on the basis of few variables like yield may not be sufficient. Overall, a multi-disciplinary approach that involves the whole farm (including crop and livestock operations), soil health improvement, management skills and objectives of the farmers is a more favorable option.

Furthermore, Wynen (2001) showed that transitional phase is the most challenging one for organic farmers. It is, of course, another matter if the objective is to find out the change in farm economics during conversion. In such cases, one full crop rotation cycle, in addition to the conversion period of three years, is the recommended minimal period for conversion experiments (Stanhill, 1990). The results are in accordance with Tripathi *et al.* (2018a) who stated that farmers practicing SPNFS in Andhra Pradesh earn substantially more than the control group of conventional farmers and SPNFS farmlands may be able to withstand droughts, high-speed winds and flooding better than non-SPNFS plots. From this, it would be concluded that the profitability of organic could only increase with premium prices, increased governmental support and higher yields. Also, long-term farming systems experiments are an important way of evaluating the potentials and limitations of different farming systems against sustainability criteria (productivity, economic viability and resource-conservation).

Table 4.22. Effect of different nutrient sources in different farming systems on benefit: cost ratio (average of two years) of kiwifruit production

Treatment code*	Quantity of input applied/vine	Cost of input/vine (₹)**	Total cost of input/ha (₹)	Labor cost of input application/ha (₹)	Total input cost/ha (₹)***	Kiwifruit yield/vine (kg) ^a			Total Income/ vine (₹)	Gross return/ ha ^b (₹)	Net Returns/ ha (₹)	B:C ratio = Net return/ Total cost
						A-grade	B-grade	C-grade				
Chemical Fertilizer Based System (CFBS)												
T ₁ (N ₈₀₀ P ₆₀₀ K ₈₀₀ + FYM ₄₀)	Urea :1.74 kg SSP: 3.75 kg MOP: 1.34 kg FYM: 40 kg	122.89	45,963	5100	1,11,063	4.56	11.78	12.87	3966.0	14,83,284	13,72,221	12.36:1
Organic Farming Based System (OFBS)												
T ₂ (VC ₄₀₀ PM ₄₀₀ + FYM ₄₀)	VC: 35.16 kg PM: 24.2 kg FYM: 40 kg	657.60	2,45,942	5400	3,11,342	6.03	12.61	12.05	4302.5	16,09,135	12,97,793	4.17:1
T ₃ (VC ₃₆₀ PM ₃₆₀ + FYM ₄₀)	VC: 31.64 kg PM: 21.78 kg FYM: 40 kg	598.20	2,23,727	5040	2,88,767	4.52	9.72	10.97	3459.0	12,93,666	10,04,899	3.48:1
T ₄ (VC ₃₂₀ PM ₃₂₀ + FYM ₄₀)	VC: 28.13 kg PM: 19.36 kg FYM: 40 kg	538.90	2,01,549	4680	2,66,229	3.34	8.63	10.52	3014.5	11,27,423	8,61,194	3.23:1
T ₅ (VC ₂₈₀ PM ₂₈₀ + FYM ₄₀)	VC: 24.61 kg PM: 16.94 kg FYM: 40 kg	479.50	1,79,333	4320	2,43,653	2.46	8.38	10.59	2808.0	10,50,192	8,06,539	3.31:1
Subhash Palekar's Natural Farming System (SPNFS)												
T ₆ (JM ₁₅ GJ ₃ + FYM ₄₀)	JM: 15 liters GJ: 3 kg FYM: 40 kg	103.00	38,522	5700	1,04,222	3.89	10.02	12.23	3504.0	13,10,496	12,06,274	11.57:1
T ₇ (JM _{22.5} GJ ₃ + FYM ₄₀)	JM: 22.5 liters GJ: 3 kg FYM: 40 kg	115.00	43,010	6150	1,09,160	4.42	11.35	12.00	3786.5	14,16,151	13,06,991	11.97:1
T ₈ (JM ₃₀ GJ ₃ + FYM ₄₀)	JM: 30 liters GJ: 3 kg FYM: 40 kg	127.00	47,498	6600	1,14,098	5.81	11.67	11.20	4032.5	15,08,151	13,94,057	12.22:1

*For detail treatment code, refer to Table 4.1 **Costs of various inputs are: Neem coated urea @ ₹ 266.5/45 kg i.e. ₹ 5.92/kg; Single super phosphate (SSP) @ ₹ 362.5/50 kg i.e. ₹ 7.24/kg; Muriate of Potash (MOP) @ ₹ 800/50 kg i.e. ₹ 16.00/kg; Farm yard manure (FYM) @ ₹ 1600/ton i.e. ₹ 1.60/kg; vermicompost (VC) @ ₹ 10/kg; poultry manure (PM) @ ₹ 10/kg; jeevaamrit (JM) @ ₹ 1.6/liter and ghana jeevaamrit (GJ) @ ₹ 5.00/kg

***Fixed cost of ₹ 60000/ha is added in input cost of each treatment. ^aSale price of A, B and C grade kiwifruits are ₹ 200, 150 and 100/kg ^bNumber of female plants per ha = 374

Chapter-5

SUMMARY AND CONCLUSION

Present investigation entitled “**Effect of nutrient sources on soil properties and productivity of kiwifruit (*Actinidia deliciosa* cv. Allison)**” was carried out to study the effect of different nutrient sources on plant growth, yield, quality parameters of kiwifruit and their effects on physical, chemical and biological properties of soil at the experimental kiwifruit orchard of the Department of Fruit Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni- Solan (HP) during the year 2018-2020.

Investigations were carried out on 6-years old kiwifruit vines cultivar Allison planted at a spacing of 4.0 m (row to row) × 6.0 m (plant to plant) spacing and trained on T bar system. The experiment was laid out in a Randomized Block Design (RBD) with 8 treatments and replicated thrice. Three farming systems viz. Chemical Fertilizer Based System (CFBS), Organic Farming Based Systems (OFBS) and Subhash Palekar’s Natural Farming System (SPNFS). The eight treatments studied are: T₁ (Recommended dose of chemical fertilizers + 40 kg FYM) under CFBS, four treatments (T₂, T₃, T₄, and T₅) under OFBS where 100, 90, 80 and 70 per cent recommended dose of nitrogen was replaced with vermicompost and poultry manure on 50:50 basis along with 40 kg FYM, respectively and three treatments (T₆, T₇ and T₈) under SPNFS where 15, 22.5 and 30 liters of *jeevaamrit* + 3 kg of *ghana jeevaamrit* (each vine), respectively was applied along with 40 kg FYM.

The salient findings of the experiment have been summarized as below:

5.1 Effect of application of different nutrient sources on plant growth under different farming systems

- ❖ Among different treatments, treatment T₈ (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM per vine) under SPNFS exhibited highest leaf area (158.1 cm²) and leaf area index (4.36) followed by 151.8 cm² and LAI (4.35) in T₂ (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) of OFBS. The lowest leaf area (132.8 cm²) was recorded under T₅ (70 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) treatment.
- ❖ Chlorophyll index values were statistically at par T₁ of CFBS and T₇ and T₈ of SPNFS measuring 51.2, 51.6 and 51.2, respectively. However, significantly lower value of

chlorophyll index (48.8) was recorded in treatment T₅ (70 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) under OFBS system.

- ❖ Significantly highest value of photosynthetically active radiation (PAR) of upper canopy was noted in T₂ (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) under OFBS which was at par with T₈ (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM per vine) under SPNFS, recording 2027 and 2020 $\mu\text{mol quanta m}^{-2} \text{ s}^{-1}$. The corresponding PAR value of lower canopy was 642 and 612 $\mu\text{mol quanta m}^{-2} \text{ s}^{-1}$ in the respective treatments. These values were at par with recommended treatment.
- ❖ Perusal of data on leaf nutrient content showed that T₁ treatment (Recommended chemical fertilizers + 40 kg FYM) recorded highest leaf N (2.21%) and Ca (4.18%) content. But, T₂ treatment (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) under OFBS observed highest P (0.35%) and K (1.80%) content in kiwifruit leaves. Among SPNFS, treatment T₈ (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM per vine) recorded highest N (1.97%), P (0.34%), K (1.71%) and Ca (4.01%) in kiwifruit leaves. Similarly, among OFBS, T₂ treatment recorded highest nutrient content.

5.2 Effect of application of different nutrient sources under different farming systems on fruit yield

- ❖ The highest kiwi fruit yield (30.7 kg vine⁻¹) was recorded with the treatment T₂ (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) under OFBS which was at par with T₁ treatment (Recommended dose of chemical fertilizers + 40 kg FYM) under CFBS and T₈ (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM per vine) under SPNFS, respectively recording 29.2 and 28.7 kg kiwifruit vine⁻¹. This clearly showed that there is no significant gain in fruit yield using organic solid/liquid manures.
- ❖ In general, higher yields of kiwifruit were obtained in 2020 compared to 2019. The per cent increase in yield was recorded 34.3% in T₁ treatment (Recommended dose of chemical fertilizers + 40 kg FYM) under CFBS, 37.3 to 63.1% in OFBS and 27.4 to 30.4% in SPNFS, respectively in the year 2020 over 2019.
- ❖ Highest per cent proportion (i.e. 20.3 per cent) of A-grade (>70 g) fruits was recorded in T₈ treatment (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM per vine) under SPNFS which was at par with T₂ (100 per cent RDN through vermicompost and poultry

manure on 50:50 basis + 40 kg FYM) under OFBS recording 19.7 per cent of A-grade fruits. The lowest per cent proportion (11.5 per cent) of A-grade fruits was recorded in T₅ (70 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) under OFBS system. However, it yields highest per cent of C-grade (<50 g) fruits. The per cent proportion of B-grade fruits didn't vary significantly among treatments.

- ❖ Among different treatments, T₁ treatment (Recommended dose of chemical fertilizers + 40 kg FYM) under CFBS was found to be the best in terms of fruit length (65.8 mm), fruit average diameter (40.9 mm), L/D ratio (1.61) and fruit weight (68.1g) during both the years of experimentation. However, average fruit diameter of T₁ treatment (40.9 mm) was at par with T₂ (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) under OFBS and T₈ treatment (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM per vine) under SPNFS recording 40.2 and 40.4 mm respectively. Therefore, replacement of chemical fertilizers with solid/liquid organic manures failed to maintain the size of kiwifruits in our two-year experiment.

5.3 Effect of application of different nutrient sources under different farming systems on quality parameters of kiwifruit

- ❖ Data pertaining to total soluble solids (TSS), titratable acidity and TSS/acid ratio did not register any significant changes. In general, values of TSS in kiwifruits ranged from 15.63 to 16.87 % in treatments under OFBS and from 14.10 to 15.62% in treatments under SPNFS. The T₁ treatment (Recommended dose of chemical fertilizers + 40 kg FYM) under CFBS observed 14.68 % TSS. Lowest percentage of titratable acidity was found in fruits under treatment T₂ (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) under OFBS and subsequently higher TSS/acid ratio (17.30). The fruits grown under T₈ treatment (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM per vine) observed lower titratable acidity (1.13%) over T₁ treatment (Recommended dose of chemical fertilizers + 40 kg FYM) under CFBS.
- ❖ The scrutiny of data revealed that significantly highest total sugar content (11.77%) in kiwifruits was recorded in T₂ treatment (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) under OFBS over T₁ treatment of CFBS. The treatments under SPNFS didn't show any significant improvement in total sugar content over chemical fertilizers.
- ❖ Pooled data on reducing and non-reducing sugars showed that T₂ treatment (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) recorded

significantly highest values of 8.31 and 3.28%, respectively over T₁ treatment under CFBS. In general, all the treatments under OFBS recorded higher content of non-reducing sugars over other systems. The treatments under SPNFS didn't show any significant improvement in reducing and non-reducing sugar over chemical fertilizers.

- ❖ The highest ascorbic acid content (81.55 mg 100g⁻¹) in kiwifruits was found in treatment T₂ (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) followed by T₈ treatment (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM) treatment of SPNFS, recording 74.51 mg 100g⁻¹. Both of them were recorded significantly higher ascorbic acid content than chemical fertilizer treatment.

5.4 Effect of application of different nutrient sources under different farming systems on soil physical, chemical and biological properties

- ❖ The pooled data on soil pH of 0-15 cm soil layer exhibited no significant variation with different organic sources. However, subsurface layers observed significant changes in soil pH. A scrutiny of data revealed that none of the treatment had significant effect on soil EC of subsurface layer during both the years of study. However, noticeable significantly higher soil EC values of surface soil layer have been observed in all treatments under OFBS over T₁ treatment under CFBS.
- ❖ In general, organic treatments under OFBS registered significantly lower bulk density values over chemical fertilizers and recorded lowest bulk density of 0.927 g cm⁻³ in T₂ (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM). Bulk densities of surface soils under SPNFS were at par with the T₁ treatment under CFBS. The soil bulk density in subsurface soil layers were not affected by application of different nutrient sources.
- ❖ Soil texture remained sandy loam in both surface and subsurface soil layers throughout the experimental period.
- ❖ Data on soil organic carbon content of 0-15 and 15-30 soil layers revealed that T₂ treatment (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) of OFBS was found superior (significantly higher) to all other treatments, recording 31.23 (+35.86% higher) and 12.38 (+24.28% higher) g kg⁻¹ SOC, respectively over conventional chemical fertilizer treatment. In SPNFS, the improvement in SOC ranged from 10.9 to 21.2 and 7.6 to 19.2 per cent, respectively in surface and subsurface soil layers over chemical treatments.

- ❖ The SOC in surface 0-15 cm has registered significant positive correlations with available N ($r = 0.890^{**}$ p value <0.01) and available P ($r = 0.687^{**}$ p value <0.01) of the soils. Likewise, SOC in subsurface soils also exhibited positive significant positive correlations with available N ($r = 0.733^{**}$ p value <0.01) and available P_2O_5 ($r = 0.646^{**}$ p value <0.01) of the soils.
- ❖ Highest content of soil available N was found in T_2 treatment (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) of 0-15 cm soil layer of OFBS, recording 365.8 kg ha^{-1} (+22.77% higher than chemical treatment) followed by T_8 treatment (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM) treatment of SPNFS, recording 341.7 (+14.67%) kg ha^{-1} , respectively. The surface soil layer under chemical treatment T_1 , contained 298 kg N ha^{-1} only. Similar trend has been observed in subsurface soil layer recording +15.57 and +12.18% higher soil available N in T_2 treatment and T_8 treatment. A significant positive correlation between soil available N and SOC ($r = 0.890^{**}$ $p <0.01$) in surface 0-15 cm and subsurface (15-30 cm) ($r = 0.733^{**}$ $p <0.01$) soil layers also exist.
- ❖ The pooled data on soil available P of 0-15 cm soil layer showed that treatment T_2 (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) of OFBS was found significantly highest P content recording 104.6 kg ha^{-1} (+8.9% higher than conventional) over chemical treatment. The treatment T_8 (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM) recording 99.4 kg ha^{-1} available P content was at par with chemical fertilizer treatment. Subsurface soil layers registered comparable soil available P content in T_2 and T_8 treatments over T_1 treatment. Soil available P has been reported significant positive correlations with SOC of 0-15 ($r = 0.69^{**}$ $p <0.01$) and 15-30 ($r = 0.66^{**}$ $p <0.01$) cm soil layers, respectively.
- ❖ The critical examination of data showed significantly highest K content was observed in T_2 treatment (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) of OFBS. It has recorded 26.9 and 21.4% higher K content over chemical fertilizer treatment in surface and subsurface soil layers respectively. Liquid organic manures (*jeevaamrit*) failed to uphold the same level of available K in surface and subsurface level during both years. SOC in surface ($r = 0.758^{**}$ $p <0.01$) and subsurface ($r = 0.540^{**}$ $p <0.05$) soil recorded significant positive correlations with available K.
- ❖ Critical scrutiny of data on micronutrient availability under different nutrient sources revealed that treatment T_2 (100 per cent RDN through vermicompost and poultry manure

on 50:50 basis + 40 kg FYM) of OFBS was found significantly maximum DTPA extractable Cu (3.63 and 3.19 mg kg⁻¹), Mn (14.92 and 12.90 mg kg⁻¹) and Zn (4.23 and 3.52 mg kg⁻¹) content in surface and subsurface soil layers, respectively over chemical fertilizer treatment. Treatments under SPNFS system didn't register any significant changes w. r. t. Cu, Mn and Zn availability. Exceptionally, a significant highest DTPA extractable Fe (63.20 mg kg⁻¹) has been found in surface soil of T₈ (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM) over chemical fertilizer treatment. In subsurface soil, Fe content declined significantly over chemical fertilizer treatment.

- ❖ The results obtained in present investigation revealed that 0-15 cm soil layer under organic manures (OFBS) recorded two to three times and SPNFS registered three to four times more bacterial count over chemical fertilizer treatment. The T₈ treatment (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM) of SPNFS observed maximum bacterial count of 200 cfu × 10⁵ g⁻¹ soil, maximum fungal (25 cfu × 10³ g⁻¹ soil) and actinomycetes count (22 cfu × 10³ g⁻¹ soil) in surface soil over chemical fertilizer. Among OFBS, treatment T₂ (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) registered maximum bacterial count of 166 cfu × 10⁵ g⁻¹ soil, maximum fungal (19 cfu × 10³ g⁻¹ soil) and actinomycetes count (13 cfu × 10³ g⁻¹ soil) in surface soil over chemical fertilizer. The data pertaining to bacterial count of subsurface (15-30 cm) soil layer revealed that deeper layers noticed small but significant changes in bacterial than surface layers and improvement was approximately 50% than that of surface layers. Subsurface soil layer recorded 113 and 130% higher bacterial count in T₂ (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) and T₈ (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM) treatments, respectively over chemical fertilizer.
- ❖ Bacterial count in surface layer exhibited strong positive correlation coefficient with many soil quality parameters like SOC (r=0.755**, p<0.01), soil available N (r=0.567*, p<0.05), fungal count (r=0.973**, p<0.01), actinomycetes count (r=0.830**, p<0.01), dehydrogenase activity (r=0.581*, p<0.05) and acid phosphatase activity (r=0.934**, p<0.01). Similarly, bacterial count in subsurface soil showed positive correlation coefficient with SOC (r=0.942**, p<0.01), soil available N (r=0.687**, p<0.01), soil available P (r=0.524*, p<0.05), fungal count (r=0.854**, p<0.01), actinomycetes count (r=0.782**, p<0.01), dehydrogenase activity (r=0.852**, p<0.01) and acid phosphatase activity (r=0.862**, p<0.01).

- ❖ Alike bacteria, fungal count in surface layer also exhibited strong positive correlation coefficient with soil parameters like SOC ($r=0.684^{**}$, $p<0.01$), soil available N ($r=0.549^*$, $p<0.05$), actinomycetes count ($r=0.910^{**}$, $p<0.01$), dehydrogenase activity ($r=0.591^*$, $p<0.05$) and acid phosphatase activity ($r=0.807^{**}$, $p<0.01$). Similarly, fungal count in subsurface soil showed positive correlation coefficient with SOC ($r=0.701^{**}$, $p<0.01$), actinomycetes count ($r=0.968^{**}$, $p<0.01$), dehydrogenase activity ($r=0.580^*$, $p<0.05$) and acid phosphatase activity ($r=0.646^{**}$, $p<0.01$).
- ❖ Actinomycetes count in surface layer revealed strong positive correlation coefficient with acid phosphatase activity ($r=0.786^{**}$, $p<0.01$) and subsurface soil exhibited positive correlation coefficient with dehydrogenase activity ($r=0.553^*$, $p<0.05$) and acid phosphatase activity ($r=0.620^{**}$, $p<0.01$).
- ❖ Organic sources exerted a significant influence on the dehydrogenase (DHA) enzyme in our study. On the basis of pooled data, the increase in DHA activity ($35.8 \mu\text{g TPF g}^{-1} \text{hr}^{-1}$) in surface soil was 20.5 and 16.5 per cent by the application of 30 liters of *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM (T_8) of SPNFS and T_2 (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM), respectively over recommended dose of chemical fertilizers and FYM (T_1 treatment). Corresponding trend was observed in subsurface layer, recording 22.9 and 21.7 per cent improvement in DHA activity. Furthermore, strong positive correlation coefficient exists between DHA and SOC, soil available nutrients and microbial count of surface and subsurface soil layers.
- ❖ Alike DHA, application of organic and liquid natural manures exhibited a significant increase in acid phosphatase activity in surface as well as subsurface soils. Maximum phosphatase activity ($119.8 \mu\text{g PNP g}^{-1} \text{hr}^{-1}$) was recorded in surface soil of treatment T_8 (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM) of SPNFS followed by T_2 treatment (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) of OFBS, recording acid phosphatase activity of $116.5 \mu\text{g TPF g}^{-1} \text{hr}^{-1}$ over chemical fertilizer treatment T_1 . Similar significant gain in acid phosphatase activity was recorded in subsurface soil layers like maximum phosphatase activity was recorded in T_2 and T_8 treatments. A strong positive correlation coefficient exists between acid phosphatase and soil pH ($r = 0.688^{**}$, $p = 0.01$), acid phosphatase and SOC ($r = 0.927^{**}$, $p = 0.01$), acid phosphatase and soil available N ($r = 0.766^{**}$, $p = 0.01$), acid phosphatase and soil available P ($r = 0.715^{**}$, $p = 0.01$), acid phosphatase and bacterial count ($r = 0.934^{**}$, $p = 0.01$), acid phosphatase and fungal count ($r = 0.807^{**}$, $p = 0.01$), acid phosphatase and actinomycetes count ($r = 0.786^{**}$, $p = 0.01$) and acid phosphatase and

DHA ($r = 0.894^{**}$, $p = 0.01$) surface soil layers. Similar trend of correlation coefficients exists in subsurface layers.

- ❖ Maximum benefit: cost ratio (12.33:1) was recorded in the conventional farming system using recommended dose of nutrients by fertilizers and farm yard manure. But application of only organic manure has registered prodigious decline in benefit cost ratio (4.17:1) in T_2 treatment (100 per cent RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM) over chemical fertilizer treatment. However, SPNFS treatments were found to sustain benefit: cost ratio (12.22:1) close to chemical fertilizers.

CONCLUSIONS

On the basis of results obtained in the two-year research investigations on effect of different nutrient sources under different farming systems concluded that growth parameters like leaf area index, chlorophyll index, photosynthetically active radiation were found better and comparable with the application of 30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM under SPNFS over recommended NPK fertilizers of CFBS. Vines receiving 100 per cent recommended dose of nitrogen (RDN) through vermicompost and poultry manure on 50:50 basis + 40 kg FYM under OFBS and 30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM under SPNFS exhibited comparable fruit yield, high percent proportion of A-grade fruits, lower L/D ratio and comparable fruit diameter over chemical fertilizer treatment. These treatments (T_2 and T_8) also showed improvement in fruit quality in terms of TSS content (16.87 and 15.62 °B), total sugars (11.77 and 10.84%), reducing sugars (8.31 and 7.72%), non-reducing sugars (3.28 and 2.97%) and ascorbic acid (81.55 and 75.04 mg/100g) over chemical fertilizer application. The treatment receiving 100% RDN through vermicompost and poultry manure on 50:50 basis under OFBS found to be the most effective to observe maximum soil organic carbon, N, P, K, Cu, Mn and Zn in surface and subsurface soil layers over chemical fertilizer treatment. The application of 30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM under SPNFS also exhibited improvement in SOC, available N and Fe, but no improvement in soil available P, K, Cu, Mn and Zn content. However, it reckoned manifold increase in bacterial, fungal and actinomycetes count and dehydrogenase and acid phosphatase soil enzymes over chemical fertilizers. The data further revealed that highest benefit: cost ratio (12.36:1) in treatment T_1 (Chemical fertilizers + 40 kg FYM) followed by 12.22:1 in T_8 treatment (30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM). Organic treatment registered much lower value of benefit cost ratio that ranged from 3.31:1 to 4.17:1.

It may be concluded that although treatment comprising 100% RDN through vermicompost and poultry manure on 50:50 basis + 40 kg FYM/vine (T₂ treatment under organic farming system) was found to be the most effective in terms of fruit yield, per cent proportion of A-grade fruits, fruit quality parameters as well as soil physico-chemical properties, however, the application of 30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM under Subhash Palekar's natural farming system (T₈ treatment) registered maximum microbial count and soil enzymes along with other fruit and soil quality parameters that may lead to comparable yields. The advantage of T₈ treatment is higher benefit cost ratio over T₂ treatment. Finally, it is concluded that the treatment comprising application of 30 liters *jeevaamrit* + 3 kg *ghana jeevaamrit* + 40 kg FYM per vine was registered to be better option replacing chemical fertilizers to the Allison cultivar of kiwifruit under mid-hill conditions of Himachal Pradesh. Thus, natural farming system may not look as yield enhancing farming practices, but would definitely increase farmers' income through cost reduction and long-term sustainability. This is only a two-year field study results and should be continued further to draw decisive inference.

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Annexure – I
Mean monthly maximum and minimum temperature, relative humidity and rainfall
during 2019 and 2020

Month	Temperature (°C)			Mean relative humidity (%)	Mean rainfall (mm)
	Maximum	Minimum	Mean		
Jan, 2019	15.70	2.00	8.85	59.00	73.00
Feb, 2019	16.30	4.40	10.35	63.00	103.10
Mar, 2019	20.30	6.40	13.35	54.00	54.60
Apr, 2019	27.30	12.70	20.00	49.00	36.80
May, 2019	30.50	14.70	22.60	44.00	21.30
Jun, 2019	33.70	17.80	25.75	48.00	98.50
Jul, 2019	27.70	19.90	23.80	79.00	218.10
Aug, 2019	28.80	20.10	24.45	79.00	225.80
Sept, 2019	28.30	18.60	23.45	78.00	151.40
Oct, 2019	25.60	11.30	18.45	66.00	5.60
Nov, 2019	22.80	8.10	15.45	61.00	32.20
Dec, 2019	19.10	1.90	10.50	58.00	33.20
Jan, 2020	15.70	2.50	9.10	68.00	168.30
Feb, 2020	20.20	4.10	12.15	57.00	38.50
Mar, 2020	21.20	7.20	14.20	62.00	171.80
Apr, 2020	27.60	10.70	19.15	51.00	47.70
May, 2020	29.70	14.40	22.05	53.00	74.80
Jun, 2020	30.80	17.40	24.10	64.00	58.70
Jul, 2020	30.20	19.90	25.05	76.00	278.10
Aug, 2020	29.20	20.70	24.95	81.00	148.60
Sept, 2020	30.60	17.60	24.10	64.00	6.00

Annexure – II

Correlation coefficient between soil parameters

		pH		EC		SOC		Bulk density		Av. N		Av. P		Av. K		Bact. count		Fung. count		Actin. count		DHA		Phos. activity	
		0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Av. Zn	0-15	0.25		0.34		0.572*		-0.51		0.748**		0.822**		0.949**		-0.049		-0.096		-0.173		0.577*		0.528*	
	15-30		-0.03		-0.51		0.46		-0.416		0.753**		0.884**		0.811**		0.298		-0.006		0.002		0.621*		0.620*
pH	0-15				-0.59		0.570*		0.32		0.539*		0.588*		0.28		0.501*		0.555*		0.644**		0.24		0.688**
	15-30						-0.08		0.561*		0.32		0.09		0.08		-0.18		0.668*		0.872**		0.848**		0.33
EC	0-15						0.23		-0.9**		0.11		-0.12		0.43		-0.09		-0.26		-0.60		0.17		-0.24
	15-30								0.05		-0.11		-0.35		-0.57		-0.30		0.08		0.00		-0.10		-0.23
SOC	0-15								-0.54		0.890**		0.687**		0.758**		0.755**		0.684**		0.46		0.739**		0.927**
	15-30								0.01		0.733**		0.646**		0.541*		0.942**		0.701**		0.667**		0.854**		0.921**
Bulk density	0-15										-0.40		-0.15		-0.65**		-0.18		-0.01		0.35		-0.41		0.17
	15-30											-0.02		-0.16		-0.53*		0.21		0.47		0.545*		0.19	
Av. N	0-15												0.911**		0.862**		0.567*		0.549*		0.43		0.900**		0.766**
	15-30													0.934**		0.833**		0.687**		0.33		0.30		0.946**	
Av. P	0-15														0.822**		0.31		0.34		0.37		0.775**		0.715**
	15-30															0.874**		0.524*		0.20		0.21		0.835**	
Av. K	0-15																0.20		0.12		-0.03		0.705**		0.48
	15-30																	0.38		-0.07		-0.12		0.643**	
Bact. count	0-15																		0.973**		0.830**		0.581*		0.934**
	15-30																			0.854**		0.782**		0.852**	
Fung. count	0-15																				0.910**		0.591*		0.807**
	15-30																					0.968**		0.580*	
Actin. count	0-15																					0.46		0.786**	
	15-30																						0.553*		
DHA	0-15																							0.894**	
	15-30																							0.864**	

**Correlation is significant at 0.01 level, *Correlation is significant at 0.05 level.

Annexure – III

Analysis of variance table for leaf area (cm²) of kiwifruit

	2019				2020			Pooled					
Source of Variation	Df*	Sum of squares	MSS**	F-cal	Sum of squares	MSS	F-cal	Source of Variation	Df	Sum of squares	MSS	F-cal	CD _{0.05}
Treatments	7	1813.2	259.0	9.30	1066.4	152.4	6.47	Rep/Year	4	233.9	58.5	2.27	NS***
Replication	2	78.3	39.1	1.41	155.6	77.8	3.30	Treatments	7	2743.0	391.9	15.25	6.00
Error	14	389.9	27.9		329.8	23.6		Year	1	60.0	60.0	2.33	NS
Total	23	2281.3			1551.9			Treat × Year	7	136.7	19.5	0.76	NS
								Pooled error	28	719.6	25.7		
CD _{0.05}	9.2				CD _{0.05}	8.5		Total	47	3893.2			

*Df = Degree of freedom

**MSS = Mean sum of squares

NS*** = Non-significant

Analysis of variance table for SPAD (Chlorophyll Index) of kiwifruit (North Side)

	2019				2020			Pooled					
Source of Variation	Df*	Sum of squares	MSS**	F-cal	Sum of squares	MSS	F-cal	Source of Variation	Df	Sum of squares	MSS	F-cal	CD _{0.05}
Treatments	7	56.4	8.05	15.19	87.81	12.54	4.26	Rep/Year	4	3.6	0.89	0.51	NS***
Replication	2	1.8	0.88	1.66	1.80	0.90	0.31	Treatments	7	133.1	19.02	10.94	1.56
Error	14	7.4	0.53		41.23	2.95		Year	1	1.6	1.61	0.93	NS
Total	23	65.6			130.84			Treat × Year	7	11.7	1.58	0.91	NS
								Pooled error	28	48.7	1.74		
CD _{0.05}	1.28				CD _{0.05}	3.01		Total	47	198.0			

*Df = Degree of freedom

**MSS = Mean sum of squares

NS*** = Non-significant

Analysis of variance table for SPAD (Chlorophyll Index) of kiwifruit (South Side)

	2019				2020			Pooled					
Source of Variation	Df*	Sum of squares	MSS**	F-cal	Sum of squares	MSS	F-cal	Source of Variation	Df	Sum of squares	MSS	F-cal	CD _{0.05}
Treatments	7	32.1	4.59	12.05	42.42	6.06	3.46	Rep/Year	4	4.1	1.03	0.97	NS***
Replication	2	3.2	1.59	4.17	0.96	0.48	0.47	Treatments	7	73.1	10.45	9.80	1.22
Error	14	5.3	0.38		24.50	1.75		Year	1	4.9	4.92	4.62	0.61
Total	23	40.7			67.88			Treat × Year	7	1.4	0.20	0.19	NS
								Pooled error	28	29.8	1.07		
CD _{0.05}	1.08				CD _{0.05}	2.32		Total	47	113.5			

*Df = Degree of freedom

**MSS = Mean sum of squares

NS*** = Non-significant

Analysis of variance table for SPAD (Chlorophyll Index) of kiwifruit (Mean)

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	42.3	6.05	33.88	59.74	8.53	6.90	Rep/Year	4	2.6	0.65	0.92	NS***
Replication	2	1.3	0.65	3.67	1.30	0.65	0.53	Treatments	7	97.9	13.99	19.77	0.99
Error	14	2.5	0.18		17.31	1.24		Year	1	0.2	0.23	0.32	NS
Total	23	46.1			78.35			Treat × Year	7	4.2	0.59	0.84	NS
								Pooled error	28	19.8	0.71		
CD_{0.05}	0.74				CD_{0.05}	1.95		Total	47	124.7			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for photosynthetically active radiation (PAR) and leaf area index (LAI) of kiwifruit

Source of Variation	PAR (upper canopy)				PAR (lower canopy)			LAI		
	<i>Degree of freedom</i>	<i>Sum of squares</i>	<i>Mean sum of squares</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>Mean sum of squares</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>Mean sum of squares</i>	<i>F-cal</i>
Treatments	7	166635	23805.1	6.63	56864	8123.4	2.89	2.38	0.34	9.10
Replication	2	12078	6039.0	1.68	1960	979.9	0.35	0.24	0.12	3.16
Error	14	50248	3589.1		39306	2807.6		0.52	0.04	
Total	23	228961			98130			3.14		
CD_{0.05}	105				CD_{0.05}	93		CD_{0.05}	0.34	

Analysis of variance table for yield of ‘A-grade’ of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	54.21	7.74	89.98	21.99	3.14	25.62	Rep/Year	4	1.16	0.29	2.77	NS***
Replication	2	1.03	0.51	5.97	0.13	0.07	0.53	Treatments	7	59.01	8.43	3.43	NS
Error	14	1.20	0.09		1.72	0.12		Year	1	4.50	4.50	43.09	0.91
Total	23	56.44			23.84			Treat × Year	7	17.18	2.45	23.53	0.54
								Pooled error	28	2.92	0.10		
CD_{0.05}	0.51				CD_{0.05}	0.61		Total	47	84.77			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for yield of 'B-grade' of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	93.47	13.35	25.99	26.39	3.77	10.78	Rep/Year	4	2.58	0.64	1.49	NS***
Replication	2	1.54	0.77	1.50	1.04	0.52	1.49	Treatments	7	102.08	14.58	5.74	2.18
Error	14	7.19	0.51		4.90	0.35		Year	1	120.71	120.71	279.57	0.39
Total	23	102.20			32.33			Treat × Year	7	17.77	2.54	5.88	1.10
								Pooled error	28	12.09	0.43		
CD_{0.05}	1.26				CD_{0.05}	1.04		Total	47	255.24			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for yield of 'C-grade' of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	14.91	2.13	1.39	55.55	7.94	3.62	Rep/Year	4	5.13	1.28	0.69	NS***
Replication	2	3.73	1.86	1.21	1.41	0.70	0.32	Treatments	7	30.64	4.38	0.77	NS
Error	14	21.49	1.53		30.71	2.19		Year	1	309.77	309.77	166.18	0.81
Total	23	40.12			87.66			Treat × Year	7	39.81	5.69	3.05	2.28
								Pooled error	28	52.19	1.86		
CD_{0.05}	NS***				CD_{0.05}	2.59		Total	47	437.55			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for total yield of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	298.03	42.58	14.93	189.28	27.04	22.42	Rep/Year	4	11.83	2.96	1.46	NS***
Replication	2	9.95	4.98	1.75	1.88	0.94	0.78	Treatments	7	449.12	64.16	11.76	3.19
Error	14	39.92	2.85		16.88	1.21		Year	1	942.95	942.95	464.84	0.84
Total	23	347.89			208.05			Treat × Year	7	38.19	5.46	2.69	2.38
								Pooled error	28	56.80	2.03		
CD_{0.05}	2.96				CD_{0.05}	1.92		Total	47	1498.89			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for fruit length of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	81.2	11.60	3.25	145.6	20.80	6.25	Rep/Year	4	38.26	9.56	2.78	NS***
Replication	2	21.9	10.97	3.08	16.3	8.16	2.45	Treatments	7	221.39	31.63	9.18	2.20
Error	14	49.9	3.57		46.6	3.33		Year	1	122.23	122.23	35.47	1.10
Total	23	153.0			208.5			Treat × Year	7	5.39	0.77	0.22	NS
								Pooled error	28	96.49	3.45		
CD_{0.05}	3.31				CD_{0.05}	3.19		Total	47	483.75			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for fruit diameter of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	18.26	2.61	3.88	14.87	2.12	3.23	Rep/Year	4	6.02	1.51	2.26	NS***
Replication	2	4.88	2.44	3.62	1.15	0.57	0.87	Treatments	7	27.04	3.86	5.81	0.96
Error	14	9.42	0.67		9.21	0.66		Year	1	15.85	15.85	23.83	0.48
Total	23	32.55			25.23			Treat × Year	7	6.09	0.87	1.31	NS
								Pooled error	28	18.63	0.67		
CD_{0.05}	1.44				CD_{0.05}	1.42		Total	47	73.64			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for L/D ratio of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.02	0.00	0.71	0.04	0.01	4.73	Rep/Year	4	0.028	0.007	3.152	NS
Replication	2	0.01	0.00	1.53	0.02	0.01	6.89	Treatments	7	0.043	0.006	2.773	0.06
Error	14	0.04	0.00		0.02	0.00		Year	1	0.016	0.016	7.143	0.03
Total	23	0.07			0.08			Treat × Year	7	0.017	0.002	1.083	NS
								Pooled error	28	0.063	0.002		
CD_{0.05}	NS***				CD_{0.05}	0.06		Total	47	0.167			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for fruit weight of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	464.7	66.38	3.77	292.88	41.84	7.33	Rep/Year	4	144.25	36.06	3.09	NS***
Replication	2	132.6	66.30	3.76	11.64	5.82	1.02	Treatments	7	725.88	103.70	8.89	4.04
Error	14	246.7	17.62		79.93	5.71		Year	1	9.90	9.90	0.85	NS
Total	23	843.9			384.45			Treat × Year	7	31.67	4.52	0.39	NS
								Pooled error	28	326.58	11.66		
CD_{0.05}	7.35				CD_{0.05}	4.18		Total	47	1238.27			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for N content in leaves of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.910	0.130	22.621	0.771	0.110	5.463	Rep/Year	4	0.157	0.039	3.019	NS***
Replication	2	0.008	0.004	0.719	0.148	0.074	3.675	Treatments	7	1.493	0.213	16.455	0.135
Error	14	0.080	0.006		0.282	0.020		Year	1	1.272	1.272	98.153	0.067
Total	23				1.202			Treat × Year	7	0.189	0.027	2.081	NS
								Pooled error	28	0.363	0.013		
CD_{0.05}	0.13				CD_{0.05}	0.25		Total	47	3.473			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for P content in leaves of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.018	0.003	6.757	0.032	0.005	9.98	Rep/Year	4	0.004	0.001	2.327	NS***
Replication	2	0.001	0.001	1.448	0.003	0.001	3.06	Treatments	7	0.047	0.007	16.001	0.024
Error	14	0.005	0.000		0.006	0.000		Year	1	0.029	0.029	68.748	0.012
Total	23	0.025			0.041			Treat × Year	7	0.003	0.000	1.024	NS
								Pooled error	28	0.012	0.000		
CD_{0.05}	0.03				CD_{0.05}	0.04		Total	47	0.095			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for K content in leaves of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.455	0.065	12.04	0.404	0.058	7.275	Rep/Year	4	0.018	0.005	0.694	NS***
Replication	2	0.014	0.007	1.28	0.005	0.002	0.294	Treatments	7	0.849	0.121	18.195	0.097
Error	14	0.076	0.005		0.111	0.008		Year	1	0.241	0.241	36.148	0.048
Total	23	0.545			0.519			Treat × Year	7	0.010	0.001	0.216	NS
								Pooled error	28	0.187	0.007		
CD_{0.05}	0.13				CD_{0.05}	0.16		Total	47	1.305			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for Ca content in leaves of kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	4.38	0.63	8.14	8.15	1.16	4.84	Rep/Year	4	0.27	0.07	0.42	NS***
Replication	2	0.25	0.12	1.62	0.02	0.01	0.04	Treatments	7	11.79	1.68	10.61	0.47
Error	14	1.08	0.08		3.37	0.24		Year	1	0.27	0.27	1.72	NS
Total	23	5.71			11.53			Treat × Year	7	0.74	0.11	0.66	NS
								Pooled error	28	4.44	0.16		
CD_{0.05}	0.49				CD_{0.05}	0.86		Total	47	17.51			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for total soluble solids (TSS) in kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	6.20	0.89	1.83	43.13	6.16	8.63	Rep/Year	4	2.18	0.54	0.91	NS
Replication	2	1.73	0.86	1.79	0.45	0.23	0.32	Treatments	7	35.71	5.10	2.62	NS
Error	14	6.77	0.48		10.00	0.71		Year	1	5.01	5.01	8.36	0.46
Total	23	14.70			53.58			Treat × Year	7	13.62	1.95	3.25	1.29
								Pooled error	28	16.77	0.60		
CD_{0.05}	NS***				CD_{0.05}	1.48		Total	47	73.28			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for titratable acidity in kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.048	0.007	1.016	0.499	0.071	51.906	Rep/Year	4	0.048	0.012	2.928	NS
Replication	2	0.043	0.022	3.200	0.004	0.002	1.589	Treatments	7	0.339	0.048	1.625	NS
Error	14	0.095	0.007		0.019	0.001		Year	1	0.005	0.005	1.273	NS
Total	23	0.186			0.523			Treat × Year	7	0.208	0.030	7.322	0.11
								Pooled error	28	0.114	0.004		
CD_{0.05}	NS***				CD_{0.05}	0.06		Total	47	0.714			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for TSS/Acidity ratio in kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	22.08	3.15	1.95	253.74	36.25	25.58	Rep/Year	4	4.96	1.24	0.82	NS
Replication	2	4.19	2.10	1.29	0.77	0.39	0.27	Treatments	7	176.18	25.17	1.77	NS
Error	14	22.67	1.62		19.84	1.42		Year	1	17.43	17.43	11.48	0.73
Total	23	48.94			274.35			Treat × Year	7	99.64	14.23	9.38	2.06
								Pooled error	28	42.51	1.52		
CD_{0.05}	NS***				CD_{0.05}	2.08		Total	47	340.72			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for total sugars content in kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	9.127	1.304	63.738	16.209	2.316	20.019	Rep/Year	4	1.11	0.28	4.06	NS***
Replication	2	0.003	0.001	0.062	1.103	0.551	4.767	Treatments	7	22.07	3.15	6.76	0.93
Error	14	0.286	0.020		1.619	0.116		Year	1	9.93	9.93	145.87	0.15
Total	23	9.416			18.931			Treat × Year	7	3.26	0.47	6.85	0.44
								Pooled error	28	1.91	0.07		
CD_{0.05}	0.25				CD_{0.05}	0.60		Total	47	38.28			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for reducing sugars content in kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	5.768	0.824	77.018	7.411	1.059	103.726	Rep/Year	4	0.07	0.02	1.64	NS***
Replication	2	0.050	0.025	2.346	0.018	0.009	0.896	Treatments	7	11.41	1.63	6.47	0.69
Error	14	0.150	0.011		0.143	0.010		Year	1	3.99	3.99	381.75	0.06
Total	23	5.968			7.572			Treat × Year	7	1.76	0.25	24.12	0.17
								Pooled error	28	0.29	0.01		
CD_{0.05}	0.18				CD_{0.05}	0.18		Total	47	17.53			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for non-reducing sugars content in kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.611	0.087	4.765	1.613	0.230	2.001	Rep/Year	4	0.86	0.21	3.21	NS
Replication	2	0.046	0.023	1.266	0.811	0.406	3.523	Treatments	7	1.86	0.27	3.99	0.31
Error	14	0.256	0.018		1.612	0.115		Year	1	1.20	1.20	17.99	0.15
Total	23	0.914			4.035			Treat × Year	7	0.36	0.05	0.78	NS
								Pooled error	28	1.87	0.07		
CD_{0.05}	0.24				CD_{0.05}	NS***		Total	47	6.15			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for ascorbic acid content in kiwifruit

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	1163.27	166.18	6.59	1053.43	150.49	80.69	Rep/Year	4	32.53	8.13	0.60	NS***
Replication	2	22.02	11.01	0.44	10.51	5.26	2.82	Treatments	7	1975.88	282.27	8.20	8.01
Error	14	353.07	25.22		26.11	1.87		Year	1	616.67	616.67	45.54	2.18
Total	23	1538.35			1090.05			Treat × Year	7	240.82	34.40	2.54	6.15
								Pooled error	28	379.18	13.54		
CD_{0.05}	8.79				CD_{0.05}	2.39		Total	47	3245.08			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for soil pH changes in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.094	0.013	5.467	0.232	0.033	4.476	Rep/Year	4	0.09	0.02	4.41	NS***
Replication	2	0.002	0.001	0.472	0.084	0.042	5.706	Treatments	7	0.19	0.03	1.48	NS
Error	14	0.034	0.002		0.104	0.007		Year	1	0.97	0.97	197.50	0.04
Total	23	0.130			0.420			Treat × Year	7	0.13	0.02	3.82	0.12
								Pooled error	28	0.14	0.00		
CD_{0.05}	0.09				CD_{0.05}	0.15		Total	47	1.52			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for soil pH changes in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.150	0.021	2.936	0.200	0.029	3.644	Rep/Year	4	0.14	0.03	4.54	NS***
Replication	2	0.009	0.004	0.586	0.129	0.064	8.216	Treatments	7	0.35	0.05	6.53	0.10
Error	14	0.102	0.007		0.110	0.008		Year	1	0.00	0.00	0.05	NS
Total	23	0.261			0.438			Treat × Year	7	0.00	0.00	0.08	NS
								Pooled error	28	0.21	0.01		
CD_{0.05}	0.15				CD_{0.05}	0.15		Total	47	0.70			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for soil EC changes in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.012	0.002	30.109	0.0157	0.0022	14.2732	Rep/Year	4	0.0001	0.0000	0.2987	NS***
Replication	2	0.000	0.000	0.222	0.0001	0.0001	0.3274	Treatments	7	0.0280	0.0040	36.9656	0.012
Error	14	0.001	0.000		0.0022	0.0002		Year	1	0.0000	0.0000	0.3606	NS
Total	23	0.013			0.0181			Treat × Year	7	0.0002	0.0000	0.2086	NS
								Pooled error	28	0.0030	0.0001		
CD_{0.05}	0.013				CD_{0.05}	0.022		Total	47	0.0314			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for soil EC changes in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.000047	6.8×10 ⁻⁶	0.34	0.00011	0.00002	0.24	Rep/Year	4	0.00026	6.4×10 ⁻⁵	1.49	NS
Replication	2	0.000074	0.000037	1.86	0.00018	0.00009	1.38	Treatments	7	4.23×10 ⁻⁵	6.1×10 ⁻⁶	0.14	NS
Error	14	0.00028	0.00002		0.00092	0.00007		Year	1	6.77×10 ⁻⁷	6.8×10 ⁻⁷	0.02	NS
Total	23	0.00040			0.00121			Treat × Year	7	0.0001	1.6×10 ⁻⁵	0.38	NS
								Pooled error	28	0.0012	4.3×10 ⁻⁵		
CD_{0.05}	NS***				CD_{0.05}	NS		Total	47	0.00162			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for soil bulk density changes in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.127	0.018	5.835	0.133	0.019	3.973	Rep/Year	4	0.041	0.010	2.623	NS***
Replication	2	0.029	0.015	4.679	0.012	0.006	1.290	Treatments	7	0.257	0.037	9.311	0.074
Error	14	0.043	0.003		0.067	0.005		Year	1	0.002	0.002	0.541	NS
Total	23	0.199			0.213			Treat × Year	7	0.003	0.000	0.099	NS
								Pooled error	28	0.110	0.004		
CD_{0.05}	0.098				CD_{0.05}	0.121		Total	47	0.414			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for soil bulk density changes in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	0.002	0.000	0.129	0.005	0.001	2.503	Rep/Year	4	0.003	0.001	0.517	NS
Replication	2	0.000	0.000	0.007	0.003	0.001	4.902	Treatments	7	0.005	0.001	0.591	NS
Error	14	0.032	0.002		0.004	0.000		Year	1	0.001	0.001	1.020	NS
Total	23	0.034			0.011			Treat × Year	7	0.001	0.000	0.162	NS
								Pooled error	28	0.036	0.001		
CD_{0.05}	NS***				CD_{0.05}	NS		Total	47	0.046			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for soil organic carbon changes in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	70.76	10.11	6.90	218.25	31.18	6.13	Rep/Year	4	65.45	16.36	4.99	NS***
Replication	2	0.29	0.14	0.10	65.16	32.58	6.40	Treatments	7	265.3	37.9	11.6	2.14
Error	14	20.52	1.47		71.26	5.09		Year	1	929.8	929.8	283.7	1.07
Total	23	91.57			354.67			Treat × Year	7	23.7	3.4	1.0	NS
								Pooled error	28	91.8	3.3		
CD_{0.05}	2.12				CD_{0.05}	3.95		Total	47	1376.0			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for soil organic carbon changes in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	5.30	0.76	6.53	30.13	4.30	6.88	Rep/Year	4	2.19	0.55	1.48	NS***
Replication	2	0.09	0.04	0.37	2.11	1.05	1.68	Treatments	7	29.56	4.22	11.39	0.72
Error	14	1.62	0.12		8.76	0.63		Year	1	273.46	273.46	737.47	0.36
Total	23	7.01			41.00			Treat × Year	7	5.87	0.84	2.26	NS
								Pooled error	28	10.38	0.37		
CD_{0.05}	0.60				CD_{0.05}	1.39		Total	47	321.47			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for soil available N changes in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	9935	1419.2	18.24	33999	4856.9	43.67	Rep/Year	4	1144	285.9	3.03	NS***
Replication	2	947	473.3	6.08	197	98.5	0.89	Treatments	7	39816	5688.0	9.67	33.1
Error	14	1089	77.8		1557	111.2		Year	1	11014	11014.2	116.53	5.7
Total	23	11971			35753			Treat × Year	7	4118	588.2	6.22	16.3
								Pooled error	28	2646	94.5		
CD_{0.05}	15.4				CD_{0.05}	18.5		Total	47	58738			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for soil available N changes in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	5834.2	833.5	17.86	9596	1370.8	13.02	Rep/Year	4	619	154.6	2.04	NS***
Replication	2	213.7	106.9	2.29	405	202.4	1.92	Treatments	7	13984	1997.8	9.67	19.6
Error	14	653.2	46.7		1474	105.3		Year	1	18813	18812.9	247.61	5.2
Total	23	6701.1			11475			Treat × Year	7	1446	206.5	2.72	14.6
								Pooled error	28	2127	76.0		
CD_{0.05}	12.0				CD_{0.05}	18.0		Total	47	36989			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for soil available P changes in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	1424.1	203.4	27.04	757.4	108.2	8.57	Rep/Year	4	76.0	19.00	1.89	NS***
Replication	2	70.8	35.4	4.70	5.2	2.6	0.21	Treatments	7	2050.2	292.89	29.06	3.8
Error	14	105.3	7.5		176.8	12.6		Year	1	68.2	68.16	6.76	1.9
Total	23	1600.2			939.4			Treat × Year	7	131.3	18.75	1.86	NS
								Pooled error	28	282.2	10.08		
CD_{0.05}	4.8				CD_{0.05}	6.2		Total	47	2607.8			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for soil available P changes in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	146.74	20.96	7.78	106.61	15.23	5.93	Rep/Year	4	14.39	3.60	1.37	NS***
Replication	2	4.45	2.23	0.83	9.94	4.97	1.93	Treatments	7	209.67	29.95	4.80	3.4
Error	14	37.72	2.69		35.97	2.57		Year	1	7.58	7.58	2.88	NS
Total	23	188.91			152.52			Treat × Year	7	43.68	6.24	2.37	2.7
								Pooled error	28	73.69	2.63		
CD_{0.05}	2.9				CD_{0.05}	2.8		Total	47	349.01			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for soil available K changes in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	26403	3771.9	9.64	81116	11588	11.71	Rep/Year	4	12909	3227	4.67	NS***
Replication	2	3217	1608.3	4.11	9692	4846	4.90	Treatments	7	94089	13441	7.01	59.8
Error	14	5478	391.3		13855	990		Year	1	31498	31498	45.62	15.5
Total	23	35098			104663			Treat × Year	7	13431	1919	2.78	43.9
								Pooled error	28	19333	690		
CD_{0.05}	34.6				CD_{0.05}	55.1		Total	47	171259			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for soil available K changes in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	18961	2709	13.7	35052	5007.4	51.63	Rep/Year	4	5599	1399.8	9.5	NS***
Replication	2	5041	2520	12.8	559	279.3	2.88	Treatments	7	52377	7482.4	50.8	14.3
Error	14	2763	197		1358	97.0		Year	1	6515	6514.7	44.3	7.2
Total	23	26765			36968			Treat × Year	7	1636	233.7	1.6	NS
								Pooled error	28	4121	147.2		
CD_{0.05}	24.6				CD_{0.05}	17.2		Total	47	70247			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for DTPA extractable Cu changes in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	2.82	0.40	7.58	3.76	0.54	2.19	Rep/Year	4	2.57	0.64	4.32	NS
Replication	2	0.02	0.01	0.22	2.55	1.27	5.21	Treatments	7	4.68	0.67	4.49	0.46
Error	14	0.75	0.05		3.43	0.24		Year	1	2.91	2.91	19.50	0.23
Total	23	3.59			9.73			Treat × Year	7	1.90	0.27	1.82	NS
								Pooled error	28	4.17	0.15		
CD_{0.05}	0.40				CD_{0.05}	NS***		Total	47	16.23			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for DTPA extractable Cu changes in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	2.99	0.43	6.09	2.71	0.39	3.64	Rep/Year	4	2.98	0.74	8.42	NS***
Replication	2	0.92	0.46	6.58	2.05	1.03	9.63	Treatments	7	5.61	0.80	9.07	0.35
Error	14	0.98	0.07		1.49	0.11		Year	1	1.91	1.91	21.62	0.18
Total	23	4.90			6.25			Treat × Year	7	0.09	0.01	0.15	NS
								Pooled error	28	2.47	0.09		
CD_{0.05}	0.46				CD_{0.05}	0.57		Total	47	13.06			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for DTPA extractable Fe changes in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	500.49	71.50	18.21	421.51	60.22	6.46	Rep/Year	4	68.1	17.02	2.57	NS***
Replication	2	62.33	31.17	7.94	5.75	2.87	0.31	Treatments	7	889.8	127.11	19.18	3.04
Error	14	54.98	3.93		130.60	9.33		Year	1	3450.1	3450.11	520.55	1.52
Total	23	617.80			557.86			Treat × Year	7	32.2	4.60	0.69	NS
								Pooled error	28	185.6	6.63		
CD_{0.05}	3.47				CD_{0.05}	5.35		Total	47	4625.8			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for DTPA extractable Fe changes in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	446.09	63.73	16.87	593.54	84.79	22.11	Rep/Year	4	239.38	59.84	15.72	NS***
Replication	2	143.90	71.95	19.05	95.47	47.74	12.45	Treatments	7	1011.70	144.53	37.98	2.31
Error	14	52.88	3.78		53.68	3.83		Year	1	448.60	448.60	117.87	1.15
Total	23	642.87			742.70			Treat × Year	7	27.94	3.99	1.05	NS
								Pooled error	28	106.56	3.81		
CD_{0.05}	3.40				CD_{0.05}	3.43		Total	47	1834.17			

Df* = Degree of freedom *MSS* = Mean sum of squares *NS**** = Non-significant

Analysis of variance table for DTPA extractable Mn changes in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	48.42	6.92	17.80	51.34	7.33	17.16	Rep/Year	4	1.83	0.46	1.12	NS***
Replication	2	1.51	0.75	1.94	0.32	0.16	0.38	Treatments	7	96.54	13.79	33.80	0.76
Error	14	5.44	0.39		5.98	0.43		Year	1	4.63	4.63	11.35	0.38
Total	23	55.36			57.65			Treat × Year	7	3.22	0.46	1.13	NS
								Pooled error	28	11.42	0.41		
CD_{0.05}	1.09				CD_{0.05}	1.14		Total	47	117.64			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for DTPA extractable Mn changes in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	71.17	10.17	6.55	95.79	13.68	10.42	Rep/Year	4	0.89	0.22	0.16	NS***
Replication	2	0.52	0.26	0.17	0.37	0.19	0.14	Treatments	7	164.99	23.57	16.45	1.42
Error	14	21.72	1.55		18.39	1.31		Year	1	19.33	19.33	13.49	0.71
Total	23	93.41			114.56			Treat × Year	7	1.97	0.28	0.20	NS
								Pooled error	28	40.12	1.43		
CD_{0.05}	2.18				CD_{0.05}	2.01		Total	47	227.30			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for DTPA extractable Zn changes in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	2.59	0.37	7.92	2.92	0.42	13.59	Rep/Year	4	0.75	0.19	4.84	NS***
Replication	2	0.31	0.15	3.30	0.44	0.22	7.17	Treatments	7	5.42	0.77	19.97	0.23
Error	14	0.65	0.05		0.43	0.03		Year	1	0.75	0.75	19.44	0.12
Total	23	3.55			3.79			Treat × Year	7	0.10	0.01	0.36	NS
								Pooled error	28	1.08	0.04		
CD_{0.05}	0.38				CD_{0.05}	0.31		Total	47	8.10			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for DTPA extractable Zn changes in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	2.474	0.353	11.349	3.96	0.57	16.20	Rep/Year	4	0.05	0.01	0.35	NS***
Replication	2	0.035	0.017	0.560	0.01	0.01	0.17	Treatments	7	6.17	0.88	26.69	0.22
Error	14	0.436	0.031		0.49	0.03		Year	1	2.79	2.79	84.32	0.11
Total	23	2.945			4.46			Treat × Year	7	0.26	0.04	1.14	NS
								Pooled error	28	0.93	0.03		
CD_{0.05}	0.31				CD_{0.05}	0.33		Total	47	10.20			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for bacterial count in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	31056	4436.5	71.50	47813.6	6830.5	78.75	Rep/Year	4	55	14	0.2	NS***
Replication	2	36.0	18.0	0.29	19.1	9.5	0.11	Treatments	7	77720	11103	149.3	10
Error	14	868.7	62.0		1214.3	86.7		Year	1	14111	14111	189.7	5
Total	23	31961			49047.0			Treat × Year	7	1150	164	2.2	NS
								Pooled error	28	2083	74		
CD_{0.05}	14				CD_{0.05}	16		Total	47	95118			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for bacterial count in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	10188	1455.4	19.6	11123	1589.0	47.9	Rep/Year	4	428.2	107.0	2.0	NS***
Replication	2	111	55.3	0.7	318	158.8	4.8	Treatments	7	21157	3022.5	56.2	9
Error	14	1041	74.4		464	33.2		Year	1	2107	2106.8	39.2	4
Total	23	11340			11905			Treat × Year	7	153.9	22.0	0.4	NS
								Pooled error	28	1506	53.8		
CD_{0.05}	15				CD_{0.05}	10		Total	47	25352			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for fungal count in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	513.0	73.28	80.99	539.2	77.0	69.2	Rep/Year	4	2	1	1	NS***
Replication	2	1.3	0.67	0.74	1.1	0.5	0.5	Treatments	7	1041	149	147	1.2
Error	14	12.7	0.90		15.6	1.1		Year	1	99	99	98	0.6
Total	23	527.0			555.8			Treat × Year	7	11	2	2	NS
								Pooled error	28	28	1		
CD_{0.05}	2				CD_{0.05}	2		Total	47	1182			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for fungal count in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	436.50	62.36	27.50	420.7	60.1	58.7	Rep/Year	4	33.9	8.5	5.2	NS***
Replication	2	11.58	5.79	2.55	22.3	11.2	10.9	Treatments	7	853.3	121.9	74.1	2
Error	14	31.75	2.27		14.3	1.0		Year	1	18.8	18.8	11.4	1
Total	23	479.83			457.3			Treat × Year	7	3.9	0.6	0.3	NS
								Pooled error	28	46.1	1.6		
CD_{0.05}	3				CD_{0.05}	2		Total	47				

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for actinomycetes count in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	482.6	68.9	14.9	486.7	69.5	18.3	Rep/Year	4	31.9	8.0	1.9	NS***
Replication	2	24.3	12.2	2.6	7.6	3.8	1.0	Treatments	7	966.0	138.0	32.7	2
Error	14	65.0	4.6		53.1	3.8		Year	1	7.5	7.5	1.8	NS
Total	23	572.0			547.3			Treat × Year	7	3.3	0.5	0.1	NS
								Pooled error	28	118.1	4.2		
CD_{0.05}	4				CD_{0.05}	3		Total	47	1127			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for actinomycetes count in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	126.96	18.14	42.92	188.29	26.90	22.04	Rep/Year	4	9.7	2.4	2.9	NS***
Replication	2	4.08	2.04	4.83	5.58	2.79	2.29	Treatments	7	303.9	43.4	52.9	1
Error	14	5.92	0.42		17.08	1.22		Year	1	48.0	48.0	58.4	1
Total	23	136.96			210.96			Treat × Year	7	11.3	1.6	2.0	NS
								Pooled error	28	23.0	0.8		
CD_{0.05}	1				CD_{0.05}	2		Total	47	396			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for dehydrogenase enzyme activity in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	207.59	29.66	10.96	169.61	24.23	5.33	Rep/Year	4	46.3	11.6	3.2	NS***
Replication	2	33.09	16.54	6.11	13.19	6.59	1.45	Treatments	7	357.7	51.1	14.1	2.3
Error	14	37.88	2.71		63.69	4.55		Year	1	660.6	660.6	182.1	1.1
Total	23	278.56			246.49			Treat × Year	7	19.5	2.8	0.8	NS
								Pooled error	28	101.6	3.6		
CD_{0.05}	2.9				CD_{0.05}	3.7		Total	47	1186			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for dehydrogenase enzyme activity in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df*</i>	<i>Sum of squares</i>	<i>MSS**</i>	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	134.71	19.24	23.50	199.24	28.46	34.72	Rep/Year	4	8.1	2.0	2.5	NS***
Replication	2	0.76	0.38	0.46	7.35	3.67	4.48	Treatments	7	318.5	45.5	20.6	2.0
Error	14	11.47	0.82		11.48	0.82		Year	1	433.0	433.0	528.4	0.5
Total	23	146.94			218.07			Treat × Year	7	15.4	2.2	2.7	1.5
								Pooled error	28	22.9	0.8		
CD_{0.05}	1.6				CD_{0.05}	1.6		Total	47	798			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for acid phosphatase enzyme activity in 0-15 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	3072.9	439.0	8.6	3229.7	461.4	49.99	Rep/Year	4	181.3	45.3	1.5	NS***
Replication	2	141.5	70.8	1.4	39.7	19.9	2.15	Treatments	7	6151.9	878.8	29.1	6.5
Error	14	717.8	51.3		129.2	9.2		Year	1	1529.3	1529.3	50.6	3.3
Total	23	3932.3			3398.7			Treat × Year	7	150.7	21.5	0.7	NS
								Pooled error	28	847.1	30.3		
CD_{0.05}	12.5				CD_{0.05}	5.3		Total	47	8860			

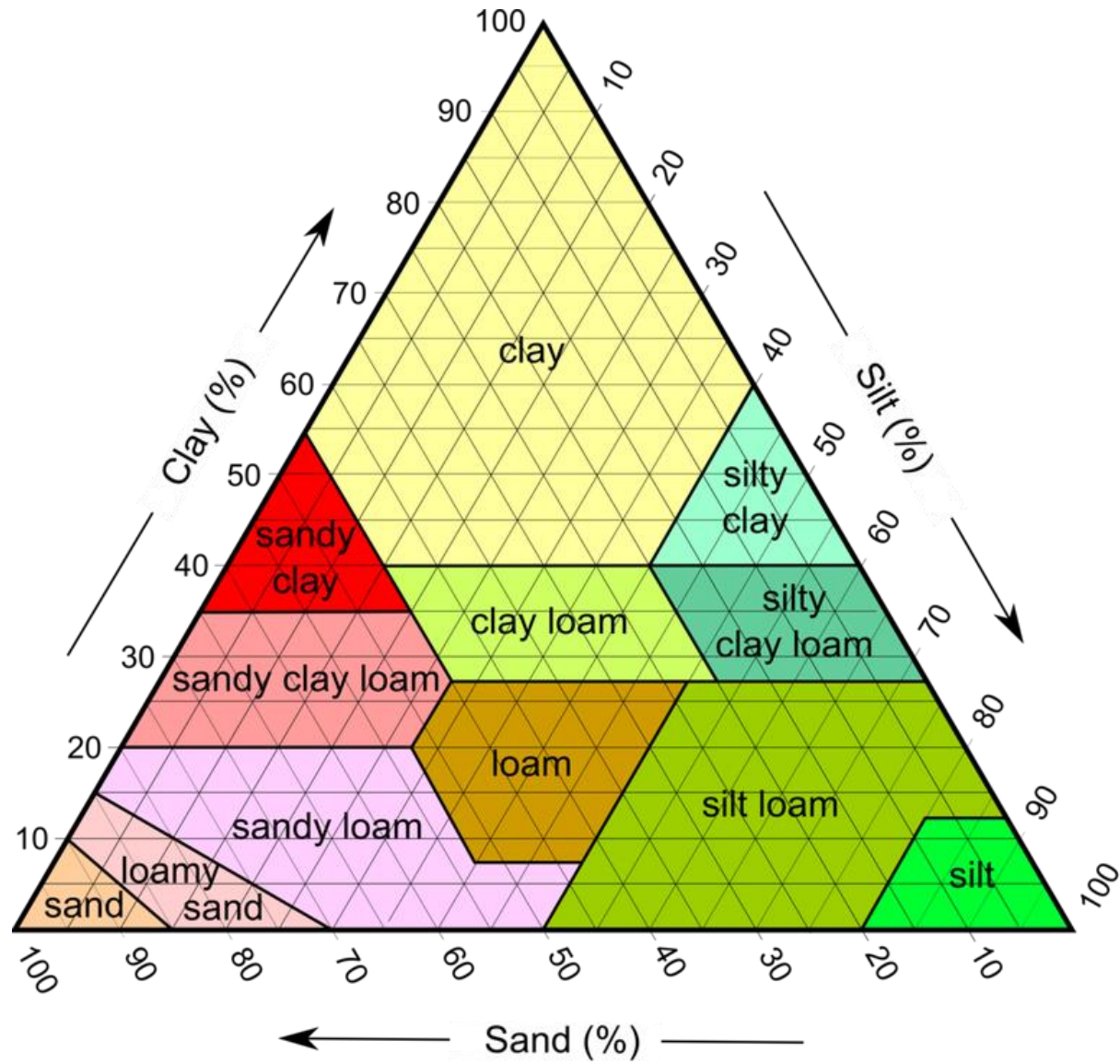
Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Analysis of variance table for acid phosphatase enzyme activity in 15-30 cm soil layer

	2019				2020			Pooled					
Source of Variation	<i>Df</i> *	<i>Sum of squares</i>	<i>MSS</i> **	<i>F-cal</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	Source of Variation	<i>Df</i>	<i>Sum of squares</i>	<i>MSS</i>	<i>F-cal</i>	CD_{0.05}
Treatments	7	1733.59	247.66	9.99	2528.1	361.16	5.10	Rep/Year	4	1161.6	290.4	6.1	NS***
Replication	2	40.94	20.47	0.83	1120.7	560.34	7.92	Treatments	7	4151.7	593.1	12.4	8.2
Error	14	346.95	24.78		990.6	70.76		Year	1	715.5	715.5	15.0	4.1
Total	23	2121.5			4639.4			Treat × Year	7	110.1	15.7	0.3	NS
								Pooled error	28	1337.6	47.8		
CD_{0.05}	8.7				CD_{0.05}	14.7		Total	47	7476			

Df = Degree of freedom **MSS = Mean sum of squares NS* = Non-significant*

Annexure – IV



Triangular textural diagram (sand, silt and clay particle sizes of 2-0.02 mm, 0.02-0.002 mm and < 0.002 mm, respectively) (ISSS, 1929)

**Department of Soil Science and Water Management
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Title of Thesis : **Effect of nutrient sources on soil properties and productivity of kiwifruit (*Actinidia deliciosa* cv. Allison)**
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Major Field : Soil Science
Minor Field : Fruit Science
Year of Award of Thesis : 2021
Number of pages in the thesis : 183+xxii
Number of words in abstract : 581

ABSTRACT

The present investigation entitled “**Effect of nutrient sources on soil properties and productivity of kiwifruit (*Actinidia deliciosa* cv Allison)**” was conducted on 6 years old kiwifruit vines cultivar ‘Allison’ at a spacing of 4.0 m × 6.0 m for two consecutive years 2018-19 and 2019-20 at experimental block of Department of Fruit Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The experiment was laid out in triplicate in Randomized Block Design with 8 treatments under three farming systems viz., Chemical Fertilizer Based System (CFBS), Organic Farming Based System (OFBS) and Subhash Palekar’s Natural Farming System (SPNFS). The eight treatments are T₁ (N: 800 g, P₂O₅: 600 g, K₂O: 800 g + 40 kg FYM per vine) under CFBS, four treatments under OFBS namely T₂ {100% Recommended dose of N (RDN) through vermicompost (VC) and poultry manure (PM) on 50: 50 basis + 40 kg FYM per vine}, T₃ (90% RDN through VC and PM on 50: 50 basis + 40 kg FYM per vine) and T₄ (80% RDN through VC and PM on 50: 50 basis + 40 kg FYM per vine) and T₅ (70% RDN through VC and PM on 50: 50 basis + 40 kg FYM per vine) and three treatments under SPNFS namely T₆ {15 liters of *Jeevaamrit* (JM) + 3 kg of *Ghana Jeevaamrit* (GJ) + 40 kg FYM per vine}, T₇ (22.5 liters of JM + 3 kg of GJ + 40 kg FYM per vine) and T₈ (30 liters of JM + 3 kg of GJ + 40 kg FYM per vine). The maximum leaf area (158.1 cm²), leaf area index (4.36), chlorophyll index, photosynthetically active radiation was found with the application of 30 liters JM + 3 kg GJ + 40 kg FYM (T₈) of SPNFS followed T₂ treatment of OFBS over T₁ under CFBS. The treatments T₂ and T₈ observed comparable fruit yield, high percent proportion of A-grade fruits, lower fruit length and weight and comparable fruit diameter over chemical fertilizer treatment. Best fruit quality parameters namely; TSS content (16.87 °B), total sugars (11.77%), reducing sugars (8.31%), non-reducing sugars (3.28%) and ascorbic acid (81.55 mg/100g) were recorded with treatment T₂. The T₂ treatment also witness maximum soil organic carbon (31.23 g kg⁻¹), available soil N (365.8 kg ha⁻¹), available soil P (104.6 kg ha⁻¹), available soil K (449.1 kg ha⁻¹), DTPA extractable Cu (3.63 mg kg⁻¹), Mn (14.92 mg kg⁻¹) and Zn (4.23 mg kg⁻¹) in surface soil layers. However, T₈ treatment of SPNFS estimated manyfold increase in bacterial (200 cfu × 10⁵ g⁻¹), fungal (25 cfu × 10³ g⁻¹), actinomycetes count (22 cfu × 10³ g⁻¹), dehydrogenase activity (35.8 µg TPF g⁻¹ hr⁻¹) and acid phosphatase activity (119.8 µg PNP g⁻¹ hr⁻¹) in addition to soil physico-chemical properties. Maximum benefit: cost ratio of 12.36:1 was obtained in T₁ followed by 12.22:1 in T₈ treatment while organic treatment T₂ enumerated much lower benefit cost of 4.17:1 despite improvement in soil quality parameters and comparable yields. This might be due to the high cost of organic inputs viz. VC and PM. Finally, it is concluded that the treatment comprising application of 30 litres JM + 3 kg GJ (3 equal splits in end of January, February and April) + 40 kg FYM per vine was found to be better option instead of chemical fertilizers to the Allison cultivar of kiwifruit under mid-hill conditions of Himachal Pradesh to achieve comparable yields and nearly equal returns accompanied by maintaining soil health.

Signature of the Student

Signature of the Major Advisor

Countersigned

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2. Dr. J. S. Kanwar Memorial Scholarship in the Soil Science during the academic year 2002-03 by PAU, Ludhiana
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2. **Garg AK**, Kaushal R and Rana VS. 2021. Comparative efficacy of different organic nutrient sources on yield and quality of kiwifruit (*Actinidia deliciosa*) cv. Allison in Western Himalayas of India. *Biological Agriculture & Horticulture* (Submitted).
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