NUTRITIONAL STATUS OF POTATO (*Solanum tuberosum* L.) IN LAHAUL VALLEY OF HIMACHAL PRADESH

Thesis

by

VISHAL THAKUR
(F-2021-58-M)

submitted to

Dr. YASHWANT SINGH PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY SOLAN (NAUNI) HP – 173230 INDIA

in

partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE) SOIL SCIENCE

DEPARTMENT OF SOIL SCIENCE AND WATER MANAGEMENT
COLLEGE OF FORESTRY

2023

Dr. R S Spehia
Major Advisor

Department of Soil Science and Water Management
Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan- 173 230 (HP)

CERTIFICATE-I

This is to certify that the thesis titled**, "Nutritional Status of Potato (*Solanum tuberosum* L.) in Lahaul valley of Himachal Pradesh**" submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (AGRICULTURE)** 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. Vishal Thakur (F-2021-58-M)** son of **Shri Virender Singh** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

Place: Nauni (Solan)
Dated:

(Dr. R S Spehia)
Major Advisor

CERTIFICATE-II

This is to certify that the thesis titled, **"Nutritional Status of Potato (*Solanum tuberosum* L.) in Lahaul valley of Himachal Pradesh"** submitted by **Mr. Vishal Thakur (F-2021-58-M)** son of **Shri Virender Singh,** to the Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP)-173 230 India in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (AGRICULTURE)** in the discipline of **SOIL SCIENCE** has been approved by the student's advisory committee after the viva-voce examination of the student in collaboration with an External Examiner.

4/11/23

Dr. R S Spehia
Senior Scientist
Major Advisor

4/11/23

Dr. D Tripathi
External Examiner

Members of the Advisory Committee

Dr. Upender Singh
(Senior Scientist)
Department of Soil Science and Water Management

04/11/23

Dr. Nitin Sharma
(Assistant Professor)
Department of Basic Science

Professor and Head
Department of Soil Science and Water Management
Dr. Y. S. Parmar, UHF, Nauni-173 230, Solan (HP)

Countersigned

Dean
College of Forestry
Dr. Y. S. Parmar, UHF, Nauni-173 230, Solan (HP)

ACKNOWLEDGEMENTS

First and foremost, I must acknowledge and thank the Almighty for wisdom and perseverance that bestowed upon me throughout this period. I could never have accomplished this without the faith I have in the Almighty.

I would like to express the deepest gratitude and indebtedness to Chairman of my advisory committee, ***Dr. R S Spehia****, Senior Scientist & Head, Krishi Vigyan Kendra, Tabo, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan for his illuminating guidance, unfailing encouragement, scholarly suggestions, unique supervision, constructive criticisms, sympathetic attitude and keen interest during the course of the investigation. I shall remain indebted for his affection, help and generosity bestowed upon me.*

I express my heartiest and sincerest regards to other committee members, ***Dr. Upender Singh****, Senior Scientist, Department of Soil Science and Water Management for his valuable help, meticulous suggestions, constant inspiration and charting the path that I should follow and also* ***Mr. Nitin Sharma****, Assistant Professor, Department of Basic Science for his support and brilliant comments.*

I extend my sincere thanks to ***Dr. Chaman Lal Thakur,*** *Dean, College of Forestry and* ***Dr. M. L Verma,*** *Professor and Head, Department of Soil Science and Water Management for providing necessary facilities and help to carry out the study.*

*Diction is not enough to express my deep regards and eternal gratitude to my beloved parents (****Sh. Virender Singh*** *and* ***Smt. Meena Devi****) and my brother* ***Akshay Thakur*** *whose selfless love, constant encouragement, obstinate sacrifices, sincere prayers, expectations and blessings have always been the most vital source of inspiration and motivation in my life.*

Additionally, I would like to express my deepest gratitude to Project Director, ATMA, Lahaul & Spiti (HP) as without their support and information, this research could not have reached its goal.

"Nothing great is ever achieved without enthusiasm". Enthusiasm, inspires confidence, raises morale, builds loyalty and is priceless, which I received from companionship of my close friends ***Yogesh, Deepak, Aditi, Charu, Anannya, Divyansh, Rishu raj, Dheeraj, Ankita, Oshmi, Arnav, Iqbal, Vikram*** *and* ***Aditya.*** *I thank them for their support, encouragement and incredible resourcefulness. Time shared with them will be cherished forever.*

I have been fortunate in getting the intelligent guidance by my respected Seniors ***Naman sir, Ashish sir, Saurabh sir, Rathi sir, Suresh sir, Akshay bhai, Archana ma'am, Anjali ma'am, Gitika ma'am, Sujata ma'am, Sonali ma'am*** *and* ***Shilpa ma'am*** *for enthusiastic co-operation. I am grateful to office and laboratory staff of the Department of Soil Science and Water Management, their kind co-operation. My special thanks to DPT computers (Nauni-Solan) for their painstaking efforts in bringing out this manuscript to present form.*

I solely claim the responsibility of all errors and omissions.

Place: Nauni, Solan
Dated: **(Vishal Thakur)**

CONTENTS

LIST OF ABBREVIATIONS

%	:	Percent
Ca	:	Calcium
$CaCO_3$	:	Calcium carbonate
cm	:	Centimeter
cmol (p^+) kg^{-1}	:	Centimole proton equivalence per kilogram
cfu	:	Colony forming units
Cu	:	Copper
dS m^{-1}	:	Deci Siemens permeter
DTPA	:	Dietylene Triamine Penta Acetic Acid
E	:	East
EC	:	Electrical conductivity
et.al	:	Co-workers
etc	:	*etcetera*
Fe	:	Iron
FYM	:	Farm yard manure
g	:	Gram
g kg^{-1}	:	Gram per kilogram
HCl	:	Hydrochloric acid
HNO_3	:	Nitric acid
$HClO_4$	:	Perchloric acid
H.P.	:	Himachal Pradesh
ha	:	Hectare (10,000m^2)
i.e.	:	*Thatis*
ISSS	:	International Society of Soil Science
K	:	Potassium
Kg ha^{-1}	:	Kilogram per hectare
me 100^{-1}g	:	Milliequivalent per hundred gram

mm	:	Millimeter
m	:	Meter
Mg	:	Magnesium
mg kg^{-1}	:	Milligram per kilogram
ml	:	Milliliters
Mn	:	Manganese
N	:	North
OC	:	Organic carbon
^{o}C	:	Degree Celsius
P	:	Phosphorus
PSB	:	Phosphorous Solubilizing Bacteria
pH	:	*Puissance de Hydrogen*
ppm	:	Parts per million
Rs	:	Rupees
S	:	Sulphur
SE	:	Standard Error
SNI	:	Soil Nutrient Index
$SnCl_2$	:	Stannous chloride
S	:	Sulphur
SSP	:	Single superphosphate
viz.	:	*Videlicet*
w.r.t	:	With respect to
Zn	:	Zinc

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Chapter-1

INTRODUCTION

Potato (*Solanum tuberosum* L.), a South American native and commonly referred to as the "king of vegetables," is a crucial component of Indian cuisine. It is one of the most important food crops after wheat, rice and maize that contribute to global food and nutrition security. Potato is a rich source of protein, minerals, vitamins and superior dietary fibre as well as an excellent source of carbohydrates, with low fat content. It is the most important food and vegetable-cum-starch supplying crop of the world. It contains 20.6% carbohydrates, 2.1% protein, 0.3% fat, 1.1% crude fibre, 0.9% ash and necessary amino acids are also present in good amount (Kumar *et al*., 2011).

Potato is a cool season crop, which is a modified underground stem that bears tubers at its stolon end. It requires low humidity, low temperature and bright sunlight with high light intensity and short days for proper growth and development of the crop. Potato is grown as summer crop in hills (March/April-September) and as winter crop in tropical and subtropical regions (October/November-February). Late maturing varieties prefer short days, whereas early varieties prefer long days for better tuber development. It can grow in all types of soil, but light, well drained sandy loam soil are best suited having pH acidic to neutral range (5.5-7.5) (Chadha, 2019).

India is the second-largest producer of potatoes in the world, behind China. In India, potato is grown in an area of 2.203 million hectares with production of 56.173 million tonnes in 2020-2021(Anonymous, 2022c). In Himachal Pradesh, potato is grown in 15.06 thousand hectares land with a production of 196.30 thousand metric tonnes and productivity of 13.03 metric tonnes/hectare in 2020-2021 (Anonymous, 2022a). Lahaul and Spiti is one of the major potato growing areas in Himachal Pradesh as well as India as it meets the demand for quality potato seed which is possible because of the favourable climate during crop growth. In Lahaul & Spiti, potato is grown in an area of 501 hectare with a production of 3 thousand metric tonnes in 2020-2021 (Anonymous, 2022b).

Mostly, inorganic fertilizers are used to produce good quality potatoes in this region. Continued usage of chemical fertilizers without organic manures or bio-fertilizers has a negative impact on soil health, which is a major concern for farmers. Intensive use of these chemical fertilizers for high production has led to deterioration of soil health in terms of physical and chemical properties of soil, decreased soil microbial activities, increased soil pollution, reduced soil humus, decreased interaction of soil micro flora and fauna and also decreased water holding capacity of soil. So in order to improve the soil health and surrounding environmental conditions with the help of integrated nutrient management practices, effective use of plant nutrients is required. Integration of chemical fertilizers with organic manures and sustainable crop production in an effective manner is one of the important technique for intensive crop production (Shubha *et al*., 2018).

Apart from integrated farming, natural farming is also being seen as an alternative to inorganic farming for maintaining soil as well as human health. Natural farming, as defined by NITI Ayog, is a chemical-free alias traditional agricultural approach that is an agroecology-based diversified farming system that blends crops, trees, and livestock with functional biodiversity. Masanobu Fukuoka, a Japanese farmer and philosopher, created the term “natural farming” in his 1975 book “The One Straw Revolution”. Zero budget means growing crops with zero production cost by using the inputs from the farm itself. Balanced soil microbial and earthworm populations by growing crops without adding any external input such as pesticides or inorganic fertilizers is the goal of Zero Budget Natural Farming. Govt. of India also mentioned ZBNF as a source of doubling farmer’s Income. Bharatiya Prakritik Krishi Paddhati Programme (BPKP) is encouraging natural farming in the states of Andhra Pradesh, Himachal Pradesh, Gujrat, Karnataka, Uttar Pradesh, Assam, and Kerela. Zero Budget natural farming is an extremely low cost farming technique that works with local biodiversity, increase farmer’s profits by preserving the surrounding environment and nature for sustainable production in future (Sarmah and Deka, 2023).

These initiatives to promote natural farming in India received both applaud and criticism from the scientific community. Therefore, effect of natural farming on soil health and crop yield needs extensive studies to arrive at some conclusion on its benefits vis-a-vis conventional farming. Keeping this in view, present studies were conducted with following objectives:

1. To evaluate the soil health and plant nutrient content under natural and conventional farming practices.
2. To work out the relationships between soil properties, plant nutrient contents and crop yield.

Chapter-2

REVIEW OF LITERATURE

Soil fertility evaluation research plays a crucial role in providing valuable insights that can help to maintain food security and human well-being while also preserving the environment. Soil fertility is influenced by a combination of natural factors including climate, the biosphere, parent material, topography, and time, as well as artificial factors such as management practices like fertilization, green manuring, and crop rotations. Soil plays a vital role in providing plants with the necessary nutrients, water, oxygen, and structural support for their growth and vitality. However, achieving high productivity goals can be challenging due to low soil fertility and inadequate nutrient management. This may be caused by various factors, including a limited understanding of soil health and nutrient needs. To protect our soils while sustaining high productivity levels, it's essential to adopt holistic production management approaches. These approaches should prioritize and improve the health of agro-ecosystems while remaining socially, ecologically, and economically sustainable. Hence, the present study **"Nutritional Status of Potato (*Solanum tuberosum* L.) in Lahaul valley of Himachal Pradesh"** was undertaken. This chapter reviews the relevant literature under following heads:

2.1 Effect of different organic sources on soil nutrient status and crop yield

2.2 Effect of different inorganic sources on soil nutrient status and crop yield

2.3 Effect of conjoint application of organic and inorganic sources on soil nutrient status and crop yield

2.4 Effect of organic and inorganic sources on plant nutrient status

2.5 Effect of organic and inorganic sources on soil microbiological properties

2.1 EFFECT OF DIFFERENT ORGANIC SOURCES ON SOIL NUTRIENT STATUS AND CROP YIELD

Blaise *et al.* (2004) assessed the soil nutrient status under organic and modern method of cultivation. Nutrient demand was met through farmyard manure (FYM) and green manure in OCS (organic cultivation system) plot and NPK fertilizer @ 90-19-37 kg per hectare was used in MMC (modern method of cultivation) plots. They observed that soil macro and micronutrient content were high in organic cultivation than modern method of cultivation and decreased with the increase in depth.

Kannan *et al.* (2005) studied the influence of different organic N sources viz, FYM, vermicompost and coir pith compost with bioferilizers on the soil physical properties, nutrient availability and biological properties in Agricultural College and Research Institute, Madurai. Treatments consisted of organic sources viz. FYM, coir pith compost, vermicompost and *Azospirillum*. Results revealed that application of 75% N as vermicompost with *Azospirillum* recorded highest organic carbon (0.78%) and available nitrogen (253 kg ha^{-1}) while, application of 100 percent N as vermicompost recorded maximum water holding capacity (48.6%).

Melero *et al.* (2008) studied the effect of organic farming on chemical and biochemical properties of an irrigated loam soil in Guadalquivir River Valley (southwest Spain) and results revealed that organically (vegetal compost and animal compost) fertilized soil contained high organic carbon and available macronutrient contents in soil.

Choudhary *et al.* (2010) conducted a field experiment at the experimental farm of KVK, Sundernagar, Himachal Pradesh to evaluate the effect of vermi-compost and biofertilizers on productivity and profitability in potato in acidic soils and found that combined application of vermi-compost @ 30 t ha^{-1} on oven dry weight basis with PSB and *Azotobacter* biofertilizers enhanced the organic carbon, available N, P and K, DTPA-exchangeable Fe, Mn, Zn and Cu in the soil.

Manjunatha *et al.* (2013) conducted a study to determine effect of organic farming on organic carbon and NPK status of soil in Northern Karnataka, India. They recorded increase in organic carbon 0.27 to 0.42%, nitrogen 136.22 to 194.72 kg ha^{-1}, phosphorus 9.63 kg ha^{-1} to 14.08 kg ha^{-1}, and potassium 131.11 to 154.61 kg ha^{-1} from fifth to tenth year while, increase in organic carbon 0.42 to 0.57%, nitrogen 194.72 to 279.53 kg ha^{-1}, phosphorus 14.08 to 18.70 kg ha^{-1}, and potassium 154.61to184.55 kg ha^{-1} from tenth to fifteenth years. Organic farming thus resulted in improvement in soil health.

Aher *et al.* (2015) conducted a field experiment to evaluate the influence of organic farming practices on soil health and crop performance of Soybean (*Glycine max*) under semi-arid tropical conditions in Central India. Nutrients were applied as cattle dung manure on nitrogen (N) equivalent basis and nutrient requirement of soybean crop and observed that soil organic carbon (11.3 g kg^{-1}), available N (125 mg kg^{-1}), P (49.7 mg kg^{-1}) and total biomass

(1927 kg ha^{-1}) were significantly higher in the plot managed organically while available K (320.1 mg kg^{-1}) was not significantly affected with respect to chemical and integrated practices.

Glab *et al.* (2016) examined the effect of organic farming on stagnic luvisol soil physical properties in Mydlniki, Poland. They observed significantly higher values of soil bulk density in organic than conventional farming practices. The highest water retention in terms of PWC (productive water retention) and AWC (available water retention) were obtained under CFS (conventional farming system) system. Organic farming resulted in lower macroporosity (0.65%), whereas under conventional farming higher microporosity (0.82%) was recorded.

Das *et al.* (2017) conducted a field experiment to assess long term impact of organic farming on soil, produce quality and crop yield in eastern Himalayan region of India from 2005-06 to 2011-12. Soil quality parameters such as available nutrients, soil organic carbon, water holding capacity were statistically higher under organic and INF (integrated farming) as compared to inorganic or control, whereas, soil microbial biomass carbon was higher under organic than other farming practices.

Kaje *et al.* (2018) observed that the application of organic amendments had a positive influence on various soil physical properties such as saturated hydraulic conductivity (Ks), field capacity (FC), and permanent wilting point (PWP) at the Experimental Farm of the ICAR-Indian Agricultural Research Institute, New Delhi. Results revealed that application of organic inputs especially FYM, improved the soil physical properties, which resulted in better soil aggregation, porosity and soil moisture retention.

Ahmed *et al.* (2019) studied the effect of organic fertilizers on potato tuber production in sandy loam soil, Bangladesh. Two potato cultivars namely Cardinal and Diamant and four organic fertilizers viz., cowdung at the rate of 8 t ha^{-1}, chicken manure at the rate of 8 t ha^{-1}, Rangpur Dinajpur Rural Service (RDRS) developed organic fertilizer at the rate of 740 kg ha^{-1} and Northern organic fertilizer at the rate of 500 kg ha^{-1} along with a control. Chicken manure treatment (8 t ha^{-1}) exhibited maximum height, leaf number, leaf fresh weight, total dry matter, absolute growth rate, tuber growth rate, and tubers per plant, as well as largest tuber size. As a result, it produced the highest tuber yield of 29.71 t ha^{-1} followed by cow dung treatment (8 t ha^{-1}) which produced a tuber yield of 28.67 t ha^{-1}.

Beeby *et al.* (2020) conducted a field experiment at Kenya to evaluate one time organic fertilizer application on long term soil quality, crop and residue yield measurements using biointensive agriculture and recorded that boron, electrical conductivity, magnesium, organic matter, phosphorus, potassium, sulfur, and zinc increased significantly. Calcium, copper, iron, pH, and sodium showed no significant changes, and only manganese levels decreased significantly. Crop edible yields increased overall for maize, sorghum, and sweet potatoes.

Kumar *et al.* (2020) analysed delineation of the major soil nutrients in Kelad valley of the district Lahaul-Spiti, Himachal Pradesh, India. Soil samples were collected from a similar landscape with different land uses viz. agriculture, horticulture, forest and grassland in Kelad Valley. They observed that pH of the soil was acidic to neutral. Organic carbon (48.52 g kg^{-1}) and phosphorous (P) (1.07-4.85 kg ha^{-1}) were found highest in agriculture field. However, available nitrogen (N) was found highest in horticultural land.

Meena *et al.* (2020) conducted a field experiment to study the effect of organic farming on soil physical properties, available micronutrients and rice yield in the research farm of IARI, New Delhi. Treatments comprised of seven combinations of different organic materials and biofertilizers (BF) viz. farmyard manure (FYM) equivalent to 60 kg N ha^{-1}, vermicompost (VC) equivalent to 60 kg N ha^{-1}, FYM + crop residue (CR) of preceding crop @ 3 t ha^{-1} for each rice, wheat and mungbean, VC+CR, FYM+CR+BF and VC+CR+BF, and control. They observed significantly high water holding capacity, aggregate stability, hydraulic conductivity, soil pH, and available NPK under conjoint application of (FYM)+CR+BF and VC+CR+BF treatments. DTPA extractable micronutrients recorded significant increase in manures applied treatments.

Choudhary *et al.* (2022) conducted a field experiment to evaluate the effect of natural farming on yield performance, and soil health, and nutrient uptake in inter cropping system under SPNF at CSKHPKV, Palampur, HP during rabi 2019-20 and 2020-21. Ghanjeevamrit + jeevamrit + mulching recorded significantly highest organic carbon (0.94 and 1.98 %) and available nitrogen (275 and 282 kg ha^{-1}) while use of ghanjeevamrit + jeevamrit recorded highest available phosphorus (17.3 and 18 kg ha^{-1}) and potassium (292 and 295 kg ha^{-1}) during both the years.

2.2 EFFECT OF DIFFERENT INORGANIC SOURCES ON SOIL NUTRIENT STATUS AND CROP YIELD

Kumar *et al.* (2004) conducted a field experiment under sub-tropical conditions in the west-central plains with different fertility levels to determine the fertilizer requirements of chipping potatoes. Eight fertility combinations were tested, viz., N_{240} P_{120} K_{140} (F_1), N_{240} P_{120} K_{180} (F_2), N_{240} P_{160} K_{140} (F_3), N_{240} P_{160} K_{180} (F_4), N_{300} P_{120} K_{140} (F_5), N_{300} P_{120} K_{180} (F_6), N_{300} P_{160} K_{140} (F_7) and N_{300} P_{160} K_{180}. Application of 240 kg N, 120 kg P_2O_5, and 140 kg K_2O ha^{-1}(F_1) resulted in maximum process-grade yield in both Chipsona varieties.

Kumar *et al.* (2007) studied phosphorus requirement of Chipsona varieties for west-central plains of India at CPRI Campus, Modipuram in sandy loam soil. The treatments comprised five level of phosphorus (0, 40, 80, 120 and 160 kg ha^{-1}) in sub-plots and two varieties (Kufri Chipsona-1 and Kufri Chipsona-2). Result revealed that the stem number, plant height, leaf number, processing grade (> 45 mm) as well as total tuber number of potato cv. Kufri Chipsona-1 and Kufri Chipsona-2 increased with the application of phosphorus upto 80 kg P_2O_5/ha. Maximum tuber yield (386.6 q ha^{-1}), net returns (Rs.59,503) and benefit cost ratio (2.43) were recorded at 80 kg P_2O_5/ha.

Adhikari (2009) studied the effect of NPK fertilizers on vegetative growth and yield of two potato cultivars, Kufri Sindhuri and Desiree, across various nutrient levels in Nepal. Sub-plots were taken with seven different combinations of N (0, 50, 100 and 150 kg ha^{-1}), P (0, 50, 75 and 100 kg ha^{-1}) and K (0, 50, 50 and 100 kg ha^{-1}) in the sandy loam soil having pH ranges from 4.8 to 5.2, organic matter ranges from 2.55 to 3.22%. Kufri Sindhuri responded positively to nitrogen up to 150 kg ha^{-1}, whereas Desiree yielded higher when 100:100:100 kg NPK ha^{-1} was applied.

Dubey *et al.* (2012) conducted an experiment to study the effect of nitrogen levels and cultivars on growth and yield components of potato at Central Agricultural University, Pasighat, Arunachal Pradesh. Treatments included three nitrogen level (F_1 = 100 kg, F_2 = 125 kg and F_3 = 150 kg/ha) in the form of urea (46% N) and three potato cultivars (Kufri Khyati, Kufri Ashoka and Kufri Jyoti) in sandy loam soil. Highest total tuber yield was recorded with application of 150 kg N/ha in cultivar Kufri Ashoka (23.92 t/ha).

Chongtham *et al.* (2015) conducted a field experiment at Potato Research Station, SDAU, Deesa, Gujarat to study the effect of different nitrogen levels on potato variety Kufri Surya. Five treatments on N levels viz., 0, 75, 150, 225 and 300 kg N/ha were laid out in randomized block design and replicated four times. They observed increased productivity upto 150 kg N/ha, whereas the agronomic use efficiency of nitrogen decreased with subsequent increase in nitrogen application thereafter.

Marthha *et al.* (2017) analyzed the performance of potato as influenced by different doses of NPK fertilizers at Bhubaneswar, Odisha. The soil was sandy in texture and slightly acidic (pH 6.03), high in organic carbon (0.41%) and available phosphorous (63.67 kg/ha), low in available nitrogen (120kg/ha) and available potassium (133.67 kg/ha). Experiment consisted of four replications and seven treatments viz. 50% RDF of NPK (T_1), 100% RDF of NPK (T_2), 150% RDF of NPK (T_3), without N fertiliser (recommended P and K) (T_4), without P fertilisers (recommended N and K) (T_5), without K fertiliser (recommended N and P) (T_6), without NPK fertiliser (absolute control) (T_7). Result revealed that the highest yield (22.52 t ha^{-1}) was achieved with the application of 150% RDF of NPK fertilizers.

Kumar *et al.* (2018) studied the NPK requirement for potato (*Solanum tuberosum* L.) in Western Indo-Gangetic plains in soil having pH (6.5–7.9), EC (0.21–0.49 d S m^{-1}), organic carbon (0.22–0.59%), available N (118.5–290.0 kg ha^{-1}), Phosphorus (8.0–56.4 kg ha^{-1}) and exchangeable K (80.0–291.1 kg ha^{-1}). Results revealed that 18 kg N, 4 kg P and 24 kg K would be required to produce one tonne of potato tubers.

Marinkovic *et al.* (2018) conducted a field survey and collected 8 samples under conventional production to access the nutrient status of the soils in conventional cropping system at Central Serbia and found that soil samples were slightly acidic (pH 5.83), moderate in $CaCO_3$ content (2.20%), low in organic matter content (2.86%), total nitrogen (0.207%), phosphorus (12.21 mg 100 g^{-1}), and potassium (20.86 mg 100 g^{-1}).

Dangi *et al.* (2019) studied the effect of nitrogen levels, cultural practices and their interactions on growth and yield of potato. The treatment combination consisted of 2 cultural operations viz. hoeing (H_1) and no hoeing (H_0) and 4 nitrogen levels viz. 0 (N_0), 75 (N_1), 150 (N_2) and 225 (N_3) kg N/ha and observed higher haulm fresh weight, haulm dry weight, and total tuber yield with application of 225 kg nitrogen/ha. Significantly higher values were observed in the interactions of N_2H_1, N_0H_0, N_1H_0, and N_1H_1 for available nutrient P (60.08 kg/ha), available nutrient N (178 kg/ha), and available nutrient K (386.77 kg/ha), at the Research Farm of ICAR-Central Potato Research Institute-RS, Gwalior (M.P.).

Lenka and Das (2019) conducted a field experiment to determine the effect of boron and zinc on growth and yield of potato in lower Gangetic plains of West Bengal having sandy clay loam soil with slightly alkaline (pH 7.3), organic carbon content of 0.57%, available N 183.26 kg/ha, available Phosphorus 16.8 kg/ha, available potassium 132.0 kg/ha, available zinc 1.48 mg/kg of soil and available boron 0.86 mg/kg.The application of treatment T_1 (recommended dose of fertilizer N, P, K @ 200, 150, 150 kg/ha) resulted in the highest soil nutrient availability in post-harvest soil with levels of 178.5 kg available N/ha, 17.75 kg available P/ha, and 129.3 kg available K/ha. Highest available zinc 2.32 mg/kg and available boron 0.92 mg/kg were found with treatment T_1 + 4.5 kg Zn/ha soil application and treatment T_1 + 2.0 kg B/ha soil application, respectively.

Zaeen *et al.* (2020) conducted an experiment during 2018 and 2019 to investigate the yield and quality of three potato cultivars under series of nitrogen rates at Maine and found that the organic matter was identified as the primary factor that exhibited a high correlation with crop yield (R^2 = 0.78). The level of organic matter content had a notable impact on the production of tuber yield, with sites containing more than 30 g kg^{-1} of organic matter showing a significant disparity compared to those with less than 30 g kg^{-1} of OM.

2.3 EFFECT OF CONJOINT APPLICATION OF ORGANIC AND INORGANIC SOURCES ON SOIL NUTRIENT STATUS AND CROP YIELD

Saha *et al*. (2007) studied the long term effect of integrated nutrient management on growth, yield, nutrient uptake, nutrient balance sheet and soil fertility at Bangladesh Rice Research Institute (BRRI) Farm, Gazipur during 1993-1999. The result showed that application of cow-dung and green manure along with chemical fertilizers not only increased soil macronutrients but also increased available micronutrients (Zn, Fe, Cu and Mn) content in soil.

Araujo *et al.* (2009) observed the microbial activity in organic and conventional agricultural management system regimes and analysed various soil chemical properties under conventional and organic farming and native vegetation. The results indicated that the soil organic carbon content was greater in the organic area (ORG) compared to the conventional area (CNV).

Sharma and Kanwar (2010) conducted a soil survey to study the copper status and its relation with soil properties in pea growing soils of high hills dry temperate zone of Himachal Pradesh and results revealed that total Copper content in soil varied from 4 to 92 mg kg^{-1} with an average value of 43 mg kg^{-1}. The soil pH varied from 6.2 to 10.3, sandy loam to sandy clay loam in texture, high in organic carbon content (4.2 to 40.8 g kg^{-1}), high calcium carbonate content (0.1 to 14.4 %) and high in CEC (3.5 to 62 cmol (p^+)/ kg) with an average values of 7.6, 18.3, 2.0 and 18.4, respectively.

Islam *et al.* (2013) observed that the soil treated with combined application of 100% recommended dose of fertilizer and poultry manure at a rate of 3 t ha^{-1} resulted in the higher nutrient availability in the soil. This treatment also showed the highest levels of organic matter, pH, total nitrogen, available phosphorus, available potassium, and available sulfur in the soil.

Gaur *et al.* (2017) studied the optimum phosphorus dose of potato (*Solanum tuberosum* L.) through organic and inorganic sources under current scenario of P use during 2015-16 at ICAR- CPRS, Gwalior M.P. Result revealed that pH and EC, both were non-significant but on the other hand organic carbon recorded slight increase as compared to initial values because of applied P doses. Application of 120 kg P_2O_5/ha through fertilizer recorded significantly higher NPK content as compared to other treatments.

Rajneesh *et al.* (2017) studied the long-term effect of fertilizers and amendments on available NPK, micronutrient cations, NPK uptake, and productivity of the maize-wheat system from 1972 at CSKHPAU, Palampur. Treatments consisted of (T_1) 50% NPK, (T_2) 100% NPK, (T_3) 150% NPK, (T_4) 100% NPK + HW, (T_5) 100% NPK + Zn, (T_6) 100% NP, (T_7) 100% N, (T_8) 100% NPK + FYM, (T_9) 100% NPK (-S), (T_{10}) 100% NPK + lime, and (T_{11}) control. Continuous application of balanced fertilizers and farmyard manure (FYM) had a significant impact on various soil properties. It influenced the pH, OC, and cation exchange capacity (CEC), as well as the availability of nitrogen (N), phosphorus (P), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu), which were more pronounced in the top soil layer (0-0.15 m) compared to deeper layers (0.15-0.30 m and 0.30-0.45 m) due to the application of fertilizers and FYM. Highest productivity of wheat (89.89 q ha^{-1}) and maize (156.52 q ha^{-1}) were recorded with application of 100% NPK + FYM, which was at par with 100% NPK + lime.

Yadav *et al.* (2017) evaluated the effect of integration of fertilizers and FYM on productivity and soil health of rainfed potato at Shillong, Meghalaya during summer season of 2012 and 2013 in sandy loam soil. Treatments consisted of T_1-100% RDF through synthetic fertilizers, T_2-75% RDF and 25% recommended dose of nitrogen (RDN) through FYM, T_3-50% RDF and 50% RDN through FYM, T_4-25% RDF and 75% RDN through FYM, T_5-100% RDN through FYM and T_6-control, farm yard manure (0.55% N, 0.30% P and 0.60% K) collected from a nearby farm. Results revealed that the application of 75% RDF along with 25% RDN through FYM gave maximum productivity and yield of potato tubers with highest net return.

Devi *et al.* (2018) conducted a field experiment to evaluate the effect of integrated nutrient management (INM) on yield and soil nutrient status in Nauni, Solan. Treatments consisted of integrated use of organic and inorganic fertilizers with PGPR strains (*Bacillus* spp.). Result revealed highest organic carbon (12.63 g kg^{-1}), available N (406.55 kg ha^{-1}), P (69.20 kg ha^{-1}), K (309.35 kg ha^{-1}) and sulphate sulphur (60.71 kg ha^{-1}) with the combined application of 130% NPKM + 50% FYM+ 50% VC on N equivalence basis + PGPR.

Dhiman *et al.* (2019) assessed the fertilizers application, manure and lime on soil and productivity of wheat at Himachal Pradesh Agricultural University, Palampur. They observed that continuous use of urea alone was found to have a detrimental effect on soil properties. The regular application of an optimal dose of chemical fertilizers and farmyard manure significantly influenced soil bulk density, porosity, water holding capacity, saturated hydraulic conductivity, mean weight diameter, pH, organic carbon content, cation exchange capacity, available nutrients such as N, P, K, and S, as well as DTPA extractable iron, zinc, copper, and manganese. Application of 100% NPK + FYM recorded highest grain yield in wheat (30.34 q ha^{-1}) which was at par with application of 100% NPK + lime (27.89 q ha^{-1}).

Gourav *et al.* (2019) observed that the combined application of 100% NPK + FYM resulted in the highest organic carbon, CEC, available N and K in silty loam soil at experimental farm of Department of Soil Science, CSK HPKV, Palampur. The available P was observed to be highest with the application of 150% NPK which was at par with 100% NPK + FYM. Combined application of 100% NPK + FYM recorded highest yield of maize and wheat, which was at par with 100% NPK + lime.

Kazamba *et al.* (2019) studied the effect of integrated nitrogen management on yield of potato (Local Cultivar, *Alu Amubi*) at Central Agricultural University, Imphal in rabi season and experiment consisted of seven treatments viz. T_1 (Control with no N applied), T_2 (100% RDN through urea), T_3 (75% RDN through urea + 25% through FYM), T_4 (75% RDN through urea + 25% through VC), T_5 (50% RDN through urea + 50% through FYM), T_6 (50% RDN through urea + 50% through VC) and T_7 (50% RDN through FYM + 50% through VC) in clay soil. Integration of 75% RDN through urea + 25% through FYM gave highest growth, tuber yield and net returns.

Bhatt *et al.* (2020) studied the effect of long-term application of balanced and imbalanced inorganic fertilizer and farm yard manure application on the chemical fraction of

DTPA-extractable micronutrients under rice–wheat cropping system after 29 years in Pantnagar and observed highest levels of DTPA-extractable zinc (Zn) in both the surface and sub-surface layers in rice and wheat when specific nutrient treatments were applied. In case of rice, the treatment N_{180}+P_{80}+K_{40}+Zn (Foliar) + FYM resulted in highest DTPA-extractable Zn (3.31 mg kg^{-1}) in surface layer and (1.62 mg kg^{-1}) in sub-surface layer. Similarly, for wheat, the treatment N_{180}+P_{80}+K_{40}+Zn (Foliar) showed highest DTPA-extractable Zn (2.96 mg kg^{-1}) in surface layer and 0.99 mg kg^{-1} in sub-surface layer. Application of N_{120}+P_{40}+K_{40}+FYM and N_{120}+P_{40}+K_{40} recorded highest DTPA-extractable Fe, Mn and Cu in rice and wheat, respectively. Highest grain yield in rice (6.74 t ha^{-1}) and wheat (3.50 t ha^{-1}) was achieved with application of (N_{180}+P_{80}+K_{40}+Zn (F) + FYM) and (N_{180}+P_{80}+K_{40}+Zn (Foliar)), respectively.

Keres *et al*. (2020) conducted a field experiment to compare the effect of organic and conventional management on the yield of field crops and soil properties at Estonian University of Life Sciences. The results showed that soil pH become more acidic (5.4-5.9) in conventional fertilizer treatments as compared to organic fertilizer treatments (5.9-6.3). The total yield of the crops was 24–25% higher in conventionally fertilised treatments than in organic treatments.

Mukhopadhyay *et al.* (2021) studied various soil physico-chemical properties under different treatments viz. T_1-farmers' practice, T_2-recommended dose N:P:K @ 200:150:150 kg/ha, 1st and 2nd top dressing with 1/3 N and 1/3 K, T_3-50% of T_2 + vermicompost @ 5 ton/ha, T_4-50% of T_2 + compost from waste decomposer @ 5ton/ha, T_5-50% of T_2 + novcom compost (@ 5ton/ha) and observed that the soil pH varied from 6.48 to 6.61, EC from 0.029 to 0.037 dSm^{-1}, organic carbon from 0.61 to 0.70 %, available nitrogen from 312.11 to 351.30 kg/ha, phosphorus from 55.41 to 63.83 kg/ha, potassium from 198.30 to 235.51 kg/ha and sulphur from 23.75 to 32.11 kg/ha. The best result was achieved through the treatment of 50% of the recommended inorganic fertilizer dose (N:P:K @ 200:150:150 kg/ha) in combination with 5 t ha^{-1} of vermi-compost.

Rana (2021) studied the traditional and conventional farming practices in legume based cropping systems under mid-hills of H.P. at Research Farm Holta of Department of Organic Agriculture and Natural farming, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur from kharif 2018 to rabi 2019-20. Result showed that organic farming increase soil microbiological properties while application of integrated farming practices in combination with mash-garlic cropping system recorded significant increase in available nitrogen, phosphorus, potassium, exchangeable calcium, magnesium and sulphur over the initial status and proved to be more economical and resulted in lowest cost of cultivation (₹ 81193 ha^{-1}), high gross returns (₹ 266493 ha^{-1}) and highest net returns per rupee invested (₹ 2.28 ha^{-1}).

Abreham *et al.* (2022) studied the combined effects of FYM and compost along with inorganic fertilizers on response of potato at Chena district, South-Western Ethiopia in clay loam soil. The experiment comprised of seven treatments viz: control, recommended NP (115 kg ha^{-1} N and 92 kg ha^{-1} P_2O_5), NPSB (115 kg ha^{-1} N + 92 kg ha^{-1} P_2O_5 + 6.5 kg ha^{-1} S. and 0.71 kg B ha^{-1}), 10 t FYM ha^{-1}, 10 t compost ha^{-1}, 5 t FYM + 50% NPSB (57.5 kg ha^{-1} N and 92 kg ha^{-1} P_2O_5), and 5 t compost + 50% NPSB ha^{-1}. Application of 5 t FYM ha^{-1} with 50% NPSB recorded maximum potato yield.

Lakra *et al.* (2022) investigated the influence of integrated nutrient management (INM) on biochemical properties of Inceptisol in Surguja district of Chhattisgarh, India during 2021-2022. Experiment comprised of seven treatments viz. T_1- control, T_2 -50% RDF, T_3-100% RDF, T_4 -150% RDF, T_5 -100% RDF + 5t/ha FYM, T_6 -50% RDF + 5t/ha FYM, and T_7 -50% RDF + 1.5t/ha. Soil organic carbon (5.69 g kg^{-1}) and available N (220.36 kg ha^{-1}) were recorded higher under treatment 100% RDF + 5t/ha FYM while, higher available phosphorus (45.81 kg ha^{-1}) and available potassium (245.42 kg ha^{-1}) in soil was recorded under 150% RDF followed by 100% RDF + 5 t/ha FYM.

Margus *et al.* (2022) studied the impact of farming system on potato yield and tuber quality in Northern Baltic Sea at Estonian University of Life Sciences in soil having sandy loam texture. Treatment comprised of three organic: Org 1 (control), Org 2 (organic crop rotation with winter cover crops) and Org 3 (organic crop rotation with winter cover crops + composted cattle manure) and four conventional: N0 (without fertilizers), N50 ($N_{50}P_{25}K_{95}$), N100 ($N_{100}P_{25}K_{95}$) and N_{150} ($N_{150}P_{25}K_{95}$) farming system. Conventional farming system recorded 25% higher yield as compared to organic farming.

Negi *et al.* (2022) conducted a field experiment to study the effect of organic and inorganic fertilizers on soil, yield and plant nutrient content in onion (*Allium cepa*) at Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during 2017–18 and 2018–19. Results revealed that maximum organic carbon (20.3%) were achieved with application of vermi-compost (on N equivalent basis of FYM) + RDF through FYM (on N equivalent basis). Application of RDF + FYM @ 250 q/ha gave highest available

N (386.0 kg/ha), P (156.6 kg/ha), K (384.1 kg/ha) in soil, dry matter yield in bulb (2805.38 kg/ha) and leaves (2068.89 kg/ha).

Zewide *et al.* (2022) conducted an experiment during 2019 onpotato variety “Belte” in Masha district, southwestern Ethiopia to evaluate the potato response to the vermicompost, mineral phosphorus, and nitrogen’s integrated applications in sandy-clay loam. The soil was acidic with pH (4.8) in Meher and pH (5.01) in the Belg season. They observed that combined application of 7.5 t vermi-compost per ha with 75% RDF or 50% RDF increased yield of potato production.

2.4 EFFECT OF ORGANIC AND INORGANIC SOURCES ON PLANT NUTRIENT STATUS

Ahmed *et al.* (2011) studied the effect of foliar application of active yeast extract and zinc on growth, yield and quality of potato in Egypt. Treatment included combinations of active yeast extract at 6 concentrations (0, 1, 2, 3, 4, and 5 g/l) and zinc at 4 concentrations (0, 100, 200, and 300 ppm) in the form of zinc chelates applied as foliar spray. Results revealed that application of yeast at the concentration of 5 g/l combined with application of zinc at the concentration of 300 ppm gave the highest values of vegetative growth characters, total tubers yield (ton/fed.), tubers quality i.e., specific gravity, starch %, protein % and dry matter % as well as N, K and Zn contents in the tubers and marketable tubers percentage. However, the tubers recorded the highest P content when treated with yeast extract (5 g/l) without any application of zinc treatment.

Kumar *et al.* (2011) conducted a field experiment at Shillong, Meghalaya to study the effect of integrated nutrient management on productivity, storage and quality of potato under rainfed condition and recorded maximum tuber yield (22.73 t/ha) and nutrient (NPK) uptake in tubers + haulms uptake (kg/ha) in treatment with application of 50% of NPK through inorganic sources and 50% RDN through PM (poultry manure).The treatment with 100% RDN through organic manures resulted in the maximum dry matter content (20.29%) and specific gravity (1.084) of the tubers.

Naz *et al.* (2011) studied the effect of different doses of NPK fertilizers on the proximate composition of potato crop at Abbottabad and recorded that decreasing the proportion of NPK fertilizers resulted in higher levels of fats and ash content, while increasing the NPK ratio led to an increase in protein, fibre and dry matter content.

Balemi (2012) conducted a field experiment to assess the effect of integrated use of cattle manure and inorganic fertilizers (Nitrogen, Phosphorus) on tuber yield of potato in Ethiopia. Treatments comprised of 4 levels of FYM (0, 10, 20 and 30 th^{-1}) and 3 level of NP fertilizers (0, 33.3%, 66.6% recommended rate). He recorded that the application of 20 or 30 tha^{-1} FYM + 66.6% inorganic NP fertilizers increased total tuber yield as compared to full dose of NP fertilizers without FYM in vertisol and in case of nitosol, application of 30 t ha^{-1} FYM + 66.6% of the recommended inorganic NP fertilizers improved total tuber yield as compared to full dose of inorganic NP fertilizers without FYM.

Rios *et al*. (2012) studied the distribution of calcium and magnesium in the leaves of Brassica rapa under varying exogenous Ca and Mg supply and observed significant increase in leaf calcium (Ca) and magnesium (Mg) content of *Brassica rapa* with Ca and Mg exogenous supply through fertilizers. The Leaf Ca and Mg concentrations were greatest in palisade and spongy mesophyll cells, respectively.

Islam *et al.* (2013) conducted a field experiment to study the effect of organic manure and chemical fertilizers on soil properties and potato yield. Results revealed that maximum NPK uptake, dry matter and tuber yieldwere achieved with the combined application of poultry manure (3 t/ha) and 100% recommended dose of fertilizers.

Tein *et al*. (2014) conducted a field experiment in Eerika to evaluated the effect of different farming systems on potato tuber and soil quality during 2009-2011. The results revealed that average yield, tuber N, NO_3^- and Mg content were significantly influenced by farming systems, year and their interaction. Fresh tuber yield were significantly higher under conventional systems in which nitrogen fertilisers were used as compared to organic farming system.

Ratna *et al.* (2016) studied the effect of integrated use of manure and fertilizer on the growth and yield of potato at Research Farm of Patuakhali Science and Technology University, Dumki, Patuakhali with two varieties of potato namely Diamant (V1) and Cardinal (V2). Treatments comprised of control (T_0), NPK (T_1), NPK + CW (cow-dung) (T_2), NPK + PM (poultry manure) (T_3) and CW (cow-dung) + PM (poultry manure) (T_4). Cultivars, organic-inorganic fertilizers and their combinations had a substantial impact on all the characters and the treatment NPK + PM showed highest dry weight, growth and yield of potato compared to other treatments.

Ahmed *et al.* (2017) conducted a field experiment at the research field tuber crop sub-station Munsigonj, Bangladesh to maximize the yield of potato (*Solanum tuberosum* L) through integrated nutrient management system. Experiment comprised of six treatments viz. T_1 (Control), T_2 (100% recommended Dose), T_3 (Poultry manure + Recommended chemical fertilizer), T_4 (Cow-dung manure + Recommended chemical fertilizer), T_5 (Poultry manure + 70% recommended chemical fertilizer) and T_6 (Cow-dung manure + 70% recommended chemical fertilizer). They observed highest tuber yield (36.48 t/ha) in treatment T_4 (Cow-dung manure + recommended chemical fertilizer) while highest dry matter (20.57%) was recorded in the treatment T_2 (100% Recommended Dose).

Gaur *et al.* (2017) conducted a field experiment at ICAR-CPRS, Gwalior M.P to determine the optimum phosphorus dose of potato through organic and inorganic sources. Results revealed that application of P_2O_5 (120 kg/ha) through fertilizer gavehighest NPK content in haulm, tuber along with achieving higher optimum physical and economical productivity, respectively.

Rajneesh *et al.* (2017) conducted a field experiment to study the long-term effect of fertilizers and amendments on NPK uptake by maize-wheat system at CSKHPAU, Palampur. The field experiment comprised of 11 treatments and three replications. Application of 100% NPK + FYM resulted in the highest total uptake of N (94.43 kg ha^{-1}), P (19.49 kg ha^{-1}) and K (61.88 kg ha^{-1}) in wheat, as well as N (170.96 kg ha^{-1}), P (27.17kg ha^{-1}) and K (90.00 kg ha^{-1}) in maize.

Barman *et al.* (2018) conducted a field experiment to study the effect of integrated nutrient management on growth and tuber yield of potato at Kumarganj, Faizabad (U.P.). Treatment viz. vermi-compost @ 2.5 t/ha + half NPK (150:100:120 kg/ha) through inorganic fertilizer recorded maximum number of haulms per plant, plant height and number of compound leaves.

Devi *et al.* (2018) studied the effect of integrated nutrient management (INM) on yield of cauliflower (*Brassica oleracea* var *botrytis*L.) and soil nutrient status in Nauni, Solan. Experiment comprised of nine treatments which included combined use of organic and inorganic fertilizers with PGPR strains (*Bacillus* spp.). Results revealed that major leaf nutrients i.e., N, P and K were recorded significantly higher when plants were treated with 75% RDF + 10 kg Vermicompost. Treatment with 80% NPKM +30% N through FYM and VC (50:50) recorded maximum curd weight (977.40 g) and yield (344.8 q ha^{-1}).

Mohammed (2018) evaluated the effect of integrated nutrient management on potato (*Solanum tuberosum* L.) growth, yield and yield components in Eastern Ethiopia. Application of farmyard manure, along with nitrogen and phosphorus, at the rates of 10 tons of FYM per hectare and 111 kg of nitrogen per hectare, combined with 92 kg of P_2O_5 per hectare, resulted in the highest marketable tuber yields of 38.65 tons per hectare and tuber dry matter yield of (4.15 t/ha).

Selvamani and Duraisami (2018) conducted a study to evaluate the yield relationship of leaf nutrient status in two major coconut growing districts (Coimbatore and Tiruppur) of Tamil Nadu. The primary yield limiting nutrients observed in the study area for coconut are N, Mg, K, B and P. It also improve and maintain the soil fertility and coconut productivity

Shubha *et al.* (2018) conducted a field experiment at department of vegetable science in College of Horticulture, Mudigere. The experiment consisted of 14 set of treatments with three replications. T_1 - control (RDF:125:100:125 Kg/ha + FYM 25 t/ha), T_2 - 75 % RDF + Vermicompost (2.5 t/ha), T_3 - 75 % RDF + Vermicompost + *Azotobacter*, T_4 - 100 % RDF + Azotobacter, T_5 - 75 % N + RD of P and K + *Azotobacter*, T_6 -100 % RDF +PSB, T_7 - 75 % P+ RD of N and K + PSB, T_8 - 100 % RDF +KSB, T_9 - 75% K + RD of N and P + KSB, T_{10} - 50% RDF + VC + *Azotobacter* + PSB +KSB, T_{11} - T_{10} + $MgSO_4$ + micronutrient mixture, T_{12} - 75% RDF + *Azotobacter* + PSB + KSB, T_{13} - T_{12} + $MgSO_4$ + micronutrient mixture, T_{14} - RDF + $MgSO_4$ + micronutrient mixture. Application of *Azotobacter* + PSB + KSB + $MgSO_4$ + micro nutrient mixture + 75 % RDF (T_{13}) recorded maximum plant height (59.33 cm), number of leaves (298), yield (21.5 t/ha), starch (18.47%) and leaf tissue nitrogen (1.85%), leaf tissue phosphorous (1.36%), leaf tissue potassium (2.83%) as compared to application of recommended dose of NPK fertilizers in potato.

Gourav *et al.* (2019) studied the effect of fertilizers and amendments on uptake of primary nutrients and sulphur in maize and wheat rotation in North Western Himalayas. Results revealed that maximum NPK and S uptake were achieved with combined application of 100% recommended dose of NPK + FYM whilelowest value of nutrient uptake was recorded in control.

Lenka and Das (2019) evaluated the effect of boron and zinc application on nutrient uptake by potato plants and found that the application of RDF (N, P, K @ 200, 150, 150 kg/ha) in combination with foliar application of 0.1% boric acid and 0.1% zinc sulphate resulted in the highest uptake of nitrogen (N), phosphorus (P), potassium (K), boron (B)and zinc (Zn) by potato plants which stimulated growth and increased the total yield of potato tubers.

Shunka *et al.* (2019) conducted a field experiment to study the effect of fertilizer sources on potato yield and yield components under acidic soil conditions in central high lands of Ethiopia. Fertilizer source treatments were control, recommended Urea (165 kg/ha) and DAP (195 kg/ha), recommended Urea (165 kg/ha) and DAP (195 kg/ha) + 225 kg/ha potassium sulfate (K_2SO_4), recommended Urea (165 kg/ha) and DAP (195 kg/ha) + 225 kg/ha potassium chloride (KCl) and 242 kg/ha blended mineral fertilizer NPSB with N=18.9%, P=37.7%, S=6.95%, B=0.1% content + 141 kg/ha urea under both limed and unlimed soil conditions. They concluded that the growing location and fertilizer sources had significant effect on the yield and yield component of potato both under limed and unlimed soil conditions.

Zaeen *et al.* (2020) studied the response of different potato cultivars under a series of N rates. Six rates of N fertilization (0–280 kg ha^{-1}) were applied with four replications. The results revealed that soil with an organic matter content of ≥30 g kg^{-1} produced significantly higher total tuber yield (39.5%), marketable yield (45.2%) and tuber weight per plant (54.9%), respectively as compared to sites with an OM content of ≤30 g kg^{-1}. Applying 168 and 112 kg N ha^{-1} to sites with organic matter content of ≤30 g kg^{-1} and ≥30 g kg^{-1}, respectively, resulted in an increase in marketable specific gravity, starch and dry matter content.

Yadav *et al.* (2020) studied the nitrogen requirement of potato for Eastern Indo-Gangetic Plain of India during 2015-16 and 2016-17 at ICAR-Central Potato Research Station, Patna, Biharand observed that highest plant height was recorded with application of nitrogen level of 300 kg/ha. However, potato's total and marketable tuber yield showed a significant increase with the increasing level of nitrogen up to 150 kg/ha.

Yadav *et al.* (2020) conducted a field experiment during 2013-14 to 2016-17 at Patna, Bihar in sandy clay loam soil. Treatments comprised of 50% recommended dose of fertilizer (RDF) of NPK; 100% RDF of NPK; 150% RDF of NPK; Without N fertilizer (PK); Without P(NK); Without K (NP) and Without NPK (control) and observed maximum plant height, yield of medium, large and very large size tuber under 150% RDF of NPK.

Yadav *et al.* (2021) conducted a field experiment to evaluate the response of zinc on potato tuber yield at Central potato Research Station, Patna, Bihar in sandy loam soil. Recommended dose of fertilizers for potato were taken as 150, 60 and 80 kg/ha. Different doses of zinc (0, 1.5, 3.0, 4.5 and 6.0 kg/ha) were applied in the field through zinc sulphate. Results revealed that combined application of RDF of NPK + 6.0 kg Zn/ha recorded highest dry matter in tuber (7.20 t/ha) and haulm (3.78 t/ha). The zinc application of 6.0 kg/ha led to an increase in potato marketable tuber yield of about 18.1% as compared to control (without zinc application).

Choudhary *et al.* (2022) studied the effect of natural farming on yield performance, soil health and nutrient uptake in wheat + gram inter cropping system at Zero Budget Natural Farm (ZBNF), Holta, Department of Organic Agriculture and Natural Farming, CSKHPKV, Palampur. The experiment consisted of 8 treatments and three replications. The results showed that the application of ghanjeevamrit + jeevamrit + mulching in wheat produced significantly highest total uptake of nitrogen (49.55 kg ha^{-1}), phosphorus (10.23 kg ha^{-1}) and potassium (52.35 kg ha^{-1}) and also produced significantly higher total uptake of nitrogen (33.41 kg ha^{-1}), phosphorus (4.02 kg ha^{-1}) and potassium (15.96 kg ha^{-1}) in Gram.

Negi *et al.* (2022) studied the effect of organic and inorganic fertilizers on soil, yield and plant nutrient content in onion (*Allium cepa*) in Nauni, Himachal Pradesh. Result revealed that application of RDF + FYM @ 250 q/ha gave highest N (2.65%), P (0.35%) and K (1.85%) content in bulb and N (2.54%), P (0.35%) and K (1.71%) content in leaves of onion.

Neogi and Das (2022) conducted a field experiment to analyzed the effect of nitrogen and zinc application when applied in nano form fertilizers on the growth and productivity of potato in inceptisols during rabi seasons of 2019-20 and 2020-21 at Nadia, West Bengal. Result showed that application of nano fertilizers significantly improved the leaf area index, plant height and dry matter production of potato. The highest total tuber yield (34.15 t ha^{-1}) was recorded in the treatment consist of 100% RDF of NPK + Foliar application of Nano Nitrogen + Nano Zinc.

Sharma *et al.* (2022) examined the effect of organic and inorganic fertilization on NPK contents, their uptake and economics of cauliflower during 2019-20 and 2020-21 at Dr. YS Parmar University of Horticulture and Forestry, Solan. Experiment comprised of 9 treatments viz. T_1 (control), T_2 (100% FYM N equivalent basis), T_3 (100% N), T_4 (100% NP), T_5 (100% NK), T_6 (100% PK), T_7 (100% NPK), T_8 (100% NPK + FYM) and T_9 (150% NPK + FYM). Application of 150% NPK + FYM recorded highest leaf (3.36, 0.63 and

2.01%), curd (4.18, 0.76 and 3.95%) and root (1.34, 0.45 and 3.68%) NPK contents, as well as their uptake (207.2, 37.6 and 163.6 kg ha^{-1}), respectively.

Yadav *et al.* (2022) studied the effect of nitrogen levels on growth and yield of two potato cultivars Kufri Surya and Kufri Sadabahar at CCS Haryana Agricultural University, Hisar. Application of 225 kg/ha of nitrogen recorded maximum values for yield parameters, dry matter content (tubers + haulms), productivity, net income and benefit to cost ratio in Kufri Sadabahar.

2.5 EFFECT OF ORGANIC AND INORGANIC SOURCES ON SOIL MICROBIOLOGICAL PROPERTIES

Kannan *et al.* (2005) conducted a field experiment in Agricultural College and Research Institute, Madurai to study the influence of different organic N sources viz, FYM, Vermicompost and coir pith compost with bioferilizers on the soil physical properties, nutrient availability and biological properties. They observed that application of 75 per cent N as vermicompost with *Azospirillum* recorded maximum bacterial population (393 cfu g^{-1}) as well as fungal population (28 cfu g^{-1}).

Liu *et al.* (2007) evaluated the impact of organic, sustainable, and conventional management strategies in grower fields on soil physical, chemical, and biological factors including soil microbial species and functional diversity and their effect on the Basidiomycete plant pathogen *Sclerotium rolfsii*, causal agent of Southern blight. They observed that soils from organic farms had improved soil chemical factors and higher levels of extractable C and N, higher microbial biomass carbon and nitrogen, and net mineralizable N. Populations of fungi and thermophiles were significantly higher in soils from organic and sustainable than conventional fields.

Melero *et al.* (2008) evaluated the effect of organic fertilizers on irrigated loam soil chemical and biochemical properties in Guadalquivir River Valley (southwest Spain) and observed that microbial biomass carbon, microbial biomass nitrogen and enzymatic activity were higher in organically fertilized soils (vegetal and animal compost @ 30 t ha^{-1}) than in conventionally fertilized soils. However, total organic carbon and nutrient content were correlated ($P < 0.001$) with microbial biomass and enzymatic activities.

Araujo *et al.* (2009) studied soil microbial activity in organic and conventional farming system. Compared to the conventional agricultural system, the soil under organic agricultural systems exhibited higher microbial activity, biomass and lower bulk density.

The decrease in soil bulk densities and increase in soil microbial activity resulting from organic farming practices can be attributed to the higher inputs of organic matter, which served as an energetic substrate for existing microbial communities. This stimulation of microbial activity allowed for the efficient turnover of applied nutrients, resulting in improved soil health and fertility.

Jannoura *et al.* (2014) studied organic fertilizer effects on growth, crop yield, and soil microbial biomass indices in sole and intercropped peas and oats under organic farming conditions at the experimental farm of the University of Kassel, Franken hausen in northern Hessia. Application of organic fertilizers resulted in an increase in the levels of microbial biomass carbon (C), nitrogen (N), phosphorus (P), and fungal ergosterol in the soil, as well as increase in CO_2 production. Result revealed that horse manure was more readily available to soil microorganisms than compost, leading to increased grain yields.

Aher *et al.* (2015) studied the effect of organic farming practices on soil health and crop performance of Soybean (*Glycine max*) at the research farm of Indian Institute of Soil Science (IISS), Bhopal and observed that soil enzyme activities viz., dehydrogenase (DHA) (98.20µg TPF g^{-1} day^{-1}) and alkaline phosphatase (178.2 µg $PNPg^{-1}$ 2 hr^{-1}) were found significantly higher in the plot managed organically with the application of cattle dung manure on nitrogen (N) equivalent basis followed by integrated and chemical practices.

Chu *et al.* (2016) examined the long-term fertilization, tillage and crop rotation effects on the activities of soil enzymes. They observed that pH, organic matter, and cation exchange capacity were important factors that were associated with enzymatic activities. Compared to conventional tillage, no-tillage treatment significantly increased activities of phenol oxidase, peroxidase, dehydrogenase, and β-glucosaminidase. Fertilization increased cellulase and β-glucosaminidase activity, but had mixed effects for phenol oxidase, peroxidase, and dehydrogenase depending on the type of fertilizer applied. The amount of nitrogen applied significantly affected soil enzymatic activities.

Lori *et al.* (2017) observed that organic farming systems exhibited 32% to 84% higher levels of microbial biomass carbon, microbial biomass nitrogen, total phospholipid fatty acids, and enzyme activities such as dehydrogenase, urease, and protease, compared to conventional farming systems. Organic farming increased total microbial population and activity in agricultural soils.

Marinkovic *et al.* (2018) investigated the impact of soil management practices on microbial properties in five different locations in Central Serbia. The soil samples were collected from abandoned soils, organic and conventional farming system and concluded that soil pH was found to be the primary factor affecting the number and activity of microorganisms in the sampled plots. The acidic soil reaction was found to promote faster fungal growth while reducing the presence of actinomycetes and *Azotobactersp*. However, the abandoned soils and soils under organic systems showed significantly higher dehydrogenase activity compared to conventional farming practices.

Ouyang *et al.* (2018) studied soil enzymatic activities and abundance of microbial functional genes involved in nitrogen transformations in organic farming system at the Greenville Research Farm in North Logan, Utah and observed that soil enzymatic activities were increased by both compost and manure treatments. The abundance of functional genes was significantly correlated with corresponding enzyme activity.

Dhiman *et al.* (2019) examined the effect of regular use of fertilizers, FYM and lime on microbiological properties of soil at Himachal Pradesh Agricultural University, Palampur and observed highest soil microbial biomass carbon (683 and 628 mg kg^{-1}), microbial biomass nitrogen (25.0 and 18.3 mg kg^{-1}) and dehydrogenase activity (44.1 and 39.6 mg TPF g^{-1} soil 24 h^{-1}) in surface and sub-surface layer, respectively with application of 100% NPK + FYM compared to other treatments.

Barakzai *et al.* (2021) studied the effect of zero budget natural farming and conventional farming systems on biological properties of soil at Experimental Farm of Entomology, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. Cauliflower (PSBK-1) was raised in conventional farming with recommended doses of fertilizers, viz. urea (300 kg), SSP (675 kg) and MOP (85 kg) andbeejamrit, jeevamrit and ghanjeevamrit in ZBNF. The population of bacteria, fungi, and actinomycetes increased by 11.36, 2.04, and 8.72 per cent in 2018-19, and by 23.69, 12.04, and 24.83 percent in 2019-20, respectively, under ZBNF compared to 8.23, 2.44, and 3.34 percent in 2018-19, and 12.87, 2.13, and 8.87 percent in 2019-20, respectively, under conventional farming.

Choudhary *et al.* (2022) conducted a field experiment to study the effect of natural farming on yield performance, soil health and nutrient uptake in wheat + gram inter-cropping system under SPNF at CSKHPKV, Palampur, HP. Experiment consisted of 8 treatments with three replications and found that the ghanjeevamrit + jeevamrit + mulching produced significantly highest viable microbial count i,e. bacterial (28.3 10^6 cfu g^{-1} soil), actinomycetes (22.0 10^5 cfu g^{-1} soil), fungi (8.5 10^3 cfu g^{-1} soil), dehydrogenase activity (4.81 µg TPF g^{-1} soil hr^{-1}) and highest seed yield in wheat (1767.3 kg ha^{-1}) and gram (734.1 kg ha^{-1}).

Lakra *et al.* (2022) studied the effect of integrated nutrient management (INM) on biochemical properties of Inceptisol in Surguja district of Chhattisgarh, India during 2021-2022. They observed significantly highest activity of soil enzyme viz. dehydrogenase (48.34 µg TPF 24 hr^{-1} g^{-1}), urease (40.07 µg $NH4^{+}$- N g^{-1} soil h^{-1}), acid phosphatase (72.93 µg p-nitrophenol g^{-1} hr^{-1}) and alkaline phosphatase (45.14 µg p-nitrophenol g^{-1} hr^{-1}) under combined application of 100% RDF + 5t/ha FYM.

Duddigan *et al.* (2023) compared ZBNF (cow dung and urine with mulch) to conventional (synthetic fertilisers and pesticides) and organic (farmyard manure and vermi-compost) treatments, all with no tillage in Andhra Pradesh. Experiment consisted of three treatments with three replications. They recorded significantly higher yield in ZBNF than organic or conventional treatment. Due to mulching, cooler soil temperature, high moisture content and a large earthworm population yielded benefits in ZBNF.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled "**Nutritional Status of Potato (*Solanum tuberosum* L.) in Lahaul valley of Himachal Pradesh**'' was carried out by collecting soil and plant samples to get information on the available nutrients and plant nutrient contents. The details of material used and methodology employed is presented in this chapter under the following heads:

3.1 General description of study area

3.2 Soil and plant Sampling

3.3 Preparation of soil and plant samples

3.4 Soil analysis

3.5 Plant analysis

3.6 Interpretation of data

3.7 Benefit cost ratio

3.8 Statistical analysis

3.1 GENERAL DESCRIPTION OF STUDY AREA

Lahaul & Spiti district is located between the longitudes 76°46′29" and 78°41′34" East and latitude 31°44′57" and 32°59′57" North and altitude ranging from 5,480 m to 6,400 m above mean sea level. The total geographical area of Lahaul and Spiti district of Himachal Pradesh is 9,11,195 hectare in which geographical area of Lahaul is 2,01,084 hectare.

Climate and rainfall

Agroclimatically, Lahaul and Spiti represents the dry temperate zone of Himachal Pradesh with severe winters and mild summers. The annual rainfall of this zone is very low (about 250 mm) and temperature (-13°C to 26.8°C) also remains low throughout the year.

3.2 SOIL AND PLANT SAMPLING

Initial soil samples were taken from 30 representative sites (15 each from potato growing areas under natural farming & conventional farming from 0-15 cm depth) during the month of June-July and final soil and tuber samples were taken after harvesting of crop during the month of September-October. All the samples were collected using standard procedure.

The leaf samples were taken in the month of August. The potato leaf samples (30-50 leaves from each sites) were also collected. The leaf samples from most recent fully developed leaf of the plant (prior to or during early bloom) were collected as per the recommendations of Tandon (1993) and Jones *et al*. (1971).

3.3 PREPARATION OF SOIL AND PLANT SAMPLES

The soil samples were passed through a 2.0 mm sieve after air-drying and stored in plastic containers. The leaf samples were washed with ordinary water and then with 0.1 N HCl followed by washing with distilled water. They were dried in an oven at 60 ± 5 °C for 72 hours. The dried samples were ground in a steel grinder to facilitate proper mixing of plant material and stored in paper bags for further analysis as per method outlined by Chapman (1964).

Digestion of leaf sample was followed as per the method given by Piper (1966). One gram of leaf sample was taken for digestion in di-acid (HNO_3 and $HClO_4$ in 4:1 ratio v/v) for determination of phosphorus and potassium. However, for nitrogen estimation one gram leaf sample was digested using concentrated H_2SO_4 and digestion mixture as per the method outlined by Jackson (1973).

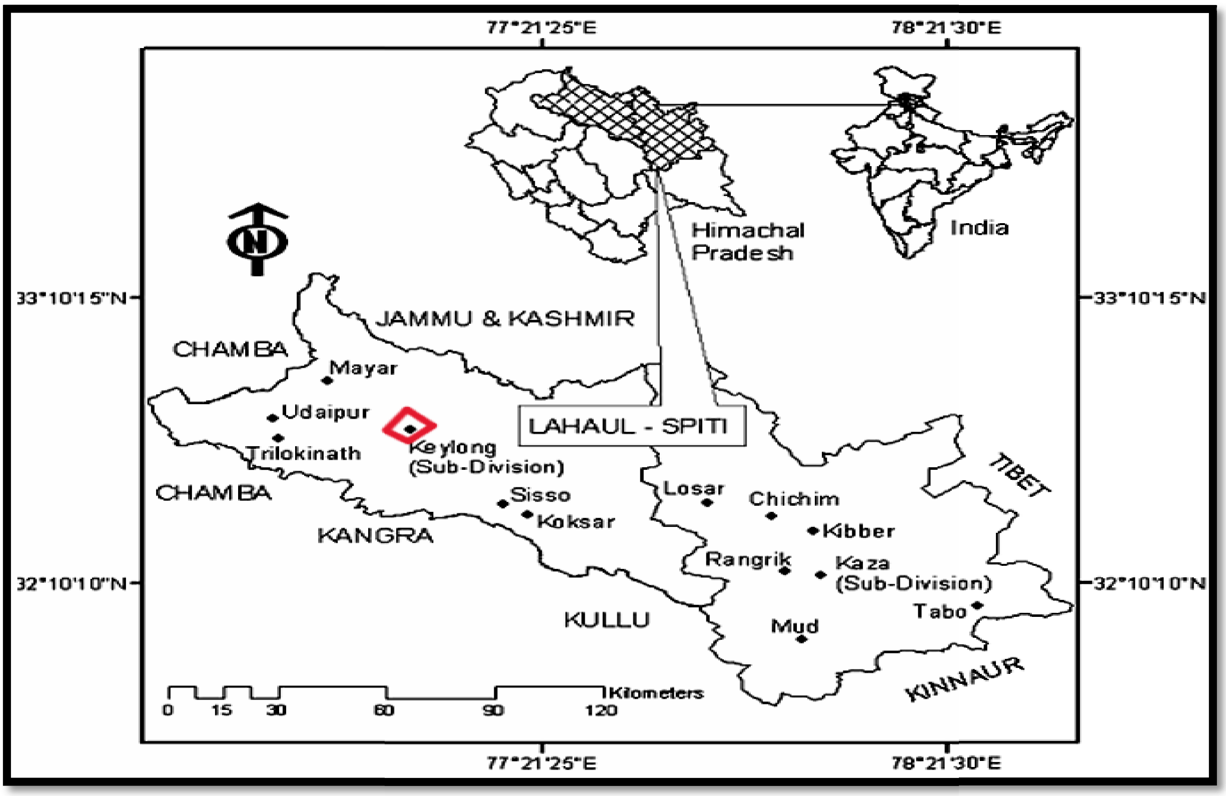
3.3.1 MATERIALS USED BY FARMERS UNDER DIFFERENT FARMING SYSTEM

3.3.1.1 Materials used by farmers under conventional farming system

Under conventional farming practices farmers used FYM (131.25 q ha^{-1}), urea (312.5 kg ha^{-1}) and NPK mixture (86.93 kg ha^{-1}) fertilizers.

3.3.1.2 Materials used by farmers under natural farming system

Under natural farming practices the farmers used jeevamrut (500 litre ha^{-1}), ghanjeevamrit (500 kg ha^{-1}), jaggery (3.12 kg ha^{-1}), pulse flour (4.37 kg ha^{-1}), cow dung (25 kg ha^{-1}) and cow urine (25 litre ha^{-1}).



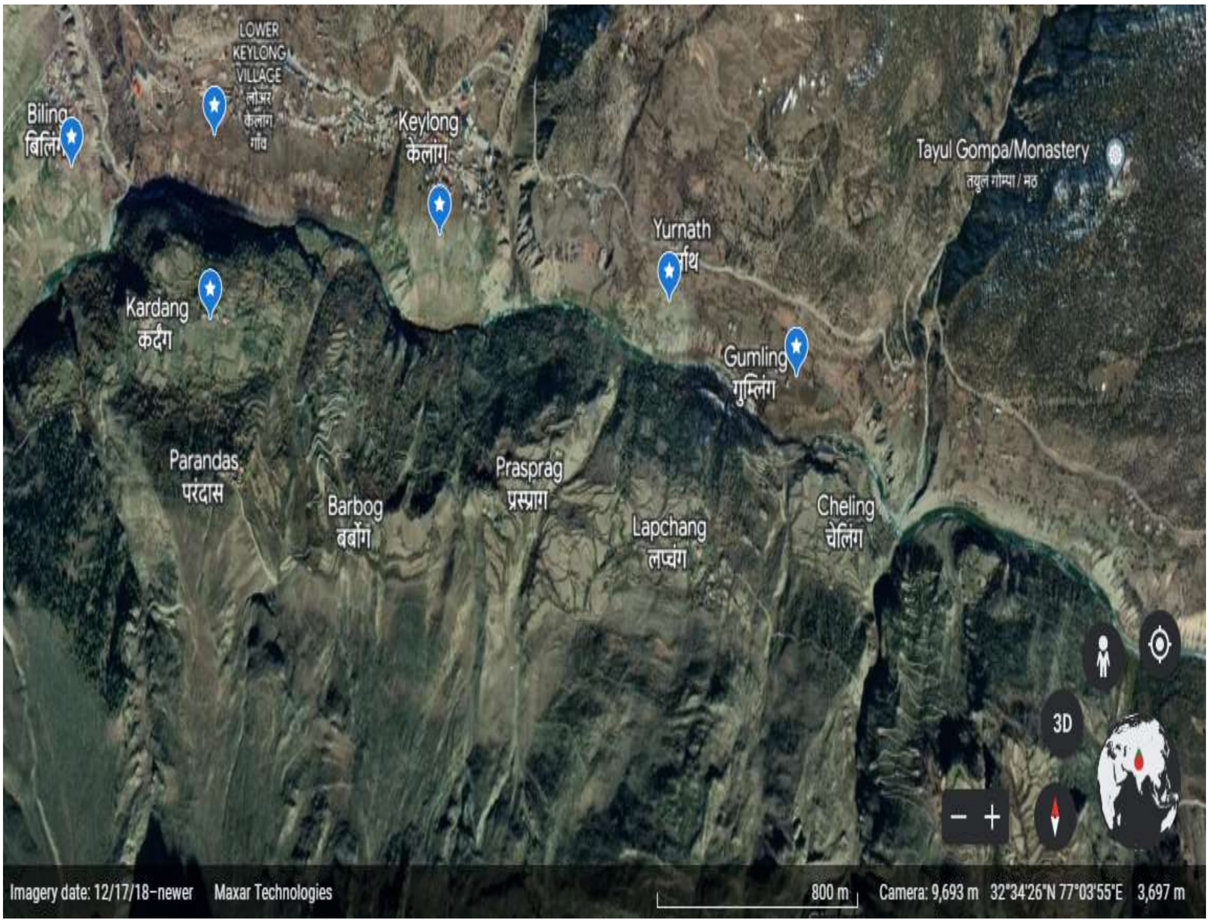


Fig. 1 Map of the study area

Table 3.4 Physical and chemical properties of soil in conventional farming system before planting of crop

Panchayats	Farmer	pH	EC (dS m^{-1})	OC (g/kg)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca [cmol (p+) kg^{-1}]	Mg [cmol (p^{+})kg^{-1}]	S (kg ha^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})
Keylong	F_1	7.46	0.29	8.20	251.53	58.73	220.76	6.62	1.28	19.06	2.43	36.82	2.25	7.86
	F_2	6.32	0.19	6.40	314.34	62.11	255.20	8.61	2.72	26.43	2.96	35.33	2.30	8.73
	F_3	6.57	0.24	10.01	325.83	70.31	224.96	15.05	3.17	28.11	1.86	35.32	2.05	9.62
	F_4	6.96	0.36	7.60	266.61	60.84	242.40	6.84	1.50	26.42	2.72	32.73	2.09	10.20
	F_5	6.49	0.28	10.70	274.81	58.64	238.62	6.94	1.82	33.01	2.98	38.62	1.75	10.41
Kardang	F_6	7.65	0.32	8.90	283.57	57.04	205.81	8.36	2.67	23.68	2.03	33.92	2.66	9.73
	F_7	7.54	0.29	8.40	326.72	74.78	234.04	11.93	3.21	29.37	2.24	36.01	1.76	9.04
	F_8	7.28	0.27	8.50	296.62	58.09	319.03	8.32	2.61	21.26	2.15	31.82	1.80	10.83
	F_9	7.19	0.28	9.40	181.82	42.74	219.67	4.77	1.26	27.51	2.77	39.35	2.69	10.72
	F_{10}	7.28	0.36	10.80	328.37	71.82	272.94	12.93	3.26	35.76	2.27	39.65	2.38	8.64
Yurnath	F_{11}	6.36	0.38	7.90	236.44	49.74	223.47	5.04	1.39	29.46	1.92	38.79	2.85	12.64
	F_{12}	7.21	0.26	8.70	274.61	44.46	212.48	7.43	2.28	26.25	2.03	30.67	2.46	9.05
	F_{13}	6.57	0.33	8.60	316.00	63.02	267.24	9.36	2.86	21.62	2.09	35.08	2.92	7.97
	F_{14}	6.93	0.18	8.70	222.21	51.88	193.08	5.64	1.29	31.03	2.08	32.34	2.12	8.70
	F_{15}	5.95	0.19	7.90	271.75	61.76	206.69	8.03	1.93	25.26	2.64	37.83	2.01	9.11
Range		5.95-7.65	0.18-0.38	6.40-10.80	181.82-328.37	42.74-74.78	193.08-319.03	4.77-15.05	1.26-3.26	19.06-35.76	1.86-2.98	30.67-39.65	1.75-2.92	7.86-12.64
Mean		6.92	0.28	8.71	278.08	59.06	235.76	8.39	2.22	26.95	2.34	35.62	2.27	9.55

Table 3.4.1 Physical and chemical properties of soil in natural farming system before planting of crop

	Farmer	pH	EC (dS m^{-1})	OC (g/kg)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca [cmol (p+) kg^{-1}]	Mg [cmol (p^{+})kg^{-1}]	S (kg ha^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})
Keylong	F_1	6.95	0.27	9.90	248.13	52.43	206.01	6.39	1.67	21.72	2.04	33.91	2.44	6.31
	F_2	6.41	0.18	13.60	292.16	58.61	233.05	9.07	2.50	25.51	2.61	34.72	1.97	9.05
	F_3	7.65	0.21	11.30	311.12	64.72	212.71	12.32	3.02	27.52	1.98	33.89	1.66	7.37
	F_4	7.28	0.36	9.80	269.21	55.71	209.15	6.43	1.65	24.82	2.77	31.72	1.85	8.77
	F_5	6.51	0.27	12.70	266.75	52.94	210.78	5.92	1.32	29.02	3.07	37.04	1.78	9.50
Kardang	F_6	7.62	0.29	9.80	276.41	51.68	207.94	7.07	2.37	21.04	2.18	29.27	2.79	9.46
	F_7	7.71	0.28	9.70	317.11	66.31	200.05	15.16	3.07	27.74	2.16	33.76	1.12	7.73
	F_8	7.45	0.26	10.40	287.43	52.07	297.04	7.34	2.31	18.34	1.93	30.07	1.14	11.72
	F_9	7.34	0.27	8.70	173.32	37.33	202.72	5.37	1.06	25.55	2.50	41.06	2.44	11.03
	F_{10}	7.49	0.34	12.90	326.21	69.15	310.61	14.83	3.10	30.06	2.56	41.81	2.14	6.72
Yurnath	F_{11}	6.28	0.42	7.30	223.10	43.32	209.62	3.94	1.26	28.45	1.87	36.27	2.92	8.21
	F_{12}	6.60	0.25	8.60	270.76	39.18	190.04	6.32	2.11	23.03	2.15	29.77	2.31	7.26
	F_{13}	7.17	0.31	12.20	302.72	59.83	277.3	8.30	2.41	19.05	1.97	34.84	2.79	8.91
	F_{14}	6.12	0.16	9.50	215.36	47.00	186.76	5.78	1.17	26.03	1.82	31.17	2.69	6.98
	F_{15}	7.04	0.18	9.30	253.42	56.85	194.64	4.08	1.01	23.92	2.50	35.02	1.60	7.58
Range		6.12-7.71	0.16-0.42	7.30-13.60	173.32-326.21	37.33-69.15	186.76-310.61	3.94-15.16	1.01-3.10	18.34-30.06	1.82-3.07	29.27-41.81	1.12-2.92	6.31-11.72
Mean		7.04	0.27	10.38	268.88	53.81	223.23	7.89	2.00	24.79	2.27	34.29	2.11	8.44

Plate.1 Collection of samples

3.4 SOIL ANALYSIS

3.4.1 Soil texture

The soil texture was determined by hydrometer method and it refers to the relative proportion of sand, silt and clay (%) in a given soil sample (Bouyoucos, 1927). The textural class for respective sample was determined by using textural triangle as suggested by ISSS.

3.4.2 Soil pH and electrical conductivity (EC)

The soil pH was determined in 1:2 soil:water suspension and the EC of the supernatant solution was recorded by following the procedure outlined by Jackson (1973).

3.4.3 Organic carbon (OC)

Organic carbon was determined using rapid titration method as outlined by Walkley and Black (1934).

3.4.4 Cation exchange capacity

Cation exchange capacity was determined using ammonium acetate as outlined by Chapman (1965).

3.4.5 Available macronutrient elements

Available nitrogen was determined by alkaline potassium permanganate method of Subbiah and Asija (1956). Available phosphorus was extracted by using 0.5 M $NaHCO_3$ extractantat pH 8.5 (Olsen *et al*., 1954) and determined by $SnCl_2$ reduced ammonium molybdate blue color method (Jackson, 1973). Available potassium was extracted by neutral normal ammonium acetate (Merwin and Peech, 1951) and determined by flame photometer. Exchangeable calcium and magnesium in the neutral normal ammonium acetate extract were determined by atomic absorption spectrophotometer (Jackson, 1967). Available sulphur was extracted by morgan's reagent and determined by turbidity method (0.15% $CaCl_2$) of Chesnin and Yien (1950).

3.4.6 DTPA-extractable cations

The available Fe, Mn, Cu and Zn contents in the soil were extracted using DTPA extractant at pH 7.3 (Lindsay and Norvell, 1978) and determined on Atomic Absorption Spectrophotometer (AAS).

3.4.7 Soil nutrient indices

Soil nutrient indices (SNI) were worked out to depict the available status of each macro and micronutrient by using the following formula proposed by Parker *et al.* (1951) as mentioned below:

$$SNI = \frac{(NL\times1) + (NM\times2) + (NH\times3)}{NT}$$

Where,

NL	=	number of samples falling in low category of nutrient status
NM	=	number of samples falling in medium category of nutrient status
NH	=	number of samples falling in high category of nutrient status
NT	=	total number of samples analyzed fora given nutrient

3.4.8 Microbiological properties

i) Viable Microbial Count

The soil microbial counts were recorded by using the serial dilution standard spread plate technique as described by Subbarao (1999) on nutrient agar (NA) medium, potato dextrose agar medium and kenknight and munaier's medium. The population was expressed as colony forming units per gram of soil (cfu g^{-1} soil).

a) COMPOSITION OF NUTRIENT AGAR MEDIUM

Peptone	:	5g
NaCl	:	5g
Beef extract	:	3g
Agar-agar	:	1.5-2%
Water pH	:	6.8 ± 0.2

b) COMPOSITION OF POTATO DEXTROSE AGAR:

Potatoes, peeled and diced	:	200g
D-Glucose	:	20g
Agar	:	15g
Distilled Water	:	1000 ml

c) COMPOSITION OF KENKNIGHT AND MUNAIER'S MEDIUM:

Dextrose	:	1.00g
KH_2PO_4	:	0.10g
$NaNO_3$	:	0.10g
KCl	:	0.10g
$MgSO_4.7H_2O$	:	0.10g
Agar	:	15.00g
Distilled Water	:	1000ml

3.5 PLANT ANALYSIS

Separate digestion was carried out for nitrogen estimation using concentrated H_2SO_4 and digestion mixture and determined by micro-kjeldhal method as outlined in A.O.A.C. (1970). The prepared leaf and tuber samples were digested in a mixture of di-acids HNO_3:$HClO_4$ (4: 1) for P, K, S, Fe, Cu, Zn and Mn (Jackson, 1973). Phosphorus in the digest was determined by vanado-molybdate yellow colour method (Jackson, 1973). Potassium and calcium in the digest were determined on flame photometer (Jackson, 1967). Magnesium in the digest was determined on atomic absorption spectrophotometer. Sulphur was determined by turbidimetric method outlined by Chesnin and Yien (1950). Micro-nutrient cations (Fe, Mn, Cu and Zn) were determined on atomic absorption spectrophotometer (Vogel, 1978).

3.6 INTERPRETATION OF DATA

The results of soil analysis were interpreted using the critical limits given in the Table 3.6.1, 3.6.2, 3.6.3 and 3.6.4 and plant analysis results were interpreted using Table 3.6.5.

A SNI value <1.67, 1.67-2.33 and >2.33 indicate low, medium and high nutrient status of soils, respectively (Ramamoorthy and Bajaj, 1969).

Table 3.6.1 Critical limits used for interpretation of soil pH

pH range	Denominations
4.0-4.5	Extremely acidic
4.6-5.0	Very strongly acidic
5.1-5.5	Strongly acidic
5.6-6.0	Moderately acidic
6.1-6.5	Slightly acidic
6.6-7.3	Neutral
7.4-7.8	Slightly alkaline

Table 3.6.2 Critical limits used for interpretation of electrical conductivity

EC (dS m^{-1})	Soil category	Reference
Below0.8	Normal-suitable for all crops	Jackson (1973)
0.8-1.6	Critical for salt-sensitive crops	
1.6-2.5	Critical for salt-tolerant crops	
Above2.5	Injurious to all crops	

Table 3.6.3 Critical limits used for interpretation of chemical properties of the soil

Sr. No.	Nutrient element	Soil fertility class			References
		Low	Medium	High	
1.	Organic carbon (g/kg)	<5.0	5.0-15.0	>15.0	Bhandari and Tripathi (1979)
2.	Available N (kg ha^{-1})	< 280.0	280.0-560.0	>560.0	FAI (1977)
3.	Available P (kg ha^{-1})	< 10.0	10.0-24.6	>24.6	FAI (1977)
4.	Available K (kg ha^{-1})	< 108.0	108.0-280.0	> 280.0	Tandon (2009)
Secondary macronutrients					
			Deficient	**Sufficient**	
1.	Exchangeable Ca [cmol (p^+) kg^{-1}]		<1.5	>1.5	Tandon (1989)
2.	Exchangeable Mg [cmol (p^+) kg^{-1}]		<1.0	>1.0	Tandon (1989)
3.	Available S (kg ha^{-1})		<22.4	>22.4	Tandon (1991)

Table 3.6.4 Critical limit for available micronutrients (Lindsay and Norvell, 1978)

Availability	Micronutrients (mg kg^{-1})			
	Zn	Cu	Fe	Mn
Low	0.5-1.0	0.1-0.3	2.0-4.0	0.5-1.2
Medium	1.0-3.0	0.3-0.8	4.0-6.0	1.2-3.5
High	3.0-5.0	0.8-3.0	6.0-10.0	3.5-6.0
Very High	<5	>3.0	>10.0	>6.0

Table 3.6.5 Critical limits of nutrients for Potato leaves samples

Sr.No.	Nutrientelement	Concentration			References
		Deficient	Sufficient	High	
	Macronutrient (%)				Tandon (1993)
1.	N	3.0-3.29	3.30-4.5	>4.5	
2.	P	0.20-0.22	0.23-0.5	> 0.5	
3.	K	0.28-3.0	3.10-4.5	>4.5	
4.	Ca	0.50-0.69	0.70-1.2	>1.2	
5.	Mg	0.30-0.34	0.35-1.0	>1.0	
6.	S	<2.0	0.2-0.5	> 0.5	
	Micronutrient (ppm)				Tandon (1993)
7.	Zn	18-19	20-50	>50	
8.	Fe	30-39	40-100	>100	
9.	Mn	30-39	40-250	>250	
10.	Cu	<5.0	5-20	>20	

3.7 BENEFIT COST RATIO

After considering the fixed cost and variable cost on the basis of current market rates, the expenditure incurred on various inputs and operations was worked out for each technique. Similarly, gross returns were also worked out for each technique based on prevailing market prices of the produce. Net returns for each technology were then worked out by deducting the expenditure incurred from the gross returns. Benefit cost ratio was worked out by using following formula:

$$\text{Benefit cost ratio} = \frac{\text{Net return (Rs ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs ha}^{-1}\text{)}}$$

Total cost of cultivation for both farming systems has been given in Appendix II and Appendix III.

3.8 STATISTICALANALYSIS

The descriptive statistics viz., range, mean, t value, p value and standard error were derived for each soil and plant parameters. Data obtained from samples was analysed through statistical software SPSS-18 using t test for different parameter compression (Gomez & Gomez, 1984).

Chapter 4

RESULTS AND DISCUSSION

A comparative study was conducted in the potato-growing areas of Lahaul and Spiti District in Himachal Pradesh to explore the differences between natural and conventional farming practices. The study involved the analysis of soil and plant samples using statistical methods. The obtained results pertaining to various soil and plant parameters are presented and discussed comprehensively. The main objective was to understand the impact of natural and conventional farming practices on soil's physical, chemical, and microbial properties. In this context, the present study entitled "**Nutritional Status of Potato (*Solanum tuberosum* L.) in Lahaul valley of Himachal Pradesh,**" was carried out by collecting soil and plant samples. The outcomes of the study are organized and discussed in the following heads:

4.1 Physical and chemical properties of soil

4.2 Soil microbiological properties

4.3 Effect of natural and conventional farming practices on plant parameter and crop yield

4.4 Correlations among nutrients uptake in soil and leaf nutrient content

4.5 Cost economics

4.1 PHYSICAL AND CHEMICAL PROPERTIES OF SOIL

4.1.1 Soil Texture

The data presented in Table 4.1.1 indicate that sand, silt and clay content under the conventional farming system ranged from 48.40-65.28, 20.36-35.67 and 11.32-18.36 per cent with mean values of 56.80, 28.71 and 14.48 per cent, respectively whereas, the respective content under the natural farming system ranged from 48.23-61.66, 23.46-35.42 and 11.23-19.45 per cent with mean values of 55.61, 29.27 and 15.12 per cent, respectively. Sharma and Kanwar (2010) observed that the soils of dry temperate zone were coarse textured. Similar findings were also reported by Kumar *et al*. (2017), who observed that the soils of cold arid region were dominated by sand and relatively substantial content of sand within these soil particles is responsible for categorizing the textural class of these soils as sandy loam in this area. Sharma and Sankhyan (2020) observed that the variation in soil texture and composition can likely be attributed to the diverse climatic conditions, vegetation, topography and distinct parent materials under which these soils have developed.

Table 4.1.1 Particle size distribution under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional				Natural			
		Sand (%)	Silt (%)	Clay (%)	Textural Class	Sand (%)	Silt (%)	Clay (%)	Textural Class
Keylong	F_1	64.34	21.97	13.69	Sandy Loam	60.47	23.97	15.56	Sandy Loam
	F_2	57.88	27.36	14.76	Sandy Loam	59.56	25.89	14.55	Sandy Loam
	F_3	55.46	29.49	15.05	Sandy Loam	52.66	33.04	14.30	Sandy Loam
	F_4	51.25	33.52	15.23	Loam	48.23	33.17	18.60	Loam
	F_5	60.28	27.03	12.69	Sandy Loam	56.27	31.36	12.37	Sandy Loam
Kardang	F_6	58.63	26.00	15.37	Sandy Loam	60.35	26.78	12.87	Sandy Loam
	F_7	56.22	29.82	13.96	Sandy Loam	55.43	31.71	12.86	Sandy Loam
	F_8	55.78	28.65	15.57	Sandy Loam	53.35	35.42	11.23	Sandy Loam
	F_9	49.35	35.67	14.98	Loam	50.32	34.34	15.34	Loam
	F_{10}	65.28	20.36	14.36	Sandy Loam	54.78	27.79	17.43	Sandy Loam
Yurnath	F_{11}	62.89	25.79	11.32	Sandy Loam	56.54	28.01	15.45	Sandy Loam
	F_{12}	60.30	27.14	12.56	Sandy Loam	60.23	25.21	14.56	Sandy Loam
	F_{13}	51.63	33.86	14.51	Loam	61.66	23.46	14.88	Sandy Loam
	F_{14}	48.40	33.24	18.36	Loam	53.11	27.44	19.45	Sandy Loam
	F_{15}	54.36	30.82	14.82	Sandy Loam	51.14	31.43	17.43	Loam
Range		48.40-65.28	20.36-35.67	11.32-18.36		48.23-61.66	23.46-35.42	11.23-19.45	
Mean		56.80	28.71	14.48		55.61	29.27	15.12	
SE		1.36	1.12	0.41		1.08	1.00	0.60	
T		0.69	0.37	0.88					
P		0.50	0.71	0.39					

4.1.2 Soil pH, electrical conductivity (EC), organic carbon (OC) and cation exchange capacity (CEC)

Soil pH

The perusal of data in Table 4.1.2, reveals that the pH of soils under conventional farming system ranged from 5.97-7.74 with the mean value of 7.04, whereas under natural farming system it varied from 6.18-7.8 with the mean value of 7.22. The relatively decreased pH values observed in the conventional farming system in contrast to the natural farming system could be attributed to the deactivation of Fe^{3+} and Al^{3+} ions due to the chelating effect, along with the release of basic cations through the decomposition of organic manure reported by Grewal *et al*. (1981). The higher accumulation of $CaCO_3$ and other salts has led to an increased soil pH in dry temperate zone. The pH values measured in these areas were in accordance with the outcomes reported by Parmar *et al*. (1999) and Sharma (2006).

Electrical Conductivity (EC)

The electrical conductivity of the soils (Table 4.1.2) under conventional farming system ranged from 0.2-0.39 (dS m^{-1}) while under natural farming practice it ranged from 0.17-0.44 (dS m^{-1}). The EC was recorded higher under conventional farming system with mean value of 0.30 (dS m^{-1}) as compared to natural farming system with mean value of 0.29 (dS m^{-1}). Similar observations have been reported by Thakare *et al*. (2017), who observed that the incorporation of farm yard manure (FYM) resulted in higher soil electrical conductivity levels in comparison to the use of vermicompost and lower soil pH indicates larger number of H^+ ions in the soil which showed a higher rate of electrical conductivity.

Table 4.1.2 pH, electrical conductivity (EC), organic carbon (OC) and cation exchange capacity (CEC) under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional				Natural			
		pH	EC (dS m^{-1})	OC (g/kg)	CEC [cmol (p+) kg^{-1}]	pH	EC (dS m^{-1})	OC (g/kg)	CEC [cmol (p+) kg^{-1}]
Keylong	F_1	7.54	0.31	8.50	19.6	7.41	0.29	11.15	19.6
	F_2	6.53	0.22	9.70	22.7	6.57	0.20	13.60	22.7
	F_3	6.68	0.27	11.23	26.3	7.74	0.24	14.38	24.4
	F_4	7.21	0.37	8.60	19.7	7.53	0.36	11.28	20.8
	F_5	6.61	0.29	10.40	20.7	6.62	0.28	14.50	19.5
Kardang	F_6	7.74	0.33	9.60	24.8	7.71	0.31	11.36	26.6
	F_7	7.62	0.32	8.71	21.8	7.80	0.30	11.12	20.9
	F_8	7.37	0.28	9.70	22.1	7.58	0.28	12.50	21.3
	F_9	7.26	0.29	7.30	18.7	7.52	0.28	10.40	17.8
	F_{10}	7.39	0.38	11.30	26.9	7.63	0.36	14.60	25.3
Yurnath	F_{11}	6.58	0.39	8.50	18.9	6.73	0.44	10.82	17.1
	F_{12}	7.29	0.29	9.03	20.9	6.83	0.27	11.21	20.4
	F_{13}	6.78	0.34	10.00	23.8	7.26	0.33	13.03	22.1
	F_{14}	7.07	0.20	8.90	18.7	6.18	0.17	11.07	18.7
	F_{15}	5.97	0.23	8.04	20.8	7.19	0.19	11.03	17.8
Range		5.97-7.74	0.20-0.39	7.30-11.30	18.7-26.9	6.18-7.80	0.17-0.44	10.40-14.60	17.1-26.6
Mean		7.04	0.30	9.30	21.76	7.22	0.29	12.14	21.00
SE		0.13	0.015	0.29	0.69	0.132	0.02	0.38	0.73
T		0.97	0.59	5.88	0.76				
P		0.34	0.56	0.00	0.45				

Organic Carbon (OC)

Organic carbon is considered as the key component of soils because of influence on physical, chemical and soil biological properties. The data enumerated in table 4.1.2 reveals that the organic carbon under conventional farming system ranged from 7.3-11.3 g kg^{-1} while under natural farming system, OC ranged from 10.4-14.6 g kg^{-1}. The organic carbon was significantly lower under conventional farming system with mean value of 9.3 g kg^{-1} as compared to natural farming practice with mean value of 12.14 g kg^{-1}. Similar findings were also reported by Araujo *et al.* (2009), Glover *et al.* (2000) and Melero *et al.* (2006), who noted that organic farming systems tend to maintain higher levels of soil organic matter compared to conventional farming systems.

Cation exchange capacity (CEC)

The cation exchange capacity of the soils (Table 4.1.2) under conventional farming system ranged from 18.7-26.9 [cmol (p+) kg^{-1}] while under natural farming practice it ranged from 17.1-26.6 [cmol (p+) kg^{-1}]. Higher CEC was recorded under conventional farming system with mean value of 21.76 [cmol (p+) kg^{-1}] as compared to natural farming system with mean value of 21.00 [cmol (p+) kg^{-1}]. Similar observations have been reported by Rajneesh *et al.* (2017) and Sharma (2015), who observed that combined application of FYM and inorganic sources of nutrients resulted in an increase in CEC by 55.2%. Sharma *et al.* (2014) observed highest cation exchange capacity with application of FYM alone twice a year, followed by treatment involving 25% nitrogen (N) along with FYM because of cropping and continue fertilization.

4.1.3 Available Macronutrients

Available Nitrogen (N)

The available nitrogen of soils (Table 4.1.3) under conventional farming system ranged from 197.62-341.81 kg ha^{-1} while under natural farming practice, it ranged from 186.71-332.53 kg ha^{-1}. The available nitrogen was lower under natural farming practice with mean value of (279.24 kg ha^{-1}) as compared to conventional farming system with mean value of (293.25 kg ha^{-1}). Increase of CEC by FYM might have resulted in availability of nitrogen for longer period with reduced nutrient losses by providing nutrients into the soil. Singh *et al.* (1998) observed that application of BGA (blue green algae) along with inorganic fertilizer increase soil N. The direct addition of N through chemical fertilizers and mineralization of N from FYM might have resulted higher available N (Sheeba and Chellamuthu 1999). Mishra *et al.* (2008) and Kumar *et al.* (2008) also observed higher buildup of soil N with NPK fertilizers alone or along with FYM.

Available Phosphorus (P)

The available P content (Table 4.1.3) under conventional farming system ranged from 49.65-78.72 kg ha^{-1} while under natural farming practice available P ranged from 43.21-74.62 kg ha^{-1}. The available P content was recorded to be lower under natural farming system (58.65 kg ha^{-1}) as compared to conventional farming system (64.83 kg ha^{-1}). Low availability of plant nutrients under natural farming is due to slower release rate of organic materials compared to conventional farming systems. Gourav *et al*. (2019) observed that the FYM increased the available P due to inactivation of potential sources of P fixation such as iron, aluminum and hydroxyl aluminum ions by organic molecules. This might be responsible for reduction in P fixation and increase in availability of phosphorus. Increased availability of P under conventional farming system might be due to the release of organic acids during decomposition which might have helped in releasing phosphorus from native pools of phosphorus in the soil under NPK fertilizer combined with organics. Findings are in resonance with results of Thakur *et al*. (2011), Reddy *et al*. (2006) and Bajpai *et al*. (2006).

Table 4.1.3 Available nitrogen, phosphorus and potassium contents under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional			Natural		
		N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Keylong	F_1	267.32	62.65	245.02	261.13	56.02	227.64
	F_2	323.76	67.21	277.54	308.35	63.13	254.21
	F_3	338.01	74.76	248.45	324.46	68.77	229.75
	F_4	274.11	66.04	267.34	281.73	60.56	234.15
	F_5	277.43	64.31	263.66	275.24	57.25	237.34
Kardang	F_6	304.06	63.76	244.42	284.75	56.07	229.87
	F_7	341.03	78.60	258.78	328.33	71.43	223.50
	F_8	317.34	63.01	343.07	301.40	58.46	322.33
	F_9	197.62	49.65	241.45	186.71	43.21	221.06
	F_{10}	341.81	78.72	317.83	332.53	74.62	333.18
Yurnath	F_{11}	252.66	54.22	247.36	235.81	47.75	231.81
	F_{12}	295.04	53.32	238.11	277.34	43.68	207.56
	F_{13}	325.33	69.46	290.03	313.67	64.03	295.12
	F_{14}	247.05	58.10	216.60	224.72	52.75	209.90
	F_{15}	296.22	68.64	233.37	252.50	62.08	221.67
Range		197.62-341.81	49.65-78.72	216.60-343.07	186.71-332.53	43.21-74.62	207.56-333.18
Mean		293.25	64.83	262.20	279.24	58.65	245.27
SE		10.58	2.24	8.63	10.76	2.41	10.16
T		0.93	1.88	1.27			
P		0.36	0.07	0.21			

Available Potassium (K)

The data recorded on available K content in soils has been presented in Table 4.1.3. Available potassium content under conventional farming system ranged from 216.6-343.07 kg ha^{-1} while under natural farming system it ranged from 207.56-333.18 kg ha^{-1}. The available K content was recorded to be lower under natural farming system (245.27 kg ha^{-1}) as compared to conventional farming system (262.20 kg ha^{-1}). Rajneesh *et al*. (2017) observed that release of organic colloids due to decomposition of FYM enhance the CEC which can hold more exchangeable K and reduces leaching losses of potassium, resulting in high availability of K. Similar results were also obtained by Vijaya Lakshmi *et al*. (2011) and Singh *et al*. (2017), who also reported increase in available K in soil with increasing doses of potassium application.

4.1.4 Exchangeable calcium and magnesium and sulphate sulphur

Exchangeable calcium (Ca)

The exchangeable Ca content (Table 4.1.4) under conventional farming system ranged from 4.93-15.3 [cmol (p+) kg^{-1}] while under natural farming system, it ranged from 4.06-15.35 [cmol (p+) kg^{-1}]. The exchangeable Ca content was recorded to be lower under natural farming system (8.09 [cmol (p+) kg^{-1}]) as compared to conventional farming system (8.60 [cmol (p+) kg^{-1}]). Similar observations have been reported by Rana (2021), who observed that highest levels of exchangeable calcium (Ca) in integrated farming practices, comparable to those in inorganic farming practices, alone and lowest in ZBNF practices.The increased calcium (Ca) levels observed in integrated farming practices could potentially might have resulted from the release of such nutrients through the mineralization of added organic sources and decomposition of organic materials which might have lead to the release of calcium and magnesium from soil exchange sites. Kaushal (2002) and Sharma *et al*. (2002) have similarly reported that integrated and organic manure treatments have the capacity to enhance the soil calcium status.

Exchangeable magnesium (Mg)

The exchangeable Mg content (Table 4.1.4) under conventional farming system ranged from 1.58-3.61 [cmol (p+) kg^{-1}] while under natural farming system, it ranged from 1.28-3.37 [cmol (p+) kg^{-1}]. The exchangeable Mg content was observed to be lower under natural farming system (2.23 [cmol (p+) kg^{-1}]) as compared to conventional farming system (2.52 [cmol (p+) kg^{-1}]). This may be due to the application of chemicals and manure which may have resulted in a significant increase in its content in the soil. Similar findings were observed by Ansari and Kumar (2010). Thakur and Sawarkar (2009) also observed that the combined application of organic and inorganic fertilizer enhance CEC which resulted increase in soil Mg content.

Sulphate sulphur (SO_4^{2-}-S)

The Sulphate sulphur content (Table 4.1.4) under conventional farming system ranged from 22.77-38.85 kg ha^{-1} while under natural farming system, it ranged from 22.61-34.02 kg ha^{-1}. The sulphate sulphur content was recorded to be lower under natural farming system (28.01 kg ha^{-1}) as compared to conventional farming system (30.09 kg ha^{-1}). This may be due to the direct addition of SSP which may have produced higher SO_4^{2-}S values (contains about 12% of the S that could be rendered free by solubizing effect), microbial activity, release of organic acids and breakdown of organic matter. Kumar *et al*. (2011) reported similar findings, who observed that integrated fertilizers enhance soil S content. Similar results were also reported by Singh *et al*. (2011), Sharma and Subehia (2014) and Thakur *et al*. (2019).

Table 4.1.4 Exchangeable calcium, magnesium and sulphate sulphur contents under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional			Natural		
		Calcium [cmol (p+) kg^{-1}]	Magnesium [cmol (p+) kg^{-1}]	Sulphate sulphur (kg ha^{-1})	Calcium [cmol (p+) kg^{-1}]	Magnesium [cmol (p+) kg^{-1}]	Sulphate sulphur (kg ha^{-1})
Keylong	F_1	6.80	1.76	22.77	6.48	1.75	23.02
	F_2	8.82	2.96	29.04	9.24	2.81	28.11
	F_3	15.30	3.40	31.46	12.56	3.24	29.72
	F_4	7.03	1.82	29.72	6.57	1.83	27.34
	F_5	7.18	2.14	35.89	6.24	1.64	32.45
Kardang	F_6	8.45	2.92	26.01	7.24	2.56	23.87
	F_7	12.17	3.46	31.12	15.35	3.24	30.06
	F_8	8.51	2.97	24.93	7.51	2.59	22.61
	F_9	4.93	1.58	30.06	5.60	1.30	28.77
	F_{10}	13.21	3.61	38.85	15.08	3.37	34.02
Yurnath	F_{11}	5.32	1.67	32.37	4.06	1.37	31.47
	F_{12}	7.56	2.44	30.40	6.57	2.42	27.62
	F_{13}	9.46	3.21	25.01	8.46	2.68	22.85
	F_{14}	5.89	1.58	35.10	6.00	1.40	30.71
	F_{15}	8.34	2.34	28.63	4.37	1.28	27.52
Range		4.93-15.30	1.58-3.61	22.77-38.85	4.06-15.35	1.28-3.37	22.61-34.02
Mean		8.60	2.52	30.09	8.09	2.23	28.01
SE		0.76	0.19	1.13	0.91	0.2	0.93
T		0.43	1.07	1.42			
P		0.67	0.29	0.17			

4.1.5 DTPA-extractable Zn, Fe, Cu and Mn

DTPA extractable Zinc (Zn)

The Zn content (Table 4.1.5) under conventional farming system ranged from 2.22- 3.41 mg kg $^{-1}$ while under natural farming system, it ranged from 1.96-3.33 mg kg $^{-1}$. The Zn content was recorded to be significantly higher under conventional farming system (2.80 mg kg $^{-1}$) as compared to natural farming system (2.47 mg kg $^{-1}$). The gradual increase in DTPA extractable zinc (Zn) in conventional farming system treated with Farm Yard Manure (FYM) over time could be attributed to the process of mineralization. This process involves the conversion of organically bound forms of zinc present in the FYM into more available forms and enhanced DTPA extractable zinc content in soil. Also FYM might have resulted in the formation of organic chelates of higher stability. Zinc has a tendency to form chelates with organic ligands that are relatively resistant to processes like adsorption, fixation, and precipitation, thereby enhancing its availability in the soil. Similar results were also reported by Verma and Mathur (2007).

DTPA extractable Iron (Fe)

The Fe content (Table 4.1.5) under conventional farming system ranged from 33.22-42.34 mg kg $^{-1}$ while under natural farming system, it ranged from 30.33-43.42 mg kg $^{-1}$. Under conventional farming system, the Fe content was recorded to be higher (38.01 mg kg $^{-1}$) as compared to natural farming system (36.54 mg kg $^{-1}$). Similar results were also reported by Dhiman *et al*. (2019).

DTPA extractable Copper (Cu)

The Cu content (Table 4.1.5) under conventional farming system ranged from 2.01-3.17 mg kg $^{-1}$ while under natural farming system, it ranged from 1.38-3.02 mg kg $^{-1}$. The Cu content was recorded to be lower under natural farming system (2.34 mg kg $^{-1}$) as compared to conventional farming system (2.56 mg kg $^{-1}$). This may be due to the higher content of organic matter and cool temperature, resulting in insoluble copper organic complexes which led to decrease in copper content. Similar findings were observed by Sharma and Kanwar (2010).

DTPA extractable Manganese (Mn)

The Mn content under conventional farming system (Table 4.1.5) also ranged from 8.15-12.92 mg kg $^{-1}$ while under natural farming system; it ranged from 6.5-12.0 mg kg $^{-1}$. The

Mn content was recorded to be significantly higher under conventional farming system (9.90 mg kg^{-1}) as compared to natural farming system (8.67 mg kg^{-1}). This may be due to the natural ability of organic carbon content in the soil to accelerate the process of mineralization of micronutrients that are bound organically within the native soil. Additionally, the presence of organic carbon content contributes to the formation of organic chelates, further influencing the availability of these micronutrients. Reddy and Reddy (2008) reported that the available manganese in soil increases with increasing doses of fertilizers.

Saha *et al*. (2007) observed that the application of cow-dung and green manure along with chemical fertilizers not only increased soil macronutrients but also increased available Zn, Fe, and Mn content in soil and slightly increase available copper (Cu) but was non-significant. Similar findings were also observed by Marathe *et al*. (2009).

Table 4.1.5 DTPA extractable iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) contents under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional				Natural			
		Zn (mg kg^{-1})	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})
Keylong	F_1	2.96	39.05	2.50	8.15	2.22	34.36	2.67	6.50
	F_2	3.33	37.56	2.56	9.07	2.87	36.72	2.18	9.23
	F_3	2.22	41.14	2.45	9.92	2.11	43.08	1.93	7.51
	F_4	3.17	38.45	2.51	10.46	2.84	36.47	2.09	9.02
	F_5	3.41	40.71	2.08	10.65	3.33	40.05	2.01	9.76
Kardang	F_6	2.43	34.68	2.98	10.05	2.48	34.61	3.02	9.62
	F_7	2.57	38.56	2.01	9.36	2.41	35.53	1.38	7.95
	F_8	2.62	42.34	2.06	11.70	2.26	43.42	1.71	12.00
	F_9	3.16	40.11	2.91	11.17	2.83	38.26	2.71	11.36
	F_{10}	2.77	34.06	2.66	8.89	2.67	33.75	2.50	6.94
Yurnath	F_{11}	2.34	41.45	3.17	12.92	2.02	37.81	3.00	8.48
	F_{12}	2.40	33.22	2.72	9.44	2.29	30.33	2.42	7.41
	F_{13}	2.76	38.04	3.10	8.42	2.12	37.78	2.99	9.25
	F_{14}	2.77	36.34	2.45	8.94	1.96	32.16	2.87	7.23
	F_{15}	3.11	34.42	2.29	9.41	2.60	33.83	1.68	7.75
Range		2.22-3.41	33.22-42.34	2.01-3.17	8.15-12.92	1.96-3.33	30.33-43.42	1.38-3.02	6.50-12.0
Mean		2.80	38.01	2.56	9.90	2.47	36.54	2.34	8.67
SE		0.10	0.75	0.09	0.33	0.10	0.95	0.14	0.41
T		2.40	1.20	1.31	2.34				
P		0.02	0.24	0.20	0.03				

4.1.6 Nutrient indices of soil

Under conventional farming system, soil had medium to high nutrient status. Nutrient index value varied from 1.60 to 3.00. The available nitrogen (1.60), available potassium (2.20) and DTPA-Zn (2.33) are medium in nutrient status with 60, 80 and

66.67 per cent samples falling in medium nutrient rating respectively (Table 4.1.6.1). However, 100 per cent samples of available phosphorus, exchangeable calcium, magnesium, sulphate sulphur, DTPA-Fe, Mn, Cu and 20 per cent samples of potassium were categorized as high in nutrient rating and 40 per cent samples of nitrogen were categorized as low in nutrient rating.

Table 4.1.6.1 Nutrient indices of conventional farming system soils

Nutrient	Percentage of samples rating			Nutrient Index	Nutrient Status
	Low	Medium	High		
	Surface soil				
N	40	60	-	1.60	Medium
P	-	-	100	3.00	High
K	-	80	20	2.20	Medium
Ca	-	-	100	3.00	High
Mg	-	-	100	3.00	High
S	-	-	100	3.00	High
Fe	-	-	100	3.00	High
Cu	-	-	100	3.00	High
Zn	-	66.67	33.33	2.33	Medium
Mn	-	-	100	3.00	High

Under natural farming system, soils had medium to high nutrient status. Nutrient index value varied from 1.53 to 3.00. The available nitrogen (1.53) and available potassium (2.20) are medium in nutrient status with 53.33 and 80 per cent samples falling in medium nutrient rating respectively (Table 4.1.6.2). However, 100 per cent samples of available phosphorus, exchangeable calcium, magnesium, sulphate sulphur, DTPA-Fe, Mn and Cu, respectively and 93.33 per cent samples of DTPA- Zn were categorized as high in nutrient rating and 46.67 per cent samples of nitrogen were categorized as low in nutrient rating.

Table 4.1.6.2 Nutrient indices of natural farming system soils

Nutrient	Percentage of samples rating			Nutrient Index	Nutrient Status
	Low	Medium	High		
	Surface soil				
N	46.67	53.33	-	1.53	Medium
P	-	-	100	3.00	High
K	-	80	20	2.20	Medium
Ca	-	-	100	3.00	High
Mg	-	-	100	3.00	High
S	-	-	100	3.00	High
Fe	-	-	100	3.00	High
Cu	-	-	100	3.00	High
Zn	-	93.33	6.67	2.07	Medium
Mn	-	-	100	3.00	High

4.2 SOIL MICROBIOLOGICAL PROPERTIES

A perusal of data cited in table 4.2 on soil microbiological properties revealed that the population of beneficial bacteria under conventional farming system ranged from 49.76-64.35×10^5 cfu g^{-1} soil while under natural farming system, it ranged from 52.34- 69.87×10^5 cfu g^{-1}. The bacterial population was significantly higher under natural farming system with mean value of 62.17×10^5 cfu g^{-1}) as compared to conventional farming system with mean value of 57.59×10^5 cfu g^{-1}. Population of fungi under conventional farming system ranged from 7.42-13.77×10^3 cfu g^{-1} soil while under natural farming system, it ranged from 9.32-14.04×10^3 cfu g^{-1}. The natural farming system had significantly higher fungi population (11.54×10^3 cfu g^{-1}) as compared to conventional farming system (9.69×10^3 cfu g^{-1}). Population of actinomycetes under conventional farming system ranged from 24.61-31.41×10^3 cfu g^{-1} soil while under natural farming system, it ranged from 25.34-32.58×10^3 cfu g^{-1}. Similarly, the population of actinomycetes was recorded highest under natural farming system (27.92×10^3 cfu g^{-1} soil) as compared to conventional farming system (27.03×10^3 cfu g^{-1} soil).

Table 4.2 Viable Microbial Count under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional			Natural		
		Bacteria (10^5cfu g^{-1} soil)	Fungi (10^3cfu g^{-1} soil)	Actinomycetes (10^3cfu g^{-1} soil)	Bacteria (10^5cfu g^{-1} soil)	Fungi (10^3cfu g^{-1} soil)	Actinomycetes (10^3cfu g^{-1} soil)
Keylong	F_1	51.03	7.84	25.86	61.85	10.62	27.48
	F_2	59.34	10.57	25.92	65.48	12.81	25.34
	F_3	64.01	13.77	31.41	66.35	12.88	32.58
	F_4	55.06	8.46	27.68	63.32	11.62	28.22
	F_5	56.81	8.72	26.83	60.42	10.51	26.76
Kardang	F_6	58.23	9.62	28.30	62.50	12.13	27.35
	F_7	63.73	11.34	24.72	69.75	14.04	27.11
	F_8	60.21	10.15	26.43	63.44	12.54	30.42
	F_9	49.76	7.61	29.62	52.34	9.45	29.15
	F_{10}	64.35	12.35	24.81	69.87	13.67	25.82
Yurnath	F_{11}	54.05	8.23	24.61	57.33	9.32	26.47
	F_{12}	57.56	9.48	27.31	63.07	11.18	27.73
	F_{13}	62.33	10.78	30.17	64.62	12.62	31.16
	F_{14}	49.94	7.42	26.31	54.18	9.67	26.15
	F_{15}	57.45	9.02	25.46	58.03	10.05	27.02
Range		49.76-64.35	7.42-13.77	24.61-31.41	52.34-69.87	9.32-14.04	25.34-32.58
Mean		57.59	9.69	27.03	62.17	11.54	27.92
SE		1.27	0.47	0.53	1.31	0.40	0.53
T		2.51	2.99	1.17			
P		0.02	0.01	0.25			

The application of organic fertilizers enhanced microbial counts, as compared to inorganic fertilizers. The highest bacterial count under natural farming system may be due to high organic matter decomposition which enhanced physical properties of the soil and provided better nutrients for growth of the micro-organisms. Similar observations were recorded by Barakzai *et al.* (2021), who observed that cow urine and dung based organic formulations under natural farming resulted in higher microbial population compared to conventional farming. Rana (2019) similarly recorded highest bacteria, fungi and actinomycetes populations under ZBNF system compared to conventional farming (CF) system. This might be due to the regular use of Jivamrit for foliar spray and drenching, acting as a microbial inoculant. Ghanjivamrit serves as a carbon source, while field mulching enhances microbial growth with improved root aeration. Vishwajeet (2020) also observed highest bacteria, fungi and actinomycetes population under the Subhash Palekar Natural Farming (SPNF) system than Conventional Farming (CF) system may be due to continue use of jeevamrit which contain microbial load that multiplies into the soil and enhance microbial activity. Similar findings were also observed by Aulakh *et al*. (2018), who observed higher microbial population with application of jeevamrit as compared to chemical fertilizer and control. Rana (2021) similarly recorded highest soil microbial population under organic and ZBNF farming system as compared to integrated and inorganic farming system. Choudhary *et al*. (2022) recorded significantly highest microbial population with application of ghanjeevamrit + jeevamrit + mulching and significantly lowest under control treatment.

4.3 EFFECT OF NATURAL AND CONVENTIONAL FARMING PRACTICES ON PLANT PARAMETER AND CROP YIELD

4.3.1 Leaf NPK content

The leaf N, P and K contents under conventional farming system exhibited a range from 3.43 to 5.02, 0.44 to 0.61 and 2.20 to 4.22 per cent with mean values of 4.26, 0.53 and 3.28 per cent, respectively (Table 4.3.1) while under natural farming system, it range from 3.22 to 4.81, 0.40 to 0.57 and 2.04 to 3.95 per cent with mean values of 4.07, 0.50 and 3.04 per cent, respectively. Leaf N, P and K content were recorded higher under conventional farming system as compared to natural farming system. Similar observations were also recorded by Goswami *et al*. (2012), who observed that use of biofertilizers enriched FYM along with half dose of recommended fertilizer recorded maximum leaf NPK content. The maximum leaf NPK content might have been recorded due to availability of NH^{4+} and NO^{3-} in aqueous solution, as sufficient urea and FYM were applied (Khan *et al*. 2017). Similar observations were also recorded by Negi *et al*. (2022), who observed highest NPK content in leaves of onion with the incorporation of organic manure with inorganic fertilizers i.e. RDF + FYM @250 q/ha. Kumar *et al*. (2011) recorded highest total uptake of N, P and K by potato crop receiving 50% RD of NPK through inorganic fertilizer and remaining 50% N through poultry manure (PM). Neogi and Das (2022) recorded highest total uptake of NPK content by potato with 100% RDF of NPK+ foliar nano-N sprays + foliar nano-Zn sprays).

Table 4.3.1 Leaf nitrogen, phosphorus and potassium contents under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional			Natural		
		Nitrogen (%)	Phosphorus (%)	Potassium (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Keylong	F_1	5.02	0.49	2.83	4.81	0.47	2.66
	F_2	4.21	0.52	3.90	3.94	0.50	3.70
	F_3	4.67	0.57	3.27	4.58	0.55	2.91
	F_4	4.51	0.51	4.00	4.20	0.49	3.70
	F_5	4.37	0.50	3.90	4.02	0.48	3.50
Kardang	F_6	3.82	0.50	2.72	3.68	0.47	2.97
	F_7	3.78	0.61	3.46	3.52	0.57	2.64
	F_8	4.60	0.52	4.11	4.45	0.49	3.85
	F_9	3.43	0.44	2.72	3.22	0.40	2.17
	F_{10}	4.73	0.60	4.22	4.61	0.56	3.95
Yurnath	F_{11}	3.72	0.49	3.21	3.62	0.47	3.23
	F_{12}	4.57	0.49	2.42	4.50	0.46	2.04
	F_{13}	4.44	0.58	4.06	4.31	0.54	3.80
	F_{14}	4.08	0.58	2.21	3.90	0.55	2.04
	F_{15}	3.96	0.49	2.20	3.73	0.47	2.43
Range		3.43-5.02	0.44-0.61	2.20-4.22	3.22-4.81	0.40-0.57	2.04-3.95
Mean		4.26	0.53	3.28	4.07	0.50	3.04
SE		0.12	0.01	0.19	0.12	0.01	0.18
T		1.12	1.59	0.94			
P		0.27	0.12	0.35			

4.3.2 Leaf secondary nutrients

The perusal of data in Table 4.3.2 reveals that leaf Ca and S contents were significantly higher under conventional farming system which ranged from 2.20 to 3.06 and 0.33 to 0.48 per cent with an average value of 2.71 and 0.39 per cent, respectively as compared to natural farming system which ranged from 2.08 to 2.86 and 0.27 to 0.43 per cent with an average value of 2.5 and 0.35 per cent, respectively. The leaf Mg contents were higher under conventional farming system (0.43 to 0.84 with mean value of 0.59 per cent as compared to natural farming system (0.40 to 0.81) with mean value of 0.56 per cent. The increase in leaf exchangeable Ca and Mg content in 100% NPK+FYM plots was reported by Sharma and Subehia (2014). The results are in line with findings of Selvamani and Duraisami (2018). Similar observation were recorded by Rios *et al*.

(2012), who observed significant increase in leaf calcium (Ca) and magnesium (Mg) content of *Brassica rapa* with Ca and Mg exogenous supply through fertilizers.

Table 4.3.2 Leaf calcium, magnesium and sulphur contents under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional			Natural		
		Calcium (%)	Magnesium (%)	Sulphur (%)	Calcium (%)	Magnesium (%)	Sulphur (%)
Keylong	F_1	2.60	0.46	0.38	2.46	0.42	0.36
	F_2	2.71	0.58	0.34	2.63	0.58	0.29
	F_3	2.79	0.70	0.33	2.45	0.54	0.27
	F_4	2.96	0.49	0.41	2.68	0.47	0.36
	F_5	2.80	0.51	0.41	2.71	0.46	0.37
Kardang	F_6	3.01	0.48	0.47	2.86	0.77	0.43
	F_7	3.06	0.79	0.37	2.77	0.46	0.32
	F_8	2.63	0.58	0.34	2.43	0.67	0.28
	F_9	2.39	0.43	0.35	2.08	0.56	0.33
	F_{10}	2.97	0.84	0.39	2.64	0.81	0.34
Yurnath	F_{11}	2.20	0.62	0.48	2.19	0.40	0.42
	F_{12}	2.50	0.64	0.34	2.20	0.63	0.29
	F_{13}	2.70	0.60	0.39	2.60	0.57	0.35
	F_{14}	2.70	0.51	0.37	2.50	0.49	0.36
	F_{15}	2.56	0.59	0.45	2.30	0.57	0.41
Range		2.20-3.06	0.43-0.84	0.33-0.48	2.08-2.86	0.40-0.81	0.27-0.43
Mean		2.71	0.59	0.39	2.5	0.56	0.35
SE		0.06	0.03	0.01	0.06	0.03	0.01
T		2.4	0.64	2.38			
P		0.02	0.53	0.02			

4.3.3 Leaf Micronutrients

The Zn content in leaves (Table 4.3.3) under conventional farming system ranged from 34.53-66.21 ppm while under natural farming system, it ranged from 30.10-58.87 ppm. The Zn content was recorded to be lower under natural farming system (39.63 ppm) as compared to conventional farming system (45.04 ppm).

The Fe content in leaves under conventional farming system ranged from 330.44-543.15 ppm while under natural farming system, it ranged from 229.94-520.12 ppm. Under conventional farming system Fe content was recorded to be higher (424.99 ppm) as compared to natural (392.91 ppm) farming system.

The Cu content in leaves under conventional farming system ranged from 25.17-52.64 ppm while under natural farming system, it ranged from 20.88-49.32 ppm. Under conventional farming system the Cu content was recorded to be higher (39.16 ppm) as compared to natural (36.10 ppm) farming system.

The Mn content under conventional farming system ranged from 57.73-84.08 ppm while under natural farming system, it ranged from 56.02-79.52 ppm. Under conventional farming system the Mn content was recorded to be higher (73.16 ppm) as compared to natural (71.20 ppm) farming system.

The results are in line with findings of Tewolde *et al.* (2019), who observed that fertilizer enhance leaf macro and micronutrients in corn. The results are in accordance with Selvamani and Duraisami (2018), who observed leaf N, P, K, Ca, Mg, S, Fe, Mn, Zn, and Cu content in coconut having mean values of 1.42%, 0.11%, 0.99%, 0.88%, 0.48%, 0.62%, 230.70 mg kg^{-1}, 315 mg kg^{-1}, 19.30 mg kg^{-1} and 10.80 mg kg^{-1}, respectively.

Table 4.3.3 Leaf zinc, iron, copper and manganese contents under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional				Natural			
		Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)
Keylong	F_1	43.32	340.05	44.61	57.73	37.00	325.88	41.92	71.17
	F_2	62.25	430.16	47.97	72.32	57.97	378.51	41.76	73.87
	F_3	36.31	536.34	30.54	77.62	30.21	502.86	26.68	70.13
	F_4	46.06	375.32	44.32	75.46	40.48	353.96	45.24	73.47
	F_5	66.21	465.63	39.14	79.12	58.87	440.60	37.36	75.05
Kardang	F_6	47.78	484.62	52.64	78.94	43.25	436.32	49.32	74.30
	F_7	36.76	392.53	25.17	76.05	30.49	425.33	23.20	72.03
	F_8	43.02	543.15	26.75	81.57	36.80	520.12	24.36	79.52
	F_9	40.83	495.11	37.38	81.24	36.57	485.31	34.80	75.63
	F_{10}	44.52	339.71	48.98	61.73	40.95	299.21	46.40	66.38
Yurnath	F_{11}	35.87	440.74	37.83	84.08	30.21	410.12	31.77	73.42
	F_{12}	54.22	349.07	29.55	77.22	49.25	229.94	27.84	68.42
	F_{13}	45.74	330.44	49.24	60.76	40.37	305.03	45.32	74.15
	F_{14}	38.19	521.18	47.79	64.11	30.10	500.21	44.72	56.02
	F_{15}	34.53	330.78	25.45	69.52	31.99	280.25	20.88	64.44
Range		34.53-66.21	330.44-543.15	25.17-52.64	57.73-84.08	30.10-58.87	229.94-520.12	20.88-49.32	56.02-79.52
Mean		45.04	424.99	39.16	73.16	39.63	392.91	36.10	71.20
SE		2.44	20.42	2.49	2.17	2.44	23.48	2.49	1.46
T		1.57	1.03	0.87	0.75				
P		0.13	0.31	0.39	0.46				

4.3.4 Tuber NPK content

The tuber N, P and K contents under conventional farming system exhibited a range from 3.28 to 4.45, 0.44 to 0.69 and 2.23 to 3.03 per cent with mean values of 3.81, 0.58 and 2.66 per cent, respectively (Table 4.3.4) while under natural farming system, it range from 3.07 to 4.26, 0.43 to 0.66 and 2.16 to 2.79 per cent with mean values of 3.68, 0.53 and 2.44 per cent, respectively. Tuber N and P content were recorded higher under conventional farming system as compared to natural farming system while, K content were recorded significantly higher under conventional farming system as compared to natural farming system.

Similar observations were recorded by Chander *et al*. (2010), who observed highest N, P, K content in different cauliflower parts (leaves, curd and roots) with increasing boron and FYM application rates. The maximum amounts of N, P and K were found in curd followed by leaves and least in roots. This may be due to the beneficial effect of FYM on nutrient availability in soil and improvement in soil physical and microbiological properties. Similar observations were recorded by Negi *et al.* (2022), who recorded significantly highest NPK content in onion bulb (2.65, 0.35 and 1.85%, respectively) under plots receiving RDF + FYM @ 250 q/ha. The results are in line with findings of Rajneesh *et al*. (2017) and Sharma *et al*. (2022).

Table 4.3.4 Tuber nitrogen, phosphorus and potassium contents under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional			Natural		
		Nitrogen (%)	Phosphorus (%)	Potassium (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Keylong	F_1	4.45	0.54	2.55	4.26	0.48	2.35
	F_2	3.79	0.60	2.71	3.64	0.56	2.54
	F_3	4.28	0.64	2.67	4.13	0.63	2.36
	F_4	3.97	0.60	2.97	3.67	0.54	2.60
	F_5	3.81	0.55	2.82	3.79	0.48	2.48
Kardang	F_6	3.49	0.52	2.53	3.37	0.46	2.43
	F_7	3.35	0.69	2.68	3.25	0.65	2.31
	F_8	4.06	0.61	2.84	3.81	0.57	2.79
	F_9	3.28	0.44	2.43	3.07	0.43	2.26
	F_{10}	4.39	0.68	3.03	4.24	0.66	2.77
Yurnath	F_{11}	3.42	0.48	2.53	3.25	0.45	2.45
	F_{12}	4.05	0.51	2.46	3.91	0.43	2.22
	F_{13}	3.84	0.65	3.00	3.88	0.60	2.62
	F_{14}	3.53	0.65	2.49	3.50	0.59	2.16
	F_{15}	3.42	0.48	2.23	3.43	0.46	2.27
Range		3.28-4.45	0.44-0.69	2.23-3.03	3.07-4.26	0.43-0.66	2.16-2.79
Mean		3.81	0.58	2.66	3.68	0.53	2.44
SE		0.10	0.02	0.06	0.09	0.02	0.05
T		0.93	1.48	2.84			
P		0.36	0.15	0.01			

4.3.5 Tuber secondary nutrients

The perusal of data in Table 4.3.5 revealed that Ca, Mg and S contents in tuber were significantly higher under conventional farming system which ranged from 0.7 to 1.1, 0.44 to 0.65 and 0.19 to 0.32 per cent with an average value of 0.84, 0.55 and 0.24 per cent, respectively as compared to natural farming system which ranged from 0.63 to 0.84, 0.33 to 0.57 and 0.16 to 0.28 per cent with an average value of 0.72, 0.48 and 0.21 per cent, respectively.

Similar observations were recorded by Verma (2019), who recorded highest nutrient (N, P, K, Ca, Mg and S) content in potato tuber under treatment comprised of combined application of RDF and organic fertilizers. The results are in line with findings of Kumar (2019).

Table 4.3.5 Tuber calcium, magnesium and sulphur contents under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional			Natural		
		Calcium (%)	Magnesium (%)	Sulphur (%)	Calcium (%)	Magnesium (%)	Sulphur (%)
Keylong	F_1	0.79	0.47	0.21	0.72	0.39	0.18
	F_2	0.83	0.56	0.21	0.74	0.52	0.16
	F_3	0.88	0.61	0.19	0.69	0.48	0.16
	F_4	0.90	0.48	0.24	0.81	0.45	0.21
	F_5	0.85	0.52	0.26	0.76	0.41	0.21
Kardang	F_6	1.03	0.48	0.32	0.84	0.57	0.28
	F_7	1.10	0.61	0.23	0.81	0.44	0.19
	F_8	0.79	0.56	0.21	0.66	0.53	0.17
	F_9	0.72	0.44	0.24	0.63	0.49	0.23
	F_{10}	0.91	0.65	0.24	0.76	0.57	0.24
Yurnath	F_{11}	0.70	0.58	0.29	0.63	0.33	0.26
	F_{12}	0.72	0.60	0.19	0.63	0.55	0.17
	F_{13}	0.81	0.59	0.25	0.73	0.51	0.23
	F_{14}	0.79	0.51	0.24	0.72	0.46	0.19
	F_{15}	0.76	0.58	0.28	0.64	0.49	0.24
Range		0.70-1.10	0.44-0.65	0.19-0.32	0.63-0.84	0.33-0.57	0.16-0.28
Mean		0.84	0.55	0.24	0.72	0.48	0.21
SE		0.03	0.02	0.01	0.02	0.02	0.01
T		3.52	2.94	2.36			
P		0.001	0.01	0.02			

4.3.6 Tuber micronutrients

The Zn content in tuber under conventional farming system ranged from 30.02-43.68 ppm while under natural farming system, it ranged from 28.77-41.70 ppm (Table 4.3.6). The Zn content was recorded to be lower under natural farming system (34.28 ppm) as compared to conventional farming system (36.02 ppm).

The Fe content in tuber under conventional farming system ranged from 441.64-580.05 ppm while under natural farming system, it ranged from 434.63-573.45 ppm. Under conventional farming system, Fe content was recorded to be higher (518.11 ppm) as compared to natural (507.77 ppm) farming system.

The Cu content under conventional farming system ranged from 23.08-32.81 ppm while under natural farming system, it ranged from 20.43-29.76 ppm. Under conventional farming system, the Cu content was recorded to be significantly higher (27.24 ppm) as compared to natural (24.65 ppm) farming system.

Table 4.3.6 Tuber zinc, iron, copper and manganese contents under conventional and natural farming potato growing soils in Lahaul valley

Panchayats	Farmer	Conventional				Natural			
		Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)
Keylong	F_1	30.02	491.65	28.67	64.32	31.66	487.63	26.13	73.18
	F_2	41.65	523.18	28.03	78.64	40.21	515.63	25.21	77.47
	F_3	33.04	531.31	24.51	86.19	30.36	537.80	20.43	72.17
	F_4	35.68	523.22	30.45	81.11	35.60	507.14	28.05	75.43
	F_5	43.68	541.75	26.72	97.83	41.70	530.17	23.65	86.55
Kardang	F_6	40.07	547.13	32.81	93.64	38.32	535.54	29.76	84.78
	F_7	32.12	578.23	23.44	82.47	30.12	555.16	21.38	73.84
	F_8	33.21	580.05	25.54	98.32	32.66	573.45	22.72	91.66
	F_9	32.77	523.55	27.67	89.04	30.83	512.88	23.66	84.01
	F_{10}	37.32	460.61	31.44	75.84	36.04	448.70	28.71	64.76
Yurnath	F_{11}	32.60	547.44	23.78	98.67	31.55	532.70	24.54	74.29
	F_{12}	40.10	441.64	26.05	84.72	38.73	434.63	22.48	68.06
	F_{13}	36.69	494.01	29.44	71.23	34.52	472.65	26.02	79.01
	F_{14}	33.72	537.54	26.97	73.97	28.77	529.13	25.62	58.03
	F_{15}	37.65	450.31	23.08	76.55	33.17	443.37	21.45	64.12
Range		30.02-43.68	441.64-580.05	23.08-32.81	64.32-98.67	28.77-41.70	434.63-573.45	20.43-29.76	58.03-91.66
Mean		36.02	518.11	27.24	83.50	34.28	507.77	24.65	75.16
SE		1.03	10.99	0.76	2.71	1.03	10.81	0.72	2.37
T		1.19	0.67	2.46	2.32				
P		0.24	0.51	0.02	0.03				

The Mn content under conventional farming system ranged from 64.32-98.67 ppm while under natural farming system, it ranged from 58.03-91.66 ppm. Under conventional farming system the Mn content was recorded to be significantly higher (83.50 ppm) as compared to natural farming system (75.16 ppm).

The results are in line with findings of Kumar (2019), who observed maximum nutrient content and uptake in brinjal at 140% recommended dose of NPK fertilizer. Similar observations were recorded by Nangliya (2014), who observed an increase in nutrient (N, P, K, Ca, Mg, Fe, Cu, Mn, and Zn) uptake by tomato plants as the levels of both organic and inorganic applications increased. This may be due to sufficient nutrient availability, higher uptake, enhanced yield, and the positive interactions among various nutrient elements that enhance nutrient uptake.

4.3.7 Crop Yield

Perusal of data presented in Table 4.3.7 revealed significantly higher (15% higher) crop yield under conventional farming system (230.00 qha^{-1}) as compared to natural (200.02 qha^{-1}) farming system.The enhanced yield observed in the conventional farming system may be a result of the higher nutrients being available, however, in the natural farming approach, the nutrient needs might not have been adequately met by the organic supplements like Jeevamrit and Ghanjeevamrit, leading to a potentially lower yield as compared to conventional farming.

Table 4.3.7 Yield of potato under conventional and natural farming system

Panchayats	Farmer	Crop Yield (q/ha)	
		Conventional	Natural
Keylong	F_1	254.8	220.4
	F_2	229.4	206.1
	F_3	247.6	219.4
	F_4	240.9	213.3
	F_5	231.1	208.5
Kardang	F_6	213.1	185.3
	F_7	224.6	180.1
	F_8	243.2	216.0
	F_9	208.1	174.4
	F_{10}	251.3	221.6
Yurnath	F_{11}	210.4	178.4
	F_{12}	228.9	196.0
	F_{13}	238.5	219.3
	F_{14}	220.4	183.2
	F_{15}	207.7	178.3
Mean		230.00	200.02
SE		4.09	4.72
t		4.80	
p		0.00	

Similar observations were recorded by Margus *et al*. (2022) who recorded 25% higher yield in conventional farming as compared to natural farming. Similar observations were recorded by Tein *et al*. (2014) and Keres *et al*. (2020).

4.4 RELATIONSHIP OF NUTRIENT ELEMENTS IN PLANTS WITH SOIL PROPERTIES

The perusal of data given in table 4.4.1 indicates that the OC contentof conventional farming system registered positive and significant correlation with leaf N (r=0.554*), P (r=0.580*), K (r=0.563*) and Mg (r=0.515*). The CEC content registered positive and significant correlation with leaf P (r=0.544*), Ca (r=0.557*) and Mg (r=0.597*). The N content registered highly positive and significant correlation with leaf P (r=0.679**), Mg (r=0.731**) and positive and significant correlation with leaf Ca (r=0.592*). The P content registered highly positive and significant correlation with leaf P (r=0.757**), Ca (r=0.744**) and Mg (r=0.679**). The K content registered highly positive and significant correlation with leaf K (r=0.841**). The Ca content registered highly positive and significant correlation with leaf P (r=0.710**), Mg (r=0.781**) and positive and significant correlation with leaf Ca (r=0.585*). The Mg content registered highly positive and significant correlation with leaf P (r=0.659**), Mg (r=0.743**) and positive and significant correlation with leaf Ca (r=0.574*). The Fe and Cu content also registered positive and significant correlation with leaf Fe (r=0.532*) and Cu (r=0.529*), respectively. The Mn content registered highly positive and significant correlation with leaf Mn (r=0.849**) and positive and significant correlation with leaf Fe (r=0.516*).

Table 4.4.1 Simple correlation coefficient of available nutrients elements in soil and leaf of conventional farming system

Leaf / Soil	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn
pH	0.114	0.136	0.049	0.404	-0.000	-0.187	-0.041	0.070	0.195	-0.033
EC	0.074	0.054	0.445	0.115	0.246	0.436	-0.104	-0.347	0.212	0.083
OC	0.554*	0.580*	0.563*	0.484	0.515*	-0.198	0.319	0.128	0.224	-0.153
CEC	0.342	0.544*	0.417	0.557*	0.597*	-0.124	0.068	-0.019	0.162	-0.159
N	0.423	0.679**	0.482	0.592*	0.731**	-0.172	0.089	-0.216	-0.111	-0.189
P	0.330	0.757**	0.491	0.744**	0.679**	-0.061	-0.094	-0.259	-0.026	-0.352
K	0.404	0.296	0.841**	0.245	0.360	-0.229	0.198	-0.013	0.024	-0.028
Ca	0.355	0.710**	0.365	0.585*	0.781**	-0.300	-0.149	-0.048	-0.176	-0.155
Mg	0.247	0.659**	0.480	0.574*	0.743**	-0.251	0.042	-0.091	-0.093	-0.102
S	-0.117	0.332	0.095	0.147	0.443	0.022	0.087	0.103	0.040	0.074
Zn	-0.023	-0.314	0.193	0.045	-0.444	-0.025	0.492	-0.198	0.227	-0.205
Fe	-0.021	-0.124	0.386	-0.261	-0.195	-0.165	-0.090	0.532*	-0.242	0.413
Cu	-0.248	-0.239	-0.136	-0.389	-0.169	0.345	-0.085	-0.155	0.529*	-0.038
Mn	-0.431	-0.455	0.105	-0.437	-0.162	0.287	-0.116	0.516*	-0.316	0.849**

* Correlation is significant at 0.05 level (2-tailed)
** Correlation is significant at 0.01 level (2-tailed)

The perusal of data given in table 4.4.2 indicates that the OC content of natural farming system registered positive and significant correlation with leaf K (r=0.639*). The CEC content registered highly positive and significant correlation with leaf Ca (r=0.642**) and Mg (r=0.705**). The N content registered positive and significant correlation with leaf K (r=0.591*), Ca (r=0632*) and highly positive and significant correlation with leaf P (r=0.701**). The P content registered highly positive and significant correlation with leaf P (r=0.786**), Ca (r=0.641**) and positive and significant correlation with leaf K (r=0.522*). The K content registered highly positive and significant correlation with leaf K (r=0.790**) and positive and significant correlation with leaf Mg (r=0.549*). The Ca content registered highly positive and significant correlation with leaf P (r=0.746**). The Mg content registered highly positive and significant correlation with leaf P (r=0.646**) and negative and significant correlation with leaf S (r=-0.553*). The Zn, Cu and Mn content registered highly positive and significant correlation with leaf Zn (r=0.681**), Cu (r=0.681**) and Mn (r=0.723**) respectively. The Fe content registered positively and significant correlation with leaf Fe (r=0.632*) and leaf Mn (r=0.639*).

As per the result obtained, it is concluded that a high positive r value (close to 1) indicates a strong positive linear relationship, while a high negative value (close to -1) indicates a strong negative linear relationship. A value near 0 indicates little to no linear relationship.

Table 4.4.2 Simple correlation coefficient of available nutrients elements in soil and leaf of natural farming system

Leaf / Soil	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn
pH	0.121	0.080	0.180	0.202	0.342	-0.129	-0.334	0.049	-0.139	0.411
EC	0.028	-0.060	0.451	0.041	-0.034	0.316	-0.091	-0.158	0.204	0.454
OC	0.490	0.475	0.639*	0.408	0.309	-0.382	0.456	0.045	0.159	0.126
CEC	0.369	0.437	0.439	0.642**	0.705**	-0.213	0.235	0.002	0.386	0.145
N	0.508	0.701**	0.591*	0.632*	0.357	-0.408	0.196	-0.183	-0.007	0.186
P	0.299	0.786**	0.522*	0.641**	0.227	-0.192	-0.078	-0.068	0.028	-0.060
K	0.420	0.338	0.790**	0.236	0.549*	-0.237	0.121	-0.045	0.183	0.304
Ca	0.247	0.746**	0.280	0.487	0.320	-0.481	-0.070	0.030	-0.025	-0.018
Mg	0.395	0.646**	0.411	0.495	0.508	-0.553*	0.114	-0.046	0.002	0.174
S	-0.228	0.260	-0.059	-0.041	-0.117	0.025	0.018	0.084	-0.063	-0.391
Zn	-0.231	-0.318	0.276	0.273	0.091	0.048	0.681**	-0.067	0.143	0.321
Fe	0.049	0.010	0.482	0.007	-0.122	-0.325	-0.040	0.632*	-0.266	0.639*
Cu	-0.039	-0.229	-0.084	-0.153	0.096	0.433	0.009	-0.090	0.681**	-0.126
Mn	-0.383	-0.449	0.310	-0.053	0.165	-0.105	0.234	0.495	-0.067	0.723**

* Correlation is significant at 0.05 level (2-tailed)
** Correlation is significant at 0.01 level (2-tailed)

As outlined by Sharma and Bhandari (1992), interactions among soil or plant nutrients can result in diverse correlations between them. The significance of these correlations for certain nutrient elements can vary, influenced by factors such as weather conditions, crop size, sampling timing, ion antagonism, and the method of estimation. Sharma (1994) also observed a positive and significant relationship of micronutrients in soils with their respective leaf nutrient contents.

4.5 COST ECONOMICS

A perusal of data enumerated in table 4.5 revealed that due to higher yield, the net return (₹2,00,053.49 ha^{-1}) was also higher under conventional farming system, though cost of cultivation (₹1,33,446.51 ha^{-1}) was also higher compared to natural farming system (₹93,675 ha^{-1}). Total 3 pickings were performed under both the farming systems. Gross return and net return were 15 per cent and 2 per cent higher, respectively, under conventional farming system over natural farming system. The B:C ratio, however, decreased under conventional farming system (1.50) compared to natural farming system (2.09) as the cost of inputs under conventional farming was almost 42 per cent higher than natural farming system. These findings corroborated the conclusions of Kumar *et al*. (2017), who recorded highest B: C ratio under organic (1.37) as compared to conventional (1.12) maize farming, which implies not only profitable but also economic viability of both the farming systems. Vala *et al*. (2018) also observed that the gross (₹102200 ha^{-1}), net realizations (₹56582 ha^{-1}) and B:C Ratio (2.24) were higher with combined application of 75% RDF + 25% N through FYM + Biofertilizer followed by 75% RDF + 25% N through vermicompost + Biofertilizer).

Table 4.5 Cost economics of potato

	Gross Return (₹ ha^{-1})	Cost of Cultivation (₹ ha^{-1})	Net Return (₹ ha^{-1})	Yield (q/ha)	B:C Ratio
Conventional	333500.00	133446.51	200053.49	230.00	1.50
Natural	290029.00	93675.00	196354.00	200.02	2.09

*The sale rate of potato was ₹ 14.50/kg.

Chapter 5

SUMMARY AND CONCLUSION

The present investigation entitled **"Nutritional Status of Potato (*Solanum tuberosum* L.) in Lahaul valley of Himachal Pradesh"** was carried out during 2022-2023 with the objective to evaluate the soil quality and plant nutrient contents under natural and conventional farming system and work out the relationship between soil nutrients status and plant nutrient content. A preliminary survey of Lahaul and Spiti district was conducted and three Panchayats were identified for soil and plant sampling. 30 representative surface soil samples along with plant samples (5 each of conventional and natural farming system from each panchayat) from same site were collected and analyzed for various properties following standard procedures. The results obtained are summarized as below:

5.1 PHYSICAL AND CHEMICAL PROPERTIES OF SOIL

5.1.1 Soil Texture

The texture of soil under both conventional and natural farming system was sandy loam to loam. Sand, silt and clay content in the conventional farming system ranged from 48.40-65.28, 20.36-35.67 and 11.32-18.36 per cent with mean values of 56.80, 28.71 and 14.48 per cent, respectively. Whereas, the respective content under the natural farming ranged from 48.23-61.66, 23.46-35.42 and 11.23-19.45 per cent with mean values of 55.61, 29.27 and 15.12 per cent, respectively.

5.1.2 Soil pH, electrical conductivity (EC), organic carbon (OC) and cation exchange capacity (CEC)

The pH, EC and CEC of soils under conventional farming system ranged from 5.97-7.74,0.2-0.39 (dS m^{-1}) and 18.7-26.9 [cmol (p+) kg^{-1}], respectively, while the corresponding values under natural farming practice varied from 6.18-7.8, 0.17-0.44 (dS m^{-1}) and 17.1-26.6 [cmol (p+) kg^{-1}]. The conventional farming system registered mean pH of 7.04, EC of 0.30 (dS m^{-1}) and CEC of 21.76 [cmol (p+) kg^{-1}] as compared to mean pH of 7.22, EC of 0.29 (dS m^{-1}) and CEC of 21.00 [cmol (p+) kg^{-1}] under natural farming practice. The organic carbon under conventional farming system ranged from 7.3-11.3 g kg^{-1} while under natural farming practice, OC ranged from 10.4-14.6 g kg^{-1}. The organic carbon was lower under conventional farming system with mean value of 9.3 g kg^{-1} as compared to natural farming practice with mean value of 12.14 g kg^{-1}.

5.1.3 Macronutrient status of soil

The available N content of soils under conventional farming system ranged from 197.62-341.81 kg ha^{-1} whereas under natural farming practice it ranged from 186.71-332.53 kg ha^{-1}. The available nitrogen was lower under natural farming practice with mean value of (279.24 kg ha^{-1}) as compared to conventional farming system with mean value of (293.25 kg ha^{-1}). Available nitrogen content in soil of both conventional as well as natural farming system were medium in range.

The available P content under conventional farming system ranged from 49.65-78.72 kg ha^{-1} while under natural farming practice, it ranged from 43.21-74.62 kg ha^{-1}. The available P content was recorded to be lower under natural farming system (58.65 kg ha^{-1}) as compared to conventional farming system (64.83 kg ha^{-1}). Available P content in soil of both conventional and natural farming system were high in range.

The available K content under conventional farming system ranged from 216.6-343.07 kg ha^{-1} while under natural farming system, it ranged from 207.56-333.18 kg ha^{-1}. The available K content was recorded to be lower under natural farming system (245.27 kg ha^{-1}) as compared to conventional farming system (262.20 kg ha^{-1}). Available K content in soil of both conventional and natural farming system were medium in range.

The exchangeable Ca content under conventional farming system ranged from 4.93-15.3 [cmol (p+) kg^{-1}] while under natural farming system, it ranged from 4.06-15.35 [cmol (p+) kg^{-1}]. The exchangeable Ca content was recorded to be lower under natural farming system (8.09 [cmol (p+) kg^{-1}]) as compared to conventional farming system (8.60 [cmol (p+) kg^{-1}]). Exchangeable Ca content in soil of both conventional and natural farming system were high in range.

The exchangeable Mg content under conventional farming system ranged from 4.09-7.46 [cmol (p+) kg^{-1}] while under ZBNF practice, it ranged from 1.58-3.61 [cmol (p+) kg^{-1}] while under natural farming system, it ranged from 1.28-3.37 [cmol (p+) kg^{-1}]. The exchangeable Mg content was observed to be lower under natural farming system (2.23 [cmol (p+) kg^{-1}]) as compared to conventional farming system (2.52 [cmol (p+) kg^{-1}]). Exchangeable Mg content in soil of both conventional and natural farming system were high in range.

The sulphate sulphur content under conventional farming system ranged from 22.77-38.85 kg ha^{-1} while under natural farming system, it ranged from 22.61-34.02 kg ha^{-1}. The sulphate sulphur content was recorded to be lower under the natural farming system (28.01 kg ha^{-1}) as compared to conventional farming system (30.09 kg ha^{-1}). Sulphate sulphur content in soil of both conventional and natural farming system were high in range.

5.1.4 Micronutrient status of soil

The Zn content under conventional farming system ranged from 2.22-3.41 mg kg^{-1} while under natural farming system, it ranged from 1.96-3.33 mg kg^{-1}. The Zn content was recorded to be lower under natural farming system (2.47 mg kg^{-1}) as compared to conventional farming system (2.80 mg kg^{-1}). The Zn content in soil of both conventional and natural farming system were medium in range.

The Fe content under conventional farming system ranged from 33.22-42.34 mg kg^{-1} while under natural farming system, it ranged from 30.33-43.42 mg kg^{-1}. Under conventional farming system, the Fe content was recorded to be higher (38.01 mg kg^{-1}) as compared to natural farming system (36.54 mg kg^{-1}). The Fe content in soil of both conventional and natural farming system were high in range.

The Cu content under conventional farming system ranged from 2.01-3.17 mg kg^{-1} while under natural farming system, it ranged from 1.38-3.02 mg kg^{-1}. The Cu content was recorded to be lower under natural farming system (2.34 mg kg^{-1}) as compared to conventional farming system (2.56 mg kg^{-1}). The Cu content in soil of both conventional and natural farming system were high in range.

The Mn content under conventional farming system ranged from 8.15-12.92 mg kg^{-1} while under natural farming system, it ranged from 6.5-12.0 mg kg^{-1}. The Mn content was recorded to be lower under natural farming system (8.67 mg kg^{-1}) as compared to conventional farming system (9.90 mg kg^{-1}). The Mn content in soil of both conventional and natural farming system were high in range.

5.1.5 Nutrient indices of soil

In natural as well as conventional farming systems, the soils have low to high nutrient status and nutrient index value varied from 1.53 to 3.00. The available nitrogen (1.60), potassium (2.20) and DTPA- Zn (2.33) in conventional farming systems were medium in nutrient status with 60, 80 and 66.67 per cent samples falling in medium nutrient rating, respectively, and 40 per cent samples of nitrogen were categorized as low in nutrient rating in conventional farming systems, while under natural farming system, available nitrogen (1.53), potassium (2.20) and DTPA- Zn (2.07) were medium in nutrient status with 53.33, 80 and 93.33 per cent samples falling in medium nutrient rating, respectively and 46.67 per cent samples of nitrogen were categorized as low in nutrient rating in natural farming systems. 100 per cent samples of available phosphorus, exchangeable calcium and magnesium, sulphate sulphur, DTPA-Fe, Mn and Cu were categorized as high in nutrient rating under both the farming system.

5.2 MICROBIOLOGICAL PROPERTIES OF SOIL

5.2.1 Viable microbial count

The population of beneficial bacteria under conventional farming system ranged from 49.76-64.35×10^5 cfu g^{-1} soil while under natural farming system, it ranged from 52.34-69.87×10^5 cfu g^{-1}. The bacterial population was lower under conventional farming system with mean value of 57.59×10^5 cfu g^{-1} as compared to natural farming system with mean value of 62.17×10^5 cfu g^{-1}. Population of fungi under conventional farming system ranged from 7.42-13.77×10^3 cfu g^{-1} soil while under natural farming system, it ranged from 9.32-14.04×10^3 cfu g^{-1}. The natural farming system had higher fungi population (11.54×10^3 cfu g^{-1}) as compared to conventional farming system (9.69×10^3 cfu g^{-1}). Population of actinomycetes under conventional farming system ranged from 24.61-31.41×10^3 cfu g^{-1} soil while under natural farming system, it ranged from 25.34-32.58×10^3 cfu g^{-1}. Similarly, the population of actinomycetes was recorded highest under natural farming system (27.92×10^3 cfu g^{-1} soil) as compared to conventional farming system (27.03×10^3 cfu g^{-1} soil).

5.3 LEAF NUTRIENT STATUS

The leaf nitrogen, phosphorus and potassium content was recorded higher under conventional farming system with mean values of 4.26, 0.53 and 3.28 per cent, respectively as compared to natural farming system with mean values of 4.07, 0.50 and 3.04 per cent, respectively. The Ca (2.71 per cent), Mg (0.59 per cent) and S (0.39 per cent) content of leaf were higher under conventional farming system as compared to natural farming system which recorded 2.50 per cent, 0.56 per cent and 0.35 per cent of Ca, Mg and S, respectively. Zn content in leaves under conventional farming system ranged from 34.53-66.21 ppm while under natural farming system, it ranged from 30.10-58.87 ppm. The Zn content was recorded to be higher under conventional farming system (45.04 ppm) as compared to natural farming system (39.63 ppm). The Fe content in leaves under conventional farming system ranged from 330.44-543.15 ppm while under natural farming system, it ranged from 229.94-520.12 ppm. Under conventional farming system Fe content was recorded to be higher (424.99 ppm) as compared to natural (392.91 ppm) farming system. The Cu content in leaves under conventional farming system ranged from 25.17-52.64 ppm while under natural farming system, it ranged from 20.88-49.32 ppm. Under conventional farming system the Cu content was recorded to be higher (39.16 ppm) as compared to natural (36.10 ppm) farming system. The Mn content under conventional farming system ranged from 57.73-84.08 ppm while under natural farming system, it ranged from 56.02-79.52 ppm. Under conventional farming system the Mn content was recorded to be higher (73.16 ppm) as compared to natural (71.20 ppm) farming system.

5.4 TUBER NUTRIENT STATUS

The tuber nitrogen, phosphorus and potassium content was recorded higher under conventional farming system with mean values of 3.81, 0.58 and 2.66 per cent, respectively as compared to natural farming system with mean values of 3.68, 0.53 and 2.44 per cent, respectively. The Ca (0.84 per cent), Mg (0.55 per cent) and S (0.24 per cent) content were higher under conventional farming system as compared to natural farming system which recorded 0.72 per cent, 0.48 per cent and 0.21 per cent of Ca, Mg and S, respectively. The Zn content in tuber under conventional farming system ranged from 30.02-43.68 ppm while under natural farming system, it ranged from 28.77-41.70 ppm (Table 4.3.6). The Zn content was recorded to be lower under natural farming system (34.28 ppm) as compared to conventional farming system (36.02 ppm). The Fe content in tuber under conventional farming system ranged from 441.64-580.05 ppm while under natural farming system, it ranged from 434.63-573.45 ppm. Under conventional farming system Fe content was recorded to be higher (518.11 ppm) as compared to natural (507.77 ppm) farming system. The Cu content under conventional farming system ranged from 23.08-32.81 ppm while under natural farming system, it ranged from 20.43-29.76 ppm. Under conventional farming system the Cu content was recorded to be higher (27.24 ppm) as compared to natural (24.65 ppm) farming system. The Mn content under conventional farming system ranged from 64.32-98.67 ppm while under natural farming system, it ranged from 58.03-91.66 ppm.

Under conventional farming system the Mn content was recorded to be higher (83.50 ppm) as compared to natural (75.16 ppm) farming system.

5.5 CORRELATION BETWEEN SOIL CHARACTERISTICS AND LEAF NUTRIENT STATUS

Under conventional farming system, OC content registered positive and significant correlation with leaf N (r=0.554*), P (r=0.580*), K (r=0.563*) and Mg (r=0.515*). The CEC content registered positive and significant correlation with leaf P (r=0.544*), Ca (r=0.557*) and Mg (r=0.597*). The N content registered highly positive and significant correlation with leaf P (r=0.679**), Mg (r=0.731**) and positive and significant correlation with leaf Ca (r=0.592*). The P content registered highly positive and significant correlation with leaf P (r=0.757**), Ca (r=0.744**) and Mg (r=0.679**). The K content registered highly positive and significant correlation with leaf K (r=0.841**). The Ca content registered highly positive and significant correlation with leaf P (r=0.710**), Mg (r=0.781**) and positive and significant correlation with leaf Ca (r=0.585*). The Mg content registered highly positive and significant correlation with leaf P (r=0.659**), Mg (r=0.743**) and positive and significant correlation with leaf Ca (r=0.574*). The Fe and Cu content also registered positive and significant correlation with leaf Fe (r=0.532*) and Cu (r=0.529*), respectively. The Mn content registered highly positive and significant correlation with leaf Mn (r=0.849**) and positive and significant correlation with leaf Fe (r=0.516*). Under natural farming system, OC content registered positive and significant correlation with leaf K (r=0.639*). The CEC content registered highly positive and significant correlation with leaf Ca (r=0.642**) and Mg (r=0.705**). The N content registered positive and significant correlation with leaf K (r=0.591*), Ca (r=0632*) and highly positive and significant correlation with leaf P (r=0.701**). The P content registered highly positive and significant correlation with leaf P (r=0.786**), Ca (r=0.641**) and positive and significant correlation with leaf K (r=0.522*). The K content registered highly positive and significant correlation with leaf K (r=0.790**) and positive and significant correlation with leaf Mg (r=0.549*). The Ca content registered highly positive and significant correlation with leaf P (r=0.746**). The Mg content registered highly positive and significant correlation with leaf P (r=0.646**) and negative and significant correlation with leaf S (r=-0.553*). The Zn, Cu and Mn content registered highly positive and significant correlation with leaf Zn (r=0.681**), Cu (r=0.681**) and Mn (r=0.723**) respectively. The Fe content registered positively and significant correlation with leaf Fe (r=0.632*) and leaf Mn (r=0.639*).

5.6 YIELD AND COST ECONOMICS OF POTATO UNDER CONVENTIONAL AND NATURAL FARMING SYSTEM

15 per cent higher yield was recorded under conventional farming system (230.00 q/ha) as compared to natural farming (200.02 q/ha) system. B:C Ratio of natural farming system (2.09) was higher as compared to conventional farming system (1.50) as cost of cultivation (₹133446.51) under conventional farming system was higher in comparison to natural farming system (₹93675).

CONCLUSION

From the present investigations, it can be concluded that potato-growing soils in Lahaul and Spiti district, when managed under a conventional farming system, exhibit significantly higher levels of available primary and secondary macronutrients, as well as micronutrients, in comparison to those under a natural farming system. The N, P, K, Ca, Mg and S were recorded 5, 10.5, 7, 6, 13 and 7.4 per cent higher, respectively, under conventional farming as compared to natural farming practice. On the other hand, organic carbon was recorded 30 per cent higher while beneficial micro-organisms viz. bacteria, fungi and actinomycetes were recorded 8, 19 and 3 per cent higher, respectively, under natural farming as compared to conventional farming system. The leaf nutrient content under conventional farming also recorded higher content of primary and secondary macronutrients (N (4.7%), P (6%), K (7.9%), Ca (8.4%), Mg (5.4%) and S (11.4%)) as well as micronutrients (Zn (13.6%), Fe (8.2%), Cu (8.5%) and Mn (2.7%)) compared to the natural farming system. The tuber nutrient content under conventional farming also recorded higher content of primary and secondary macronutrients (N (3.5%), P (9.4%), K (9%), Ca (16.7%), Mg (14.6%) and S (14.3%)) as well as micronutrients (Zn (5%), Fe (2%), Cu (10.5%) and Mn (11%)) compared to the natural farming system. As a result, yield of potato was significantly higher under conventional farming system as compared to natural farming system. However, the most important benefit of natural farming is exhibited on the soil health, which recorded increase in OC and beneficial microbial population. Despite lower nutrient content and crop yields, the natural farming system appears to have an economic advantage over conventional farming due to its lower cost of cultivation. Improvement in soil health besides economic benefit can make natural farming an attractive option for farmers, as it can lead to cost cuttings and potentially higher profits, even if crop yields are slightly lower or nutrient levels in crops are not as high as in conventional farming.

Therefore, it can be concluded that application of recommended dose of inorganic fertilizers in conventional farming exhibited significantly higher nutrient content (in soil as well as in plants and tubers) and crop yield albeit with higher input costs as maximum inputs are to be purchased. Whereas natural farming helps in improving long-term soil health which can contribute to its economic viability, especially in the context of sustainable and environmental friendly agriculture with reduced input cost. However, further studies are required to be undertaken before arriving at any conclusion.

LITERATURE CITED

A.O.A.C. 1970. Official and tentative methods of analysis. Association of official Analytical Chemists. William Star Wetglad, Washington.

Abreham K, Guja U, Mekuria T and Tsegaye H. 2022. Response of potato (*Solanum tuberosum* L.) to the combined application of organic and inorganic fertilizers at Chena district, South Western Ethiopia. *International Journal Agricultural Research, Innovation and Technology* **12(1)**: 18-23.

Adhikari R C. 2009. Effect of NPK on vegetative growth and yield of Desiree and Kufri Sindhuri potato. *Nepal Agriculture Research Journal* **9**: 67-75.

Aher S B, Lakaria B L, Kaleshananda S, Singh A B, Ramana S, Ramesh K and Thakur J K. 2015. Effect of organic farming practices on soil and performance of soybean (*Glycine max*) under semi-arid tropical conditions in Central India. *Journal of Applied and Natural Science* **7(1)**: 67-71.

Ahmed A A, Abd El-Baky M M H, Zaki M F and Abd El-Aal F S. 2011. Effect of foliar application of active yeast extract and zinc on growth, yield and quality of potato plant (*Solanum tuberosum* L.). *Journal of Applied Sciences Research* **7(12)**: 2479-2488.

Ahmed F, Mondal M M A and Akter M B. 2019. Organic fertilizer effect on potato (*Solanum tuberosum* L.). *International Journal of Plant & Soil Science* **29(3)**: 1-11.

Ahmed N U, Mahmud N U, Salim M, Halder S C and Ullah H. 2017. Yield maximization of potato (*Solanum tuberosum* L.) through integrated nutrient management system. *International Journal of Natural and Social Sciences* **4(1)**: 49-56.

Anonymous. 2022a. Area and production under crops, Department of Agriculture Himachal Pradesh. https://agriculture.hp.gov.in/en/production-2/. [accessed 30 August, 2023].

Anonymous. 2022b. Economics & Statistics Department, Govt. of Himachal Pradesh. https://himachalservices.nic.in/economics/en-IN/publications.html. [accessed 14 June, 2023].

Anonymous. 2022c. Final Estimates of 2020-2021 of Area and Production of Horticulture Crops, Ministry of Agriculture and Farmers Welfare. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1810624:~:text=Potato%20production%20is%20expected%20to,Million%20Tonne%20in%202020-21. [accessed 21 October, 2022].

Ansari A A and Kumar S. 2010. Effect of vermiwash and vermicompost on soil parameters and productivity of okra (*Abelmoschus Esculentus*) in Guyana. *Pakistan Journal of Agricultural Research* **23(3-4)**: 137-142.

Araujo A S F, Leite L F C, Santos V B and Carneiro R F V. 2009. Soil microbial activity in conventional and organic agricultural systems. *Sustainability* **1(2)**: 268-276.

Aulakh C S, Singh H, Walia S S, Phutela R P and Singh G. 2018. Evaluation of nutrient sources for organic production of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system in north-west India. *Indian Journal of Agronomy* **63(2)**: 137-144.

Bajpai R K, Chitale S, Upadhyay S K and Urkurkar J S. 2006. Long-term studies on soil physico-chemical properties and productivity of rice-wheat system as influenced by integrated nutrient management in Inceptisol of Chhattisgarh. *Journal of the Indian Society of Soil Science* **54(1)**: 24-29.

Balemi T. 2012. Effect of integrated use of cattle manure and inorganic fertilizers on tuber yield of potato in Ethiopia. *Journal of Soil Science and Plant Nutrition* **12(2)**: 253-261.

Barakzai A W, Chandel R S, Verma S, Sharma P L, Bharat N K, Singh M P and Yankit P. 2021. Effect of Zero Budget Natural Farming and Conventional Farming systems on biological properties of soil. *International Journal of Current Microbiology and Applied Sciences* **10(2)**: 1122-1129.

Barman K S, Kumar A, Kasera S and Ram B. 2018. Integrated nutrient management in potato (*Solanum tuberosum*) cv. Kufri Ashoka. *Journal of Pharmacognosy and Phytochemistry* **7(1)**: 1936-1938.

Beeby J, Moore S, Taylor L and Nderitu S. 2020. Effects of a one-time organic fertilizer application on long-term crop and residue yields, and soil quality measurement using biointensive agriculture. *Frontiers in Sustainable Food Systems* **4**: 67.

Bhandari A R and Tripathi B R. 1979. Soil testing in fertilizer recommendations. Department of Soil Science, Technical Bulletin 10, Department of Agriculture, Himachal Pradesh, Shimla.

Bhatt M K, Raverkar K P, Chandra R, Pareek N, Labanaya R, Kumar V, Kaushik S and Singh D K. 2020. Effect of long-term balanced and imbalanced inorganic fertilizer and FYM application on chemical fraction of DTPA-extractable micronutrients and yields under rice-wheat cropping system in mollisols. *Soil Use and Management* **36(2)**: 261-273.

Blaise D, Rupa T R and Bonde A N. 2004. Effect of organic and modern method of cotton cultivation on soil nutrient status. *Communications in Soil Science and Plant Analysis* **35(9)**: 1247-1261.

Bouyoucos G J. 1927. The hydrometer as a new method for the mechanical analysis of soils. *Soil Science* **23**: 343-52.

Chadha K L. 2019. Handbook of horticulture (second edition). Indian Council of Agricultural Research, New Delhi, India, 680p.

Chander G, Verma T S and Sharma S. 2010. Nutrient content of cauliflower (*Brassica oleracea* L. var. *botrytis*) as influenced by boron and farmyard manure in North West Himalayan Alfisols. *Journal of the Indian Society of Soil Science* **58(2)**: 248-251.

Chapman H D. 1964. Suggested foliar sampling and handling techniques for determining the nutrient status of some field, horticultural and plantation crops. *Indian Journal of Horticulture* **21**: 97-17.

Chapman H D. 1965. Cation-exchange capacity. Methods of soil analysis: Part 2 Chemical and microbiological properties. **9**: 891-901.

Chesnin L and Yien C H. 1950. Turbidimetric determination of available sulphates. *Soil Science Society of America Journal* **15**: 149-151.

Chongtham S K, Patel C K, Patel C K, Patel D, Patel C R, Zapadiya D M and Patel J K. 2015. Yields, nutrient and water use efficiency and economics of potato variety Kufri Surya as influenced by different nitrogen levels. *International Journal of Agriculture Science* **7**: 785-787.

Choudhary A K, Rahi S, Singh A and Yadav D S. 2010. Effect of vermi-compost and biofertilizers on productivity and profitability in potato in north-western Himalayas. *Current Advances in Agricultural Sciences* **2(1)**: 18-21.

Choudhary R, Kumar R, Sharma G D, Sharma R P, Rana N and Dev P. 2022. Effect of natural farming on yield performances, soil health and nutrient uptake in wheat+gram inter cropping system in sub-temperate regions of Himachal Pradesh. *Journal of Crop and Weed* **18(2)**: 01-08.

Chu B, Zaid F and Eivazi F. 2016. Long-Term effects of different cropping systems on selected enzyme activities. *Communications in Soil Science and Plant Analysis* **47(6)**: 720-730.

Dangi R S, Singh S P, Gaur D, Dixit J P, Sharma S K, Singh N and Patidar R. 2019. Effect of nitrogen levels, cultural practices and their interactions on growth and yield attributes and yield of potato (*Solanum tuberosum* L.). *Journal of Pharmacognosy and Phytochemistry* **8(1)**: 113-117.

Das A, Patel D P, Kumar M, Ramkrushna G I, Mukherjee A, Layek J, Ngachan S V and Buragohain J. 2017. Impact of seven years of organic farming on soil and produce quality and crop yields in eastern Himalayas India. *Agriculture, Ecosystems and Environment* **236**: 142-153.

Devi M, Sephia R S, Mogta A and Verma A. 2018. Influence of integrated management on growth and yield of cauliflower *(Brassica oleraceae)* var. *botrytis)* and soil nutrient status. *International Journal of Chemical Studies* **6(2)**: 2988-2991.

Dhiman D, Sharma R, Sankhyan N K, Sepehya S, Sharma S K and Kumar R. 2019. Effect of regular application of fertilizers, manure and lime on soil health and productivity of wheat in an acid alfisol. *Journal of Plant Nutrition* **42(19)**: 2507-2521.

Dubey R K, Singh V, Devi K and Kartek K. 2012. Effect of nitrogen levels and cultivars on growth and yield components of potato in foot hills of Arunachal Pradesh. *Indian Journal of Horticulture* **69(4)**: 545-549.

Duddigan S, Shaw L J, Sizmur T, Gogu D, Hussain Z, Jirra K, Kaliki H, Sanka R, Sohail M, Soma R, Thallam R, Vattikuti H and Collins C H. 2023. Natural farming improves crop yield in SE India when compared to conventional or organic systems by enhancing soil quality. *Agronomy for Sustainable Development* **43(2)**: 31.

FAI. 1977. Hand book of fertilizer usage, 54th ed., The Fertilizer Association of India, New Delhi.

Gaur D, Dixit J P, Singh S P, Sharma K, Sharma S K and Dhakad H. 2017. Optimization of phosphorus requirement of potato (*Solanum tuberosum* L.) through organic and inorganic sources under current scenario of P use. *International Journal of Chemical Studies* **5(4)**: 2014-2018.

Glab T, Puzynska K, Puzynski S, Palmowska J and Kowalik K. 2016. Effect of organic farming on a stagnic luvisol soil physical quality. *Geoderma* **282**: 16-25.

Glover J D, Reganold J P and Andrews P K. 2000. Systematic method for rating soil quality of conventional organic and integrated apple orchards in Washington State. *Agriculture, Ecosystems & Environment* **80(1-2)**: 29-45.

Gomez K A and Gomez A A. 1984. Statistical procedures for agricultural research. John wily and Sons.

Goswami A K, Lal S and Misra K K. 2012. Integrated nutrient management improves growth and leaf nutrients status of guava cv. Pant Prabhat. *Indian Journal of Horticulture* **69(2)**: 168-172.

Gourav, Sankhyan N K, Sharma R P and Sharma G D. 2019. Long term effect of fertilizers and amendments on the properties of an acid Alfisol and uptake of primary nutrients and sulfur in maize-wheat rotation in North Western Himalayas. *Journal of Plant Nutrition* **42(15)**: 1770-1788.

Grewal J S, Sharma R C and Sud K C. 1981. Effect of continuous application of PK-fertilizer and FYM on potato yield and some soil properties. *Journal of Indian Society of Soil Science* **29**: 129-31.

Islam M M, Akhter S, Majid N M, Ferdous J and Alam M S. 2013. Integrated nutrient management for potato (*Solanum tuberosum*) in grey terrace soil (Aric Albaquipt). *Australian Journal of Crop Science* **7(9)**: 1235-1241.

Jackson M L. 1967. Soil Chemical Analysis. Oxford and IBH Publishing House, Bombay. 38p.

Jackson M L. 1973. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi. 498p.

Jannoura R, Joergensen R G and Bruns C. 2014. Organic fertilizer effects on growth, crop yield, and soil microbial biomass indices in sole and intercropped peas and oats under organic farming conditions. *European Journal of Agronomy* **52**: 259-270.

Jones J B Jr, Large R L, Pfleifederer D P and Klosky H S. 1971. How to properly sample for a plant analysis. *Crops and Soils* **23**: 15-18.

Kaje V V, Sharma D K, Shivay Y S, Jat S L, Bhatia A, Purakayastha T J, Bandyopadhyay K K and Bhattacharya R. 2018. Long-term impact of organic and conventional farming on soil physical properties under rice *(Oryza sativa)*-wheat *(Triticum aestivum)* cropping system in north-western Indo-Gangetic plains. *Indian Journal of Agricultural Sciences* **88(1)**: 107-113.

Kannan P, Saravanan S, Krishnakumar S and Natarajan S K. 2005. Biological properties of soil as influenced by different organic manures. *Research Journal of Agriculture and Biological Sciences* **1(2)**: 181-183.

Kaushal V. 2002. Studies on long-term effects of chemical fertilizers and amendments on sustainable use of soil in wet temperate zone of western Himalayas. M.Sc. Thesis. Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. 99p.

Kazamba K, Singh M S and Abonmai T. 2019. Effect of integrated nitrogen management on yield of potato (*Solanum tuberosum* L.): Local cultivar, Alu Amubi. *International Journal of Chemical Studies* **7(3)**: 4049-4052.

Keres I, Alaru M, Eremeev V, Talgre L, Luik A and Loit E. 2020. Long-term effect of farming systems on the yield of crop rotation and soil nutrient content. *Agricultural and Food Science* **29(3)**: 210-221.

Khan S, Godara R K and Sharma J R. 2017. Effect of different combination of nitrogen and organic manure on leaf nutrient content of japanese pear (*Pyrus pyrifolia*) cv. Punjab Beauty. *Current Journal of Applied Science and Technology* **23(4)**: 1-5.

Kumar B, Gupta R K and Bhandari A L. 2008. Soil fertility changes after long-term application of organic manures and crop residues under rice–wheat system. *Journal of the Indian Society of Soil Science* **56(1)**: 80–85.

Kumar L. 2019. Studies on the effect of different NPK levels on productivity of brinjal (*Solanum melongena* L.). M.Sc. Thesis. Department of Soil Science and Water Management, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP). 84p.

Kumar M, Baishya L K, Ghosh D C and Gupta V K. 2011. Yield and quality of potato (*Solanum tuberosum*) tubers as influenced by nutrient sources under rainfed condition of Meghalaya. *Indian Journal of Agronomy* **56(3)**: 105-111.

Kumar M M, Adarsha L K, Singh S P and Boppana K L. 2017. Economics of Organic Farming over Conventional Farming-A Case Study in Karnataka, India. *International Journal of Current Microbiology and Applied Sciences* **6(11)**: 2810-2817.

Kumar P, Dua V K, Sharma J, Byju G, Minhas J S and Chakrabarti S K. 2018. Site-specific nutrient requirements of NPK for potato (*Solanum tuberosum* L.) in Western Indo-gangetic plains of India based on QUEFTS. *Journal of Plant Nutrition* **41(15)**: 1988-2000.

Kumar P, Kumar P, Sharma M, Butail N P, Singh V and Shukla A K. 2020. Delineation of the major soil nutrients in Seabuckthorn (*Hippophae spp*.) stand and its comparison to other land uses from extreme landscape of trans-Himalaya. *Indian Journal of Ecology* **47(3)**: 799-802.

Kumar P, Pandey S K, Singh B P, Rawal S, Singh S V and Kumar D. 2004. Fertilizer requirements of chipping potato (*Solanum tuberosum* L.) cultivars in west-central plains. *Potato Journal* **31**: 3-5.

Kumar P, Pandey S K, Singh B P, Singh S V and Kumar D. 2007. Optimizing phosphorus requirement of chipsona varieties for west-central plains of India. *Potato Journal* **34**: 3-4.

Kumar R, Paliyal S S, Sharma S K and Rana S. 2017. Status and distribution of available macronutrients in relation to physic-chemical properties under different land uses of cold arid soils of Spiti valley in Himachal Pradesh. *Environment Conservation Journal* **18(3)**: 79-86.

Kumar V, Pandey A K, Prasad R K and Prasad B. 2011. Long-term influence of organic and inorganic sulphur and fertility levels on yields, distribution and build-up of sulphur under rice-wheat cropping system in Calciorthents. *Journal of the Indian Society of Soil Science* **59(3)**: 278-282.

Lakra N U, Anurag, Soni P, Bachkaiya V, Choukse R, Tikariha S and Kumar R. 2022. Influence of Integrated Nutrient Management (INM) on Biochemical Properties of Inceptisol of Surguja District of Chhattisgarh, India. *International Journal of Plant & Soil Science* **34(22)**: 741-749.

Lenka B and Das S K. 2019. Effect of boron and zinc application on growth and productivity of potato (*Solanum tuberosum*) at alluvial soil (Entisols) of India. *Indian Journal of Agronomy* **64(1)**: 129-137.

Lindsay W H and Norvell W A. 1978. Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Science Society of American Journal* **42**: 420-28.

Liu B, Tu C, Hu S, Gumpertz M and Ristaino J B. 2007. Effect of organic, sustainable, and conventional management strategies in grower fields on soil physical, chemical, and biological factors and the incidence of Southern blight. *Applied Soil Ecology* **37**: 202-214.

Lori M, Symnaczik S, Paul M, Gerlinde D D and Andreas G. 2017. Organic farming enhances soil microbial abundance and activity-A meta-analysis and meta-regression. *Plos one* **12(7)**: DOI:e0180442.

Manjunatha G R, Ashalatha K V, Patil K R and Vishwajith K P. 2013. Effect of organic farming on organic carbon and NPK status of soil in Northern Karnataka, India. *Journal of Crop and Weed* **9(1)**: 79-82.

Marathe R A, Bharamble P R, Sharma R and Sharma U C. 2009. Soil properties of vertisols and yield of sweet orange (*Citrus sinensis*) as influenced by integrated use of organic manures, inorganic and bio fertilizer. *Indian Journal of Agricultural Sciences* **79(1)**: 3-7.

Margus K, Eremeev V, Loit E, Runno-Paurson E, Maeorg E, Luik A and Talgre L. 2022. Impact of farming system on potato yield and tuber quality in Northern Baltic Sea climate conditions. *Agriculture* **12(4)**: 568.

Marinkovic J, Bjelic D, Ninkov J, Vasin J, Tintor B and Zivanov M. 2018. Effect of different soil usage on microbial properties in soils of Central Serbia. *Ratar. Povrt.* **55(2)**: 58-64.

Marthha D, Sahu G S, Sahu P and Mishra N. 2017. Performance of potato cv. Kufri Asoka as influenced by graded levels of N, P and K. *Plant Archives* **17(2)**: 1435-1438.

Meena A L, Pandey R N, Kumar D, Dotaniya M L, Sharma V K, Singh G, Meena B P, Kumar A and Bhanu C. 2020. Impact of 12-year-long rice based organic farming on soil quality in terms of soil physical properties, available micronutrients and rice yield in a typic ustochrept soil of India. *Communications in Soil Science and Plant Analysis* 1-18.

Melero S, Madejon E, Herencia J F and Ruiz J C. 2008. Effect of implementing organic farming on chemical and biochemical properties of an irrigated loam soil. *Agronomy Journal* **100(1)**: 136-144.

Melero S, Porras J C R, Herencia J F and Madejon E. 2006. Chemical and biochemical properties in a silty loam soil under conventional and organic management. *Soil and Tillage Research* **90(1-2)**: 162-170.

Merwin H D and Peech M. 1951. Exchangeability of soil potassium in the sand, silt and clay fractions as influenced by the nature and complementary exchangeable cations. *Soil Science Society of America Journal* **15**: 125-128.

Mishra B, Sharma A, Singh S K, Prasad J and Singh B P. 2008. Influence of continuous application of amendments to maize–wheat cropping system on dynamics of soil microbial biomass in Alfisol of Jharkhand. *Journal of the Indian Society of Soil Science* **56(1)**: 71-75.

Mohammed A, Mohammed M, Dechasa N and Abduselam F. 2018. Effects of integrated nutrient management on Potato (*Solanum tuberosum* L.) growth, yield and yield components at Haramaya Watershed, Eastern Ethiopia. *Open Access Library Journal* **5**: e3974.

Mukhopadhyay K, Ansary S H, Saha S, Debnath M, Kundu M K, Pramanick S J, Dhang S C and Islam S. 2021. Integrated nutrient management in potato with compost made through different bio-degradation processes. *Journal of Experimental Biology and Agricultural Sciences* **9(3)**: 306-313.

Nangliya A K. 2014. Evaluation of organic and inorganic inputs on soil health and quality parameters of tomato. M.Sc. Thesis. Department of Soil Science and Water Management, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP). 121p.

Naz F, Ali A, Iqbal Z, Akhtar N, Asghar S and Ahmad B. 2011. Effect of different levels of NPK fertilizers on the proximate composition of potato crop at Abbottabad. *Sarhad Journal of Agric*ulture **27(3)**: 353-356.

Negi M, Sharma J C and Shukla Y R. 2022. Effect of organic manures and inorganic fertilizers on dry matter yield, soil and plant nutrient content in onion (*Allium cepa*). *Indian Journal of Agricultural Sciences* **92 (6)**: 680–683.

Neogi S and Das S. 2022. Effect of nitrogen and zinc in nano forms on growth and productivity of potato (*Solanum tuberosum* L.) in inceptisols. *Journal of Crop and Weed* **18(1)**: 32-38.

Olsen S R, Cole C U, Wattannabe F and Sandean D A. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. *USD Acircular* **939**: 1-19.

Ouyang Y, Jennifer R R and Jeanette M N. 2018. Soil enzyme activities and abundance of microbial functional genes involved in nitrogen transformations in an organic farming system. *Biology and Fertility of Soils* **54**: 437-450.

Parker F W, Nelson W L, Winters E and Miles I E. 1951. The broad interpretation and application of soil test information. *Agronomy Journal* **43**: 105-12.

Parmar D K, Sharma V, Sharma K D and Sharma T R. 1999. Micronutrient status of vegetable growing pocket in cold desert areas of Himachal Pradesh. *Journal of the Indian Society of Soil Science* **47(2)**: 280-283.

Piper C S. 1966. Soil and plant analysis, Academic Press, New York, 47-77p.

Rajneesh, Sharma R P, Sankhyan N K and Kumar R. 2017. Long-term effect of fertilizers and amendments on depth-wise distribution of available NPK, micronutrient cations, productivity, and NPK uptake by maize-wheat system in an acid alfisol of NorthWestern Himalayas. *Communications in Soil Science and Plant Analysis* **48(18)**: 2193-2209.

Ramamoorthy B and Bajaj J C. 1969. Available nitrogen, phosphorus and potassium status of Indian soils. *Fertilizer News* **14**: 25-36.

Rana A. 2019. Insect-pests, natural enemies and soil micro-flora in cabbage under Zero Budget Natural Farming and Conventional Farming systems. M.Sc. Thesis. Department of Agronomy, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP). 65p.

Rana N. 2021. Evaluation of traditional and conventional farming practices in legume based cropping systems under mid-hills of H.P. Himalayas. Ph.D. Thesis. Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. 216p.

Ratna S A, Howlader M H K, Hasan M M, Mallickv M R and Shanta U K. 2016. Effect of integrated use of manure and fertilizer on the growth and yield of potato. *Progressive Agriculture* **27(4)**: 435-443.

Reddy M D, Rama Lakshmi C S, Rao C N, Rao K V, Sitaramayya M, Padmaja G, and Raja Lakshmi T. 2006. Effect of long-term integrated nutrient supply on soil chemical properties, nutrient uptake, and yield of rice. *Indian Journal of Fertilizers* **2(2)**: 25–28.

Reddy R U and Reddy M S. 2008. Uptake of nutrients by tomato and onion as influenced by integrated nutrient management in tomato-onion cropping system. *Crop Research* **36(3)**: 174-178.

Rios J J, Lochlainn S O, Devonshire J, Graham N S, Hammond J P, King G J, White P J, Kurup S and Broadley MR. 2012. Distribution of calcium (Ca) and magnesium (Mg) in the leaves of *Brassica rapa* under varying exogenous Ca and Mg supply. *Annals of Botany* **109(6)**: 1081-1089.

Saha P K, Ishaque M, Saleque M A, Miah M A M, Panaullah G M and Bhuiyan N I. 2007. Long-term integrated nutrient management for rice-based cropping pattern: effect on growth, yield, nutrient uptake, nutrient balance sheet, and soil fertility. *Communications in Soil Science and Plant Analysis* **38(5-6)**: 579-610.

Sarmah A and Deka P C. 2023. Zero budget natural farming in Assam. *The Pharma Innovation Journal* **12(1)**: 1208-1210.

Selvamani V and Duraisami V P. 2018. Evaluating the primary yield limiting leaf nutrient deficiency of coconut (*Cocos nucifera* Linn.) in a major coconut growing zone of Tamil Nadu. *Journal of Plantation Crops* **46(2)**: 112-117.

Sharma A and Sankhyan N K. 2020. Fractionation of sulphur with different physico-chemical properties of cultivated soils from north western Himalayas. *International Journal of Chemical Studies* **8(4)**: 3275-3280.

Sharma A, Sharma J C, Gautam R, Gautam K L and Sharma D. 2022. Effect of organic and inorganic fertilization on NPKcontents, their uptake and economics of cauliflower. *The Pharma Innovation Journal* **11(8)**: 2209-2213.

Sharma S P, Subehia S K and Sharma P K. 2002. Long-term effects of chemical fertilizers on soil quality, crop productivity and sustainability. Research Bulletin CSK Himachal Pradesh Krishi Vishvavidyalaya. 33p.

Sharma T. 2015. Response of integrated nutrient supply on yield of wheat and physical-chemical properties of soil. *The Bioscan* **10(1)**: 77–80.

Sharma U and Bhandari A R. 1992. Survey of the nutritional status of apple orchards in Himachal Pradesh. *Indian Journal of Horticulture Research* **49(3)**: 234-241.

Sharma U and Subehia S K. 2014. Effect of long-term integrated nutrient management on rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) productivity and soil properties in north-western Himalaya. *Journal of Indian Society of Soil Science* **62(3)**: 248-254.

Sharma U. 1994. Studies on the nutrient status in the soil and trees of apple orchards in Chamba district of Himachal Pradesh. Ph.D. Thesis. Department of Soil Science and Water Management, Dr. YS Parmar University of Horticulture and Forestry, Solan, (H.P.), India. 200p.

Sharma V and Kanwar B B. 2010. Copper status and its relation with soil properties in pea growing soils of high hills dry temperate zone of Himachal Pradesh. *Indian Journal of Agricultural Research* **44(1)**: 32-37.

Sharma V. 2006. Delineation of micronutrient cations status and response of pea (*Pisum sativum* L.) to zinc in dry temperate zone of Himachal Pradesh. Ph.D. Thesis. Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. 168p.

Sheeba S and Chellamuthu S. 1999. Long-term influence of organic and inorganic fertilization on the macronutrient status of inceptisols. *Journal of the Indian Society of Soil Science* **47(4)**: 803–804.

Shubha A S, Srinivasa V, Shanwaz A, Anusha R B and Sharavathi M B. 2018. Effect of Integrated Nutrient Management on Growth and Yield Attributes in Potato (*Solanum tuberosum* L.). *International Journal of Current Microbiology Applied Sci*ences **7(09)**: 830-836.

Shunka E, Adela A, Chindi A, Negash K and Woldegiorgis G. 2019. Effect of fertilizer sources on potato yield and yield components under acidic soil condition in central high lands of Ethiopia. *Journal of Natural Sciences Research* **9(23).**

Singh A K, Amgain L P and Singh S S. 1998. Integrated nutrient management in rice wheat under medium land situation In: Extended Summaries of 21st International Congress on Agronomy, held at New Delhi. 450-451p.

Singh R H, Singh S, Prasad S S, Singh V K and Kumar P. 2011. Effect of integrated nutrient management on soil fertility, nutrient uptake and yield of rice-pea cropping system on an upland acid soil of Jharkhand. *Journal of the Indian Society of Soil Science* **59(2)**: 158-163.

Singh Y, Duhan B S and Sharma N L. 2017. Physico-Chemical properties of soil, influenced by different levels of NPK, FYM and sulphur in mustard-Moong cropping sequence. *International Journal of Current Microbiology and Applied Sciences* **6(12)**: 4187-4195.

Subba Rao N S. 1999. Soil microorganism and plant growth. Oxford & IBH publishing Company, New Delhi. 252p.

Subbiah B V and Asija G L. 1956. Rapid procedure for the estimation of the available nitrogen in soils. *Current Science* **25**: 259-60.

Tandon H L S. 1989. *Secondary and Micronutrient Recommendation for Soils and Crops*. A Guide book. Fertilizer Development and Consultation Organization, New Delhi. 22p.

Tandon H L S. 1991. *Sulphur Research and Agricultural Production in India.* (3rd Edition). The Sulphur Institution, Washington D. C. 140p

Tandon H L S. 1993. Methods of Analysis of Soils, Plants, Waters, and Fertilisers. New Delhi, Fertiliser Development and Consultation Organisation.

Tandon H L S. 2009. *Methods of analysis of soils, plants, waters, fertilisers and organic manures*. Fertiliser Development and Consultation Organisation, New Delhi. 204p.

Tein B, Kauer K, Eremeev V, Luik A, Selge A and Loit E. 2014. Farming systems affect potato (*Solanum tuberosum* L.) tuber and soil quality. *Field Crops Research* **156**: 1-11.

Tewolde H, Sistani K R, Feng G, and Menkir A. 2019. Does fertilizing corn with poultry litter enrich the grain with mineral nutrients?. *Agronomy Journal* **111(5)**: 2472–2484.

Thakare R, Chaudhari R D and Zanje H B. 2017. Changes in soil chemical properties due to moisture regimes and sources of organic manures. *International Journal of Chemical Studies* **5(6)**: 875-879.

Thakur J, Kumar P, Mohit and Dhindsa R K. 2019. Influence of integrated nutrient management (INM) on soil physico chemical properties and nutrient uptake of cauliflower (*Brassica oleracea* var. *botrytis* L.). *Indian Journal of Soil Conservation* **47(1)**: 74-80.

Thakur R and Sawarkar S D. 2009. Influence of long-term continuous application of nutrients and spatial distribution of sulphur on soybean-wheat cropping sequence. *Journal of Soils and Crops* **19(2)**: 225-228.

Thakur R, Sawarkar S D, Vaishya U K and Singh M. 2011. Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a Vertisol. *Journal of the Indian Society of Soil Science* **59(1)**: 74-81.

Vala F G, Vaghasia P M, Zala K P and Akhatar N. 2018. Response of integrated nutrient management on nutrient uptake, economics and nutrient status of soil in bold seeded summer groundnut. *International Journal of Current Microbiology and Applied Sciences* **7(1)**: 174-180.

Verma A. 2019. Effect of organic nutrient sources on growth and production of potato and turmeric. Ph.D. Thesis. Department of Soil Science and Water Management, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP). 169p.

Verma G, and Mathur A K. 2007. Effect of continuous application of organic and inorganic fertilizers on micronutrient status in maize-wheat system on Typic Ustochrept. *Asian Journal of Soil Science* **2(2)**: 146–149.

Vijaya Lakshmi D, Padmaja G and Rao P C. 2011. Effect of levels of nitrogen and potassium on soil available nutrient status and yield of potato (*Solanum tuberosum* L.). *Indian Journal of Agricultural Research* **46(1)**: 36-41.

Vishwjeet. 2020. Population dynamics of insect-pests of brinjal and their natural enemies under Subhash Palekar Natural Farming and Conventional Farming systems. M.Sc. Thesis. Department of Entomology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP). 58p.

Vogel A I. 1978. Text book of quantitative inorganic analysis. Richard clay, The Chances press Ltd., Britain.

Walkey A and Black T A. 1934. An experimentation of vegetative method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science* **37**: 38-39.

Yadav R, Panghal V P S, Duhan D S and Bhuker. 2022. Investigation of nitrogen effects on growth and yield of two potato cultivars in Northern Plains of India. *Potato Research* **65(4)**: 853-861.

Yadav S K, Singh R K, Dua V K, Singh S K, Yadav S and Bakade R R. 2020. Nitrogen requirement of potato for eastern Indo-Gangetic plain of India. *Journal of AgriSearch* **7(3)**: 134-137.

Yadav S K, Singh R K, Dua V K, Yadav S, Singh S K and Yadav V P. 2021. Response of potato to zinc application in eastern Indo-Gangetic plains of India. *Journal of AgriSearch* **8(1)**: 18-20.

Yadav S K, Singh R K, Singh S K, Yadav S and Bakade R R. 2020. Site specific nutrient management in potato through nutrient omission plot technique. *Journal of AgriSearch* **7(2)**: 59-62.

Yadav S K, Srivastava A K and Bag T K. 2017. Effect of integration of fertilizers and FYM on productivity and soil health of rainfed potato. *Journal of AgriSearch* **4(1)**: 23-26.

Zaeen A A, Sharma L K, Jasim A, Bali S, Buzza A and Alyokhin A. 2020. Yield and quality of three potato cultivars under series of nitrogen rates. *Agrosystems, Geosciences & Environment* **3(1)**: 20062.

Zewide I, Singh S and Kassa H. 2022. Tuber yield and economics of potato as affected by application of vermicompost, mineral nitrogen and phosphorus in Southwestern Ethiopia. *AGRIVITA Journal of Agricultural Science* **44(1)**: 65-73.

APPENDIX-I

Table: 1 List of farmer's and GPS location used in the study

Panchayats	Samples No.	Farmer's Name	Villages	Farming System	GPS Location (Natural Farming)	GPS Location (Conventional farming)
Keylong	F_1	Phunchog Dawa	Lower keylong	Both natural and conventional	$32^0$34'14" N, $77^0$01'20" E	$32^0$34'15" N, $77^0$01'28" E
	F_2	Chhering Dorje	keylong	Both natural and conventional	$32^0$34'07" N, $77^0$01'57" E	$32^0$34'08" N, $77^0$01'58" E
	F_3	Sonam Angrup	keylong	Both natural and conventional	$32^0$34'08" N, $77^0$02'02" E	$32^0$34'07" N, $77^0$02'03" E
	F_4	Chhime Angmo	Biling	Both natural and conventional	$32^0$34'15" N, $77^0$00'52" E	$32^0$34'13" N, $77^0$00'53" E
	F_5	Duku Ram	Biling	Both natural and conventional	$32^0$34'13" N, $77^0$00'47" E	$32^0$34'11" N, $77^0$00'45" E
Kardang	F_6	Sonam Dangrpa	Kardang	Both natural and conventional	$32^0$33'56" N, $77^0$01'09" E	$32^0$33'55" N, $77^0$01'08" E
	F_7	Gialchhan	Kardang	Both natural and conventional	$32^0$33'55" N, $77^0$01'10" E	$32^0$33'57" N, $77^0$01'18" E
	F_8	Urgian	Kardang	Both natural and conventional	$32^0$33'58" N, $77^0$01'15" E	$32^0$33'59" N, $77^0$01'19" E
	F_9	Chimme Angmo	Kardang	Both natural and conventional	$32^0$33'57" N, $77^0$01'22" E	$32^0$33'56" N, $77^0$01'24" E
	F_{10}	Ramesh Kumar	Kardang	Both natural and conventional	$32^0$33'55" N, $77^0$01'02" E	$32^0$34'04" N, $77^0$01'10" E
Yurnath	F_{11}	ChheringTobdan	Gumling	Both natural and conventional	$32^0$33'58" N, $77^0$02'48" E	$32^0$33'58" N, $77^0$02'53" E
	F_{12}	Devi Singh	Gumling	Both natural and conventional	$32^0$33'54" N, $77^0$02'58" E	$32^0$33'51" N, $77^0$02'54" E
	F_{13}	Tashi Dawa	Gumling	Both natural and conventional	$32^0$33'53" N, $77^0$03'02" E	$32^0$33'51" N, $77^0$03'01" E
	F_{14}	Chetan Dorje	Yurnath	Both natural and conventional	$32^0$34'01" N, $77^0$02'35" E	$32^0$34'04" N, $77^0$02'32" E
	F_{15}	Tenzin Norbu	Yurnath	Both natural and conventional	$32^0$34'00" N, $77^0$02'35" E	$32^0$34'06" N, $77^0$02'27" E

APPENDIX-II

Table: 2 Cost economics of potato under conventional farming system

	Composition	Cost (₹ ha^{-1})
A.	**Fixed cost**	
1	**Ploughing with tractor** (₹ 800/hr) for 5 bigha	2000.00
2	**Land preparation** (9-man days @ ₹ 500/men)	4500.00
3	**Cost of seed** (3 bag/bigha @ ₹1400/bag)	52500.00
4	**Interculture** (12-man days @ ₹ 500/men)	6000.00
5	**Harvesting** (24-man days @ ₹ 500/men)	12000.00
6	**Land rental value including depreciation and interest**	2300.00
	Total	79300.00
B.	**Variable cost**	
7	**FYM** (1050 kg/bigha @ ₹ 2.75/kg)	36093.75
8	**Fertilizers** (Urea ₹ 2500 + NPK ₹ 2955.68)/ha	5455.68
9	**Plant protection chemical**	
	Kaptan 1.5 litre/bigha @ ₹ 650/litre	12187.50
	Carbofuran 0.71litre/bigha @ ₹ 46/litre	409.57
	Total	54146.51
Total cost of cultivation		133446.51
Gross Return Yield (230.00 q/ha) Average sale rate of potato ₹ 14.50/kg		333500.00
Net Return (Gross return-total cost of cultivation)		200053.49
B:C Ratio (Net Return/Total cost of cultivation) 1.50		

APPENDIX-III

Table: 3 Cost economics of potato under natural farming system

	Composition	Cost (₹ ha^{-1})
A.	**Fixed cost**	
1	**Ploughing with tractor** (₹ 800/hr) for 5 bigha	2000.00
2	**Land preparation** (9-man days @ ₹ 500/men)	4500.00
3	**Cost of seed** (3 bag/bigha @ ₹1400/bag)	52500.00
4	**Interculture** (12-man days @ ₹ 500/men)	6000.00
5	**Harvesting** (24-man days @ ₹ 500/men)	12000.00
6	**Land rental value including depreciation and interest**	2300.00
	Total	79300.00
B.	**Variable cost**	
7	**Jeevamrut** (500 litre/ha @ ₹ 5)	2500.00
8	**Ghanjeevamrit** **(**500 kg/ha @ ₹ 15)	7500.00
9	**Jaggery** (3.12 kg/ha @ ₹ 40)	125.00
10	**Pulse flour** (4.37 kg/ha @ ₹ 40)	175.00
11	**Cow dung** (2 kg/bigha @ ₹ 5)	125.00
12	**Cow urine** (2 litre/bigha @ ₹ 8)	200.00
13	**Preparation of jeevamrut** (2.5-man days @ ₹ 500/men)	1250.00
14	**Application of jeevamrut** (5-man days @ ₹ 500/men)	2500.00
	Total	14375.00
Total cost of cultivation		93675.00
Gross Return Yield (200.02 q/ha) Average sale rate of potato ₹ 14.50/kg		290029.00
Net Return (Gross return-total cost of cultivation)		196354.00
B:C Ratio (Net Return/Total cost of cultivation) 2.09		

Dr Yashwant Singh Parmar University of Horticulture and Forestry
Nauni, Solan (HP) 173230
Department of Soil Science and Water Management

Title of Thesis	**:**	**"Nutritional Status of Potato (*Solanum tuberosum* L.) in Lahaul valley of Himachal Pradesh"**
Name of the Student	**:**	Vishal Thakur
Admission Number	**:**	F-2021-58-M
Major Advisor	**:**	**Dr. R S Spehia**
Major Field	**:**	Soil Science and Water Management
Minor Field(s)	**:**	a) Vegetable Science b) Plant Physiology
Degree Awarded	**:**	M.Sc. (Agri.) Soil Science
Year of Award of Degree	**:**	2023
Number of pages of Thesis	**:**	74+iii
Number of words in abstract	**:**	300

ABSTRACT

The present investigation entitled **"Nutritional Status of Potato (*Solanum tuberosum* L.) in Lahaul valley of Himachal Pradesh"** was carried out during 2022-2023 in Lahaul and Spiti district of Himachal Pradesh with the objective to evaluate the soil quality and plant nutrient content under natural and conventional farming practice and work out the relationship between soil nutrient status and plant nutrient contents. A preliminary survey of district Lahaul was conducted and three panchayats were identified for soil and plant sampling. 30 representative surface soil samples along with plant samples (5 each of conventional and natural farming system from each panchayat) from same site were collected and analyzed. Potato growing soils of Lahaul and Spiti district under conventional farming system had significantly higher available primary and secondary nutrients as well as micronutrients compared to the natural farming system. The soil N, P, K, Ca, Mg and S were recorded 5%, 10.5%, 7%, 6%, 13% and 7.4%, respectively, higher under conventional farming as compared to natural farming system. Similarly, micronutrients viz. Zn, Fe, Cu and Mg were recorded 13.4%, 4%, 9.4% and 14%, higher, respectively under conventional farming system as compared to natural farming system. However, organic carbon was recorded 30.5% higher under natural as compared to conventional farming system. Viable microbial count (62.17×10^5 cfu g^{-1} bacteria, 11.54×10^3 cfu g^{-1} Fungi and 27.92×10^3 cfu g^{-1} Actinomycetes) were also recorded higher under natural compared to conventional farming system, which indicating improved soil biological properties under natural farming. Further, conventional farming system recorded higher macro as well as micronutrients in leaf and tuber compared to the natural farming system. Consequently, yield of potato was significantly higher (230.00 q ha^{-1}) under conventional farming system as compared to natural farming (200.02 q ha^{-1}) but natural farming system appears to have an economic advantage over conventional farming system.

Signature of Student	**Signature of Major Advisor**
Mr. Vishal Thakur	**Dr. R S Spehia**
Dated:	**Dated:**

Countersigned

Professor & Head
Department of Soil Science and Water Management
Dr. Y.S. Parmar University of Horticulture & Forestry
Nauni, Solan- 173 230 (H.P.)

BRIEF BIO-DATA

Name	:	Vishal Thakur
Father's Name	:	Shri. Virender Singh
Mother'Name	:	Smt. Meena Devi
Date of Birth	:	26 November, 2000
Sex	:	Male
Marital status	:	Unmarried
Nationality	:	Indian
Permanent Address	:	VPO Mundkhar, Tehsil Bhoranj, District Hamirpur (HP) Pin-176044

Academic Qualification:

Examination Passed	Year of Passing	University/Board	Marks (%)	Division
Matriculation	2015	HPBOSE, Dharamshala	80.7	FIRST
10+2	2017	HPBOSE, Dharamshala	86.6	FIRST
B.Sc. (Hons) Forestry	2021	Dr. Y.S. Parmar UHF, Nauni, Solan (H.P)	7.37	FIRST

Whether sponsored by some state/ Central Govt./Univ./SAARC	:	NA
Scholarship/ Stipend/ Fellowship, any other financial assistance received during the study period	:	Universitystipend

(Vishal Thakur)