Evaluation of Natural Farming Practices in Wheat

THESIS

Submitted to the

Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.)

In partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE

In

AGRICULTURE

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

By

SURUBHI KANER

Department of Soil Science and Agricultural Chemistry
Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
College of Agriculture, Gwalior (M. P.) - 474002

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CERTIFICATE- I

This is to certify that the thesis entitled **“Evaluation of Natural Farming Practices in Wheat”** *submitted in partial fulfillment of the requirements for the degree of* **MASTER OF SCIENCE** in **Soil Science and Agricultural Chemistry** *of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) is a record of the bonafide research work carried out by* **MS. SURUBHI KANER** *under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.*

No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of the investigations have been acknowledged by the scholar.

Place : Gwalior **(Dr. Shashi S.Yadav)**

Date : **Chairman of the Advisory Committee**

THESIS APPROVED BY THE STUDENT’S ADVISORY COMMITTE

Committee	**Name**	**Signature**
Chairman	Dr. Shashi S.Yadav	…………………………
Co-advisor	Dr. A. B. Singh	…………………………
Co-advisor	Dr. Bharat P. Meena	…………………………
Member	Dr. Akhilesh Singh	…………………………
Member	Dr. Varsha Gupta	…………………………
Member	Dr. V. B Singh	…………………………

CERTIFICATE-II

Aadhar no 945882303562
ID. NO. 19111311

This is to certify that the thesis entitled **"Evaluation of natural farming practices in wheat"** *submitted by* **Surubhi Kaner** to the **Rajmata Vijayaraje Scindia Vishwa Vidyalaya, Gwalior** *in partial fulfillment of the requirements for the degree of* **Master of Science in Agriculture (Soil Science)** *in the* **Department of Soil Science and Agricultural Chemistry, College of Agriculture, Gwalior** *has been accepted , after the evaluation, by the External Examiner and by the Student's Advisory Committee after an oral examination on the same.*

Place: Gwalior **(Dr. Shashi S.Yadav)**

Date: **Chairman of the Advisory Committee**

MEMBERS OF THE ADVISORY COMMITTEE

Committee	**Name**	**Signature**
Chairman	Dr. Shashi S.Yadav	…………………………
Co-advisor	Dr. A.B. Singh	…………………………
Co-advisor	Dr. Bharat P. Meena	…………………………
Member	Dr. Akhilesh Singh	…………………………
Member	Dr. Varsha Gupta	…………………………
Member	Dr. V. B Singh	…………………………
Head of Department :	Dr. S. K. Trivedi	…………………………
Director of Instructions :	Dr. A. K. Singh	…………………………

ICAR-Indian Institute of Soil Science
NABIBAGH, BERASIA ROAD, BHOPAL -462038 M.P., INDIA
Phone No:-0755-2730970 Fax No:-0755-2733310,
Mobile No:-09425013470
Email: - abs980649@gmail.com/A.Singh@icar.gov.in

Dr. A.B. Singh, FISAB, FISNS, Principal Scientist & Head

CERTIFICATE

This is to certify that the thesis entitled **"Evaluation of Natural Farming Practices in Wheat"** submitted by **Surubhi Kaner** in partial fulfillment of the requirement for the degree of Master of Science in Agriculture (Soil Science) of the **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya**, **Gwalior**, is a record of the *bona fide* research work carried out her thesis work under my guidance at Division of Soil Biology, ICAR-Indian Institute of Soil Science, Bhopal.

During this period she had successfully and skillfully carried out the thesis work and she familiarized herself in various analytical techniques of this work. It is further certified that this thesis work has not been submitted elsewhere for any master degree. All the assistance and help received during the course of investigation is duly acknowledged by her.

Date: -

Place: - Bhopal

Dr. A.B. Singh,
(Co-Chairman)
(ICAR-IISS, Bhopal)

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(Surubhi Kaner)

Place: Gwalior
Date

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ABBREVIATIONS

@	At the rate of
%	Per cent
$^{\circ}C$	Degree Celsius
LSD	Least significant difference
cm	Centimetre
d.f.	Degree of freedom
DAP	Di-ammonium phosphate
DAS	Days after sowing
dS/m	Deci Siemens per metre
ECe	Electrical conductivity of Saturation
Fig.	Figure
g/ha	Gramme per hectare
ha	Hectare
kg/ha	Kilogram per hectare
mg/g	Milligram per gramme
Mg/m^3	Mega gramme per cubic metre
ml	Milliliter
mm	Millimeter
Mms	Mean sum of square
NS	Non significant
ppm	Part per million
SEm$\pm$	Standard error of mean
SMW	Standard meteorological week
t/ha	Tonnes per hactare
USDA	United States Department of Agriculture
USWB	United States Weather Bureau
NF	Natural Farming
AI-NPOF	All India Network Programme on Organic Farming
ICM	Integrated crop management
CGR	Crop growth rate
NRA	Nitrate reductase activity
TTC	Total chlorophyll content
LAD	Leaf area duration
LAI	Leaf area index
SOC	Soil organic carbon
DMSO	Dimethyl sulfoxide
ICAR	Indian Council of Agricultural Research
ZBNF	Zero budget natural farming
EC	Electrical conductivity
CDM	Cattle dung manure
VM	Vermicompost
PM	Poultry manure

CHAPTER- I

INTRODUCTION

Agriculture has been the mainstay of the Indian economy for centuries. Agriculture employed about 50% of the Indian work force and contributed 17–18% to country's GDP (Madhusudhan, 2015). Agriculture in India has transitioned from subsistence to commercial farming in order to reduce the country's import dependence on food grains. However, the excessive and imbalanced use of synthetic fertilizers and pesticides, etc has resulted in groundwater pollution, soil erosion, genetic erosion, water shortages, reduced soil fertility, build up of soil salinity and water logging etc. (Bhandari, 2014; Meena *et al.,* 2020; Ganguly *et al.,* 2021). Further, it had also contributed to loss of biodiversity in farmlands. The use of such inputs exposed also had subjected smallholder farmers to a high degree of credit risk, and traps them in a perpetual cycle of debt. These small holdings are a critical source of livelihoods in developing countries and produce about 80 per cent of the food consumed. As a result, alternative low-input farming practices such as organic farming and natural farming have emerged in pockets across the world promising reduced input costs and higher yields for farmers, chemical-free food for consumers and improved soil fertility (Khadse *et al.,* 2018; Koner and Laha, 2021).

Organic farming is a system, which avoids or largely excludes the use of synthetic inputs (such as fertilizers, pesticides, hormones, feed additives etc) and to the maximum extent feasible relies upon crop rotations, crop residues, animal manures, off-farm organic waste, mineral grade rock additives and biological system of nutrient mobilization and plant protection (Ramesh *et al.,* 2010). This process involves the use of biological materials, avoiding synthetic substances to maintain soil fertility and ecological balance thereby minimizing pollution and wastage. It aims at the human welfare without any harm to the environment which is the foundation of human life itself. However, the organic farming is not free from limitations. It needs a massive amount of organic manures to produce the crops. Another weakness is of organic agriculture in the country is the absence of linkages between the farmers and markets and absence of financial support from the governments. Another alternative to conventional chemical high input agriculture is Zero Budget Natural Farming (ZBNF) or simple natural farming which is a low-input, climate-resilient type of farming that encourages farmers to use low-cost locally-sourced inputs, eliminating the use of artificial fertilizers, and industrial pesticides. Natural farming was first popularized by the Japanese scientist and philosopher, Masanobu Fukuoka, who practiced it on his family farm in the island of Shikoku (Fukuoka, 1985). Natural farming eliminates energy/ production costs, fertilizer and other input costs, improves underground water level without any contamination, helps in conserving moisture and prevent crop from effect of climate change. Above all, it reduces global warming by reducing the greenhouse gases emission and helps in sustainable food grain production to feed the increasing global population. It cannot be an exaggeration, if we say that cattle based natural farming has the answer for the problem of farmers suicides, mitigation of economic recession, empowerment of the farmers' and improvement of the rural economy.

In India, noted agriculturist Sh Subhash Palekar (2019) has helped popularize ZBNF practices across the country. There are four integral part of the ZBNF namely (1) beejamrutham, or microbial coating of seeds using cow dung and urine based formulations; (2) jeevamrutham, or the application of a bioinoculum made with cow dung, cow urine, jaggery, pulse flour, water and soil to multiply soil microbes; (3) mulching, or applying a layer of organic material to the soil surface in order to prevent water evaporation, and to contribute to soil humus formation; and (d) waaphasa, or soil aeration through a favorable microclimate in the soil. For insect and pest management, ZBNF encourages the use of various kashayams (decoctions) made with cow dung, cow urine, lilac and green chillies. The potential benefits of technique are; it creates conductive environment for biological processes in the soil, most of the freely available resources in nature are used in this technique, production is non toxic, non use of chemicals and fertilizers will reduce subsidy burden of these inputs and minimizes the risk of crop failure, etc. Natural farming has sofar been adopted most prominently in the states of Andhra Pradesh and Karnataka (Bharucha *et al.,* 2020).

NF differs from traditional organic farming in that it does not attempt to provide nutrients needed for crop growth using animal manures, but instead aims to change the functioning of the soil / crop system so that nutrients are made available to crops without the need for external inputs. It uses zero inputs of synthetic fertilizers to avoid reliance on purchased inputs and credit, and low inputs of animal manures to avoid limitations in available manure (Smith *et al.,* 2020). Natural farming is a grassroots movement that aims to improve farm viability by reducing costs. In Andhra Pradesh alone, 5, 23,000 farmers have converted 13% of productive agricultural area to natural farming. However, sustainability of natural farming is questioned because external nutrient inputs are limited, which could cause a crash in food-production. Therefore, in higher-input systems, yield penalties are likely. Since biological fixation from the atmosphere is only possible with nitrogen, natural farming could limit supply of other nutrients. Further research is needed in higher-input systems to ensure mass conversion to ZBNF does not limit India's capacity to feed itself (Smith *et al.,* 2020). Further, till date, no systematic studies are available on available in the literature about natural farming and its impact on crop growth and yield. Wheat is the important and strategic cereal crop land is the most important staple food of about two billion people (36% of the world population).Worldwide, wheat crop provides nearly 55% of the carbohydrates and 20% of the food calories consumed (Breiman and Gaur, 1995).The acreage and production of wheat is greater when compared to other grain crops including rice, maize, etc. It is cultivated over a wide range of climatic conditions. Therefore, the present experiment was conducted with the following objectives:

1. To study the effect of natural, organic and integrated nutrient management practices on some physiological and biochemical aspects of wheat and
2. To assess the impact of natural, organic and integrated nutrient management practices on productivity of wheat and soil health

CHAPTER-II

REVIEW OF LITERATURE

The literature survey pertaining to the study on **'Evaluation of natural farming practices in wheat'** is reviewed in this Chapter. Natural farming (NF) is an environmentally friendly agricultural practice similar to organic farming. It involves the use of on-farm inputs to fulfill the requirement of the plants. The naturally occurring biological diversity in soil and environment is used to control the pest, nutrient mobilization etc. The NF involves the use of various manures and composts, liquid organics such as Jeevamrit, Beejamrit, Ghanjeebamrit, Panchagavya, Cow urine, etc. to fulfill the nutrient requirement of the plants. Similarly, the irrigation management involves the use of different mulches, intercropping, Whapasa etc. The crop protection is generally done by using neem oil, cow urine, Neemastra, Agniastra, Brahmastra, Dashparni ark etc. Considering the wide components of NF, the literature reviewed under different sub-heads. As the integrated nutrient management (INM) is also one of the important components of the present investigation, the literature pertaining to the effect of INM on crop performance and soil properties has also discussed:

2.1 Effect of natural, organic and integrated nutrient management on crop physiological parameters

2.2 Effect of natural, organic and integrated nutrient management on crop performance

2.3 Effect of natural, organic and integrated nutrient management on soil properties

2.1 Effect of natural, organic and integrated nutrient management on physiological and biochemical parameters of crop

Nehra *et al.* (2001) conducted a field experiment at Hisar and reported that the application of organic manures irrespective of source and rate increased the DMA, LAI, effective tillers, grains ear^{-1}, grain and straw yields, photosynthetic pigments (chlorophyll 'a', 'b' and carotenoids) and photosynthesis of wheat significantly over no organic manure during both years.

Chen *et al.* (2004) studied the effects of nitrate supply on plant growth, nitrate accumulation and nitrate reductase activity (NRA) under five nitrate supply rates, 0.00 (N_1), 0.15 (N_2), 0.30 (N_3), 0.45 (N_4), and 0.60 (N_5) g N kg^{-1} soil and reported that from N_1 to N_2, NRA increased most rapidly. The highest NRA occurred at N_4. However, nitrate reductase (NR) activities were not significantly different between N_3, N_4 and N_5, which imply that there is a threshold of nitrate concentration in MP (NMP) to induce NRA.

Amujoyegbe *et al.* (2007) studied the effects of amending soil with poultry manure and inorganic fertilizer on yield and chlorophyll content of maize and reported that sorghum had the highest leaf area (2752.9 cm^2 $plant^{-1}$) and total chlorophyll content of 3.28 mg g^{-1} under poultry manure while maize on the other hand had the highest leaf area (1969.5 cm^2 $plant^{-1}$) and total chlorophyll content of 2.63 mg g^{-1} under PM.

Sadur *et al.* (2010) evaluated the effect of various levels of inorganic fertilizers (NPK) in combination with organic fertilizer in the form of FYM on phenology, LAI and grain yield of wheat and reported that different levels of NPK and FYM alone or in combination had significant effect on tillers m^{-2}, days to 50% heading, days to maturity, LAI, plant height and grain yield. Maximum LAI (2.50) was recorded at 80-60-30 kg ha^{-1}, while minimum LAI (2.23) was found at low level of 40-30-30 kg NPK ha^{-1}.

Pradhan and Moharana (2015) carried out a field experiment at Bhubaneswar and reported that the organic nutrient management expressed significant effect on dry matter accumulation, crop growth rate, relative growth rate, crop yield and productivity in treatment receiving Dhanicha + FYM + Vermicompost in kharif and FYM+Vermicompost in summer (75.99 and 75.80 g hill DM).

Ashraf *et al.* (2016) also reported that maximum growth parameters i.e., plant height, leaf area index (LAI), crop growth rate (CGR), cob length and diameter as well as yield and yield components i.e., grains rows/cob, grains/row, grains/cob, grain weight/cob, 100-grain weight, grain yield, biological yield and harvest index, water and nitrogen use efficiencies as well as transpiration and photosynthetic activities were recorded with 250 kg N ha^{-1}.

Balotf *et al.* (2016) studied the activity of nitrate reductase, nitrite reductase, glutamine synthetase, and glutamate synthase in wheat seedlings and reported that the differential effects between the type and the amount of nitrogen on NR, NiR, GS, and GOGAT activities in wheat seedlings.

Singh *et al.* (2016) also reported that the growth parameters (plant height, number of shoots, DMA, LAI and CGR were significantly greater in RDF through inorganic sources which was at par with 75% RDF through inorganic sources + 25% N through VC and 75 % RDF through inorganic sources + 25 % N through FYM over other treatments.

2.2 Effect of natural, organic and integrated nutrient management on crop performance

The comparative effectiveness of composts and recommended dose of fertilizers (RDF) on crop productivity was studied by various researches in different soils of India. Application of 10 t ha^{-1} of phosphosulpho-nitro compost along with 100% RDF in black soils increased productivity of groundnut and soil organic carbon (SOC) (Ghosh *et al.,* 2001). Similarly, Manna *et al.* (2001) observed that continuous application of 75% RDF coupled with 5 tons of PSNC to soybean crop increased yield and soil health. Combined use of compost + 50% fertilizer dose increased yield of soybean by 13% to 16% over fertilizer alone.

Agrawal *et al.* (2003) revealed that the application of vermicompost significantly increased biomass production and yields of wheat, whereas, application of 75% vermicompost + 25% FYM resulted in the highest growth and yield attributing characteristics of wheat.

Sable *et al.* (2007) were also reported at Parbhani that the organic mode of plant nutrition via various combinations of neem cake and vermicompost was found superior than chemical fertilizers and the highest number of branches and fruit yield were recorded with the combination of 50 % N through neem cake and 50 % N through vermicompost.

Ghosh *et al.* (2004) reported significantly higher nodule biomass and total chlorophyll content of soybean and grain yield in the treatment receiving 75% NPK along with FYM @ 5t ha^{-1} over sole application of 75% NPK.

Kumpawat (2004) conducted a long term (15 year) field experiment at Bhilwara; Rajasthan revealed that the application of 100% recommended dose of N through FYM recorded the higher plant height and test weight of maize. Similarly, a field experiment was conducted to study the effect of organic and inorganic nutrient sources on growth and yield of tomato on a calcareous Vertisol and recorded highest dry matter yield and fruit yield over control with the application of 50% nutrients through chemical fertilizers and 50% nutrients through combination of FYM + cow dung urine slurry (Poul *et al.,* 2004).

Dash *et al.* (2005) also reported higher plant height, number of branches plant^{-1}, leaf area index (LAI), dry matter accumulation (DMA), number of nodules plant^{-1}, their dry weight and seed yield with the application of crop residue @ 5 t ha^{-1} + FYM @ 5 t ha^{-1} + Zn @ 5 kg ha^{-1} over other treatments. Kler and Walia (2006) opined that the treatment supplemented with FYM along with crop residue incorporation and green manuring recorded higher growth parameters *viz.* DMA and LAI over chemical fertilizers and increase in wheat yield by 12.4% as compared to chemical fertilizers under maize-wheat cropping system.

Kannan *et al.* (2006) reported that the application of full dose of N through FYM recorded higher plant height, number of branches plant^{-1} and yield as compared to 100% N through chemical fertilizers. However, Poinkar *et al.* (2006) conducted studies on the effect of organic manure and biofertilizers on growth and yield of turmeric at Nagpur and recorded higher plant height, number of leaves, size and surface area of leaves, girth of pseudo stem, number of tillers plant^{-1} and fresh yield (t ha^{-1}) of turmeric with the application of N:P_2O_5:K_2O @ 120:60:60 kg ha^{-1} over FYM applied @ 10 t ha^{-1} in combination with bio-fertilizers.

Santoshkumar and Shashidhara (2006) conducted a field experiment on integrated nutrient management in chili genotypes at Dharwad and reported that the application of organics *viz.* FYM @ 10 t ha^{-1} along with 100% RDF resulted in higher fruit yield over 100% RDF followed by the combined application of FYM @ 5 t ha^{-1} + chili stalk @ 5 t ha^{-1} along with 100 per cent RDF + secondary and micronutrients + bio-fertilizers (727 kg ha^{-1}) with the genotype Byadagi dabbi.

Singh *et al.* (2006) noticed significantly higher seed yield of soybean with the application of 100%RDF+FYM@2 t ha^{-1}. In legume based cropping system, application balanced fertilizer alone or along with FYM observed positive effect on soil C and N and sustenance of crop productivity (Manna *et al.,* 2007).

Kumar *et al.* (2010) found that the application of FYM and non edible oil cake each supplied at 50% of nutrient sources recorded the highest yield of rice (3450 kg ha^{-1}) and black gram (438 kg ha^{-1}) followed by application of enriched compost + VC+ FYM each at 1/3 proportion (3562 and 366 kg ha^{-1}, respectively).

A four year study by Ramesh *et al.* (2010) on the effect of different combination of organic manures in black soils of central India showed that the highest soybean grain yield (1069 kg ha^{-1}) was obtained with the application of cow dung manure @ 4 t ha^{-1} which was at par with the yield obtained by the recommended dose of fertilizers (1028 kg ha^{-1}).

Davari *et al.* (2012) studied the effect of different combinations of organic manures (FYM equivalent to 60 kg N ha^{-1}, FYM + rice residue of preceding crop @ 6 t ha^{-1}, FYM + RR + bio-fertilizers vermicompost equivalent to 60 kg N ha^{-1} recorded highest growth and yield attributing parameters of wheat.

Kumar *et al.* (2013) reported that application of FYM @ 125% of RDN resulted in maximum grain yield, which was at par with FYM @ 100% and 75% of RDN, but significantly higher than 50% of RDN. Yadav *et al.* (2013) revealed at Varanasi the that application of FYM, VC and PM $1/3^{rd}$ each applied on the basis of RDF of nitrogen recorded the highest rice equivalent yield (35.3 t ha^{-1}) and production efficiency (95.7 and 97.8 kg ha^{-1} day^{-1}).

Bilsborrow *et al.* (2013) evaluated the performance of winter wheat was under organic and conventional production system in the Nafferton Factorial Systems Comparison (NFSC) under long-term trial and reported that the conventional system produced on average a 3.0% higher protein content than organic in all years (12.5% vs. 9.7%). However the organic system produced higher protein levels than conventional. In contrast, the higher hectolitre weight had highest under organic system than the conventional system (71.6 kg hl^{-1} vs. 71.0 kg hl^{-1}).

Kalhapure *et al.* (2014) also reported increase in maize grain yield by 252% over the control and 148% over application of 100% RDF under integrated treatment involving combination of 25% RDF + organic manure + biofertilizers + green manure. Prajapat *et al.* (2014) observed application of 50% N through FYM along with biofertilizers + 25% recommended dose of fertilizer (RDF) to soybean crop resulted significantly highest crop yield. Singh *et al.* (2014) also reported that application of FYM @ 6t ha^{-1} with recommended dose of mineral fertilizer resulted in the highest grain and straw yields of wheat as compared to other treatments. Ram *et al.* (2013) reported maximum nodules $plant^{-1}$, dry weight of nodules, seed yield and net return in Lentil with the combined application of inorganic fertilizers+ vermicompost (2 t ha^{-1}) over control.

Meena *et al*. 2019) conducted a long-term field experiment and reported that the grain yield and system yield were observed to be significantly higher with 75% NPK of STCR + FYM at 5 Mg ha^{1} treatment and recorded an increase of 20.9% and 13.08% in mean grain yield of maize and chickpea, respectively over GRD. Sulok *et al.* 2018) stated the essential role of effective microorganisms in natural farming and their potential in crop cultivation. Through the action of effective microorganisms, this approach should be able to transform a degraded soil ecosystem into one that is fertile and has high nutrients availability. The mixed culture of effective microorganisms applied must be mutually compatible and coexist with one another to ensure its favorable establishment and interaction in the soil. Therefore, it is anticipated that introducing natural farming in black pepper cultivation can enhance the predominance of effective microorganisms in the soil, which in turn could lead to promising growth and yield of the crop.

Khadse and Rosset (2019) analyzed about peasant agro-ecology movements and examined Zero Budget Natural Farming, a grassroots peasant agro-ecology movement in Karnataka, India. The ZBNF ends reliance on external inputs and loans for farming, positioning itself as a solution to extreme indebtedness and suicides among Indian farmers. The ZBNF movement has achieved massive scale not only because of effective farming practices, but because of a social movement and self organized pedagogical activities

Korav *et al.* (2020) stated that ZBNF is the best solution to reduce the input cost of farmers. The word zero budget means “no credit” and natural farming means “growing of crops without chemicals. 1st time in the world, Japanese agriculturist M Fukuoka developed natural farming and the same trend was made in India by Mr. Subhash Palekar, he started the ZBNF concept and made successful in south India. 523,000 farmers have already converted to ZBNF in Andra Pradesh and 1 lakh farming houses in Karnataka. This concept works on four concepts they are Jeevamrith, Bijamrith, mulching, and soil aeration. These four concepts help better soil health, increased microbial population, and enhanced crop yield. Different astras used to control pest infestation in natural farming. Here we discussed ZBNF is requires low input cost, good soil health management, and focused on major challenges and opportunities to adopt ZBNF and what are the policies need to improve this system.

Kumar and Kumari (2020) stated that ZBNF promises to drastically cut production costs. Zero budget farmers use mulching, soil protection techniques, natural pesticides and fertilizers. The principal methods of Zero budget natural farming has basically four pillars Jivamrita, Bijamrita, Acchadana (Mulching) and Whapasa. Palekar also gave formulae for fungicides *i.e.* sour buttermilk (Khatti Lassi), Sonthastra for pest management *i.e*. Agniastra, Brahmastra, Neemastra, Dashparni ark. Saptdhanyankur ark also been used for shining in fruits, vegetables and seeds. By using ZBNF farmer will be able to grow chemical free food.

Kaur *et al.* (2021) conducted a field experiment during Rabi 2017-18 at organic farm of Department of organic agriculture, CSK HPKV, Palampur to evaluate the doses and application time of Jeevamrit in wheat under natural farming system. Ten treatments comprising of jeevamrit application @ 5% at 2, 3 & 4 weeks interval, jeevamrit @ 10% at 2, 3 & 4 weeks interval, jeevamrit @ 20 per cent at 2, 3 & 4 weeks interval and vermicompost @ 10 t ha^{-1} + 3 sprays of vermiwash @ 750 l ha^{-1} (T10) were randomly allocated and replicated thrice under randomized block design.

As per the findings, significantly higher grain yield (3117 kg ha^{-1}) was recorded with Jeevamrit application @ 20% at 2 weeks interval, which was at par with application of Jeevamrit @ 10% at 2 & 3 weeks interval, Jeevamrit

@ 20% at 3 weeks interval and to the check (Vermicompost @ 10 t ha^{-1} + 3 sprays of Vermiwash @ 750 l ha^{-1}). Maximum B: C ratio (1.69) was recorded with application of Jeevamrit @ 10% at 3 weeks interval which was followed by application of Jeevamrit @ 10% at 2 weeks interval. The results showed that application of Jeevamrit in natural farming system is capable of producing high yields of good quality and is commercially viable since it registered better net returns and B: C ratio.

2.3 Effect of natural, organic and integrated nutrient management on soil properties

The chemical and biological properties of soils are changed to a certain extent by growing of crops under different natural farming/organic nutrient management systems.

2.3.1Soil chemical properties

Anand and Yaduvanshi (2000) reported that the soil organic carbon (SOC) Zn and Mn in soil were significantly lower in treatments receiving inorganic fertilizers compared to the treatments involving organics with fertilizers. Zaller and Koepke (2004) reported that the application of FYM @ 30 Mg ha^{-1} y^{-1} significantly increased soil pH, P and K concentrations than without FYM application for nine years to wheat near Bonn in Germany on a Fluvisol.

Pandey *et al.* (2006) reported that application of manures, irrespective of sources and rates, recorded significantly higher SOC, available N, P_2O_5 and K_2O compared to control. Higher content of SOC might be due to increased yield of roots and plant residues of garden pea as well as external application of organic manures.

Gathala *et al.* (2007) revealed that the application of FYM @ 20 t ha^{-1} significantly increased the SOC (10.7 g kg^{-1}), CEC (19.79 cmol kg^{-1}), water stable aggregates (61.52% > 0.25 mm) and humus fractions of the soil on a *Haplustept* of Udaipur, Rajasthan. However, the bulk density of the soil decreased (0.31 Mg m^{-3}) with the application of FYM alone over inorganic fertilizers after harvest of wheat.

Datt *et al.* (2003) reported higher available N (398 kgha^{-1}), P (38.3 kg ha^{-1}), K (328 kg ha^{-1}) and greater SOC (7.7 g kg^{-1}) content in soil under the application of FYM @ 10 t ha^{-1}.

Rajeshwari (2005) observed higher available N (286 kg ha^{-1}), P (35.7 kg ha^{-1}) and K (311 kg ha^{-1}) with 100% RDN through distillery yeast sludge (DYS) followed by 100% RDN through FYM and 50% RDN through fertilizer + 50% RDN through DYS. However, the lowest available N, P and K were recorded in the treatment 100% RDN through fertilizer in maize.

Manjunatha (2006) found that the soils under organic manure application recorded higher amounts of available N, P, K, S and micronutrients (Zn, Fe, Mn and Cu) than the soils under conventional farming.

Jagtap *et al.* (2007) conducted a study on the influence of INM on soil properties and release of nutrients in a medium black saline sodic soil under laboratory condition and revealed that application of FYM @ 2200 mg kg^{-1} soil recorded higher available Zn and Fe over no manure application.

Yadav and Chhipa (2007) from a field experiment at Jaipur revealed that N, S and Fe contents of soil increased with the application of FYM up to 30 t ha^{-1} whereas P and K contents increased significantly with the application of FYM up to 20 t ha^{-1}. Shwetha (2008) reported that the SOC content and available soil nutrients *viz.* N, P and K after harvest of soybean and wheat were significantly higher with the application of organic manures alone or in combination with fermented organics over organics alone. The higher organic carbon, available N, P and K values which ranged between 0.72 and 0.74%, 263.4 and 269.6 kg ha^{-1}, 17.5 to 17.9 kg ha^{-1} and 383 and 391 kg ha^{-1} respectively, were recorded with combined application of fermented organic manures (Beejamrut, Jeevamrut and panchagavya) and organics (Compost, Vermicompost and Green leaf manure) than the individual application of fermented organics and RDF+FYM after harvest of soybean under soybean wheat cropping system.

Kumar *et al.* (2008) recorded a decrease in soil pH and EC from its initial values (7.6 and 0.36 dS m^{-1}, respectively) and an increase in organic carbon, available N, P, and K from its initial values (3.7%, 119, 25 and 123 kg ha^{-1}, respectively) by the addition of green manure and crop residue with inorganic fertilizers in rice-wheat system.

Organic manures (*viz.* vermicompost, poultry manures and cattle dung manures) were evaluated vis-a-vis chemical fertilizers on the soil fertility of soybean-durum wheat cropping system and concluded that soil organic carbon, available N and K status of the soil were significantly improved in the organic manure treatments as compared to chemical fertilizers (Ramesh *et al.* 2008).

Results of field experiment at Akola, Kotangle *et al.* (2009) revealed that application of 100% RDF+10 t FYM ha^{-1} increased the SOC and available nutrient contents (N, P, K and S) in the soil as compared to 150% RDF under sorghum-wheat cropping sequence. Similarly, Ram *et al.* (2013) noticed improved SOC (0.17 g kg^{-1} soil) and buildup of nutrients (N, P, K and S) to the tune of 4.7, 0.75, 11.5 and 2.9 kg ha^{-1} over initial soil fertility in treatment involving application of FYM @ 5 t ha^{-1} along with inorganic fertilizers.

Panwar *et al.* (2010) reported that the most significant buildup of SOC and nutrients was in organic management practice, followed by integrated management practice and then chemical management practice under a soybean—durum wheat cropping system.

Ramesh *et al.* (2010) also reported that combined application of cow dung manure + vermicompost + poultry manure resulted in the improvement of SOC content, available soil N, P and K compared to either recommended dose of fertilizers or control measured at the end of the fourth cropping cycle. Meena *et al.* (2010) reported improved values of SOC, soil nutrients (NPK) and biological properties in the treatment receiving poultry manure @ 150% recommended nitrogen dose compared to those receiving varying doses of vermicompost and farmyard manure and over the control.

The field study conducted by Vajantha *et al.* (2013) on the available N, P, K and S in soil with the application of *panchagavya* sprayed to plants and applied to soil with different concentrations (3 and 5 per cent to plant and 9 and 15 per cent to soil) at different intervals (3 sprays - 30, 60 and 90 DAS; 4 sprays - 20, 40, 60 and 80 DAS) revealed that the available nutrients *viz.* N, P, K, and S was found significantly higher with the application of *panchagavya* over control. Angelopoulou *et al.* (2013) studied the response of apple and wine grape crops to conventional, organic and biodynamic farming systems. They observed significant increase in total N (0.22% w/w), organic C (66 mg 100 g^{-1} soil) and mycorrhizal colonization rate (31%) under long term biodynamic farming systems. Whereas, Heinze *et al.* (2011) reported that, the application of biodynamic preparations did not affected the contents of soil organic C and total N.

Moe *et al.* (2019) carried out a field experiment to study the nitrogen, phosphorus, and potassium (NPK) status, growth characteristics and yield of rice under the application of poultry manure (PM), cow manure (CM) and compost (CP). Organic fertilizers were applied as EMN (estimated mineralizable N) based on their total N content. Six treatments were assigned in a randomized complete block design: (1) no-N fertilizer (N_0); (2) 50% CF (CF_{50}), (3) 100% CF (CF_{100}); 50% CF + 50% EMN from (4) PM or (5) CM or (6) CP. Compared with CF_{100}, the $CF_{50}PM_{50}$ (total N ≥ 4%) accumulated higher N, P and K content in leaf, sheath, panicle and seeds, resulting in greater growth and yield. The $CF_{50}PM_{50}$ increased yield by 8.69% and 9.70%, dry matter by 4.76% and 5.27% over CF_{100} in both years. The continuous application of $CF_{50}CM_{50}$ (total N < 4%) and $CF_{50}CP_{50}$ (total N < 4%) treatments led to similar NPK contents but higher yields than those of CF_{100} treatment in 2018. In conclusion, the organic fertilizer (total N ≥ 4%) with the EMN method enhances higher N availability in each year. Continuous application of organic fertilizer (total N < 4%) over two year's effectively increased N availability in the second year. The 50% organic fertilizer (total N ≥ 4%) and 50% CF led to increased NPK availability and rice yields over the 100% CF treatment, reducing CF usage and leading for sustainable agriculture.

Shyam *et al.* (2019) conducted a study was to assess performance of zero budget natural farming and found that ZBNF partially improved soil health compared to lands of non-adopters possibly due to building the heterotrophic microbial communities and flora quickly. Many studies proved that the capacity to improve the soil microbes in N fixation and P solubilization was improved with the application of organic manures with cow urine. The ability to produce chemical-free food and reduce fertilizer and pesticide cost was cited by the farmers as the primary reason for the adoption of ZBNF. Meena *et al.* 2019) noticed that the application of higher level of FYM (20 Mg ha^{-1}) significantly increased the SOC, SOC stock, carbon sequestration rate, $KMnO_4$-N, Olsen-P and NH_4OAc-K concentration in surface soil.

2.3.2. Soil biological properties

Zaller and Köepke (2004) studied the effects of applications of traditionally composted FYM and biodynamically composted FYM on soil biological properties under wheat crop and reported that application of FYM @30 Mg ha^{-1} y^{-1} significantly altered microbial biomass, dehydrogenase activity, microbial turnover and decomposition rates in the soil. Graham and Haynes (2005) observed that long-term application of fertilizer enhanced soil enzyme activity due to improvement in water soluble carbon (WSC).

Rajeshwari (2005) reported maximum dehydrogenase activity (16.40 µg TPF g^{-1} soil day^{-1}) were recorded in treatment receiving 100 per cent RDN through FYM as compared to 100 per cent RDN through fertilizer (12.18 µg TPF g^{-1} soil day^{-1}) during harvest stage of crop.

Marinari *et al.* (2006) showed significantly better soil nutritional and microbiological conditions; with increased level of total nitrogen, nitrate and available phosphorus, and an increased microbial biomass content, and enzymatic activities (acid phosphatase, protease and dehydrogenase) under organic management practice over the period of 7 year in Central Italy. Mandal *et al.* (2007) investigated that balanced application of NPK + FYM gave highest DHA and phosphates activity over control.

Mathew and Varughese, (2008) observed that integration of organic sources with 100% RDF increase the activity of soil enzyme like phosphatase, urease, cellulase and microbial population *viz.* actinomycetes, bacteria and fungi and improves the fertility of soil.

Chang *et al.* (2007) revealed that the soil microbial biomass, populations of bacteria, fungi and actinomycetes, as well as soil enzyme activities (FDA, dehydrogenase, β-glucosidase, acid and alkaline phosphatases and urease) increased significantly in compost treated soils over application of only chemical fertilizers. Okur *et al.* (2008) observed that application of FYM or tobacco waste compost alone or in combination significantly increased dehydrogenase, urease, FDA, alkaline phosphatase and β-glucosidase soil enzyme activities and improved soil organic matter content.

Shwetha (2008) reported that the combined application of fermented organics *viz. Beejamrut*, *Jeevamrut*, *panchagavya* along with compost, vermicompost, and green leaf manure recorded the highest soil biological activity. Similarly, dehydrogenase activity was also higher with combined application of organics and fermented organics than their individual applications and RDF + FYM. The highest dehydrogenase activity of 34.84 μg TPF g^{-1} soil day^{-1} was observed with compost + vermicompost + green leaf manure + *Jeevamrut* + *Beejamrut* and was on par with the treatment receiving vermicompost + green leaf manure + *Jeevamrut* + *Beejamrut* + *panchagavya*. The lowest dehydrogenase activity of 24.27 μg TPF g^{-1} soil day^{-1} was noticed with the application of RDF + FYM at 60 DAS of soybean in soybean-wheat cropping system.

Yadav *et al.* (2013) reported the effect of organic nutrient sources on soil biological properties by conducting a field experiment at Varanasi. They revealed that application of farmyard manure, vermicompost and poultry manure (FYM+VC+PM) $1/3^{rd}$ each applied on the basis of recommended dose of nitrogen (kg ha^{-1}) recorded significantly higher soil biological indictors like dehydrogenase activities, urease activities, soil microbial biomass carbon and soil microbial biomass nitrogen in the treatment receiving FYM+VC+PM combined with biofertilizers. Lori *et al.* (2017) reported that organic systems had 32% to 84% greater microbial biomass carbon, microbial biomass nitrogen, total phospholipids fatty-acids, and dehydrogenase, urease and protease activities than conventional systems. Aher *et al*. (2018) noticed that the organic agriculture registered 27-102% higher enzymatic activities than conventional agriculture. Similarly, Meena et al. (2019) reported that the soil enzymes, dehydrogenase (DHA), alkaline phosphates (Alk-P) and fluorescein diacetate (FDA) were enhanced significantly with the application of FYM at 20 Mg ha^{1} and STCR based 75% NPK + FYM at 5 Mg ha^{-1}.

Ghosh *et al*. (2020) studied four major cropping systems of India i.e. soybean-wheat, soybean-mustard, soybean-pea and soybean-linseed under six nutrient management practices, namely, M1 (mineral fertilizers as used by farmers), M2 (recommended dose of mineral fertilizers), M3 (50% Inorganic +50% Organic), M4 (25% Inorganic +75% Organic), M5 (75% Organic + Innovative) and M6 (Organic; 100% Organic) in a Vertisol and reported that the soil microbial enzyme activities were significantly ($P < 0.05$) increased by organic amendments (~50–75%).

CHAPTER-III

MATERIALS AND METHODS

A field study entitled **“Evaluation of natural farming practices in wheat”** was conducted during the *Rabi* season of 2020-21 on an ongoing experiment under All India Network Project on Organic Farming (NPOF) at Research Farm of the ICAR Indian Institute of Soil Science, Bhopal. The details of the materials used in the experiment and analytical methods adopted during the investigation are presented in this chapter:

3.1 Location and Climate

Geographically, the ICAR-Indian Institute of Soil Science, Bhopal lies between 23°18' N latitude and 77°24' E longitudes. The elevation above mean sea level is 495 m.

ICAR Indian Institute of Soil Science, Bhopal falls under sub-humid tropics with an average annual rainfall of 1208 mm and mean annual air temperature of 25°C. About 80 per cent rainfall is received from South-West monsoon (June to September), while the rest from North-East monsoon (October and November). Agro-ecologically, the study region lies in Vindhya plateau region (Zone No. IV) having sub-humid climate.

3.2 Meteorological parameters

The meteorological data recorded during the crop growth period (November 2020 to March 2021) is presented in Figure 3.1. The data revealed that the minimum temperature, maximum temperature and relative humidity ranged 6.2-22.8 °C, 23.4-41.3 °C and 10.8-81.2%, respectively. During this period, total rainfall received was 46.3 mm. The average minimum temperature, maximum temperature and humidity during crop growth period were 13.9 °C, 30.4 °C and 40.5%, respectively.

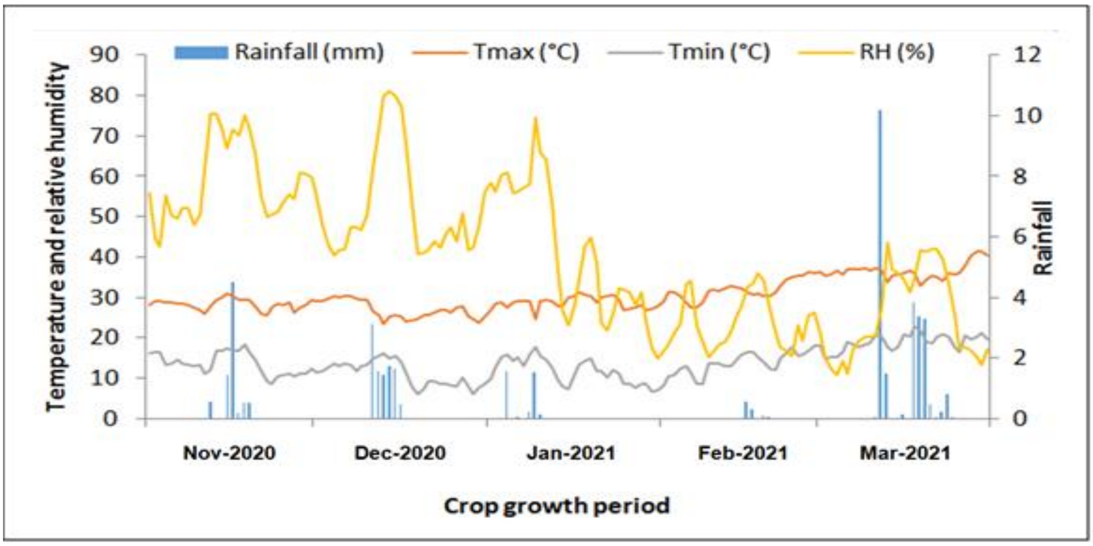

Figure 3.1 Mean monthly weather parameters during crop growth period.

3.3 Soil

The soil of experimental site is classified as Vertisol *(Typic Haplustert)* with smectite as the dominant clay mineral. Vertisols are churning heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years.

3.3.1 Initial characteristics of experimental field

The soil of the experimental site is clayey in texture (*Typic Haplusterts)* with 25.2, 18 and 56.8 per cent of sand, silt and clay, respectively. Initially, the soil (0 to 15 cm depth) was medium in soil organic carbon (Walkley and Black easily oxidizable carbon) (0.53%), low in available N (68.8 mg kg^{-1}), medium in available P (12.8 mg kg^{-1}) and high in available K (237 mg kg^{-1}). The soil was normal in reaction (pH 7.76) and non saline in nature (EC 0.181 dS m^{-1}).

3.4 Treatments

The field experiment was conducted with nine treatment combinations and replicated three times in a randomized block design. The details of the Treatments are as follows in Table 3.1

3.5.1 Organic manures

The various organic manures *viz*., cattle dung manure (CDM), poultry manure (PM) and vermicompost (VC) were based on dry weight basis in present experiment.

3.5.2 Liquid organics

The various liquid organics *viz*., Beejamrit, Ghanjeevamrit, Jeevamrit, Neemashtra, Agniashtra, Brahmashtra, Mixed Leaf extract (decoction, Chill-garlic extract and Dashparni extract for the purpose of seed treatment, fertilization, pest control etc. were prepared as per the standard protocol of All India Network Programme on Organic Farming (AI-NPOF), ICAR-Indian Institute of Farming Systems Research, Modipuram and used accordingly.

3.5.3 Chemical fertilizers

Urea, single super phosphate (SSP) and murate of potash (MOP) were used to supply N, P_2O_5 and K_2O as per treatment details

3.5.4 Seeds

Disease and pest free seeds of wheat (cv.HI-8759) were used for sowing. HI-8759 wheat variety is suitable for irrigated timely sown condition and rich in protein iron and zinc contents. It showed that resistance to Loose smut and foot rot than all the checks, and comparable resistance to flag smut *(Urocystis tritici)* and karnal bunt (*Neovossia indica*).

Table 3.1 the details description of treatment combinations for wheat crop under ZBNF

Treatment	Abbreviation	Details description
T_1	Control	Control
T_2	NF	Complete NF (1. Beejamrit+Ghanjeevamrit+Jeevamrit 2. Crop residue mulching (Soybean @ 5 t/ha) 3. Intercropping (Wheat + Mustard (8: 2) 4. Whapasa(Irrigation in alternate furrows at noon)
T_3	NF-1	NF-1 (1 Crop residue mulching 2. Intercropping, 3. Whapasa)
T_4	NF-2	NF-2 (1.Beejamrit+Ghanjeevamrit+Jeevamrit) + 2. Intercropping + 3. Whapasa)
T_5	NF-3	NF-3 (1. Beejamrit+Ghanjeevamrit+Jeevamrit 2. Crop residue mulching 3. Whapasa)
T_6	NF-4	NF-4 (1. Beejamrit+Ghanjeevamrit+Jeevamrit 2. Crop residue mulching 3. Intercropping)
T_7	AL-NPOF	AI-NPOF package (Sole crop (Wheat) Nutrients were applied through organic manures (cattle dung manure, vermicompost and poultry manure) on N equivalent basis.
T_8	ICM	Integrated Crop Management (50% nutrient application through organic manure and 50% nutrient application through inorganic sources with application of need based pesticides for pest management)
T_9	ICM-P	Integrated Crop Management (50% Nutrient application through organic manures and 50% nutrient application through inorganic sources with use of Neemastra, Agniastra, Brahmastra and Dashparni ark for pest management)

3.6 Field experiment

The wheat crop in *rabi* (2020-21) was grown with the selected set of treatments (Table 3.2).

Table 3.2 Experimental details

Particulars	**Details**
Design	RBD
Replications	3
Crop & variety	Wheat (HI 8759)
Row spacing	22.5 X 5 cm
Plot size	10 m X 10 m
Seed rate	100 kg/ha
Fertilizer dose (N,P_2O_5, K_2O)	120,60,40 kg/ha

In natural farming and organic treatments, nutrients were applied through a combination of cattle dung manure + vermicompost + poultry manure (one third each) to wheat during the winter season. These manures were applied on the N equivalent basis to with adjustment of moisture in manure. The nutrients in the integrated treatment plots were supplied partially through chemical fertilizers and organic manures. The sowing of wheat (HI 8759) was carried out manually in each plot. Wheat was grown as irrigated crop therefore four irrigations (excluding pre-sowing) were given to wheat crop at about 20, 45, 75 and 100 days after sowing whereas in natural farming treatments the irrigation was scheduled as per the treatment requirement. The mulching was carried using crop residue to the assigned treatments. Doses of fertilizers in recommended dose of chemical fertilizer treatment were supplied in split doses *viz.* basal application, 30 and 45 days after sowing; whereas, organic manures were supplied as basal application. The liquid organics were used as per the treatments. Two hand weedings were carried out for soybean and wheat crops to keep the plots weed free. The crop was harvested at physiological maturity stage.

3.7 Observations

3.7.1 Growth parameters

3.7.1.1 Plant height

In each net plot, 10 plants were selected randomly and tagged for periodic observations. The height was recorded at 30, 60 DAS and at harvest in all the each plots and expressed in cm. It was measured from ground level to the base of the last unfolded leaf at the top of the main stem. The mean plant height of these 10 tagged plants was computed and used for statistical analysis.

3.7.1.2 Leaf area

Area of all the fully opened leaf lamina per plant were measured at 30, 60 and 90 DAS with the help of leaf area meter and expressed in cm^2 $plant^{-1}$.

3.7.1.3 Leaf area index (LAI)

The leaf area of 10 randomly selected plants was recorded and thereafter, it was divided by land area to obtain leaf area index (LAI). It was determined plot wise at 30, 60 and 90 DAS by using formula as suggested by Watson (1952).

3.7.1.4 Crop growth rate (CGR)

The crop growth rate was determined by following equation given by Roderick (1978):

$$Crop\ growth\ rate(CGR) = \frac{W2 - W1}{P(t2 - t1)}$$

Where,

W1-Biomass yield at previous harvest date

W2-Biomass yield at current harvest date

P-The area of ground where W1 and W2 have been realized

t1- Time of harvesting biomass yield W1

t2- Time of harvesting biomass yield W2

3.7.2 Yield and yield attributes

3.7.2.1 Number of tillers

The number of tillers per meter square area was counted from the plot.

3.7.2.2 Weed biomass

The weed biomass from the plot was recorded and expressed as kg ha^{-1}.

3.7.2.3Test weight

After threshing of wheat one thousand grains were counted from the produce of each plot and then weighed and expressed in gram (g).

3.7.2.4 Grain yield

The wheat crop was harvested at maturity and the plot wise bundles were tagged and allowed them to sun dry. After proper sun drying the bundles where threshed manually and plot wise grain yield was determined. The obtained grain yield was converted to kg ha^{-1} using appropriate factor.

3.8 Soil sampling and analysis

3.8.1 Soil Sampling

Composite samples were collected randomly with the help of khurpi and spade from a depth of 0-15 cm after harvesting of crop. The samples were mixed thoroughly and dried in air, crushed, sieved through 2 mm sieve. The samples so prepared were analyzed for various physicochemical and microbial properties.

3.8.2 Analysis of soil samples

The collected and processed soil samples were analysed for soil chemical and biological properties. Soil pH was determined using pH meter with glass electrode in a 1:2 soil: water suspension (Piper, 1950).The supernatant solution of the soil suspension 1:2 formerly used for pH determination was used for the determination of electrical conductivity using electrical conductivity meter (Piper, 1950).The soil organic carbon was estimated by the Walkley and Black (1934) method. Soil available N was estimated by alkaline permanganate method (Subbiah and Asija, 1956).The determination of available P was done by using Olsen's reagent (Olsen *et al.,* 1954).Available K was determined by using 1N neutral ammonium acetate solution using flame photometer (Jackson, 1973).

The soil microbial enzyme activities *viz.* alkaline phosphatase (Tabatabai and Bremner, 1969), soil dehydrogenase activity (*Casidaet al.,* 1964) soil fluorescein diacetate enzyme activity (Schnurer and Rosswall, 1982) and β-Glucosidase activity were measured by following the standard methods. The β –glucosidase and alkaline phosphatase enzyme activities were assayed using 1 g of air-dried soil with their appropriate substrate and incubated for 1 h (37 8C at their optimal pH as described in Tabatabai (1994).

3.9 Plant sampling and analysis

The flag leaves of wheat were samples and analyzed for chlorophyll content and nitrate reductase activity.

3.9.1 Chlorophyll content

The fresh wheat flag leaf samples were collected and brought to laboratory. The samples were cut in to small pieces. The samples were treated with dimethyl sulphoxide (DMSO) and kept for 1hr at 60°C in an oven the colour intensity of the content was measured on a spectrophotometer at 645 and 663 nm and chlorophyll content was calculated as follows:

$$\boldsymbol{ChlorophyllA} = \frac{[(\mathbf{12.7} \times \mathbf{Abs663}) - (\mathbf{2.69} \times \mathbf{Abs645})] \times \mathbf{V}}{\boldsymbol{W} \times \mathbf{1000}}$$

$$\boldsymbol{ChlorophyllB} = \frac{[(\mathbf{22.9} \times \mathbf{Abs645}) - (\mathbf{4.68} \times \mathbf{Abs663})] \times \mathbf{V}}{\boldsymbol{W} \times \mathbf{1000}}$$

$$\boldsymbol{TotalChlorophyll} = \frac{[(\mathbf{20.2} \times \mathbf{Abs645}) + (\mathbf{8.08} \times \mathbf{Abs645})] \times \mathbf{V}}{\boldsymbol{W} \times \mathbf{1000}}$$

Where,

Abs645 = Absorbance measured at 645nm wavelength

Abs663 = Absorbance measured at 663 nm wavelength

V = Volume of DMSO (ml) and

W = Weight of sample (g)

3.9.2 Nitrate reductase (NR) activity

NR activity was measured according to Yaneva *et al*. (2002) and Savidov *et al.* (1997). Wheat leaf segments were homogenized in a medium containing 5 mM EDTA, 5 mM GSH, 1% (w/v) casein, PVP and 50 mM HEPES pH 7.5 and centrifuged 15 min at 17000 g. The assay mixture contained: 200 mmol KNO3, 0.2 mmol NADH and 100 mL of the homogenate. After incubation at 30 C for 20 min, the reaction was finished by the addition of 50 mL 1 M zinc acetate. The mixture was centrifuged 5 min at 7600 g and the supernatant was used to determine nitrite production by reading the absorbance at 540 nm after the addition of 1% sulphanylamide in 1.5 M HCl and 0.01% N-(1-Naphthyl)-ethylenediammonium dichloride.

3.10 Statistical analysis

The obtained data were arranged and tabulated and statistically analyzed by method of analysis of variance as described Gomez and Gomez (1984). The significant differences between different treatments were judged by using critical differences (C.D.) which was calculated as follows:

S.E (m) ± = MSE/r
S.Ed=S.E (m).* 2
C.D. =S.Ed.*t" (0.05)

Table 3.3 Skeleton of ANOVA table

Sources of variance	**Degree of freedom**	**Sum of Square**	**Mean sum of square**	**Fcal**
Replications	(r-1)	RSS	RMSS	RMSS/ EMSS
Treatment	(t-1)	TrSS	TMSS	TMSS/ EMSS
Error	(r-1) × (t-1)	ESS	EMSS	
Total	[r × (t-1)]	TSS		

Where,

SEm (±) = standard error means

SEd = standard error of differences between two treatments means

MSE = Error mean sum of square i.e. Error variance

t’ (0.05) = Tabulated ‘t’ value at error degree of freedom at p = 0.05

L.S.D. = Least significance difference

CHAPTER-IV

RESULTS

The results obtained from the present field experiment entitled '**Evaluation of natural farming practices in wheat'** has been presented in this Chapter.

2.1 Effect of natural, organic and integrated nutrient management on crop physiological parameters

2.1.1 Leaf area index

The leaf area index (LAI) of wheat recorded at 15, 30, 45, 60 and 75 days after sowing (DAS) are presented in Table 4.1 and Fig. 4.1. The results revealed that the various treatments significantly influenced the LAI of wheat at 15 DAS. The LAI recorded at 15 DAS ranged 0.21-0.34 under different treatment combinations. The highest LAI was recorded under the treatment T_8 (ICM) and T_9 (ICM-P) followed by the treatment receiving AINPOF package. The complete natural farming practice (T_2–NF) showed significantly higher LAI than the treatment T_1 (control), T_3, T_4, T_5 and T_6.

The LAI recorded at 30 DAS ranged 0.71–1.01 under different treatments tested. The highest leaf area index was recorded under the treatment T_8 (ICM) and T_9 (ICM-P) followed by the treatment receiving AINPOF. The NF showed significantly higher LAI than the treatment T_1 (Control), T_3, T_4, T_5 and T_6. The data revealed that the various treatments significantly influenced the LAI of wheat recorded at 30 DAS.

Similarly, the LAI recorded at 45 DAS ranged 0.86-1.36 under different treatments tested. The highest LAI was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF package. The NF showed significantly higher LAI than the treatment T_1, T_3, T_4 and T_5. The data revealed that the various treatments significantly influenced the LAI of wheat recorded at 45 DAS.

Further, the LAI recorded at 60 DAS ranged 1.33-2.08 under different treatments tested. The highest LAI was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. These treatments were found statistically at par. The NF showed significantly higher LAI than the treatment T_1, T_3 and T_5.

Similarly, the LAI recorded at 75 DAS ranged 2.23-3.36 under different treatments tested (Table 4.1). The highest LAI was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF package. The NF showed significantly higher LAI than the treatment T1 (Control), T_3, T_4, T_5 and T_6.

Table 4.1 Leaf area index (LAI) of wheat at different growth stages under nutrient management practices

Treatment		Leaf area index (leaf area /m²)				
		15 DAS	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**
T_1	Control	0.21	0.71	0.86	1.33	2.13
T_2	Complete NF	0.31	0.96	1.25	1.96	3.09
T_3	NF-1	0.28	0.93	1.12	1.78	2.72
T_4	NF-2	0.28	0.93	1.14	1.81	2.78
T_5	NF-3	0.28	0.94	1.15	1.83	2.82
T_6	NF-4	0.30	0.95	1.21	1.91	2.96
T_7	AI-NPOF package	0.32	0.99	1.28	2.00	3.17
T_8	ICM	0.34	1.01	1.35	2.07	3.35
T_9	ICM-P	0.34	1.01	1.36	2.08	3.36
LSD(P=0.05)		0.01	0.05	0.08	0.15	0.08

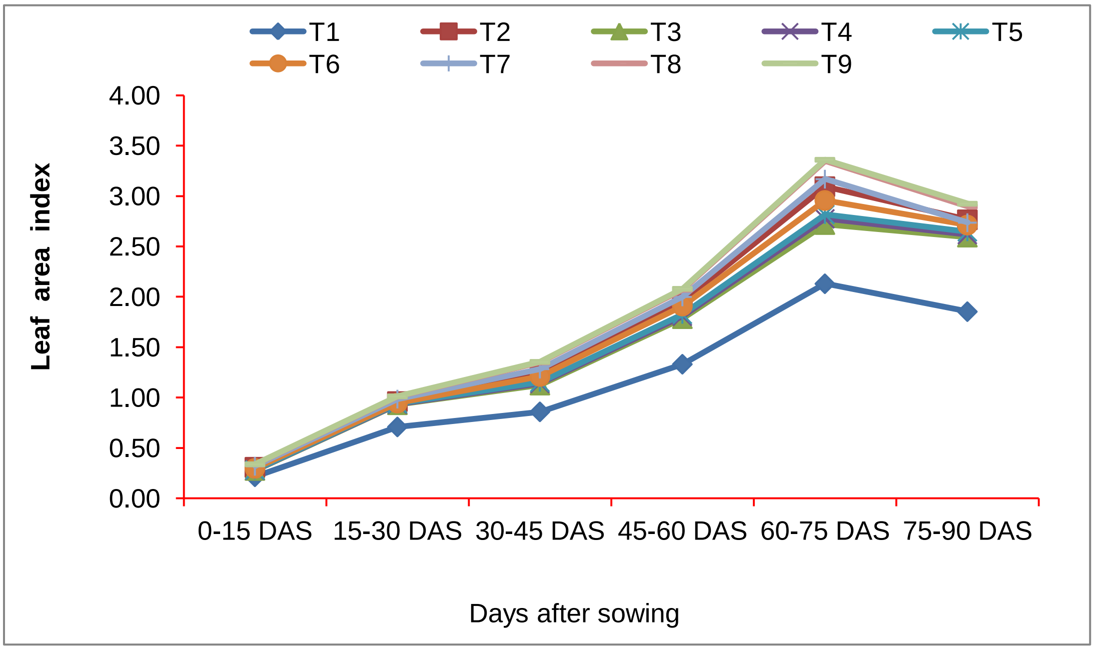

Figure 4.1 Leaf area index of wheat under various treatments

2.1.2 Leaf area duration

The leaf area duration (LAD) of wheat significantly influenced under the various applied treatment combinations and recorded at 15, 30, 45, 60 and 75 DAS (Table 4.2; Fig. 4.2). The LAD recorded at 15 DAS ranged 6.9-10.1 under different treatments. The highest LAD was recorded under the treatment T_8 (ICM) and T9 (ICM-P) followed by the treatment receiving AINPOF-package. The NF showed significantly higher LAD as compared to treatment T_1, T_2, T_3, T_4 and T_6.

The LAD recorded at 30 DAS ranged 11.8-17.8 under different treatments (Table 4.2). The highest LAD was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. The NF showed significantly higher LAD than the treatment T_1, T_3, T_4, T_5 and T_6. Similarly, the LAD recorded at 45 DAS ranged 20.9-25.8 under different treatments tested (Table 4.2). The highest LAD was recorded under

The treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. The NF showed significantly higher LAD than the treatment T_1, T_3, T_4 and T_5.

Furthermore, the LAD recorded at 60 DAS ranged 26.0-40.8 under different treatments tested (Table 4.2). The highest LAD was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package however, these treatments were found statistically at par in respect to LAD at 60 DAS. The NF showed significantly higher LAD than the treatment T_1, T_3, and T_5.

At 75 DAS, the LAD ranged 29.9-47.1 under different treatments (Table 4.2). The highest LAD was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package and these treatments were found statistically at par. The NF showed significantly higher LAD than the treatment T_1, T_3, $T_{4,}$ T_5. And T_6 (Table 4.2)

Table 4.2 Leaf area duration (LAD) of wheat at different growth stages under various treatments

Treatment		Leaf area duration (leaf area /m²)				
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
T_1	Control	6.9	11.8	20.9	26.0	29.9
T_2	Complete NF	9.5	16.6	24.0	37.9	43.9
T_3	NF-1	9.1	15.4	21.8	33.8	39.8
T_4	NF-2	9.1	15.6	22.1	34.4	40.5
T_5	NF-3	9.2	15.7	22.3	34.8	41.0
T_6	NF-4	9.3	16.2	23.4	36.5	42.5
T_7	AI-NPOF package	9.8	17.0	24.6	38.8	44.3
T_8	ICM	10.1	17.7	25.7	40.6	46.8
T_9	ICM-P	10.1	17.8	25.8	40.8	47.1
LSD(P=0.05)		0.16	0.45	0.8	1.6	1.6

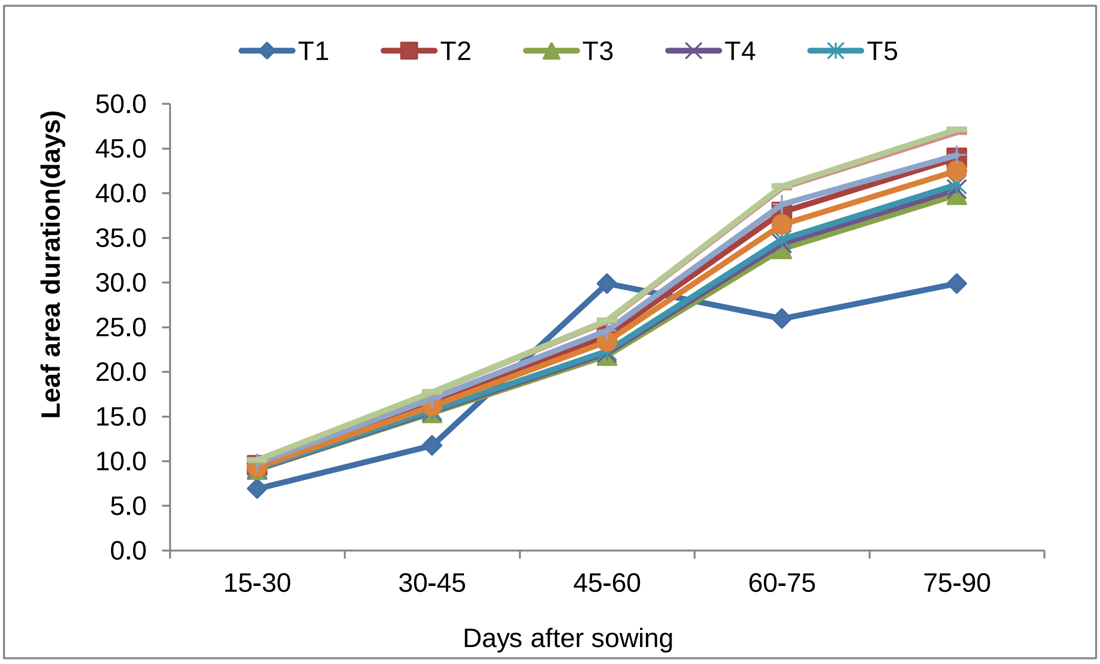

Figure 4.2 Leaf area duration of wheat under various treatments

2.1.3 Chlorophyll content

The chlorophyll content in wheat leaf recorded at 23, 55, 70 and 85 are presented in Table 4.3 and Fig. 4.3. The data revealed that the chlorophyll content recorded at 23, 70 DAS and 85 DAS did not show any significant difference whereas, at 55 DAS the chlorophyll content showed significant difference in wheat leaf under different treatment combinations.

The wheat leaf chlorophyll content recorded at 55 DAS was ranged 1.62-2.30 under different treatments tested. The highest chlorophyll content was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. The NF showed significantly higher chlorophyll content than the treatment T_1, T_3, T_4, T_5. and T_6. The data revealed that the various treatments significantly influenced the chlorophyll content of wheat at 55 DAS.

Table 4.3 Chlorophyll content in wheat leaf at different growth stages under various treatments

Treatment		Chlorophyll content (mg/g FW)			
		23 DAS	**55 DAS**	**70 DAS**	**85 DAS**
T_1	Control	1.40	1.62	1.69	1.72
T_2	Complete NF	1.51	1.99	1.81	1.88
T_3	NF-1	1.45	1.87	1.82	1.86
T_4	NF-2	1.47	1.88	1.82	1.83
T_5	NF-3	1.45	1.86	1.81	1.85
T_6	NF-4	1.47	1.91	1.78	1.88
T_7	AI-NPOF package	1.60	2.01	1.83	2.02
T_8	ICM	1.62	2.15	1.88	2.08
T_9	ICM-P	1.64	2.30	1.86	2.14
LSD(P=0.05)		NS	0.23	NS	NS

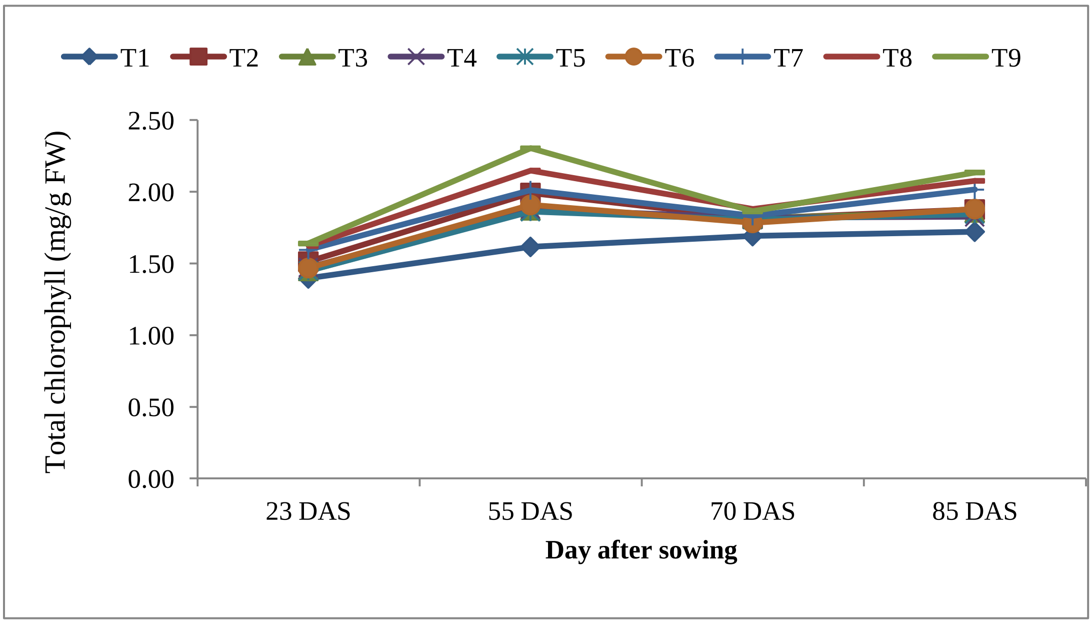

Figure 4.3 Chlorophyll content in wheat leaf under various treatments

2.1.4 Nitrate reductase (NR) activity

The NR activity of wheat recorded at 23, 41, 65 and 105 DAS are presented in Table 4.4 and Fig. 4.4. The NR activity recorded at 23 DAS ranged 23-61 under different treatments tested. The highest NR activity was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. The NF showed significantly higher NR activity than the treatment T_1 whereas; it was statistically at par with the treatments T_3, T_4, T_5. And T_6. The data revealed that the various treatments significantly influenced the NR activity of wheat at 23 DAS. The NR activity recorded at 41 DAS ranged 41-77 under different treatments tested (Table 4.4). The highest NR activity was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. The NF did not show significant effect on NR activity as the treatments T_1, T_3, T_4, T_5, And T_6 including the AINPOF-package. The data revealed that the INM treatments recorded significantly higher NR activity of wheat at 41 DAS.

Similarly, the NR activity recorded at 65 DAS ranged 56-82 under different treatments tested (Table 4.4). The highest NR activity was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. The NF showed significantly higher NR activity than the treatment T_1. The treatments T_2, T_3, T_4, T_5, T_6 and T_7 found statistically at par with respect to wheat NR activity recorded at 65 DAS.

Finally, the NR activity recorded at 105 DAS ranged 38-66 under different treatments tested (Table 4.4). The highest NR activity was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package however, these treatments were found statistically at par. The NR activity of wheat recorded at 105 DAS did not show significant effect as it was decreased as compared to the activity recorded at 65 DAS, irrespective of the treatment (Table 4.4).

Table 4.4 Nitrate reductase (NR) activity in wheat at different growth stages under various treatments

Treatment		Nitrate reductase (NR) activity ((µM NO2/g fresh weight/ hour)			
		23 DAS	**41 DAS**	**65 DAS**	**105 DAS**
T_1	Control	23	41	56	38
T_2	Complete NF	42	65	70	54
T_3	NF-1	37	61	66	49
T_4	NF-2	37	60	68	47
T_5	NF-3	39	62	68	48
T_6	NF-4	40	63	69	52
T_7	AI-NPOF package	51	64	73	61
T_8	ICM	57	76	78	65
T_9	ICM-P	61	77	82	66
LSD(P=0.05)		10	12	12	13

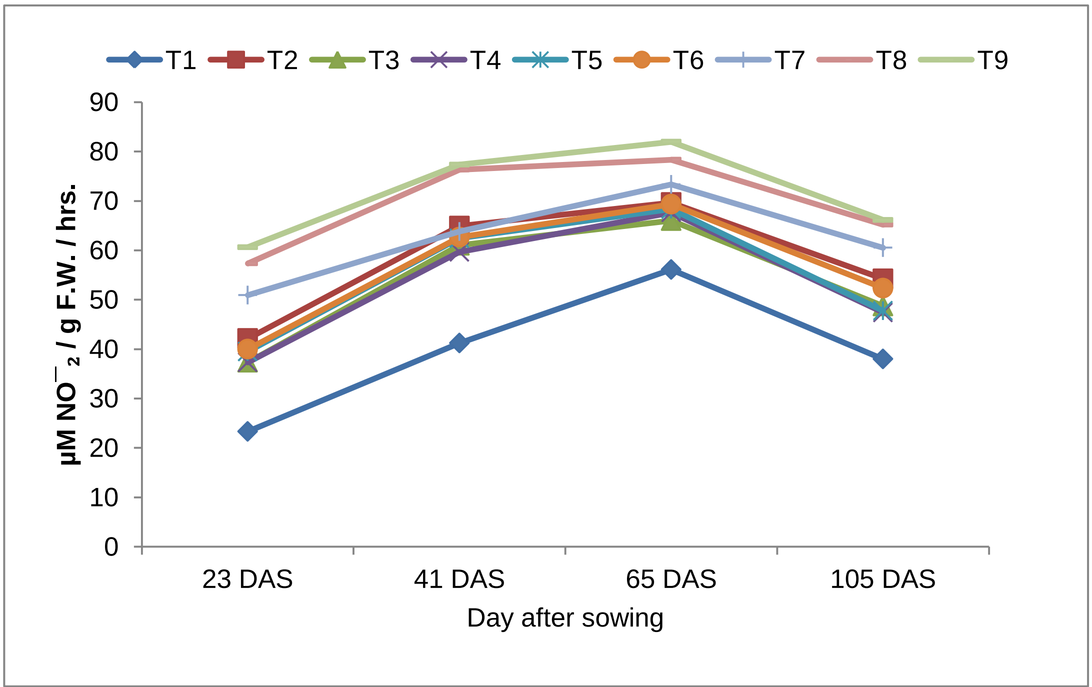

Figure 4.4 Nitrate reductase activity of wheat leaf under various treatments

2.1.5 Crop growth rate

The crop growth rate (CGR) of wheat recorded at 0-15, 15-30, 30-45, 45-60, 60-75 DAS and 75-90 DAS are presented in Table 4.5 and Fig. 4.5. The CGR recorded between 0-15 DAS ranged 0.7-1.2 under various treatments combinations. The highest CGR was recorded under the treatment T_9 (ICM-

P) followed by T_8 (ICM) and the treatment receiving All India NPOF package i.e. T7. At initial stage, the CGR was found differed marginally under the various treatment tested.

The CGR recorded during 15-30 DAS ranged 1.2-2.0 under different treatments tested. The highest CGR was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. The treatment involving the application of complete NF showed significantly higher CGR as compared to the treatment T_1 and T_3.

The CGR recorded during 30-45 DAS ranged 4.0-6.4 under different treatments tested. The highest CGR was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. The treatment involving the application of complete NF showed significantly higher CGR as compared to the treatment T_1 and T_3. The INM practice showed significantly higher CGR during 30-45 DAS of wheat growth whereas, most of the treatments found statistically at par with respect to CGR.

The CGR recorded during 45-60 DAS ranged 15-24 under different treatments tested. The highest CGR was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. The treatment involving the application of complete NF. Showed significantly higher CGR as compared to the treatment T_1, T_3, T_4 and T_5. The various nutrient management practices showed significant effect on CGR of wheat during 45-60 DAS.

The CGR recorded during 60-75 DAS ranged 16-26 under different treatments tested. The highest CGR was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. The treatment involving the application of complete NF showed significantly higher CGR as compared to the treatment T_1, T_3, and T_4. The various nutrient management practices showed significant effect on CGR of wheat during 60-75 DAS.

Finally, the CGR recorded during 75-90 DAS ranged 20-31 under different treatments tested. The highest CGR was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving AINPOF-package. The treatment involving the application of complete NF showed significantly higher CGR as compared to the treatment T_1, T_3, T_4 and T_5. The various nutrient management practices showed significant effect on CGR of wheat during 75-90 DAS. Irrespective of the treatments, the CGR of wheat showed increasing trend with the duration of crop. Similarly, all the treatments showed almost identical trend in CGR during various growth stages viz., 0-15 DAS, 15-30 DAS, 30-45 DAS, 45-60 DAS, 60-75 DAS and 75-90 DAS (Table 4.5)

Table 4.5 Crop growth rate of wheat at different growth stages under various treatments

Treatment		Crop growth rate (g/m²/day)					
		0-15 DAS	**15-30 DAS**	**30-45 DAS**	**45-60 DAS**	**60-75 DAS**	**75-90 DAS**
T_1	Control	0.7	1.2	4.0	15	16	20
T_2	Complete NF	1.0	1.7	5.6	21	22	28
T_3	NF-1	0.8	1.4	4.4	17	18	23
T_4	NF-2	0.9	1.5	4.9	18	20	25
T_5	NF-3	0.9	1.6	5.1	19	21	26
T_6	NF-4	1.0	1.7	5.4	20	22	28
T_7	AI-NPOF package	1.1	1.8	5.9	22	24	30
T_8	ICM	1.1	1.9	6.2	23	25	31
T_9	ICM-P	1.2	2.0	6.4	24	26	31
LSD(P=0.05)		0.2	0.3	0.7	1.2	1.5	2

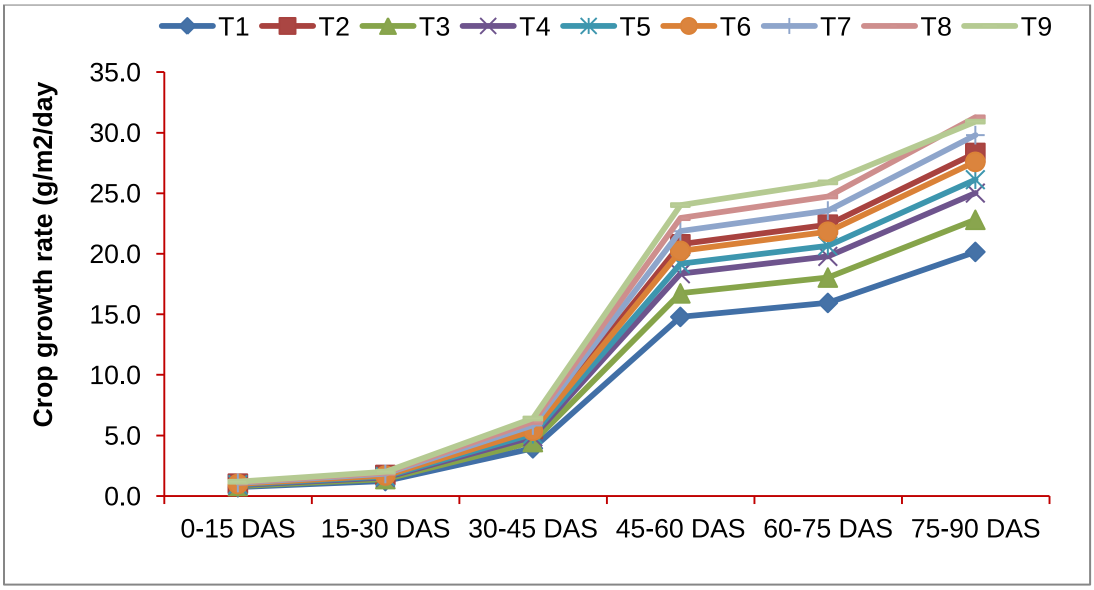

Figure 4.5 Crop growth rate of wheat leaf under various treatments

2.2 Effect of natural, organic and integrated nutrient management on crop performance

The data pertaining to the performance of wheat (main crop) and mustard (intercrop) has been presented in Table 4.6 to Table 4.9. The performance of wheat was measured in terms of plant height, spikes per plant, spikes per meter length, grains per spike, 100 seed weight, grain yield and total biomass whereas the performance of intercrop (mustard) was measured in terms of seed yield and total biomass.

2.2.1 Performance of wheat (main crop)

2.2.1.1 Plant height

The plant height of wheat recorded at crop harvest ranged 72.6–80.1 cm among different treatments (Table 4.6; Fig. 4.6). The highest plant height was recorded under the treatment receiving ICM i.e. T_8 followed by T_9 (79.5 cm). It has been observed that the studied treatments significantly influenced the plant height of wheat. The treatments T_7, T_8 and T_9 were found statistically at par and these treatments recorded significantly higher plant height of wheat as compared to the other treatments including complete NF (T_2) treatment.

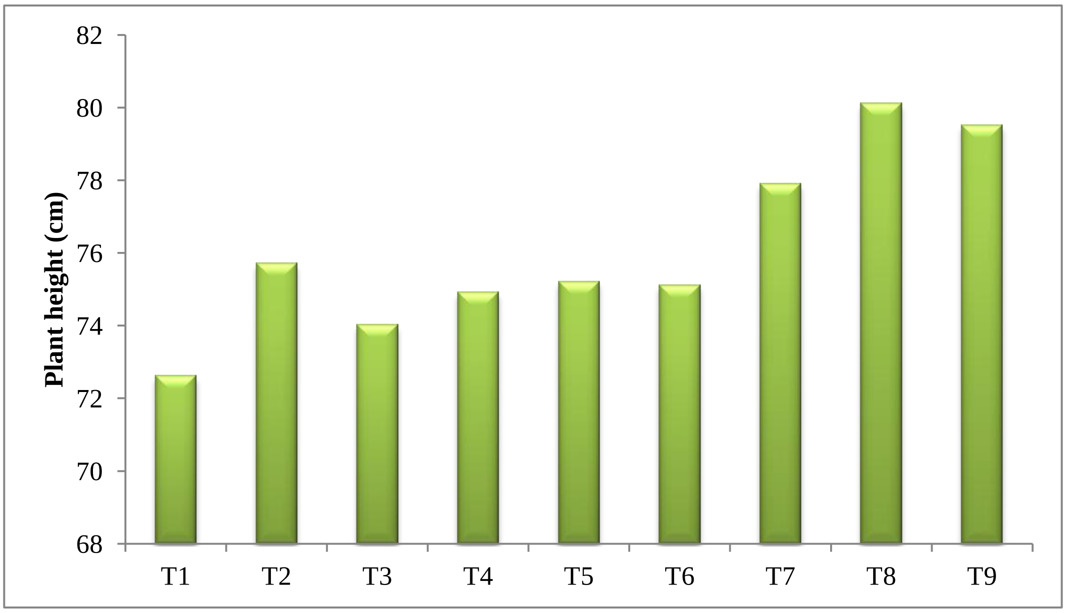

Figure 4.6 Plant height of wheat under various treatments

2.2.1.2 Spikes per plant

The spikes plant^{-1} in wheat ranged 7.2–8.3 among different treatments studied (Table 4.6). It has been observed that the studied treatments did not show any significant effect on spikes plant^{-1} in wheat.

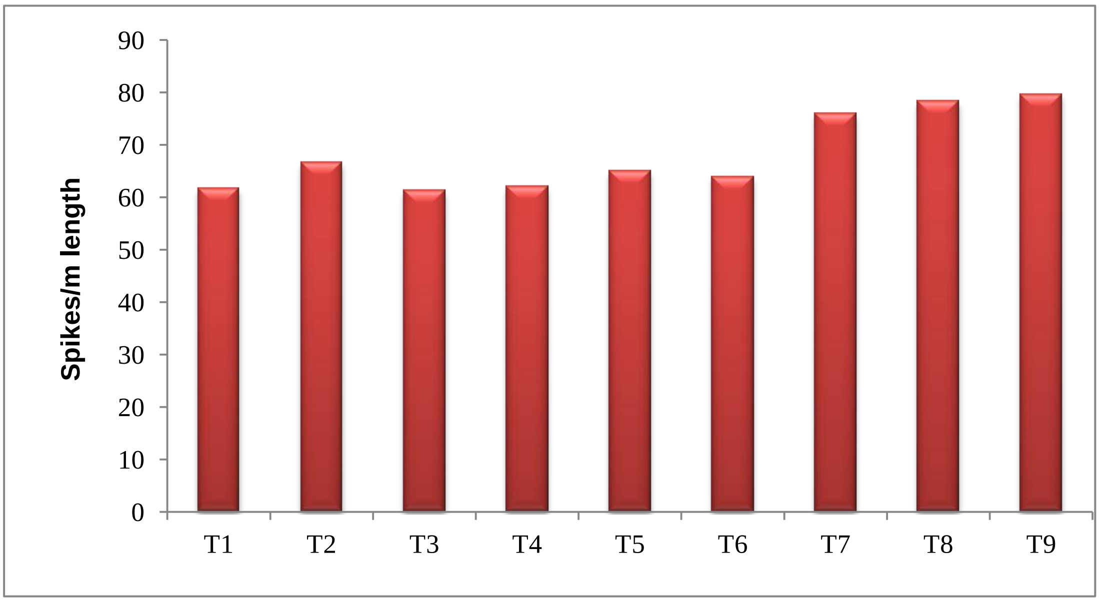

Figure 4.7 Spikes per meter length in wheat under various treatments

2.2.1.3 Spikes per meter length

The number of spikes per meter row length in wheat ranged 61.7–79.7 among different treatments studied (Table 4.6; Fig. 4.7). The highest number of spikes per meter row length was recorded under the treatment receiving ICM-P i.e. T_9 followed by the treatment T_8 (78.3), however these treatments were found statistically at par. It has been observed that the studied treatments significantly influenced the number of spikes per meter length in wheat. The treatments T_7, T_8 and T_9 were found statistically at par and these treatments recorded significantly higher number of spikes in wheat as compared to the other treatments including complete NF (T_2) treatment. The other treatments *viz*., T_1, T_2, T_3, T_4, T_5 and T_6 were found statistically at par with respect to the number of spikes per meter row length.

Table 4.6 Growth and yield attributes of wheat under various treatments

Treatment		Plant height (cm)	Spikes/ plant	Spikes/ m length
T_1	Control	72.6	7.2	61.7
T_2	Complete NF	75.7	7.9	66.7
T_3	NF-1	74.0	7.5	61.3
T_4	NF-2	74.9	7.6	62.0
T_5	NF-3	75.2	7.8	65.0
T_6	NF-4	75.1	7.7	64.0
T_7	AI-NPOF package	77.9	8.1	76.0
T_8	ICM	80.1	8.3	78.3
T_9	ICM-P	79.5	8.1	79.7
LSD(P=0.05)		3.3	NS	5.0

2.2.1.4 Grains per spike

The grains per spikes in wheat recorded at harvest ranged 59.3-68.2 among different treatments combinations (Table 4.7; Fig. 4.8). The highest number of grains per spike was recorded under the treatment receiving ICM-P i.e. T_9 followed by the treatment T_8 (67.7), however these treatments were found statistically at par. The treatments T_7, T_8 and T_9 were found statistically at par and these treatments recorded significantly higher number of spikes in wheat as compared to the other treatments including complete NF (T_2) treatment. It has been observed that the studied treatments significantly influenced the number of grains per spike in wheat.

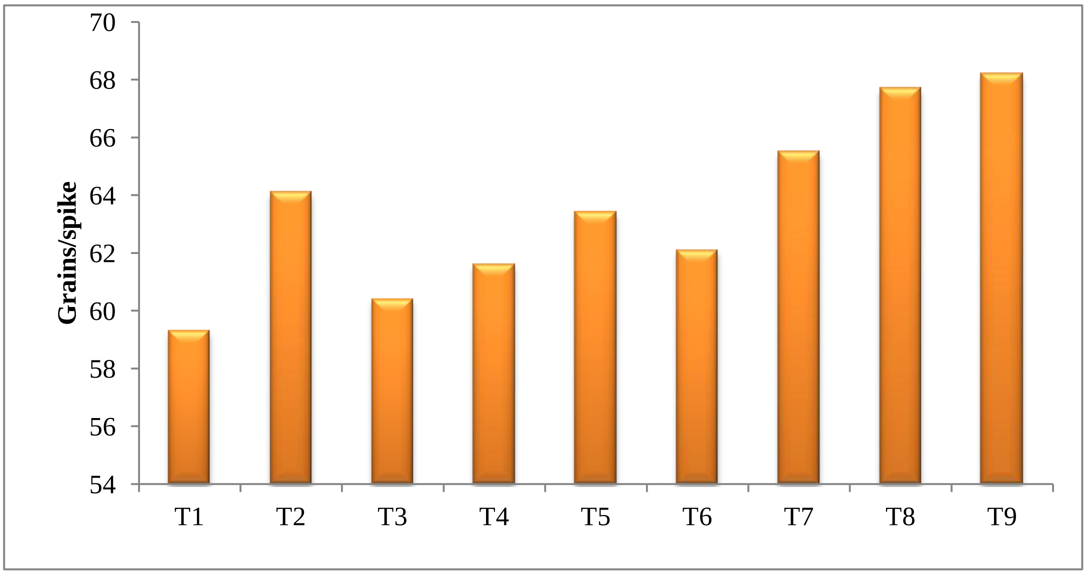

Figure 4.8 Grains per spike in wheat under various treatments

2.2.1.5 100 seed weight

The 100 seed weight of wheat ranged 6.0-6.6 g among different treatments (Table 4.7). It has been observed that the studied treatments did not show any significant effect on 100 seed weight in wheat.

Table 4.7 Grains per spike and 100 seed weight in wheat under various treatments

Treatment		Grains/ spike	100 seed weight (g)
T_1	Control	59.3	6.0
T_2	Complete NF	64.1	6.2
T_3	NF-1	60.4	6.0
T_4	NF-2	61.6	6.2
T_5	NF-3	63.4	6.0
T_6	NF-4	62.1	6.1
T_7	AI-NPOF package	65.5	6.2
T_8	ICM	67.7	6.4
T_9	ICM-P	68.2	6.6
LSD(P=0.05)		2.6	NS

2.2.1.6 Grain yield

The grain yield of wheat recorded at crop harvest ranged 2097-4163 kg ha^{-1} among the studied treatments (Table 4.8; Fig. 4.9). The highest yield of wheat was recorded in the treatment receiving ICM-P i.e. T_9 followed by T_8 (4007 kg ha^{-1}) and T_7 (3890 kg ha^{-1}), however these treatments found statistically at par. The lowest yield of wheat was recorded in the treatment control i.e. T_1. The treatment Complete NF (T_2) recorded significantly higher wheat yield as compared to the treatments T_1, T_3, T_4 and T_6. It has been observed that the studied treatments significantly influenced the rain yield of wheat.

2.2.1.7 Total biomass

The total biomass yield of wheat recorded at crop harvest ranged 4983-9183 kg ha^{-1} among the studied treatments (Table 4.8; Fig. 4.9). The highest total biomass yield of wheat was recorded in the treatment receiving ICM-P i.e. T_9 followed by T_8 (9060 kg ha^{-1}) and T7 (8520 kg ha^{-1}), however these treatments found statistically at par. The lowest biomass yield of wheat was recorded in the treatment control i.e. T_1. The treatment Complete NF (T_2) recorded significantly higher total biomass of wheat as compared to the treatments T_1, T_3, T_4 and T_6. It has been observed that the studied treatments significantly influenced the rain yield of wheat.

Table 4.8 Grain yield and total biomass of wheat under various treatments

Treatment		Wheat yields (kg ha^{-1})	
		Seed yield	Total biomass
T_1	Control	2097	4983
T_2	Complete NF	3010	6793
T_3	NF-1	2440	5800
T_4	NF-2	2560	5950
T_5	NF-3	2860	6580
T_6	NF-4	2717	6477
T_7	AI-NPOF package	3890	8520
T_8	ICM	4007	9060
T_9	ICM-P	4163	9183
LSD(p=0.05)		316	523

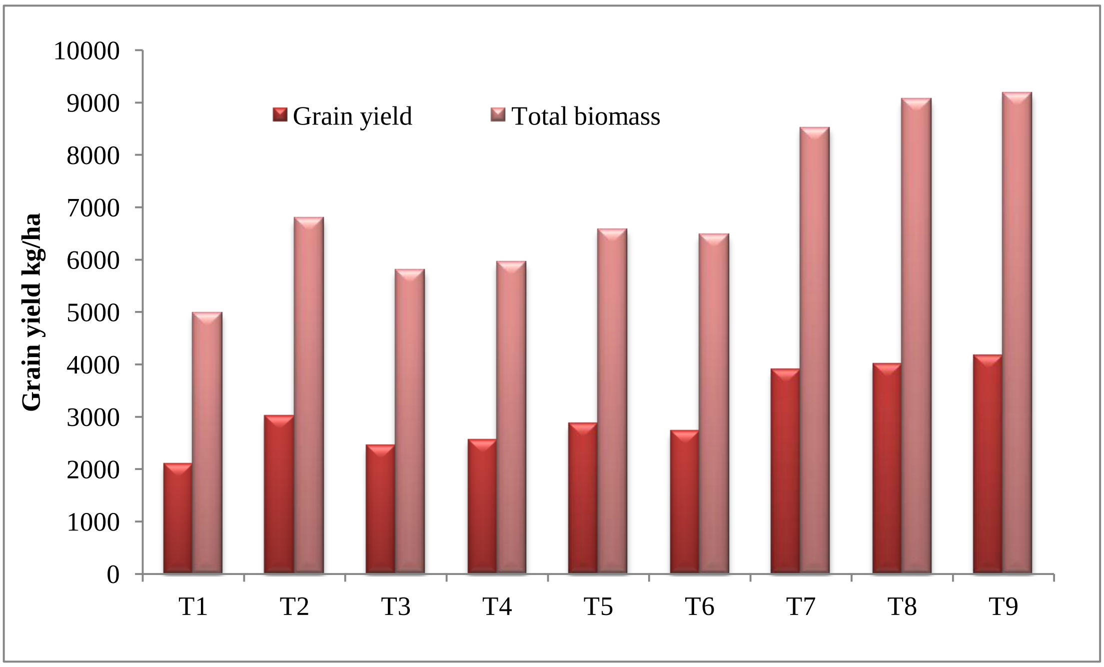

Figure 4.9 Grain yield and total biomass of wheat under various treatments

2.2.2 Performance of mustard (intercrop)

The mustard crop was grown as intercrop in the treatments T_2 (Complete NF), T_3 (NF-1: without Beejamrit + Ghanjeevamrit + Jeevamrit), T_4 (NF-2: without-Crop residue mulching) and T_6 (NF-4: without Whapasa). The yield and total biomass of mustard recorded under these treatments are presented in Table 4.9

2.2.2.1 Seed yield

The seed yield of mustard recorded at crop harvest ranged 1337–1577 kg ha^{-1} among the four treatments (T_2, T_3, T_4 and T_6) involving mustard as intercrop. The highest yield of mustard was recorded in the treatment T_2 followed by T_6 (1471 kg ha^{-1}) and T_4 (1368 kg ha^{-1}). The lowest yield of mustard was recorded in the treatment receiving NF-1 (without Beejamrit + Ghanjeevamrit + Jeevamrit) i.e. T_3.

2.2.2.2 Total biomass

The total biomass of mustard recorded at crop harvest ranged 4418-5247 kg ha^{-1} among the four treatments (T_2, T_3, T_4 and T_6) involving mustard as intercrop. The highest total biomass of mustard was recorded in the treatment T_2 followed by T_6 (4770 kg ha^{-1}) and T_4 (4418 kg ha^{-1}). The lowest total biomass of mustard was recorded in the treatment receiving NF-1 (without Beejamrit + Ghanjeevamrit + Jeevamrit) i.e. T_3.

Table 4.9 Grain yield and total biomass of mustard (intercrop) under various treatments

Treatment		Mustard yields (kg ha-1)	
		Seed yield	Total biomass
T_1	Control	-	-
T_2	Complete NF	1577	5247
T_3	NF-1	1337	4263
T_4	NF-2	1368	4418
T_5	NF-3	-	-
T_6	NF-4	1471	4770
T_7	AI-NPOF package	-	-
T_8	ICM	-	-
T_9	ICM-P	-	-
LSD(P=0.05)		-	-

2.3 Effect of natural, organic and integrated nutrient management on soil properties

The data pertaining to the soil pH, electrical conductivity (EC) and soil organic carbon (SOC) after wheat harvest is presented in Table 4.10.

2.3.1 Soil pH

The soil pH recorded at wheat harvest ranged 7.71-7.76 among different treatments studied (Table 4.10). It has been observed that the studied treatments did not show any significant effect on soil pH.

2.3.2 Soil EC

The soil EC recorded at wheat harvest ranged 0.181-0.191 dS m^{-1} among different treatments studied (Table 4.10). It has been observed that the studied treatments did not show any significant effect on soil EC.

2.3.3 Soil organic carbon

The soil organic carbon (SOC) recorded at wheat harvest ranged 0.51–0.69% among different treatments studied (Table 4.10; Fig. 4.10). The highest SOC was recorded under the AI-NPOF package (T_7) followed by the treatment receiving ICM i.e. T_8. It has been observed that the studied treatments significantly influenced the SOC. The treatments T_7, T_8 and T_9 were found statistically at par and these treatments recorded significantly higher SOC as compared to the rest other treatments including complete NF (T_2) treatment.

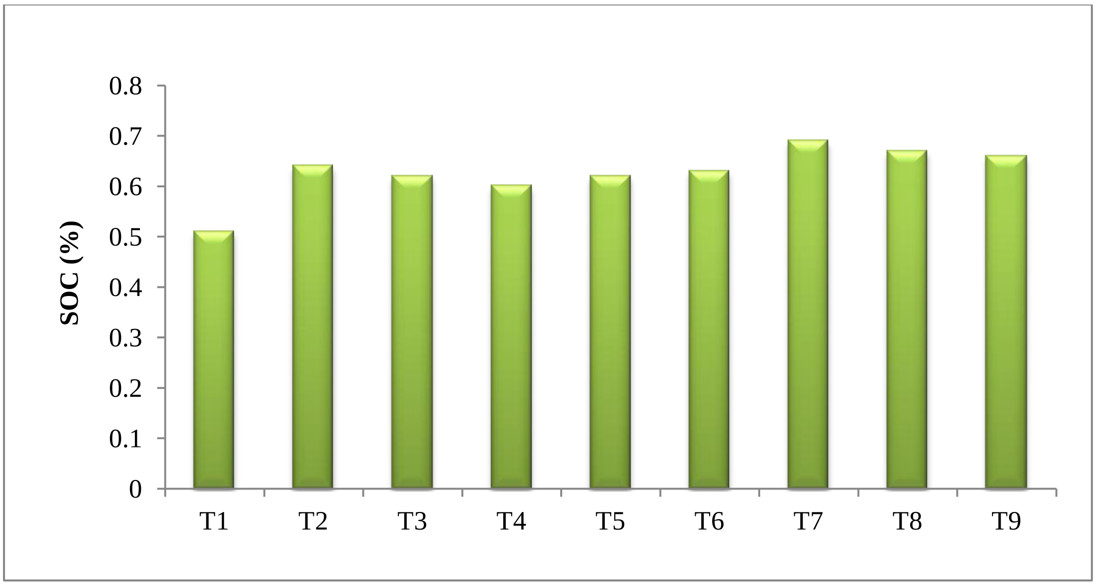

Figure 4.10 Soil organic carbons at wheat harvest under various treatments

Table 4.10 Effect of various natural farming practices on soil properties at wheat harvest

Treatment		pH	EC (dS m^{-1})	SOC (%)
T_1	Control	7.76	0.181	0.51
T_2	Complete NF	7.74	0.188	0.64
T_3	NF-1	7.74	0.183	0.62
T_4	NF-2	7.73	0.186	0.60
T_5	NF-3	7.74	0.183	0.62
T_6	NF-4	7.74	0.186	0.63
T_7	AI-NPOF package	7.71	0.191	0.69
T_8	ICM	7.72	0.190	0.67
T_9	ICM-P	7.72	0.189	0.66
LSD(P=0.05)		NS	NS	0.03

2.3.4 Soil available N

The soil available N recorded after wheat harvest ranged 180-226 kg ha^{-1} among different treatments studied (Table 4.11; Fig. 4.11). The highest soil available N was recorded under the treatment T_8 (ICM) followed by the treatment receiving ICM-P i.e. T_9 (224 kg ha^{-1}). However, these treatments were found statistically at par. It has been observed that the studied treatments significantly influenced the soil N availability. The lowest soil available N was recorded under the treatment control (T1, 180 kg ha^{-1}). The treatment AI-NPOF recorded significantly higher soil available N as compared to the treatments T_1, T_3, T_5 and T_6. The treatments AI-NPOF and complete NF (T_2) were found statistically at par and recorded significantly higher soil available N as compared to the rest other treatments except T_8 and T_9.

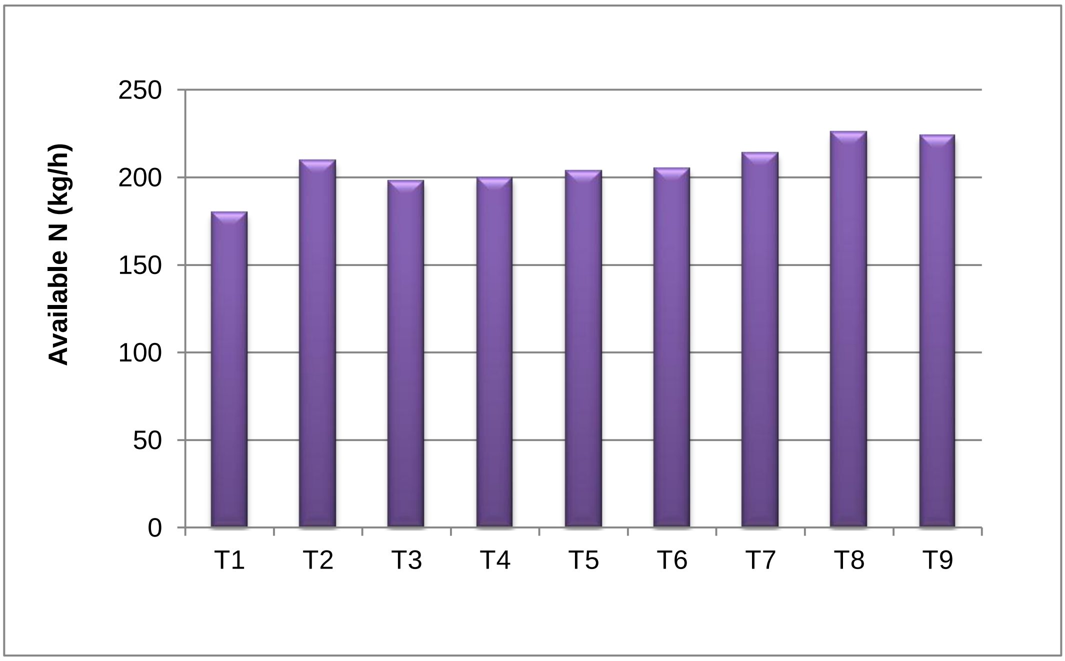

Figure 4.11 Soil available N at wheat harvest under various Treatments

2.3.5 Soil available P

The soil available P recorded after wheat harvest ranged 20.0-34.7 kg ha^{-1} among different treatments studied (Table 4.11; Fig. 4.12). The highest soil available P was recorded under the treatment receiving ICM-P i.e. T_9 followed by the treatment T_8 (ICM) (33.9 kg ha^{-1}). However, these treatments were found statistically at par. It has been observed that the studied treatments significantly influenced the soil P availability. The lowest soil available P was recorded under the treatment control (T_1, 20.0 kg ha^{-1}). The treatment T_2 (Complete NF) recorded significantly higher soil available P than treatment T_3 and Control (T_1) whereas found at par with treatment T_4, T_5 and T_6.

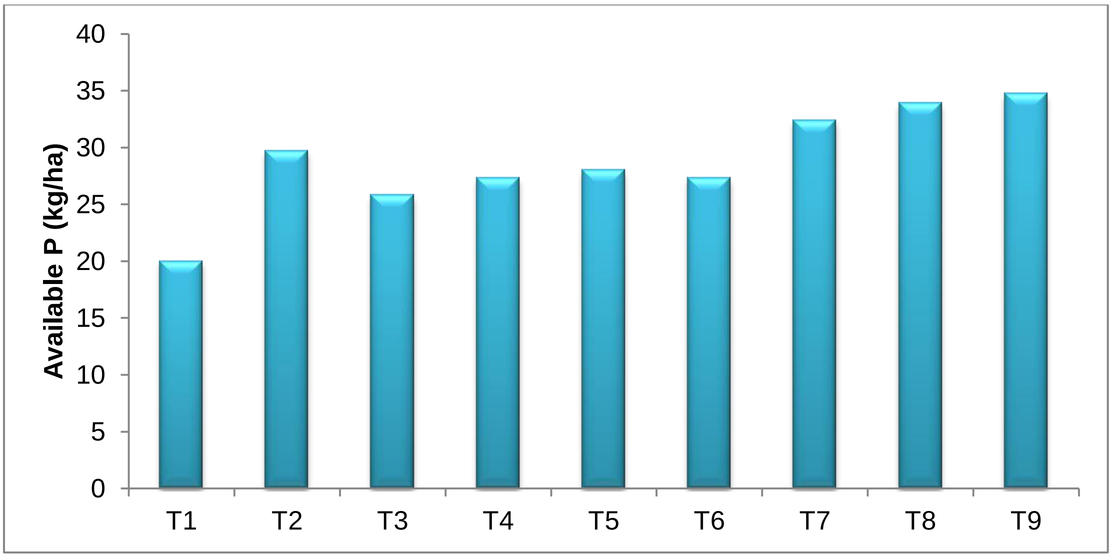

Figure 4.12 Soil available P at wheat harvest under various treatments

2.3.6 Soil available K

The soil available K recorded after wheat harvest ranged 440-513 kg ha^{-1} among different treatments studied (Table 4.11; Fig. 4.13). The highest soil available K was recorded under the treatment receiving ICM-P i.e. T_9 followed by the treatment T_8 (ICM) (510 kg ha^{-1}) and treatment T_7 (499 kg ha^{-1}). However, these treatments were found statistically at par. It has been observed that the studied treatments significantly influenced the soil K availability. The lowest soil available K was recorded under the treatment control (T_1, 440 kg ha^{-1}). The treatment complete NF (T_2) recorded significantly higher soil available K than the treatments T_1, T_3 and T_4.

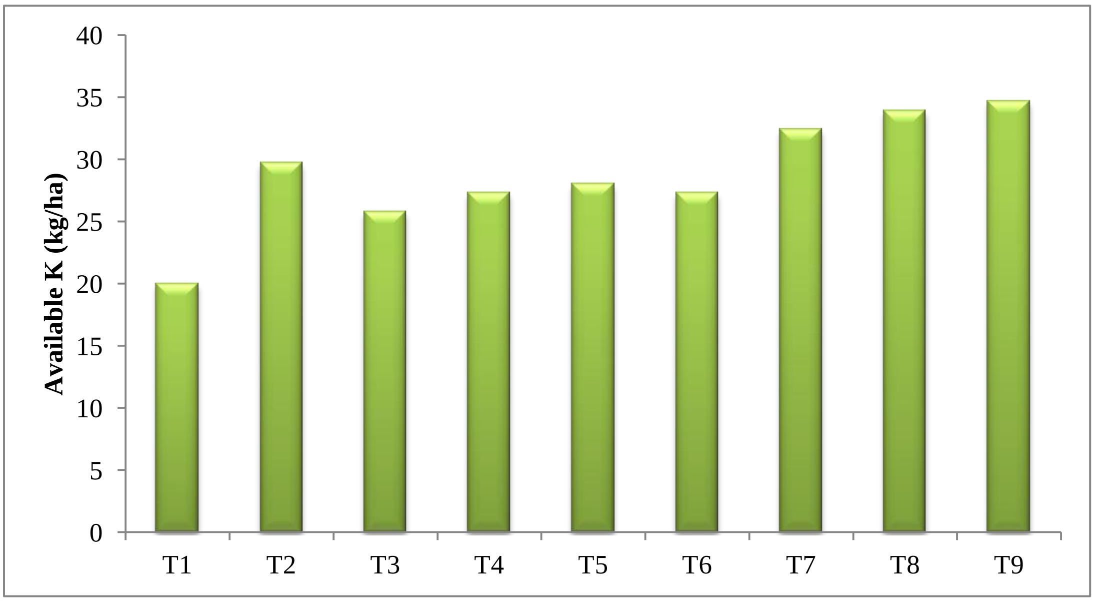

Figure 4.13 Soil available K at wheat harvest under various treatments

Table 4.11 Effect of various natural farming practices on soil nutrient status at wheat harvest

Treatment		Soil available nutrients (kg ha^{-1})		
		N	P	K
T_1	Control	180	20.0	440
T_2	Complete NF	209	29.7	490
T_3	NF-1	198	25.8	474
T_4	NF-2	200	27.3	474
T_5	NF-3	203	28.0	487
T_6	NF-4	205	27.3	480
T_7	AI-NPOF package	214	32.4	499
T_8	ICM	226	33.9	510
T_9	ICM-P	224	34.7	513
LSD(P=0.05)		7.8	3.4	12.1

2.3.7 Soil enzyme activity

2.3.7.1 Dehydrogenase activity (DHA)

The soil DHA recorded after wheat harvest ranged 56-92 µgTPF/g soil/d among different treatments studied (Table 4.12; Fig. 4.14). The highest soil DHA was recorded under the treatment receiving AI-NPOF package (T_7) followed by the treatments T_8 (84 µgTPF/g soil/d) and T_9 (82 µgTPF/g soil/d). The treatment T_7 showed significantly higher DHA as compared to the all other treatments studied. The complete NF treatment (T_2) found statistically at par with T_6, T_8 and T_9. The treatment control (T_1) showed lowest soil DHA (56 µgTPF/g soil/d).

2.3.7.2 Fluorescein diacetate activity (FDA)

The soil FDA recorded after wheat harvest ranged 45-77 µg fluorescein/ g soil/ h among different treatments studied (Table 4.12; Fig. 4.14). The highest soil FDA was recorded under the treatment receiving AI-NPOF package (T_7) followed by the treatments T_8 (67 µg fluorescein/ g soil/ h) and T_9 (64 µg fluorescein/ g soil/ h). The treatment T_7 showed significantly higher FDA as compared to the all other treatments studied. The complete

NF treatment (T_2) found statistically at par with T_6, T_8 and T_9. The treatment control (T_1) showed lowest soil FDA (45 µg Fluorescein/ g soil/ h).

Table 4.12 Effect of various natural farming practices on soil dehydrogenase and Fluorescein diacetate enzyme activity at wheat harvest

Treatment		DHA (µgTPF/g soil/d)	FDA (µg fluorescein/ g soil/ h)
T_1	Control	56	45
T_2	Complete NF	79	60
T_3	NF-1	69	47
T_4	NF-2	71	49
T_5	NF-3	73	55
T_6	NF-4	76	57
T_7	AI-NPOF package	92	77
T_8	ICM	84	67
T_9	ICM-P	82	64
LSD(P=0.05)		7.1	9.2

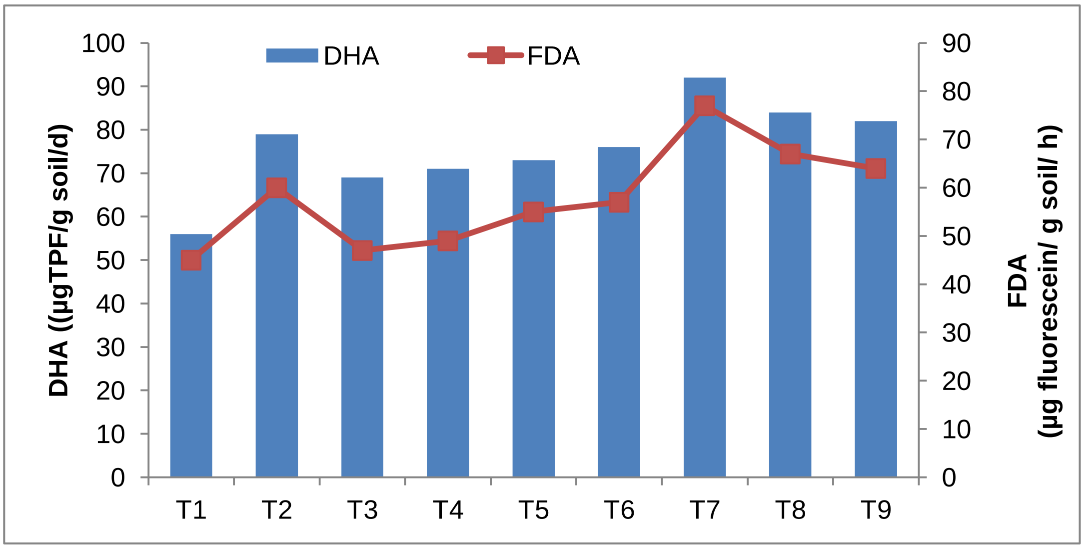

Figure 4.14 Soil DHA and FDA at wheat harvest under various treatments

2.3.7.3 Alkaline phosphatase activity (Alk-PO_4)

The soil Alk-PO_4 activity recorded after wheat harvest ranged 246-334 µg PNP/g soil/h among different treatments studied (Table 4.13; Fig. 4.15). The highest soil Alk-PO_4 activity was recorded under the treatment receiving

AI-NPOF package (T_7) followed by the treatments T_8 (319 µg PNP/g soil/h) and T_9 (314 µg PNP/g soil/h). The treatment T_7 showed significantly higher Alk-PO_4 activity as compared to the all other treatments studied. The complete NF treatment (T_2) found statistically at par with T_6, T_8 and T_9. The treatment control (T_1) showed lowest soil Alk-PO_4 activity (246 µg PNP/g soil/h).

2.3.7.4 β-glucosidase activity

The soil β-glucosidase activity recorded after wheat harvest ranged 268-364 µg PNP/g soil/h among different treatments studied (Table 4.13; Fig. 4.15). The highest soil β-glucosidase activity was recorded under the treatment receiving AI-NPOF package (T_7) followed by the treatments T_8 (343 µg PNP/g soil/h) and T_9 (338 µg PNP/g soil/h). The treatment T_7 showed significantly higher β-glucosidase activity as compared to the all other treatments studied. The complete NF treatment (T_2) found statistically at par with T_6, T_8 and T_9. The treatment control (T_1) showed lowest soil β-glucosidase activity (268 µg PNP/g soil/h).

Table 4.13 Effect of various natural farming practices on soil alkaline phosphatase and β-glucosidase enzyme activity at wheat harvest

Treatment		Alk-PO_4 activity (µg PNP/g soil/h)	β-glucosidase (µg PNP/g soil/h)
T_1	Control	246	268
T_2	Complete NF	302	323
T_3	NF-1	270	292
T_4	NF-2	276	298
T_5	NF-3	287	310
T_6	NF-4	294	314
T_7	AI-NPOF package	334	364
T_8	ICM	319	343
T_9	ICM-P	314	338
LSD(P=0.05)		14.3	12.1

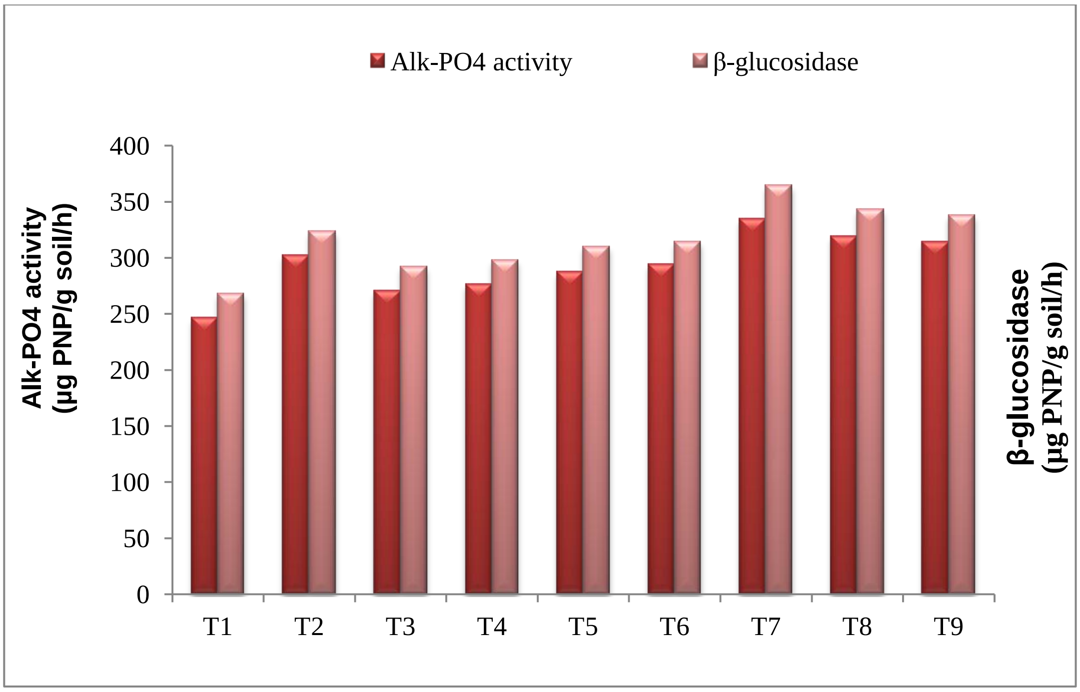

Figure 4.15 Soil Alk-PO_4 and β-glucosidase activity at wheat harvest under various treatments

CHAPTER-V

DISCUSSION

The results obtained from the present field experiment entitled '**Evaluation of natural farming practices in wheat**' conducted at the Research Farm of ICAR-Indian Institute of Soil Science, Bhopal have been discussed in this Chapter under following subheads:

5.1 Effect of natural, organic and integrated nutrient management on crop physiological parameters

The crop physiological parameters *viz*., leaf area index, leaf area density, nitrate reductase activity, chlorophyll content and crop growth rate of wheat were significantly influenced with the application of natural, organic and integrated nutrient management (INM) practices in wheat.

The highest leaf area index (LAI) was recorded under the treatment involving ICM i.e. T_8 and T_9 followed by the treatment receiving All India NPOF package and completes natural farming practice (T_2). Similarly, the leaf area density also followed similar trend. The data revealed that the various treatments significantly influenced the LAI and LAD of wheat at various growth stages. Further, the LAI and LAD showed increasing trend at different crop growth stages irrespective of the treatments. Nehra *et al.* (2001) reported that the application of organic manures irrespective of source and rate, the LAI significantly increased over no organic manure in wheat crop. Similarly, Sadur *et al.* (2010) also reported significantly higher LAI with higher levels of fertilizer application. Maximum LAI (2.50) was recorded at 80-60-30 kg NPK ha^{-1}, while minimum LAI (2.23) was found at low level of fertilizers (40-30-30 kg NPK ha^{-1}). The findings of Ashraf *et al.* (2016) and Singh *et al.* (2016) are also in line with the obtained results of present investigation.

The chlorophyll content in wheat leaf recorded at 23, 70 DAS and 85 DAS did not show any significant difference whereas the chlorophyll content recorded at 55 DAS and 110 DAS showed significant difference in wheat leaf chlorophyll content. The highest chlorophyll content was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving All India NPOF package i.e. T_7. The complete natural farming practice (T_2)

showed significantly higher chlorophyll content as compared to T_1, T_3, T_4, T_5 and T_6 treatments. Thus, the various treatments significantly influenced the chlorophyll content of wheat. Amujoyegbe *et al.* (2007) reported significant effects of amending soil with poultry manure and inorganic fertilizer on chlorophyll content of maize. Further they reported that highest total chlorophyll content of 3.28 mg g^{-1} and 2.63 mg g^{-1} under poultry manure in sorghum and maize, respectively. Similar findings with respect to photosynthetic pigments (chlorophyll ‘a’, ‘b’ and carotenoids) were reported by Nehra *et al.* (2001) in wheat under organic manure application.

The NR activity of wheat recorded at 23, 41, 65 and 105 DAS were found significantly influenced under different treatments. The highest NR activity was recorded under the INM treatments followed by All India NPOF package and complete natural farming practice (T_2). The NR activity showed increasing trend with progress in crop growth. The plant leaf NR activity is dependent on the soil available N. Chen *et al.* (2004) reported that the application of higher amount of nitrogenous fertilizer showed significant effect on plant NR activities. Balotf *et al.* (2016) also reported higher NR activity under higher soil N allocation treatment.

The crop growth rate (CGR) at different growth stages were significantly differed with the application of natural, organic and INM treatments in wheat crop. The results indicated that the highest CGR was recorded under the treatment T_9 (ICM-P) followed by T_8 (ICM) and the treatment receiving All India NPOF package i.e. T_7. The treatment involving the application of complete NF i.e. T_2 were also showed significantly higher CGR as compared to the treatment T_1, T_3, T_4 and T_5. Furthermore, irrespective of the treatments, the CGR of wheat showed increasing trend with the duration of crop and biomass. Similarly, all the treatments showed almost identical trend in CGR during various growth stages *viz*., 0-15 DAS, 15-30 DAS, 30-45 DAS, 45-60 DAS, 60-75 DAS and 75-90 DAS (Table 4.5). Pradhan and Moharana, (2015) reported significant effect of organic nutrient management on dry matter accumulation (DMA), CGR and relative growth rate (RGR) especially in treatment receiving dhanicha+FYM + vermicompost. Similar findings were recorded by Singh *et al.* (2016).

5.2 Effect of natural, organic and integrated nutrient management on crop performance

The performance of wheat was measured in terms of growth parameters, yield attributes and yields. The plant height of wheat recorded at crop harvest ranged 72.6-80.1 cm among different treatments studied. The highest plant height of wheat was found significantly influenced under the studied treatments. Similarly, the number of spikes per meter row length and grains per spikes were also found significantly influenced under different treatments whereas spikes plant^{-1} and 100-seed weight of wheat did not show any significant effect. The results revealed that the studied treatments significantly influenced the grain yield and total biomass of wheat. The grain yield of wheat ranged 2097–4163 kg ha^{-1} under the studied treatments (Table 4.8). The highest yield of wheat was recorded in the treatment receiving INM practice followed by AI-NPOF and complete NF treatments. Santoshkumar and Shashidhara (2006) reported the significant effect of integrated nutrient management in chili in which they found the application of organics *viz.* FYM @ 10 t ha^{-1} along with 100% RDF resulted in significantly higher yield over 100% RDF followed by the combined application of FYM @ 5 t ha^{-1} + chili stalk @ 5 t ha^{-1}. Meena *et al.* (2019) and Sulok *et al.* (2018) were also reported that the adoption of INM practices improved crop performance as compared to organics and inorganics alone. Similarly, Davari *et al.* (2012) reported higher growth and yield attributing parameters of wheat with the integration of organic manures (FYM and Vermicompost), bio-fertilizers and rice residue. The effectiveness of natural farming in improvement of growth, yield attributes and yields of various crops were also documented by Khadse and Rosset (2019), Korav *et al.* (2020), Kumar and Kumari (2020) and Kaur *et al.* (2021).

5.3 Effect of natural, organic and integrated nutrient management on soil properties

5.3.1 Soil organic carbon and nutrient availability

The chemical and biological properties of soils were also changed to a certain extent by growing of crops under different natural farming/organic nutrient and INM systems. In present investigation, the soil pH and EC under various treatments recorded after wheat harvest did not show any significant difference whereas the other soil parameters *viz.,* soil organic carbon (SOC), available N, P and K showed significant variation under these treatments. The SOC recorded after wheat harvest ranged 0.51-0.69% among different treatments studied (Table 4.10). The highest SOC was recorded under the AI-NPOF package (T_7) followed by the treatment receiving ICM i.e. T_8. It has been observed that the studied treatments significantly influenced the SOC. Panwar *et al.* (2010) reported that the most significant buildup of SOC and soil available nutrients were in organic management practices, followed by integrated management practices and then chemical management practices under a soybean-durum wheat cropping system. Further, Meena *et al.* (2019) noticed that the application of higher level of FYM (20 Mg ha^{-1}) significantly increased the SOC, soil N, P and K concentration in surface soil.

The highest soil available N recorded after wheat harvest was recorded under the INM treatments followed by the treatment receiving AI-NPOF package and complete NF treatment (T2) were found statistically at par and recorded significantly higher soil available N as compared to the rest other treatments except T8 and T9. The soil available P recorded after wheat harvest ranged 20.0-34.7 kg ha^{-1} among different treatments studied and highest soil available P was recorded under the INM treatments followed by NPOF and NF treatments. Similarly, the soil available K also found significantly influenced under studied treatments and found to be ranged 440-513 kg ha^{-1}. The studied treatments significantly influenced the soil K availability. Datt *et al.* (2003) reported higher available N (398 $kgha^{-1}$), P (38.3 kg ha^{-1}), K (328 kg ha^{-1}) and greater SOC (7.7 g kg^{-1}) content in soil under the application of FYM @ 10 t ha^{-1}. Manjunatha (2006) found that the soils under organic manure application recorded higher amounts of available N, P, K and S as compared to chemical fertilizations. The findings of Moe *et al.* (2019) and Shyam *et al.* (2019) also revealed significant effect of natural farming practices on soil properties. These findings are in close agreement with the results of present study.

5.3.2 Soil enzyme activities

The soil DHA, FDA, Alk-PO_4 and β-glucosidase enzyme activities in soil recorded after wheat harvest ranged 56-92 µgTPF/g soil/d, 45-77 µg fluorescein/ g soil/ h, 246-334 µg PNP/g soil/h and 268-364 µg PNP/g soil/h under the different treatments under study. The highest soil enzyme activities were recorded under the treatment receiving AI-NPOF package (T_7) followed by the INM treatments and complete NF treatment. Aher *et al.* (2018) noticed that the organic farming registered 27-102% higher enzymatic activities than conventional farming. Similarly, Meena *et al.* (2019) reported that the soil enzymes, DHA, Alk-P and FDA were enhanced significantly with the application of FYM at 20 tha^{1} and STCR based 75% NPK + FYM at 5 tha^{-1}. Similar findings were also observed by Ghosh *et al.* (2020).

CHAPTER-VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

The findings obtained from the present field experiment entitled '**Evaluation of natural farming practices in wheat**' carried out at the Research Farm of the Indian Institute of Soil Science, Bhopal during *rabi* 2020-21 has been summarized in this Chapter. The final conclusion has also been drawn and mentioned after summarized results. Finally, the suggestions for further work have also been placed at the end.

6.1. Summary

Crop physiological parameters

- The leaf area index recorded at 15 DAS, 30 DAS, 45 DAS, 60 DAS and 75 DAS ranged 0.21-0.34, 0.71-1.01, 0.86-1.36, 1.33-2.08 and 2.23-3.36 under different treatments tested, respectively.
- The highest leaf area index (LAI) was recorded under the treatment T_8 (ICM) and T_9 (ICM-P) followed by the treatment receiving All India NPOF package.
- The complete natural farming practice (T_2) showed significantly higher LAI than the treatment T_1 (Control), T_3, T_4, T_5 and T_6 at almost all growth stages. The LAI of wheat was found to be significantly influenced under various treatments.
- The leaf area duration of wheat recorded at 15 DAS, 30 DAS, 45 DAS, 60 DAS and 75 DAS ranged 6.9-10.1, 11.8-17.8, 20.9-25.8, 26.0-40.8 and 29.9-47.1 under different treatments tested, respectively.
- The highest LAD was recorded under the INM practice followed by All India NPOF package.
- The complete natural farming practice (T_2) showed significantly higher LAD than the treatment T_1 (Control), T_3, T_4, T_5 and T_6. The various treatments significantly influenced the LAD of wheat.
- The chlorophyll content recorded at 23 DAS, 70 DAS and 85 DAS did not show any significant difference whereas the chlorophyll content recorded at 55 DAS showed significant difference.

- The wheat leaf chlorophyll content recorded at 55 DAS was ranged 1.62-2.30 under different treatments tested, respectively.
- The highest chlorophyll content was recorded under the INM practices followed by All India NPOF package and the complete natural farming practice.
- The data revealed that the various treatments significantly influenced the chlorophyll content of wheat at 55 DAS.
- The NR activity of wheat recorded at 23, 41, 65 and 105 DAS ranged 23-61, 41-77, 56-82 and 38-66 under different treatments tested, respectively.
- The highest NR activity was recorded under the treatments involving integrated nutrient management followed by the treatment receiving All India NPOF package and NF treatment.
- The CGR of wheat recorded at 0-15 DAS, 15-30 DAS, 30-45 DAS, 45-60 DAS, 60-75 DAS and 75-90 DAS ranged 0.7-1.2, 1.2-2.0, 4.0-6.4, 15-24, 16-26 and 20-31, respectively under different treatments tested.
- The highest CGR was recorded under the treatment Integrated Crop Management followed by the treatment receiving All India NPOF and NF practice.
- The CGR of wheat showed increasing trend with the duration of crop. Similarly, all the treatments showed almost identical trend in CGR during various growth stages.

Crop growth and yield

- The plant height of wheat recorded at crop harvest ranged 72.6-80.1 cm among different treatments studied. The highest plant height was recorded under the treatment receiving Integrated nutrient Management
- The spikes plant^{-1} in wheat did not show any significant effect.
- The number of spikes per meter row length in wheat ranged 61.7-79.7 among different treatments studied.
- The INM treatments showed highest number of spikes per meter row length followed by the AI-NPOF and NF treatments.
- The grains per spikes in wheat recorded at harvest ranged 59.3-68.2 among different treatments studied. The highest number of grains per spike was recorded under the treatment receiving integrated nutrient management.
- The grain yield of wheat recorded at crop harvest ranged 2097–4163 kg ha^{-1} among the studied treatments.

- The highest yield of wheat was recorded in the treatment receiving integrated nutrient management followed by AI-NPOF and NF treatments.
- The treatment complete NF (T_2) recorded significantly higher wheat yield as compared to the treatments T_1, T_3, T_4 and T_6. The studied treatments significantly influenced the grain yield of wheat.
- The total biomass yield of wheat recorded at crop harvest ranged 4983-9183 kg ha^{-1} among the studied treatments.

Soil properties

- The soil pH and EC recorded after wheat harvest did not show any significant effect.
- The SOC recorded after wheat harvest ranged 0.51-0.69% among different treatments studied.
- The highest SOC was recorded under the AI-NPOF package (T_7) followed by the treatment receiving INM practices.
- The soil available N recorded after wheat harvest ranged 180-226 kg ha^{-1} among different treatments studied. The highest soil available N was recorded under the treatment integrated nutrient management.
- The soil available P recorded after wheat harvest ranged 20.0-34.7 kg ha^{-1} among different treatments studied. The highest soil available P was recorded under the treatment receiving Integrated Crop Management
- The soil available K recorded after wheat harvest ranged 440-513 kg ha^{-1} among different treatments studied. The studied treatments significantly influenced the soil K availability. The lowest soil available K was recorded under the treatment control (T_1, 440 kg ha^{-1}).
- The soil DHA recorded after wheat harvest ranged 56-92 µgTPF/g soil/d among different treatments studied.
- The soil FDA recorded at wheat harvest ranged 45-77 µg fluorescein/ g soil/ h among different treatments studied.
- The soil Alk-PO_4 activity recorded at wheat harvest ranged 246-334 µg PNP/g soil/h among different treatments studied.
- The soil β-glucosidase activity recorded after wheat harvest ranged 268-364 µg PNP/g soil/h among different treatments studied.
- The highest soil enzyme activities were recorded under the treatment receiving AI-NPOF package followed by the treatments receiving INM treatments and NF treatment.

6.2 Conclusions

In present investigation wheat crop was tested under various set of treatments, the performance of wheat crop was found highest under the treatment receiving INM treatments followed by AI-NPOF package and natural farming. As wheat is nutrient demanding crop and natural and organic farming practices has some limitations. However, the long-term adoption of organic farming/natural farming subsequently improves the soil health through the improvement in soil physico-chemical and biological properties.

6.3 Suggestions for further work

The study was conducted in vertisol and the test crop was wheat. Further studies may be undertaken in future to evaluate the effect and utility of natural farming:

- The effect of natural farming practices may study in diverse soils and crops.
- The effect of natural farming practice on soil microbial population may be studied.
- The water use efficiency and productivity may be studied under natural farming practices.
- The soil essential nutrient release pattern may be studied under natural farming practice.
- The various quality parameters of produce under natural farming practices may be studied.
- The crop economics also studied under natural farming practice in order to determine the economic viability of the nutrient management.

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VITAE

Name of examination : **Surubhi Kaner**

Mother's Name : Smt. Asama Kaner

Father's Name : Shri G. S. Kaner

Permanent Address : Ayodhyapuri colony
Bistan road Khargone
(M.P.) 451001

Contact : 8225099921

Educational Qualification :

Qualification	Board/ University	Year	Stream	Percentage	Division
High school	M.P.	2011	All subject	74%	First
Higher secondary	M.P.	2013	Mathematics	66%	First
Graduation	RVSKVV	2019	Agriculture	71.5%	First
Post Graduation	Rvskvv	2020	M.Sc. (Soil Science)	75.1%	First

I have submitted my thesis in 2021, during the course work in partial fulfillment of the requirement for the degree of M.Sc. (Ag) in Soil Science and Agriculture Chemistry,

Date ……………………

Place …………………… **Surubhi Kaner**