

**Performance of different varieties of wheat
(*Triticum aestivum* L.) under integrated
nutrient management system**

**BY
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2016A06D**

*Thesis submitted to the Chaudhary Charan Singh Haryana
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**DEPARTMENT OF AGRONOMY
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2022

CERTIFICATE-I

This is to certify that this thesis entitled "**Performance of different varieties of wheat (*Triticum aestivum* L.) under integrated nutrient management system**" submitted for the degree of **Doctor of Philosophy** in the subject of **Agronomy** of the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** is a bonafide research work carried out by **Mr. Aniket Diwedi** Admission No. **2016A06D** under my supervision and that no part of the thesis has been submitted for any other degree.

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

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CONTENTS

CHAPTER	TITLE	PAGE No.
I	INTRODUCTION	1-3
II	REVIEW OF LITERATURE	4-22
III	MATERIALS AND METHODS	23-40
IV	RESULTS	41-72
V	DISCUSSION	73-81
VI	SUMMARY AND CONCLUSION	82-86
	BIBLIOGRAPHY	i-xii
	APPENDICES	I-XXX

LIST OF TABLES

Table No.	Description	Page No.
1.	Standard meteorological week and the mean weather parameters (2017-18)	24
2.	Standard meteorological week and the mean weather parameters (2018-19)	27
3.	Physico-chemical properties of the experimental site	28
4.	Cropping history of the field at RRS, Kaul	28
5.	General characteristics of wheat varieties	30
6.	Agronomic practices and inter-cultural operations during the experiments in 2017-18 and 2018-19	32
7.	Chemical studies and method of estimation in plant	37
8.	Analysis of variance (ANOVA) for split plot with factor A with v (varieties) levels in main plots and factor B with n (nutrient sources) levels in sub-plots	40
9.	Effect of integrated nutrient management system on mean plant population (per metre row length) of different varieties of wheat at 30 DAS during 2017-18 and 2018-19	41
10.	Effect of integrated nutrient management system on mean plant height (cm) of different varieties of wheat at 30, 60, 90, 120 DAS and at harvest during 2017-18 and 2018-19	43
11.	Effect of integrated nutrient management system on mean leaf area index (LAI) of different varieties of wheat at 30, 60, 90 and at 120 DAS during 2017-18 and 2018-19	44
12.	Effect of integrated nutrient management system on mean leaf area duration (LAD) of different varieties of wheat at 30, 60, 90 and 120 DAS during 2017-18 and 2018-19	45
13.	Effect of integrated nutrient management system on mean dry matter accumulation (g/plant) of different varieties of wheat at 30, 60, 90, 120 DAS and at harvest during 2017-18 and 2018-19	47
14.	Effect of integrated nutrient management system on mean shoot length (cm) at 90 DAS in different varieties of wheat during 2017-18 and 2018-19	48
15.	Effect of integrated nutrient management system on phenological parameters of different varieties of wheat during 2017-18 and 2018-19	51
16.	Effect of integrated nutrient management system on mean yield attributes of different varieties of wheat during 2017-18 and 2018-19	53
17.	Effect of integrated nutrient management system on mean yields (kg/ha) and harvest index of different varieties of wheat during 2017-18 and 2018-19	54
18.	Interaction effect of varieties and nutrient sources on mean grain yield (kg/ha) of wheat in 2017-18	56
19.	Interaction effect of varieties and nutrient sources on mean grain yield (kg/ha) of wheat in 2018-19	56
20.	Interaction effect of varieties and nutrient sources on mean straw yield (kg/ha) of wheat in 2017-18	57

21.	Interaction effect of varieties and nutrient sources on mean straw yield (kg/ha) of wheat in 2018-19	57
22.	Effect of integrated nutrient management system on mean protein and starch content (%) of different varieties of wheat during 2017-18 and 2018-19	59
23.	Effect of integrated nutrient management system on mean N, P and K content (%) in grain in different varieties of wheat during 2017-18 and 2018-19	61
24.	Effect of integrated nutrient management system on mean N, P and K content (%) in straw of different varieties of wheat during 2017-18 and 2018-19	62
25.	Effect of integrated nutrient management system on mean N, P and K uptake (kg/ha) by grain in different varieties of wheat during 2017-18 and 2018-19	63
26.	Effect of integrated nutrient management system on mean N, P and K uptake (kg/ha) by straw of different varieties of wheat during 2017-18 and 2018-19	64
27.	Effect of integrated nutrient management system on mean nitrogen balance sheet/removal ratio (kg/kg) of different varieties of wheat during 2017-18 and 2018-19	66
28.	Effect of integrated nutrient management system on mean nitrogen use efficiency of nutrient (AE, PE and AR) of different varieties of wheat during 2017-18 and 2018-19	67
29.	Effect of integrated nutrient management system on mean organic carbon, available N, P and K content of soil at harvest during 2017-18 and 2018-19 in wheat	69
30.	Effect of integrated nutrient management system on mean DTPA-extractable cationic micronutrients of soil (mg/kg) at harvest during 2017-18 and 2018-19 in wheat	70
31.	Effect of integrated nutrient management system on mean economics of different varieties of wheat during 2017-18 and 2018-19	71

LIST OF FIGURES/PLATES

Fig. No.	Content	Page No.
1.	Weekly mean weather parameters during crop growth period (2017-18)	25
2.	Weekly mean weather parameters during crop growth period (2018-19)	26
3.	Layout of the experiment plot	31
4.	Grain and straw yield of different varieties of wheat during 2017-18 & 2018-19	55
5.	Grain and straw yield under different nutrient sources during 2017-18 & 2018-19	55
6.	Economic of different varieties of wheat during 2017-18 & 2018-19	72
7.	Economic of different nutrient sources during 2017-18 & 2018-19	72

LIST OF ABBREVIATION

Abbrevia tion	Meaning	Abbrevia tion	Meaning
%	Per cent	INM	Integrated nutrient management
₹	Rupees	Mm	Millimetre
@	At the rate	ml	Millilitre
°C	Degree Celsius	Mg	Mega gram
°E	Degree East	MT	Million Tonne
°N	Degree North	Mn	Manganese
-1	Per	MOP	Muriate of potash
/	Per	MP-AES	Microwave Plasma-Atomic Emission Spectroscopy
&	And	N	Nitrogen
<	Less than	NaOH	Sodium Hydroxide
≤	Less than or equal to	Nm	Nanometre
>	More than	NMR	Nuclear Magnetic Resonance
μ	Micro	No.	Number
a.i.	Active ingredient	NS	Non significant
AAS	Atomic Absorption Spectrophotometry	PGPR	Plant Growth Promoting Rhizobacteria
ADP	Adenosine-di-phosphate	P	Page
AE	Agronomic efficiency	P	Phosphorus
ATP	Adenosine-tri-phosphate	PE	Pre-emergence
AM	<i>Arbuscular mycorrhiza</i>	PE	Physiological efficiency
APEDA	Agricultural processed product export development Authority	pH	Potential of hydrogen ion
Av.	Average	Ppm	Parts per million
BCR or B:C	Benefit Cost Ratio	PSB	Phosphate Solubilizing Bacteria
CCSHAU	Chaudhary Charan Singh Haryana Agricultural University	P ₂ O ₅	Phosphorus pentoxide
Ca	Calcium	Q	Quintal
CaCl ₂	Calcium Chloride	RD	Recommended Dose
CEC	Cation exchange capacity	RDF	Recommended Dose of Fertilizers
CD	Critical Difference	RDN	Recommended Dose of Nitrogen
CFU	Colony forming unit	RE	Recovery efficiency
C/N ratio	Carbon nitrogen ratio	RH	Relative Humidity
Cm	Centimetre	RPM	Revolution per minute
cv.	Cultivar	SAARC	South Asian Association of Regional Corporation
C V	Co-efficient of Variance	SEm	Standard Error of Mean
DAS	Days after sowing	SPAD	Soil Plant Analysis Development
DAP	Days after planting/Diammonium phosphate	SSP	Single Super Phosphate
d.f.	Degree of Freedom	Std.	Standard
DGCIS	Directorate general of commercial intelligence and statistics	T	Tonne
DM	Dry matter	Temp.	Temperature
dS	Deci Siemens	USDA	United State Department of Agriculture
DTPA	Diethyl Triamine Penta Acetic Acid	var.	Variety
DOES	Directorate of Economics and Statistics	Viz.	Videlicet (Namely)
EC	Electrical Conductivity/Emulsifiable Concentrate	Zn	Zinc
ed	Edition		
etc.	<i>et cetera</i> or so on		
et al	Et alia or co-workers		
Evapo.	Evaporation		
Fe	Iron		
Fig.	Figure		
Fw	Fresh weight		
FYM	Farmyard manure		
G	Gram		

CHAPTER-I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is world's leading cereal crop in terms of area harvested. Wheat is most successfully grown between 30° and 60° N and between 27° and 40° S latitudes. It is the third most-produced cereal after maize and rice in the world. In the world, wheat is grown on 220.8 million ha area, with production of 775.7 M metric tonnes and productivity of 3.5 t/ha (FAO, 2020). India achieved remarkable progress in wheat production during the last four decades and is the second largest wheat producer after China in the world. Wheat in India is the second most important crop after rice, both in terms of area and production. In India wheat has an area of 31.5 million ha and production of 107.6 M tonnes and productivity of 3.5 t/ha, while Haryana produced 11.9 M tonnes of wheat from 2.5 M ha area with productivity of 4.6 t/ha during 2019-20 which accounted 11.0% of total wheat production in India (DOES, 2020). The India's share in world wheat area is about 12.5%, whereas it occupies 13.9% share in the total world wheat production (FAO, 2020). Wheat is a thermo-sensitive and long day plant. Mexican dwarf wheat (*Triticum aestivum* L.) presently grown in India, also known as common bread wheat and belongs to dinkale series (hexaploid $2n=4x=42$), was evolved by Dr. N. E. Borlaug at CIMMYT, Mexico. It has highest protein among all cereals, ranging from 10 to 12%, which is known as gluten and is important for the bakery purpose. Wheat also has high amount of niacin and thiamine amino acids.

India share in export of wheat is less than 1%. This share of export has increased from 0.14% in 2016-17 to 0.54% in 2020-21. A major chunk of wheat produced in India is used for domestic consumption. The top ten importing countries for Indian wheat in 2020-21 were Bangladesh, Nepal, United Arab Emirates, Sri Lanka, Yemen, Afghanistan, Qatar, Indonesia, Oman and Malaysia (Directorate General of Commercial Intelligence and Statistics, 2020).

In India, wheat is mainly grown in the North-Western Indo-Gangetic plains regions. Uttar Pradesh, Punjab, Haryana, Rajasthan, Madhya Pradesh, Gujarat, and Bihar are India's major wheat producing states. Globally, wheat yields have increased considerably as a result of breeding programmes that have incorporated the short-straw trait from Mexican varieties. Such varieties are more responsive to applied nutrients and are also more resistant to lodging as compared with the local wheat varieties (Buchi *et al.* 2016).

The adoption of an intensive cropping system will help to meet the growing population's demand for food, but it also increases the cost of production and requires a lot of energy input. Chemical fertilizer production is extremely cost-effective and relies on non-renewable fossil fuel, which is severely in short supply. Due to the ongoing global energy and

fertilizer crises, using organic dung as a renewable resource is becoming increasingly important. It is necessary to use the right combination of organic and inorganic fertilizer in this endeavour to increase output while also maintaining soil health (Weber *et al*, 2007). For providing plant nutrients, including micronutrients, and enhancing the physical, chemical, and biological properties of the soil, indigenous sources like FYM, vermicompost, and biofertilizers should be encouraged as a substitute for the supply of costly inorganic fertilizers. This will increase the fertility and productivity of the soil. It is known that soil contains free-living microorganisms that can fix atmospheric nitrogen and mobilize fixed phosphorus and make them available.

Nutrient management plays key role in sustaining the productivity, as the wheat crop is high nutrient-requiring ones and responds well to higher levels of chemical fertilizers. But deterioration in soil health associated with continuous use of chemical fertilizers and environmental hazards due to excessive use of fertilizers, call for supplementation or substitution of chemical fertilizers with low priced nutrient sources such as organic manure and biofertilizers (Roy, 2017).

According to Prasanna *et al.* (2014), *Azotobacter* and *Azospirillum* can fix 15-20 kg/ha and 20-30 kg/ha of nitrogen in field conditions, respectively, saving fertilizer costs. The beneficial effect of *Azotobacter* on plants is linked to the synthesis of complex biologically active compounds like nicotinic acid, pantothenic acid, pyridoxine, biotin, and gibberellins, which stimulate seed germination and speed up plant growth in favourable environmental conditions. These compounds are not only involved in the process of nitrogen fixation but also improved nutrition of plants (Mishustin, 1970). One of the most crucial and expensive inputs in agricultural productivity are nitrogen. Proteins, hormones, chlorophyll, vitamins, and enzymes necessary for plant life are important constituents of it. Phosphorus is an equally important ingredient for photosynthesis, protein synthesis, seed germination, and nearly every other component of plant growth and metabolism. Any farming system intended to increase and sustain productivity must include the practise of managing soil fertility. Therefore, it is imperative that technology be developed for the proper fertilizer dosage that can guarantee an economic optimal crop yield, maintain soil nutrient reserves, and not have a long-term negative impact on the environment. Chemical fertilizers, organic manures, recycled wastes and by products, biological nitrogen fixation, natural minerals, and to a lesser extent nutrients recycled through irrigation fluids and precipitation can all be used to meet the nutritional demands of crop plants. These add to the soil's existing supply of nutrients for crop nutrition. The organic and biological sources of nutrition are typically few and have poor nutrient levels. To maintain soil fertility levels, a large quantity of organic manure would be needed. So, the key to sustainability is a mix of both synthetic/chemical and organic fertilizers.

Integrated nutrient management (INM) system has multifaceted potential for the improvement of plant performance and resource efficiency while also addressing the protection of the environment and resource quality. INM enhanced crop yields by 8-150% of different crops compared with conventional practices, increased water-use efficiency, and offered economic returns to farmers, while improving grain quality and soil health and sustainability (Sharma *et al*, 2019). Lower inputs of chemical fertilizer and therefore lower human and environmental costs (such as intensity of land use, N use, reactive N losses and greenhouse gas emissions) were achieved under advanced INM practices without compromising crop yields. Strong and convincing evidence indicates that INM practice could be an innovative and environmentally friendly strategy for sustainable agriculture worldwide (Wu and Ma, 2015). The conjunctive use of various sources of nutrients including chemical, biological and organic sources of nutrient is one of the options available for mitigating the nutrient deficiencies in many areas. Therefore, it is necessary to compare various organic manures with chemical fertilizers to find the most effective combination. There is large variation in genetic potential of different varieties and accordingly their requirement also differ depending on their growth habit, crop duration and yield potential under particular agro-climatic condition. So, the appropriate variety selection is utmost in the cultivation of wheat in combination with integrated nutrient management technique. In view of the above facts, the present field experiment entitled **“Performance of different varieties of wheat (*Triticum aestivum* L.) under integrated nutrient management system”** was conducted during *Rabi* 2017-18 and *Rabi* 2018-19 with the following objectives:

1. To study the effect of different INM treatments on growth, yield and quality of wheat varieties
2. To study the effect of different INM treatments on chemical and biological properties of soil
3. To find out the most profitable nutrient management system

CHAPTER-II

REVIEW OF LITEATURE

Literature pertaining to the present investigation entitled “**Performance of different varieties of wheat (*Triticum aestivum* L.) under integrated nutrient management system**” has been reviewed in this chapter. The similar research work done on wheat and other crops by the eminent scientists in India and abroad has also been included.

2.1 Review on integrated nutrient management

2.1.1 Effect of integrated nutrient management on growth parameter

2.1.2 Effect of integrated nutrient management on phenological parameter

2.1.3 Effect of integrated nutrient management on yield attributes and yields

2.1.4 Effect of integrated nutrient management on quality

2.1.5 Effect of integrated nutrient management on nutrient studies

2.1.6 Effect of integrated nutrient management on chemical properties of soil

2.1.7 Effect of integrated nutrient management on economics

2.1.1 Growth attributes

Kumar *et al.* (2015) reported significantly higher leaf area index (LAI) of wheat with 50% RDF through inorganic source + 50% RDN through FYM over control in variety HD 2967.

Mondal *et al.* (2015) reported application of 100% RDF + 25% RDN through organic manure + biofertilizer gives higher plant height, leaf area index (LAI) and dry matter accumulation (g/m^2) over 100% RDF, 75% RDF + 25% RDN through mustard oil cake (MOC), 50% RDF + 50% RDN through MOC, 25% RDF + 75% RDN through MOC, 100% RDN through MOC, 100% RDF + 25% RDN through MOC, 75% RDF + 25% RDN through MOC + biofertilizer and 100% RDF + 25% RDN through MOC + biofertilizer in rice variety PHB 71.

Kakraliya *et al.* (2017) revealed that application of 100% RDF + vermicompost @ 2.5 t/ha + FYM @ 5 t/ha + *Azotobacter* gave the maximum plant population, dry matter accumulation and leaf area index of wheat over control.

Saleemi *et al.* (2017) reported that mixture or co-inoculation treatment (NFB + PSB) have significantly increased shoot length and dry matter accumulation as compared to uninoculated treatment in rainfed wheat.

Akhtar *et al.* (2018) obtained significantly higher values of growth parameters *viz.*, plant population, plant height, dry matter accumulation/plant, leaf area index and leaf area duration with application of 100% RDF + ZnSO_4 @ 25 kg/ha (P from DAP), and being at par with treatments 100% RDF, RDF + ZnSO_4 @ 25 kg/ha (P from SSP), RDF (N from Zn coated

urea + P from SSP), 75% RDF + *Azotobacter* + PSB, RDF (N from neem coated urea + P from SSP) and RDF (50% N from neem coated urea + 50% N from Zn coated urea) + P from SSP.

Rani and Sharma (2018) reported maximum plant height, leaf area index and leaf area duration at 30, 60, 90 and 120 DAS with RDF + AM fungi followed by RDF + *Azotobacter* + PSB and RDF only, while lowest in 75% RDF + AM fungi followed by 75% RDF + AM fungi + *Azotobacter* in wheat variety WH 1142.

Mangaraj *et al.* (2022) reported that application of 50% RDF through fertilizers + 50% RDN through FYM increased the plant height, dry matter accumulation, leaf area and leaf area duration in aromatic rice in comparison to 100% RDF (N:P₂O₅:K₂O @ 60:30:30 kg/ha), 75% RDF + 25% RDN through FYM, 50% RDF + 50% RDN through FYM, 50% RDF + 25% RDN through FYM, 75% RDF + green manuring and 50% RDF + green manuring.

2.1.2 Phenological parameter

Mondal *et al.* (2015) observed that application of 100% RDF + 25% RDN through organic manure + biofertilizer took more number of days to anthesis, flowering, heading and maturity in high yielding long duration variety of rice (PHB 71) over control treatment.

Redda and Abay (2015) observed that integrating 75 kg of nitrogen through inorganic fertilizer and FYM @ 9 t/ha required more time to reach days to 50% heading, days to 50% anthesis and days to 50% maturity than inorganic fertilizer alone in rice.

Khan *et al.* (2016) reported that longest duration to spike initiation (116 days) and maturity (152 days) in wheat were recorded in control whereas minimum days to spike initiation (107 days) and maturity (148 days) in wheat were recorded with 50% N through Urea + 25% N through FYM + 25% N through poultry manure.

Singh *et al.* (2018) observed that application of 50% RDF through inorganic fertilizers + 50% N through FYM resulted in maximum number of days (99 days) to 50% anthesis and maturity (137 days) in rice, which was at par with 100% RDF. The control plots took minimum of days to 50% anthesis (91 days) and maturity (126 days).

2.1.3 Yield attributes and yields

El-Sirafy *et al.* (2006) reported that the highest grain yield (5.76-6.74 Mg/ha) and straw yield (11.49-3.32 Mg/ha) was with N @ 183 kg/ha. Combined application of polymer coated urea @ 183 kg/ha + biofertilizer (*Azotobacter chroococcum*, *Azospirillum liposerum* and *Bacillus megatherium*) recorded highest mean grain yield (6.88 Mg/ha) in wheat variety Sakha 69.

Gupta and Aggarwal (2008) noticed that increasing levels of FYM up to 15 t/ha significantly increased number of effective tillers/m², grain weight/spike and number of grains/spike over control and 5 t/ha during both years.

Pandey *et al.* (2009) observed that application of FYM @ 10 t/ha + ZnSO @ 25 kg/ha together with 100% RDF, 125% RDF and 150% RDF resulted in significantly higher values of yield attributes, grain (3.5-3.7, 3.6-3.8 and 3.8-3.9 t/ha, respectively) and straw (5.2-5.4, 5.3-5.5 and 5.5-5.6 t/ha, respectively) yields than application of 100% RDF (2.9-3.1 t/ha), 125% RDF (3.2-3.5 t/ha) and 150% RDF (3.3-3.6 t/ha) alone. Application of FYM @ 10 t/ha with 100% RDF produced similar grain yield (3.4-3.6 t/ha) as the yield obtained under 150% RDF alone (3.3-3.6 t/ha). Application of 150% RDF together with FYM @ 10 t/ha + ZnSO₄ @ 25 kg/ha produced maximum grain yield (3.8-3.9 t/ha).

Behera and Rautaray (2010) observed that application of 100% NPK gives higher number of spikes/m², number of grains/spike, 1000-grain weight, harvest index, grain yield and straw yield over control, 50% NPK, 50% NPK + *Azotobacter spp.* (AS), 50% NPK + *Azospirillum brasilense* (AB), 50% NPK + *Proteus vulgaris* (PV), 50% NPK + *Kurthia Spp* (KP), 50% NPK + *Klebsiella planticola* (KP), 50% NPK + *Bacillus subtilis* (PSB), 50% NPK + VAM, 50% NPK + PV + KS + KP, 50% NPK + PV + KS + KP + AS, 50% NPK + PV + KS + KP + AB, and 50% NPK + PSB + AB.

Singh *et al.* (2011) observed that combined application of organic manures and inorganic fertilizers increased the number of grains/spike, grain yield and straw yield in wheat crop compare to application of 100% RDF applied through inorganic (urea, single superphosphate and MOP).

Mane *et al.* (2014) reported application of 125 % RDF + *Azotobacter* + PSB significantly higher number of effective tillers/plant, number of spikelets/panicle, number of grains/panicle, weight of grains/panicle, grain yield, straw yield and biological yield than all other treatments (125% RDF and 100% RDF + *Azotobacter* + PSB) in wheat variety Trimbak (NIAW 301).

Hasim *et al.* (2015) revealed that application of 50% RDF (N: P₂O₅: K₂O @ 120:60:40 kg/ha) + 50% RDN (N @ 120 kg/ha) through crop residue mixed FYM resulted in significantly higher maize grain yield (4.2 t/ha) over the control (2.2 t/ha) during first year, but during the second year (5.2 t/ha) it was significantly higher than the control (3.1 t/ha) and 50% RDF + 25% RDN + biofertilizer (4.8 t/ha). In wheat crop, 100% RDF showed significantly higher growth and yield attributes over the control.

Mayer *et al.* (2015) reported application of 100% RDF + rotted manure + slurry give higher mean number of ears/m², number of grains/ear, 1000-grain weight, grain yield and straw yield over control, 50% RDF + composted manure + slurry, 50% RDF + rotted manure + slurry, 100% RDF + composted manure + slurry in winter wheat (*Triticum aestivum* L.) in Switzerland.

Bhatt *et al.* (2016) recorded that application 100% NPK + FYM @ 15 t/ha gives higher grain and straw yield of wheat over 50% NPK, 100% NPK, 100% NPK + Zn, 100% NP, 100% N and control in pooled.

Tripathi *et al.* (2016) reported that application of 150% recommended NPK fertilizers produced the maximum grain yield (6.10 t/ha), which was 7.7% higher over the 100% NPK fertilizers, followed by FYM @ 15 t/ha application along with 150 (5.98 t/ha) and 125% (5.96 t/ha) NPK application.

Argal *et al.* (2017) reported that significantly higher grain yield (3984 kg/ha) and straw yield (4454 kg/ha) of wheat was found with application 75% RDF + FYM @ 2.5 t/ha + PSB + ZnSO₄ @ 25 kg/ha practices followed by 150% RDF and soil test crop response (STRC) based NPK application.

Kakraliya *et al.* (2017) reported that application 100% RDF + vermicompost @ 2.5 t/ha + FYM @ 5 t/ha + *Azotobacter* gave higher grain (5.6 t/ha) and straw yield (7.5 t/ha) in wheat over control (2.9 and 4.1 t/ha).

Meena *et al.* (2017) found that the yield contributing characters of wheat viz., number of spikes/plant and number of grains/spike were recorded significantly higher when the crop was supplied with combined application of RDF or 75% RDF along with FYM, biofertilizer and zinc over control and treatment receiving RDF only. However in case of integrated nutrient management, RDF + FYM + biofertilizers (seed treatment) + Zn treatment produced 50.4 and 52.7 q/ha wheat yield respectively. The grain and straw yields increased significantly with treatment RDF + FYM + Zn over control and RDF alone. The increase in grain yield with application of RDF + FYM + BF + Zn over RDF alone was 16.8% and 14.1% during 2007-08 and 2008-09, respectively.

Pal *et al.* (2017) noticed that wheat variety HS 562 produced an average grain yield of 3.6 t/ha with 6.2% grain yield advantage over best check variety HS 507 under dryland conditions of north hill zone.

The highest grain yield of wheat was recorded with 100% RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB in the first year, and with RDF + vermicompost @ 10 t/ha + *Azotobacter* + PSB in second year, though both these treatments gave grain yield at par during both the years (Khan *et al.*, 2017).

Verma *et al.* (2017) reported that the application of FYM @ 7.5 t/ha + vermicompost @ 3 t/ha resulted in significantly higher grain yield (4.6 t/ha), straw yield (6.6 t/ha), biological yield (11.1 t/ha), and harvest index (41.1%) over other treatments but it was on par with vermicompost @ 6 t/ha (4.3 t/ha, 6.3 t/ha, 10.6 t/ha and 40.7%).

Molla *et al.* (2018) reported treatment combinations of vermicompost (0, 2, 4 and 6 t/ha) and NPK fertilizers (0, 33.3%, 66.6% and 100%) significantly increased the wheat grain yield and biological compared to the control. Highest grain and biological yield was obtained

with treatments vermicompost @ 4 t/ha + 100% RDF over vermicompost @ 2 t/ha + 33.3% RDF, and vermicompost @ 2 t/ha + 66.6% RDF.

Reddy Tummala *et al.* (2018) recorded the highest total number of tillers/metre², length of panicle, number of grains/panicle, 1000-grain weight and grain weight/panicle with combine application of 75% RDN + 25% RDN through press mud cake + 100% RDP and K, which was at par with 100% RDF.

Tahir *et al.* (2018) observed that application of RDF @ 150:100:00 + PSB + bio-organic phosphate gives higher number of productive tillers/m², number of spikelets/spike, grains/spike, 1000-grain weight (g), grain yield (mg/ha), straw yield (mg/ha) and harvest index (%) over control, RDF @ 150:100:00 kg/ha + PSB and RDF @ 150:100:00 kg/ha + bioorganic phosphate.

Arif *et al.* (2019) reported that among four wheat varieties, viz. Raj 4120, Raj 4037, Raj 4079 and Raj 4238, Raj 4037 produced the highest of grain yield (5707 kg/ha) and straw yield (8869 kg/ha). Among different nutrients combination, 125% RDN + ZnSO₄ @ 25 kg/ha (soil application) recorded significantly higher grain (5681 kg/ha) and straw yield (8265 kg/ha) over 100% RDN, 100% RDN + ZnSO₄ @ 25 kg/ha (soil application), 100% RDN + ZnSO₄ @ 0.5% (foliar application), 100% RDN + ZnSO₄ @ 25 kg/ha (soil application) + ZnSO₄ @ 0.5% (foliar application), 125% RDN + ZnSO₄ @ 25 kg/ha (soil application), 125% RDN + ZnSO₄ @ 0.5% foliar application and 125% RDN + ZnSO₄ @ 25 kg/ha (soil application) + ZnSO₄ @ 0.5% (foliar application).

Jat *et al.* (2020) noted that the application of FYM @ 5 t/ha + NPK @ 200 kg/ha + NPK-biofertilizer + urea @ 20 kg/ha at 40 DAS + NPK @ 1% foliar spray at 55 and 70 DAS + bio-stimulant-L @ 625 ml/ha foliar spray each at 55 and 70 DAS led to significantly highest number of tillers/m² (106.2 and 107.5), ear length (12.4 and 12.6 cm), number of spikelets/spike (17.4 and 17.9), number of grains/spike (49.7 and 49.8), 1000-grain weight (40.1 and 40.3 g), grain yield (4751 and 4764 kg/ha) and straw yield (6319 and 6479 kg/ha) over control during both year in wheat.

Kalhapure *et al.* (2020) revealed application of 125% RDF + FYM @ 15 t/ha resulted in higher grain yield (5.5 t/ha). Similarly, treatments 100% RDF + FYM @ 15 t/ha and 125% RDF + FYM @ 15 t/ha recorded 114 and 128% higher grain yield, respectively, over application of only 100% RDF.

Amanullah *et al.* (2021) reported that application of foliar macro nutrients (N, P and K) resulted in more number of effective tillers/m², longer spikes, number of grains/spike and higher grain yield of wheat over control.

Kumari *et al.* (2021) recorded that the application of 125% RDF produced significantly higher grain yield (38.7 q/ha) than control and it was found statistically at par with 100% RDF (37.1 q/ha) which in turn was found superior over control (24.1 q/ha).

Walia and Patidar (2021) reported that application of 50% RDF + 50% RDN through FYM resulted in the maximum 1000-grain weight, grain and straw yields of maize than sole organic farming and chemical farming treatments. However, treatment with organic management package, comprising bio-fertilizer containing N and P carriers was at par with integrated application of nutrients through organic sources and fertilizers. The lowest value of yield attributes was recorded with 50% RDN as FYM + *Azotobacter* + rockphosphate + phosphorus.

Kabato *et al.* (2022) reported application of the 100% RDF + compost @ 6 t/ha produced the higher grain yield (8.2 t/ha) than 100% RDF produced (6.2 t/ha). Application of 75% RDF through inorganic source combined with compost resulted in increased wheat yield by 27.5% over sole application of inorganic fertilizer indicating that the integrated approach could save up to 25% of commercial fertilizers and increase the yield of wheat.

Kumar *et al.* (2015) obtained higher number of effective tillers/m² (341), spike length (11.4 cm), number of spikelet/spike (22.6), number of grains/spike (39.3) 1,000-grain weight (40.1 g), grains yield (4.1 t/ha), straw yield (6.6 t/ha) and biological yield (10.6 t/ha) in wheat variety HD 2967 over WR 544 (303.4, 10.1cm, 20.2, 36.4, 37.4 g, 3.6 t/ha, 5.9 t/ha and 9.4 t/ha), HD 2987 (313.5 10.4 cm, 20.7, 37.5, 38.0 g, 4.0 t/ha, 7.0 t/ha and 11.0 t/ha) and HD 2931(308.4, 9.9 cm, 19.7, 35.6, 37.1, 3.5 t/ha, 6.0 t/ha and 9.5 t/ha).

2.1.4 Quality

Gashaw *et al.* (2013) found that identifying superior varieties and suitable environments coupled with optimum level of nitrogen fertilization would improve durum wheat grain yield and pasta making qualities, which is influenced by protein and starch content in durum wheat. Mean grain protein content ranged from 11.0 to 11.9%, where wheat variety Waha consistently yielded the maximum mean protein content. Grain protein content (ranging from 12-16%) is optimum for pasta processing. Protein content less than 11% will yield poor quality pasta while protein content greater than 16% might be associated with lower hectolitre weight. Therefore, in terms of protein content, varieties Waha, Ilani, Malefiaand and Boohai meet the minimum standard of protein content for pasta products.

Gerba *et al.* (2013) evaluated two medium tall (Arsi-Robe and Kilinto) and two semi-dwarfs (Ude and Yerer) durum wheat varieties under five N rates (0, 60, 120, 180 and 240 kg/ha). Protein and starch content were higher in semi-dwarf compared to medium tall varieties. There was no significant difference between varieties × fertilizer interaction.

Maximum protein contents in grain (11.1%) and straw (3.4%) was obtained with application of 100% RDF. The integrated use of fertilizers and FYM improved the starch content in grain and maximum value (54%) was recorded with 75% RDF + FYM @ 5 t/ha + biofertilizer (*Azotobacter*) (Singh, 2017).

Dereje *et al.* (2019) observed that in terms of grain protein content, the Lemu variety outperformed the Wane variety, although both varieties showed higher levels of dry and wet gluten. Protein content between 11 to 14% in grains. Application of 138 and 184 N kg/ha, respectively, increased the grain's protein content by 12 and 15.1% over 46 and 92 N kg/ha.

Hammad *et al.* (2020) noticed protein content of wheat was significantly affected by sources and quantity of applied nutrients. The treatments were: control, 100% RDF (N:P₂O₅:K₂O @ 150:100:60 kg/ha), FYM + poultry litter, FYM + poultry manure, FYM + sewage sludge, poultry litter + poultry manure and poultry litter + sewage sludge. Each type of organic manure was applied at the rate of 10 t/ha during both growing season. Maximum protein content (13.2% and 13.3% during 2005–06 and 2006–07, respectively) was observed by application of poultry litter @ 10 t/ha + sewage sludge @ 10 t/ha and it was 67% higher over control treatment followed by 100% RDF treatment. Whereas, the minimum values of protein content (7.9% and 8.0% during 2005-06 and 2006-07, respectively) was obtained from the control treatment.

2.1.5 Nutrient studies

Singh and Arora (2001) observed that nitrogen uptake showed 1.4 and 1.5 fold varietal variation at harvest for limited N @ 40 kg/ha and normal N @ 120 kg/ha supply, respectively. NUE for dry matter production showed 1.28 and 1.38 fold varietal variation while nitrogen use efficiency for grain production varied by 1.25 and 1.21 fold at lower and RDN supply, respectively. Traditional varieties (K 68) were found to have higher N uptake and NUE for dry matter production, while modern varieties (HD 2285) had greater NUE for grain production. Nitrogen uptake was found to be strongly positively associated with dry matter production, indicating an important effect of growth rate on N uptake.

Kachroo and Razdan (2006) reported that nitrogen use efficiency (kg/kg) and apparent nitrogen recovery (%) of absorbed nitrogen was higher with 100% RDN (80 kg/ha) and thereafter decreased with increasing N level in wheat variety PBW 343.

Shafi *et al.* (2012) observed maximum total soil N and organic matter in the combined application of 75% poultry manure + 25% RDN. Maximum grain and straw N uptake was recorded with application of FYM as sole N source. However, among integrated application of N sources, 25% poultry manure + 75% RDN source resulted in the highest uptake of nitrogen by grain and straw in wheat.

Tripathi *et al.* (2016) reported that agronomic efficiency was the maximum (13.6 kg grain/kg fertilizer) with the recommended rate of fertilizers and it decreased with increasing rates. Addition of FYM didn't increase the agronomic efficiency due to inclusion of 75 kg N contribution from 15 t/ha of FYM.

Verma *et al.* (2016) reported that uptake of N, P and K in wheat grain and straw was significantly higher after the application of 50% RDF + 25% RDN through vermicompost +

biofertilizer, and it was on par with 100% RDF and 50% RDF + 25% RDN through organic manure + biofertilizer.

Datta *et al.* (2018) observed that highest N, P and K content and uptake by grain and straw with application of 100% NPK + FYM @ 10 t/ha over control and 100% NPK.

Jahan and Amiri. (2018) revealed that application of RDF @ 145:34:0 kg/ha + FYM @ 30 t/ha resulted in considerably high agronomic nitrogen use efficiency of 16.5 (kg/kg).

Faizly *et al.* (2020) observed significantly highest agronomical nitrogen use efficiency (kg/kg), recovery efficiency of nitrogen (%), and nutrient removal ratio (kg/kg) of wheat with application of 100% RDN in both years. Application of 25% RDN + 75% N through FYM was registered significantly higher physiological nitrogen use efficiency and nutrient efficiency ratio, being at par with application of 25% RDN + 75% N through vermicompost.

Lu *et al.* (2020) found that the ratio of the relative contribution of soil fertility and N application level to wheat yield was 0.5:1, and their contribution ratios to utilization efficiencies of nitrogen were 1.1:1, 1.4:1 and 1.9:1, respectively. A ratio of N application level decrement to integrated soil fertility increment greater than 0.89 was necessary to increase the recovery efficiency of N to 55%.

Gadisa and Wakgari (2021) reported that the Wane variety of wheat applied with vermicompost @ 5 t/ha + RDN @ 46 kg/ha through inorganic source had the maximum total nitrogen uptake (154.3 kg/ha), while the control plot had the lowest total nitrogen uptake (33.2 kg/ha). Application of nitrogen @ 23 kg/ha resulted in highest grain nitrogen use efficiency (93.4 kg/kg). As the rate of vermicompost and N fertilizer levels increased, the value of nitrogen use efficiency decreased. The lowest grain nitrogen use efficiency (29.6 kg/kg) was obtained in Danda'a variety with application of vermicompost @ 7.5 t/ha and 69 kg/ha nitrogen fertilizer through inorganic source. Wane variety applied with combined application of vermicompost @ 5 t/ha and nitrogen @ 46 kg/ha had the highest nitrogen apparent recovery efficiency (111.4%) and agronomic efficiency (42.6 kg/kg).

Darjee *et al.* (2022) revealed that application of 100% RDF + *Azotobacter* + *Mycorrhiza* improved N, P and K content by grain (%) and straw (%) and nitrogen use efficiency (kg/kg) as compared to 100% RDF only.

2.1.6 Chemical properties of soil

Abbasi and Yousra. (2012) noticed that biofertilizer (a mixture of *Pseudomonas*, *Azospirillum* and *Agrobacterium* strains) supplemented with 100% poultry manure @ 200 N mg/kg improved soil properties, such as available organic carbon, N, P, K and DTPA-extractable Fe, Mn, Cu and Zn over control, 50% urea nitrogen, biofertilizer only, 100% urea N @ 200 N mg/kg, 25% poultry manure @ 200 N mg/kg, 50% urea nitrogen + 100% poultry manure + biofertilizer, 50% urea nitrogen + 50% poultry manure + biofertilizer and 50%

poultry manure + biofertilizer in wheat grown under greenhouse condition. The use of biofertilizer improved the effectiveness of both mineral and organic N fertilizers.

Bhattacharyya *et al.* (2007) obtained that overall increase of 11.0 and 13.9 C Mg/ha in soil organic carbon content with 100% RDF (N:P₂O₅:K₂O @ 120:26:33 kg/ha) + FYM @ 10 t/ha treatment as compared to 100% RDF and control treatments, respectively.

Datta *et al.* (2018) observed that highest organic carbon content in soil with application of 100% NPK + FYM @ 10 t/ha (7.8 g/kg) over control (4.6 g/kg) and 100% NPK (7.7 g/kg).

Sepehya *et al.* (2012) reported improvement in both physical and chemical properties of soil at harvest. Application 100% RDF to wheat was the best practice than rest of the treatments (50% RDF and 75% RDF) not only in sustaining higher crop yields, but also improving the soil properties. The highest values of pH, organic carbon, CEC, available N, P and K were recorded with 100% RDF integrated with 50% RDN through FYM. Further, the 50% substitution of N through any of the organics source (through FYM, wheat cut straw and green manure) proved better over 25% substitution rate.

Rathod *et al.* (2013) revealed that vermicompost only had an impact on the availability of micronutrients in wheat, but FYM treatment boosted soil macronutrient and micronutrient availability. For available N, there was still a residual effect from FYM and mineral fertilizers. As a result of organic amendments, the soil's residual status of micronutrients (Mn and Zn with FYM; Fe and Zn with vermicompost) was either maintained or significantly improved.

Rutkowska *et al.* (2014) reported that the highest DTPA-extractable Fe, Mn Zn and Cu in soil were observed in the treatment with the lowest pH (NPK). The concentration of Zn and Fe in the soil significantly increased under FYM @ 30 t/ha application and Mn and Cu with compost @ 10 t/ha.

Brar *et al.* (2015) reported that the soil organic carbon pool was the lowest in control at 7.3 Mg/ha and increased to 11.6 Mg/ha with 100% NPK (150:33:31 kg/ha) + FYM @ 10 t/ha.

Bhatt *et al.* (2016) noticed that among several treatment combinations of control, 50% RDF, 100% RDF, 150% RDF, 100% RDF + FYM @ 15 t/ha the soil organic carbon and available N after rice and wheat, respectively, were highest with 100% RDF + FYM @ 15 t/ha, which were significantly higher over all the other treatments .

Ram *et al.* (2016) revealed that soil organic carbon and available N, P, K, and Zn in the control plot decreased the most, whereas 100% RDF + FYM @15 t/ha improved available N, P and K, maintained soil organic carbon, and decreased Zn over initial levels. Grain yield and SYI (sustainable yield index) were more significantly correlated with soil organic carbon.

Bharali *et al.* (2017) reported higher soil organic carbon in soil was recorded in the soil treated with 100% RDF (NPK@ N:P₂O₅:K₂O @ 80:34:42 kg/ha) + rice husk dust @ 5

t/ha followed by 100% RDF + *Azolla caroliniana* compost @ 2 t/ha, 100% RDF + cow dung @ 5 t/ha, 100% RDF + *Sesbania aculeata* @ 5 t/ha and 100% RDF winter-wheat cropping system in Tezpur, Assam, India. The higher soil organic carbon concentration at 100% RDF + rice husk dust @ 5 t/ha may be attributed to the greater C:N ratio of rice husk dust.

According to Datta *et al.* (2018) long-term intensive cropping with balanced NPK (15.1%) and NPK + FYM (22%) caused a net enrichment in soil organic carbon over the control treatment.

Kalhapure *et al.* (2020) noticed that with application of 125% RDF and FYM @ 15 t/ha efficiently improved the soil properties, viz. decreased bulk density (by 0.14 Mg/m) and pH and increased, organic carbon (by 0.06%), available P₂O₅ (by 3.2 kg/ha) and K₂O (by 45.8 kg/ha) content compared with the initial status.

Dhaliwal *et al.* (2021) observed that integrated nutrient management technique (RDF @ 150:60:30 + FYM @ 10 t/ha) enhanced the organic carbon content (0.44 to 0.66%), available N (152.8 to 164.9 kg/ha), P (22.8 to 31.4 kg/ha) and K (140.6 to 168.0 kg/ha). The DTPA-extractable micronutrients (Fe, Mn, Zn and Cu) status also improved significantly with application of FYM @ 10 t/ha.

Singh and Saini (2022) conducted experiment with different treatment combinations comprising control, 50% RDF + FYM, 50% RDF + GM, 100% RDF, 100% RDF + FYM, 100% RDF + GM and 150% RDF. Results revealed that continuous use of chemical fertilizers along with organic amendments in rice–wheat cropping system for 19 years resulted to an increase in the availability of DTPA-extractable Zn, Fe, Mn and Cu (mg/kg). Build-up of soil organic carbon and decrease in soil pH resulted in the increase of bio-available forms of micronutrients.

2.1.7 Economics

Gupta and Aggarwal (2008) recorded highest net return (18880 Rs./ha) and BCR (1.74) with application of 100% RDF over FYM @ 15 t/ha + *Azotobacter chroococcum*.

Shah and Kumar (2014) observed that application 50% RDF + FYM @ 15 t/ha gives maximum mean net returns with BCR over 50% RDF + neem cake @ 5.0 t/ha, 50% RDF + vermicompost @ 5 t/ha, 50% RDF + FYM @ 5 t/ha + *Azotobacter* + Neem cake @ 2.5 t/ha + PSB and 50% RDF + Wheat cut straw @ 10 t/ha in both years of study.

Kumar *et al.* (2015) revealed application of 50% RDF through inorganic source + 50% RDN through FYM gave significantly the highest gross returns, net returns and BCR over control during both year of study.

Verma *et al.* (2015) reported application of 100% RDF + vermicompost @ 5 t/ha + seed treatment with *Azotobacter* and PSB gave higher gross return, net return and BCR over 100% RDF + vermicompost @ 5 t/ha, 100% RDF + FYM @ 10 t/ha, 100% RDF + seed

treatment with *Azotobacter* and PSB and 100% RDF + FYM @ 10 t/ha + seed treatment with *Azotobacter* and PSB during 2011-12 and 2012-13, respectively in wheat variety PBW 502.

Dawlatzai *et al.* (2016) reported that application of either two or three species of bacterial inoculants with 75% RDN, on an average, saved 37.5 N kg/ha and hence proved economical.

Chaudhry *et al.* (2017) obtained the highest gross income was achieved with 100% RDF + vermicompost @ 5 t/ha + *Azotobacter* + PSB in the first year, and with 100% RDF + compost @ 10 t/ha + *Azotobacter* + PSB in the second year. However, the highest net returns and BCR were obtained with 100% RDF + vermicompost @ 10 t/ha + *Azotobacter* + PSB. Use of 100% RDF alone gave the least values of gross income and net income.

Parewa *et al.* (2019) recorded significantly highest net return with FYM @ 10 t/ha + vermicompost @ 1.25 t/ha whereas BCR (2.43) was highest with FYM @ 5 t/ha + neem green leaves @ 2 t/ha + vermicompost @ 1.25 t/ha. Application of FYM @ 5 t/ha + neem green leaves @ 2 t/ha + vermicompost @ 1.25 t/ha led to increase grain yield by 94.8% over control (19.0 q/ha).

Highest net returns were obtained with application of 150% of RDF (N:P₂O₅:K₂O @ 225: 90: 60 kg/ha) in wheat crop in Varanasi, Uttar Pradesh (Paik *et al.*, 2020).

Tanwar *et al.* (2022) revealed that in both the *rabi* and *kharif* seasons, the application of FYM @ 15 t/ha and RDN @ 120 kg/ha resulted in the highest gross returns, net returns, and BCR in case of wheat crop. The combined application of FYM @ 15 t/ha + RDN @ 120 kg/ha in both the *rabi* and *kharif* seasons, considerably increased wheat growth and yields as well as the crop's economic returns over control.

2.2 Review on performance of varieties

2.2.1 Effect of varieties on growth parameter

2.2.2 Effect of varieties on phenological parameter

2.2.3 Effect of varieties on yield attributes and yields

2.2.4 Effect of varieties on quality

2.2.5 Effect of varieties on nutrient studies

2.2.6 Effect of varieties on chemical properties of soil

2.2.7 Effect of varieties on economic

2.2.1 Growth parameter

Hazari *et al.* (2019) observed that plant height was highest in C 306 and lowest in case of Sonalika.

Kumar *et al.* (2018) reported that wheat variety MP 4010 give higher plant height (cm) and dry matter accumulation (g/plant) over variety RVW 4106.

Singh *et al.* (2021) reported that plant height, dry matter accumulations and leaf area index was higher in DBW 187 followed by HD 2967, which being at par with each other but exhibited statistical superiority over NW 5054 and NW 1014.

Manschadi and Soltani (2021) recorded that wheat variety Arnold give highest dry matter accumulation (443.0 g/m²) over varieties Bernstein (418.7 g/m²) and Emilio (328.9 g/m²) and Aurelius (168.7 g/m²).

Kumar *et al.* (2019) reported that among wheat varieties, VL 907 recorded higher leaf area index (at 30, 60 and 90 DAS), plant height at harvest (cm) and dry matter accumulation (g) at harvest over varieties PBW 343, PBW 373 and UP 262.

Khatik *et al.* (2021) reported that Raj 4037 was showed significantly highest dry matter accumulation per metre row length and leaf area index (LAI) than Raj 4083 and Raj 3777.

Singh *et al.* (2013) reported that wheat variety UP 2425 (91.2 cm, 4.96 and 704.5 g/m²) produced higher plant height, leaf area index and dry matter accumulation over other wheat varieties HUW 234 (86.2 cm, 4.5 and 657.6 g/m²) and HP 1744 (81.9 cm, 4.1 and 616.8 g/m²).

Chauhan *et al.* (2020) recorded that wheat variety PBW 343 gives higher plant height (cm), dry matter accumulation/m² (g) and leaf area index at 90 DAS over wheat varieties Malviya 234 and NW 1012.

Hiltbrunner and Liedgens. (2008) reported that wheat variety Ataro give maximum plant population/m², plant height, dry matter accumulation, leaf area duration (LAD) and leaf area index over varieties Arina, Asketis, Segor, Habicht, Levis, Pegassos, Titlis, and Zinal.

Wang *et al.* (2021) reported that wheat variety Filderstolz and Oberkulmer Rotkorn produce more grain protein that comply with bread-making quality standards over Rubiota and Zuricher Oberlander.

2.2.2 Phenological parameter

Alam *et al.* (2013) recorded that wheat variety DBW 39 took minimum number of days for heading and anthesis over varieties Raj 4229, K 0906, K 0307 and HD 2733.

Raza *et al.* (2018) reported that maximum days to 50% heading were recorded in line 14 (110 days) and the minimum number were recorded in line 1 (118days).

Awulachew (2019) observed that among two wheat variety wane took less number of days to 50% heading and 50% anthesis over variety kingbird.

Gemechu *et al.* (2019) reported that Hidase had the shortest (days) heading and anthesis followed by wheat varieties Mada walabu and Hogana.

Hazari *et al.* (2019) observed days to heading were longest in HD 2967 and shortest in Sonalika. Days to anthesis, it was highest in HD 2967 and was lowest in Sonalika variety.

Legesse *et al.* (2019) reported that wheat variety Asassas took less number of days to heading, days to flowering, and days to maturity over varieties Mangudo, Ude, Dembi, Yerer, Kronis, Quamy and ude.

Chauhan *et al.* (2020) recorded significantly higher leaf production rate, more number of days to 50% anthesis, 50% heading and 50% flowering was reported in the wheat variety PBW 343 over Malviya 234 and NW 1012.

Ajay *et al.* (2022) reported that the higher plant height at maturity in WH 283 (95.7 cm) followed by WH 1105 (92.7 cm) and Raj 3765 (85.5 cm), while lowest values were recorded with NABI Black (77.5 cm).

Joshi *et al.* (2022) reported that early heading in PBW 50 (65.5), which was at par with HD 3086 (69 days) and delay heading in HD 2967 (94 days), which was at par with HD 2733(92 days).

2.2.3 Yield attributes and yields

Alam *et al.* (2013) reported that among wheat varieties K 0307 proved superiority in total tillers/m² (492) and grain yield (45.4 q/ha) than that of mean of rest of the four varieties i.e. Raj 4229, K 0906, HD 2733 and DBW 39.

Singh *et al.* (2013) reported that wheat variety UP 2425 produced higher number of effective tillers/m², number of spikelets/spike, number of grains/spike, grain weight/spike (g), spike length (cm), 1000-grain weight, grain yield and straw yield over other wheat varieties HUW 234 and HP 1744.

Doring *et al.* (2015) reported that wheat variety Deben outperformed Bezostaya, Buchan, Claire, Wembley, Mercia, Pastiche, Renana and Thatcher for yield and yield attributes.

Khavse *et al.* (2015) observed that highest grain yield of 2807 kg/ha was recorded in varieties Kanchan, which was significantly superior over Sujata (2486 kg/ha), GW273 (2447 kg/ha) and Amar (2310 kg/ha).

Kumar *et al.* (2015) obtained higher number of effective tillers/m² (341), spike length (11.4 cm), number of spikelet/spike (22.6), number of grains/spike (39.3) 1,000-grain weight (40.1 g), grains yield (4.1 t/ha), straw yield (6.6 t/ha) and biological yield (10.6 t/ha) in wheat variety HD 2967 over WR 544 (303.4, 10.1cm, 20.2, 36.4, 37.4 g, 3.6 t/ha, 5.9 t/ha and 9.4 t/ha), HD 2987 (313.5 10.4 cm, 20.7, 37.5, 38.0 g, 4.0 t/ha, 7.0 t/ha and 11.0 t/ha) and HD 2931(308.4, 9.9 cm, 19.7, 35.6, 37.1, 3.5 t/ha, 6.0 t/ha and 9.5 t/ha).

Kaur *et al.* (2016) recorded highest grain yield in variety PBW 550 which was statistically on par with variety PBW 621 but significantly higher than HD 2967 and DBW 17 varieties in 2011-12 but in 2012-13, the variety PBW 550 recorded significantly higher grain yield than DBW 17 but statistically at par with PBW 621 and HD 2967 varieties. The number

of effective tillers/m² were the lowest in the variety PBW 550 which were significantly less than HD 2967, PBW 621 and DBW 17 varieties.

Kumar *et al.* (2018) reported that wheat variety MP 4010 give higher number of effective tillers/plant, ear length (cm), number of grains/ear, test weight (g), grain yield (kg/ha), straw yield (kg/ha), biological yield (kg/ha) and harvest index (%) over variety RVW 4106.

Tahir *et al.* (2018) observed that wheat variety Galaxy 2013 gives higher number of productive tillers/m², number of spikelets/spike, grains/spike, 1000-grain weight (g), grain yield (mg/ha), straw yield (mg/ha) and harvest index (%) over wheat variety Punjab-2011.

Gemechu *et al.* (2019) reported that wheat variety Sanate had the highest grain yield (7212 kg/ha) than Hobora (6367 kg/ha) and Hidase (5668 kg/ha) while Hogana variety provided the lowest grain yield (4214 kg/ha).

Hazari *et al.* (2019) observed highest grain yield was found in HD 2967 over varieties C 306 and DBW 39.

Khan *et al.* (2019) reported that Wheat cultivars K 1006 registered higher main shoot height (cm), number of effective tillers/plant, number of spikelets/spike, number of grains/spike, grain weight/spike (g), grain weight/plant (g), 1000-grain weight (g) and yield (q/ha) compared to other cultivars of wheat (K 1317, K 402, K 607 and HD 2967).

Kumar *et al.* (2019) observed that wheat variety VL 907 produced the higher spike length (9.8 cm), fertile spikelets/spike (18.3), grains/spike (43.8), grain wt/spike (2.1 g), test weight (51.3 g), grain yield (42.2 q/ha), straw yield (69.9 q/ha), biological yield (112.0 q/ha) and harvest index (39.8) values for wheat followed by PBW 343, UP 262 and PBW 373.

Chauhan *et al.* (2020) recorded that wheat variety PBW 343 gives higher grain yield (q/ha), straw yield (q/ha) and harvest index (%) wheat varieties Malviya 234 and NW 1012. Gupta *et al.* (2020) reported wheat variety WH 1105 give highest grain yield over HD 2967 and RSP 561.

Singh *et al.* (2020) recorded wheat variety GW 366 gives higher length of ear head (cm), number of grains/ear head, weight of ear head (g), 1000-grain weight (g), number of ear head per metre row length, grain yield (kg/ha), straw yield (kg/ha) and harvest index (%) over varieties MP 1203, RVW 4106, MP 4010 and Lok 1.

Khatik *et al.* (2021) reported that wheat variety Raj 4037 recorded significantly highest total number of tillers per metre row length, test weight, grain yield and straw yield over varieties Raj 4083 and Raj 3777.

Kumari *et al.* (2021) revealed among the varieties, DBW 107 performed better in terms of grain yield (35.8 q/ha) over Sabour Shreshtha (32.2 q/ha) and Sabour Samridhi (30.0 q/ha) and it was statistically comparable to HD 2967 (35.0 q/ha). The interaction effect wheat variety DBW 107 with 125% RDF was recorded significantly higher grain yield than the

other combinations but it was comparable with combination of HD 2967 with 125% RDF and DBW 107 with 100% RDF. However, the combination of variety HD 2967 with 125% RDF and 100% RDF were found statistically comparable in case of grain yield.

Manschadi and Soltani (2021) recorded that wheat variety Arnold give highest grain yield (663.1 g/m^2) and harvest index (44.9%) over varieties Aurelius (534.6 g/m^2 and 42.0%), Bernstein (657.8 g/m^2 and 42.7%) and Emilio (591.4 g/m^2 and 40.3%).

Singh and Verma. (2021) recorded that wheat variety HD 3059 significantly gives higher number of effective tillers/ m^2 , number of grains/spike, 1000-grain weight (g) and grain yield (kg/ha) over varieties MP 4010, K 7903, WH 1129, GW 273, HD 3059 and WH 1021.

Singh *et al.* (2021) recorded that wheat variety HD 3086 gives higher number of tillers/plant, number of reproductive tillers/plant, number spike/plant, spike length, number of grain/spike, test weight, grain yield, straw yield, and harvest index over other varieties HD 2967, WH 1105, PBW 343 and PBW 226.

Singh *et al.* (2021) reported that wheat variety DBW 187 produced higher number of effective tillers/ m^2 , spike length (cm), number of grain/spike, grain weight/spike (g) and test weight (g) over varieties HD 2967, NW 1012 and NW 5054. Variety DBW 87, produced significantly highest grain yield (56.0 q/ha), straw yield (72.4 q/ha) and biological yield (138.8 q/ha) followed by HD 2967 which gave grain yield (52.1 q/ha), straw yield (68.3 q/ha) and biological yield (110.3 q/ha).

Joshi *et al.* (2022) reported that wheat variety NL 971 produced highest grain and straw yield over other varieties WH 1105, HD 2733, HD 2824, HD 2967, Borlaug 100, HD 3086, PBW 550 and PBW 373.

Sirohi *et al.* (2022) recorded significantly highest grain yield in wheat variety WH 1105 followed by WH 542, HD 2967, HD 943 and DPW 621-5.

2.2.4 Quality

Hiltbrunner and Liedgens. (2008) reported that wheat variety Segor content highest protein over varieties Arina, Asketis, Ataro, Habicht, Levis, Pegassos, Titlis and Zinal.

Gashaw *et al.* (2013) found that identifying superior varieties and suitable environments coupled with optimum level of nitrogen fertilization would improve durum wheat grain yield and pasta making qualities, which is influenced by protein and starch content in durum wheat. Mean grain protein content ranged from 11.0 to 11.9%, where wheat variety Waha consistently yielded the maximum mean protein content. Grain protein content (ranging from 12-16%) is optimum for pasta processing. Protein content less than 11% will yield poor quality pasta while protein content greater than 16% might be associated with lower hectolitre weight. Therefore, in terms of protein content, varieties Waha, Ilani, Malefiaand and Boohai meet the minimum standard of protein content for pasta products.

Gerba *et al.* (2013) evaluated two medium tall (Arsi-Robe and Kilinto) and two semi-dwarfs (Ude and Yerer) durum wheat varieties under five N rates (0, 60, 120, 180 and 240 kg/ha). Protein and starch content were higher in semi-dwarf compared to medium tall varieties. There was no significant difference between varieties \times fertilizer interaction.

Doring *et al.* (2015) reported that wheat variety Deben outperformed varieties Bezostaya, Buchan, Claire, Wembley, Mercia, Pastiche, Renana and Thatcher for protein content, protein yield and starch content.

Kaur *et al.* (2016) recorded protein content in wheat grain didn't differ significantly during both year of study but variety PBW 550 contain higher protein in grain (%) over varieties HD 2967, PBW 621 and DBW 17 during both year of study. The variety PBW 550 had significantly higher hectolitre weight over HD 2967 and DBW 17 however it was statistically on par with PBW 621 in both the years. The variety PBW 621 recorded similar hectolitre weight as in variety DBW 17 but significantly higher than HD 2967.

Widodo *et al.* (2015) tested ten high-yielding cultivars (AT 528, H 20, H 127, H 128, H 157, H 249, H 418, H4 26, JRCT 74 and Tahara) for amounts and types of protein, fat, and non-starch polysaccharides. The tested cultivars exhibited little variation, and the difference in nutritional content between wet and dry harvest years were negligible.

Arif *et al.* (2019) reported that wheat variety Raj 4037 give higher protein content (%), grain appearance score, hectolitre weight (kg/hl) and sedimentation volume over Raj 4120, Raj 4079 and Raj 4238.

2.2.5 Nutrient studies

Rodgers and Barneix (1988) found that at least two mechanisms regulate nitrogen uptake, one operating when plant demand is low and another operating when plant demand is high. The difference in nitrogen uptake rate across cultivars may just be a function of their different growth rates.

Singh and Arora (2001) observed traditional varieties (K 68) were found to have higher NUE for dry matter production, while modern varieties (HD 2285) had greater NUE for grain production.

Buchi *et al.* (2016) observed that nitrogen concentration (%) and uptake (kg/ha) by grain differed significantly between wheat varieties. On average (on all treatments and years), the lowest nitrogen content in grain was observed for variety Tapidor (1.9%), and the highest for Aszita (2.3%). The lowest nitrogen uptake by grain was measured for Toras (99 kg/ha), and the highest for Farandole (108 kg/ha) wheat varieties.

Gill *et al.* (2004) observed that highest P uptake by PBW 343 over WH 711, HD 2329 and WH 147 respectively.

Kumar *et al.* (2015) recorded that highest total N, P and K uptake HD 2967 (92.6, 29.9 and 142.0 kg/ha) over varieties WR 544 (75.6, 25.0 and 113.4 kg/ha), HD 2987 (95.8, 30.3 and 147.8 kg/ha) and HD 2931 (74.2, 24.6 and 113.6 kg/ha).

Kaur *et al.* (2016) recorded wheat varieties had non-significant effects on agronomic use efficiency. Wheat variety DBW 17 had higher agronomic use efficiency over varieties HD 2967, PBW 621 and PBW 550 during both year of study.

Daba (2017) found that among four varieties (Danda'a, Digalu, Kakaba and Local), Kakaba had the maximum nitrogen content and uptake by grain and straw with application RDN @ 120 kg/ha. Kakaba variety also gives highest grain nitrogen use efficiency (kg grain/kg nitrogen applied), agronomic and physiological efficiency with application 120 N kg/ha.

Khan *et al.* (2017) studied the effects of RDN from urea and FYM on the four newly developed wheat varieties i.e. Siran 2009, Ata Habib, Janbaz 2009 and Pirsabak 2008 for yield improvement, quality and soil fertility status. Results of the experiment showed that Janbaz 2009 gives better nitrogen use efficiency (14.8%); whereas Siran 2010 performed better for grain N contents (2.3%). Siran 2010 and Janbaz 2009 performed better in FYM and combined application of FYM and urea for most of the parameters. Siran 2010 had improved the grain N content.

Arif *et al.* (2019) reported that wheat variety Raj 4037 had highest N, P and K content and uptake by grain and straw over Raj 4120, Raj 4079 and Raj 4238.

Kumar *et al.* (2019) reported that among wheat varieties, VL 907 recorded higher available organic carbon, N, P and K in soil at harvest over varieties PBW 343, PBW 373 and UP 262.

Tahir *et al.* (2020) recorded that wheat variety Elnielain 90 (43.8) gives highest nitrogen use efficiency (kg grain/kg N applied) over Beladi 60 (33.8), Giza 155 (37.2), Condor 78 (38.0), Debeira 82 (40.4), Wadi Elneel 87 (42.7), Nesser 96 (39.7), Argine 96 (38.7), Imam 00 (39.3), Tagana 04 (39.9), Khalifa 04 (43.0) and Bohaine 06 (40.6).

Gadisa and Wakgari (2021) reported that the Wane variety of wheat gives maximum total nitrogen uptake, highest nitrogen apparent recovery efficiency and agronomic efficiency over Danda'a variety.

Khatik *et al.* (2021) reported that Raj 4037 gave significantly highest N, P, K content and uptake by grain and straw than Raj 4083 and Raj 3777.

Manschadi and Soltani (2021) recorded that highest N uptake by wheat variety Aurelius (16.1 g/m²) over varieties Bernstein (15.8 g/m²), Arnold (14.2 g/m²) and Emilio (14.2 g/m²).

2.2.6 Chemical properties of soil at harvest

Alam *et al.* (2013) recorded that wheat variety DBW 39 having higher available organic carbon, N, P, K and DTPA-extractable micronutrient over varieties Raj 4229, K 0906, K 0307 and HD 2733.

Kumar *et al.* (2018) recorded that wheat variety MP 4010 didn't differ significantly but having higher available organic carbon, N, P, K and DTPA-extractable micronutrient over variety RVW 4106.

Daba (2017) found variety Kakaba having highest available organic carbon, N, P, K, DTPA-extractable micronutrient in soil at harvest over varieties Danda'a, Digalu, and Local during both year of study.

Arif *et al.* (2019) reported that wheat variety Raj 4037 didn't differ significantly for organic carbon content, available N, P and K content in soil at harvest over varieties Raj 4120, Raj 4079 and Raj 4238.

Manschadi and Soltani (2021) recorded that highest available N, P and K at harvest in soil was reported in wheat variety Aurelius over varieties Bernstein, Arnold and Emilio.

Singh and Verma (2021) reported that wheat variety GW 273 didn't differ significantly for available N, P and K in soil at harvest but having higher available N, P and K over varieties MP 4010, K 7903, WH 1129, HD 3059 and WH 1021.

Ndjadi *et al.* (2016) recorded that wheat variety Kayira having higher available N, P, K and DTPA-extractable micronutrient over varieties Farari, Kima, Lokale, Mbega, Nyumbu and Popo.

2.2.7 Economics

Singh *et al.* (2010) recorded that wheat variety Shalimar wheat 1 gives higher gross return, net return and BCR over VL 738, HS 240 and HS 365 in temperate valley conditions.

Alam *et al.* (2013) reported that among wheat varieties K 0307 proved superiority in net return (31090 Rs./ha) and BCR (1.14) than that of mean of rest of the four varieties i.e. Raj 4229, K 0906, HD 2733 and DBW 39.

Singh *et al.* (2013) reported that wheat variety UP 2425 gave higher gross income (29434 Rs./ha), net income (13757 Rs./ha) and BCR (0.88) over other wheat varieties HUW 234 (26686 Rs./ha, 11000 Rs./ha and 0.70) and HP 1744 (24143 Rs./ha, 8457 Rs./ha and 0.54).

Kumar *et al.* (2015) observed that HD 2967 gave higher gross returns over the other varieties (WR 544, HD 2987 and HD 2931) during both year of study.

Tripathi *et al.* (2016) results showed that variety DBW 17 recorded significantly higher grain yield (4.9%), straw yield (6.3%) and HI (1.1%) as compared to DPW 621-50. There was no significant difference in yield attributes between two varieties.

Khan *et al.* (2019) reported that wheat cultivars K 1006 registered higher gross returns, net returns and BCR compared to other cultivars of wheat (K 1317, K 402, K 607 and HD 2967).

Gemechu *et al.* (2019) reported Sanate had the maximum net return, followed by Hobora and Hidase. Variety Hogana has recorded the least net return over all other varieties.

Khatik *et al.* (2021) reported that wheat variety Raj 4037 gave significantly highest net returns (72.9×10^3 Rs./ha) and B: C ratio (3.71) than Raj 4083 and Raj 3777.

2.3 Interaction effect of wheat varieties and nutrient sources on grain and straw yield

Gashaw *et al.* (2013) reported that interaction between wheat variety Laste and 100% RDF recorded significantly higher grain and straw yield over interaction between variety Boohai and 75% RDF and Waha and 100% RDF.

Swain *et al.* (2014) observed that interaction between wheat variety Cordiale \times 100% RDN through ammonium nitrate, Scaro \times 100% RDN through ammonium nitrate, Cordiale \times dairy manure and Scaro \times dairy manure was non-significant for harvest index (%) during both year of study.

Kandil *et al.* (2016) recorded that interaction among cultivars, foliar spraying treatments and nitrogen fertilizer levels exhibited significant effect on grain and straw yield (kg/ha) in both seasons. The highest values of grain and straw yield (kg/ha) resulted from interaction of wheat variety Giza 168 with the mixture of humic acid + amino acids + inorganic fertilizer with nitrogen @ 262 kg/ha.

Zhang *et al.* (2020) showed that there was no interaction effect between wheat cultivar (Heshangtou, Long-chun 30, Nabuq 6, and Ganchun 27, Jinbaoyin and Dingxi 24) and fertilization on harvest index (%).

Kumar *et al.* (2021) reported that among different interactions, HD 2967 produced the highest total biomass yield with 100% RDF under assured irrigation followed by the same variety provided with 50% RDN through inorganic + 50% RDN through FYM, both were significantly superior to WR 544 \times 100% RDF, WR 544 \times 50% RDN through inorganic + 50% RDN through FYM, HD 2932 \times 100% RDF and HD 2932 \times 50% RDN through FYM.

CHAPTER-III

MATERIALS AND METHODS

A field experiment entitled “**Performance of different varieties of wheat (*Triticum aestivum* L.) under integrated nutrient management system**” was carried out during winter 2017-18 and 2018-19. The details of experimental materials used, procedures followed, and techniques adopted during the course of present investigation are described in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was conducted at Regional Rice Research Station, Kaul situated at 29°84' N latitude, 76°66' E longitude in district Kaithal, Haryana.

3.2 CLIMATE AND WEATHER CONDITIONS

The weather of Kaul remains warm during *kharif* season and the temperature varies from 15 to 25⁰ C in morning hours and 25 to 35⁰C during day hours in the normal season while it goes above 35⁰C during the mid of the June month. During the *rabi* season, the minimum temperature varies from 10-12⁰ C during the morning hours and maximum 15-20⁰ C during noon hours. The relative humidity varies from 50-55% during morning hours and reduced at noontime i.e. 40-45%. At evening hours the relative humidity again increases from 55 to 60%. The geography of the region makes the climate more humid due to accessibility of canal water being in the region of Ghaggar river. The mean weekly weather data are presented in the (Tables 1 and 2). During the commencement of the study i.e. during the sowing week 16th November, 2017 to 23rd November, 2017 (47th), the mean weekly maximum temperature was 24.2°C and minimum was 7.7°C. The mean weekly maximum and minimum temperature ranged from 18.9°C to 37.6°C and 2.6°C to 20.0°C respectively during 2017-18. The mean weekly rainfall during 2017-18 was received in the 50th (0.54 mm), 03rd (1.56 mm) and 06th (0.17 mm) and 14th (2.00 mm) week, respectively. The mean weekly minimum and maximum pan evaporation ranged between 0.7 mm to 7.5 mm. The mean weekly minimum and maximum relative humidity was 66.7% and 96.7% in the morning hours and 24.9% and 65.7% in the evening hours (Table 1 and Figure 1) respectively. In the second year of the study i.e. 2018-19, rain occurred during 01st week (1.04 mm), 04th week (0.93 mm), 09th week (2.11 mm) and during 14th week (1.04 mm). The mean weekly maximum and minimum temperature ranged between 16.8 to 37.0°C and 1.9 to 20.0°C during 2018-19. The mean weekly minimum and maximum relative humidity was 66.7% and 96.7% in the morning hours and 26.9% and 68.0% in the evening hours (Table 2 and Figure 2).

Table 1: Weekly mean weather parameters during crop growth period (2017-18)

SWM	Standard meteorological week	Temperature (°C)		Relative humidity (%)		PET (mm)	Rainfall (mm)
		Max.	Min.	M	E		
47 th	16-23 Nov., 2017	24.2	7.8	82.5	33.3	3.4	0.0
48 th	24-30 Nov., 2017	26.8	6.5	86.0	23.5	3.0	0.0
49 th	2-8 Dec, 2017	23.3	6.9	86.1	33.1	1.6	0.0
50 th	9-15 Dec., 2017	20.6	7.5	89.0	57.4	1.1	0.5
51 st	16-22 Dec., 2017	21.2	5.8	90.4	41.7	1.2	0.0
52 nd	23-29 Dec., 2017	23.9	5.0	94.0	43.9	1.2	0.0
1 st	30 Dec., 2017-5 Jan., 2018	18.9	4.4	100.0	56.6	0.7	0.0
2 nd	6-12 Jan., 2018	20.3	2.6	95.4	40.3	1.2	0.0
3 rd	13-19 Jan., 2018	23.3	4.7	94.6	48.9	1.5	0.0
4 th	20-26 Jan., 2018	19.4	6.3	95.1	63.3	1.7	1.6
5 th	27 Jan.,-2 Feb., 2018	21.4	6.3	98.4	65.7	1.0	0.0
6 th	3-9 Feb., 2018	21.9	3.7	90.0	65.0	1.8	0.0
7 th	10-16 Feb., 2018	22.3	8.3	90.9	60.6	2.0	0.2
8 th	17-23 Feb., 2018	26.5	8.4	89.9	41.3	1.9	0.0
9 th	24 Feb.,-2 March., 2018	28.0	12.6	92.1	48.1	2.7	0.0
10 th	3-9 March., 2018	28.5	11.3	86.7	41.0	2.8	0.0
11 th	10-16 March., 2018	32.2	12.6	82.1	32.0	3.6	0.0
12 th	17-23 March., 2018	29.7	12.2	80.4	41.4	3.7	0.0
13 th	24-30 March., 2018	33.4	12.6	77.7	24.9	4.6	0.0
14 th	31 March.,-6 April., 2018	35.6	19.2	62.0	35.3	5.6	0.0
15 th	7-3 April., 2018	33.5	18.4	76.4	42.3	5.5	2.0
16 th	14-20 April., 2018	37.6	20.0	52.4	28.3	7.0	0.0
17 th	21-24 April., 2018	35.6	15.3	58.8	30.3	7.5	0.0

Max.-Maximum; Min.-Minimum; M-Morning; E-Evening and PET.-Potential evapotranspiration

The mean weekly morning and evening relative humidity at the time of harvest (15th week) was 66.7 and 27.0%, respectively. Mean weekly minimum and maximum PET ranged between 0.8 mm to 6.4 mm respectively. From the meteorological data (Table 1 & 2 and Figure 1 & 2), it is clear that the weather parameters such as temperature, relative humidity and PET were more or less congenial for growth and development of wheat crop during 2017-18 and 2018-19, respectively.

3.3 PHYSICO-CHEMICAL PROPERTIES OF THE SOIL

A composite soil sample was collected from 0-30 cm depth of the experimental field before commencement of the experiment to record the physico-chemical properties of the soil. The values of soil analysis along with methods followed are furnished in (Table 3). The data presented in (Table 3) indicated that the soil of the experimental plot was clay loam in texture and slightly alkaline in reaction with pH 7.9 and EC of 0.27 dS/m.

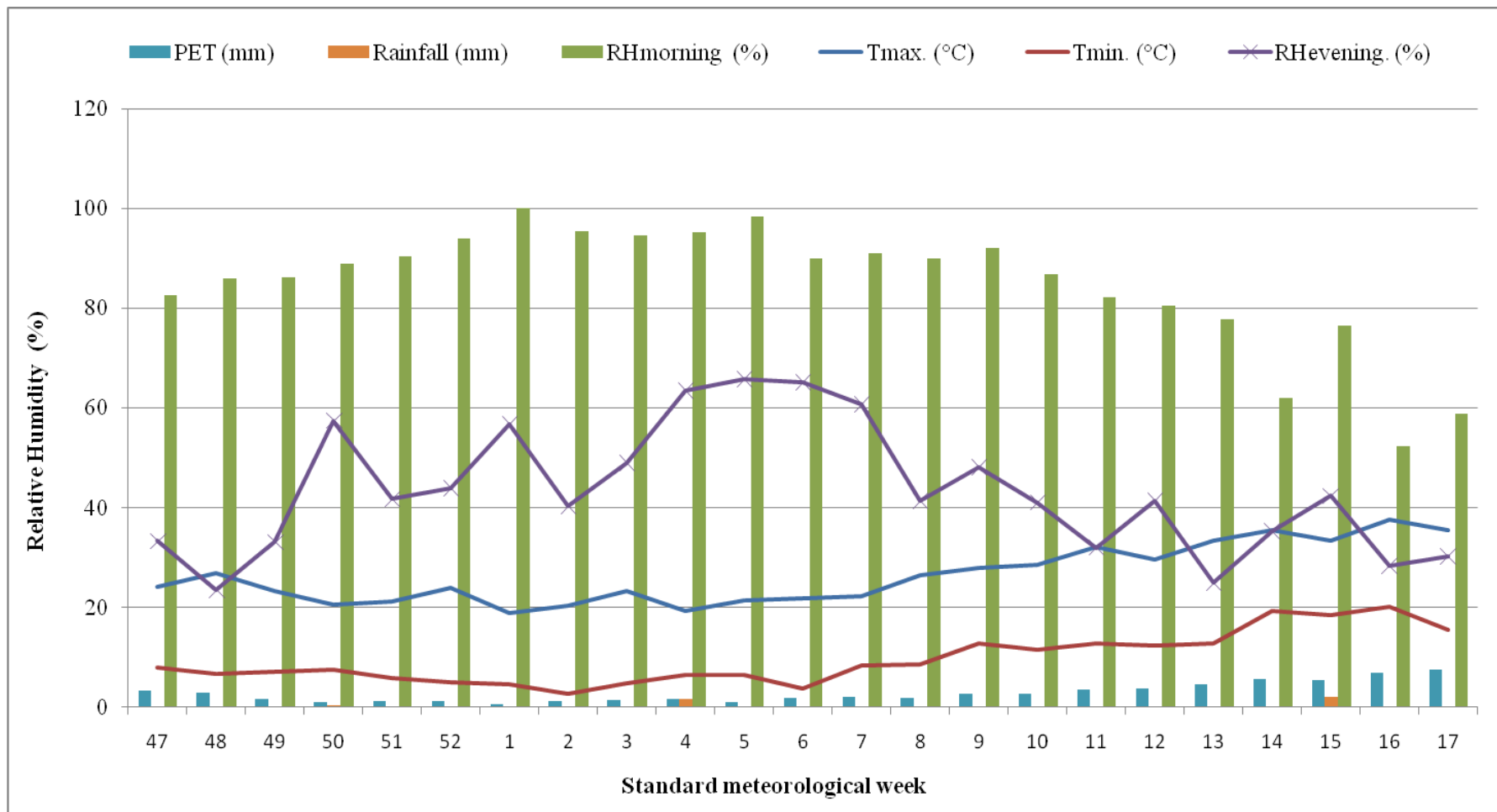


Fig.1: Weekly mean weather parameters during crop growth period (2017-18)

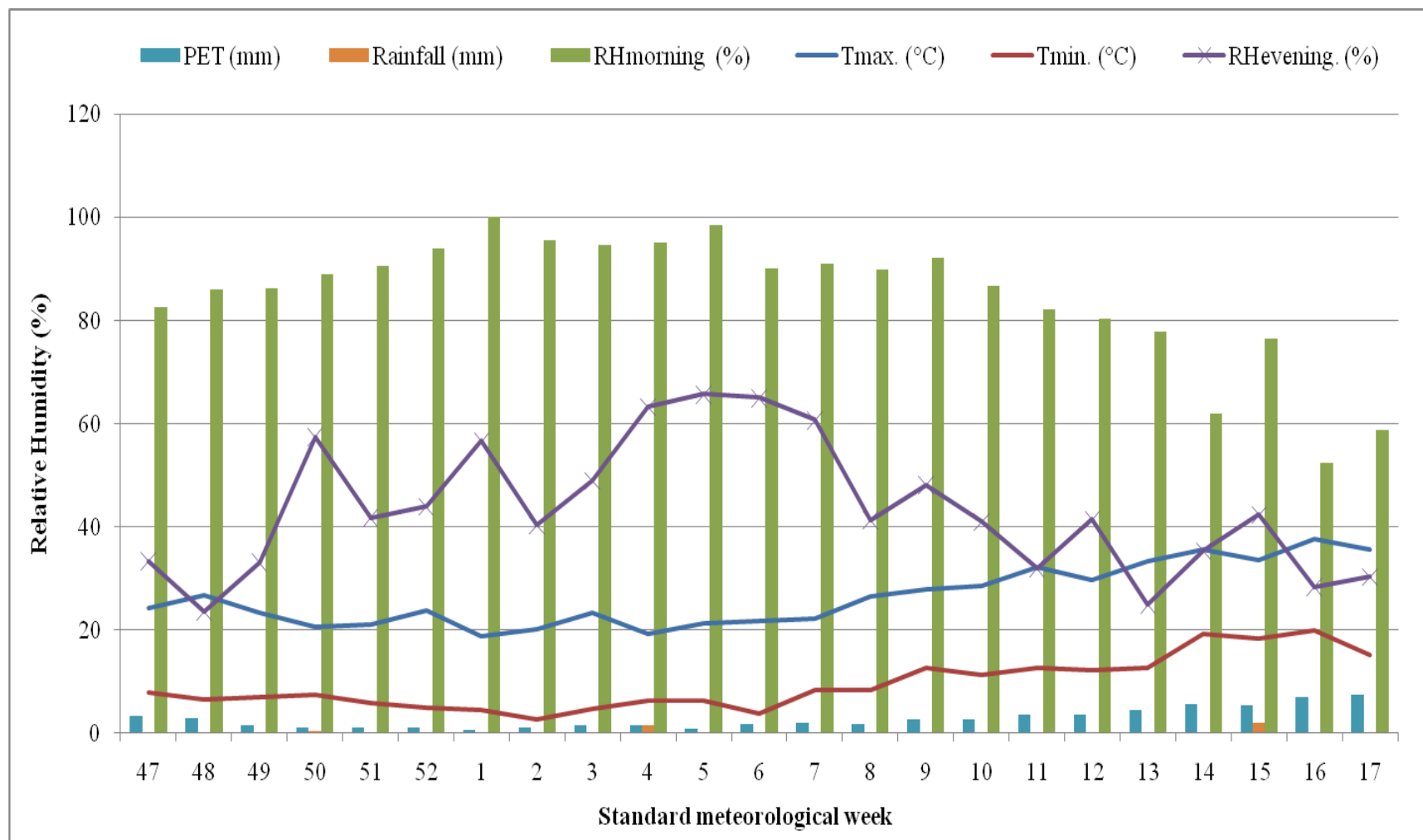


Fig.2: Weekly mean weather parameters during crop growth period (2018-19)

Table 2. Weekly mean weather parameters during crop growth period in 2018-19

SWM	Standard meteorological week	Temperature (°C)		Relative humidity (%)		PET (mm)	Rainfall (mm)
		Max.	Min.	M	E		
47 th	18-25 Nov., 2018	27.4	10.9	87.4	44.2	2.3	0
48 th	26 Nov.-2 Dec. 2018	27.2	9.4	93.1	46.3	1.7	0
49 th	3-9 Dec, 2018	24.9	7.5	95.9	44.9	1.2	0
50 th	10-16 Dec., 2018	21.0	7.7	90.5	57.3	1.4	0
51 st	17-23 Dec., 2018	20.7	2.0	93.2	49.6	1.2	0
52 nd	24-30 Dec., 2018	19.3	1.9	93.7	48.0	0.8	0
1 st	31 Dec.-6 Jan., 2019	19.6	5.3	94.8	62.4	1.0	1.04
2 nd	7-13 Jan., 2019	19.1	5.9	94.8	61.5	0.9	0
3 rd	14-20 Jan., 2019	19.6	3.6	91.7	53.0	1.0	0
4 th	21-27 Jan., 2019	19.4	6.2	96.7	68.0	1.1	0.93
5 th	28 Jan.,-3 Feb., 2019	16.8	5.0	95.1	62.3	1.2	0
6 th	4-10 Feb., 2019	20.9	6.9	92.5	57.3	1.5	0
7 th	11-17 Feb., 2019	19.8	8.9	96.2	66.0	1.3	0
8 th	18-24 Feb., 2019	22.0	9.6	88.0	50.6	2.0	0
9 th	25 Feb.,- March, 2019	21.3	7.5	91.5	53.5	2.1	2.11
10 th	4-10 March, 2019	23.3	8.1	91.9	39.5	2.4	0
11 th	11-17 March, 2019	24.8	9.9	90.5	49.0	2.6	0
12 th	18-24 March, 2019	28.5	11.1	79.2	40.6	3.7	0
13 th	25-31 March, 2019	32.1	13.7	82.4	31.8	3.7	0
14 th	1-7 April, 2019	35.6	15.0	74.1	26.9	5.1	1.04
15 th	8-12 April, 2019	37.0	20.0	66.7	27.0	6.4	0
16 th	13-19 April, 2019	37.4	21.2	67.2	27.5	6.4	0
17 th	20-27 April, 2018	37.1	21.8	68.1	28.2	6.6	0.0

Max.-Maximum; Min.-Minimum; M-Morning; E-Evening and PET.-Potential evapotranspiration

The soil was low in available nitrogen (107.8 kg/ha), high in available phosphorus (25.4 kg/ha), high in available potassium (313.2 kg/ha), copper (1.37 mg/kg), iron (13.45 mg/kg), manganese (2.85 mg/kg) and zinc (1.76 mg/kg).

Table 3: Physico-chemical properties of the experimental site

Properties	Contents	Method employed
A. Mechanical composition		
Sand (%)	41.2	International Pipette method (Piper, 1966)
Silt (%)	32.3	
Clay (%)	26.3	
Texture class	Clay loam	
Bulk density (Mg/M ³)	1.41	Core sampler (Piper, 1966)
B. Chemical Composition		
Soil pH (1:2.5)	7.9	pH metre (Richards, 1954)
Electrical conductivity (dS/m) at 25°C (1:2.5)	0.27	EC metre (Jackson, 1973)
Organic carbon (%)	0.41	Walkley and Black wet oxidation method (Jackson, 1973)
Available N (kg/ha)	107.8	Alkaline KMnO ₄ method (Subbiah and Asija, 1956)
Available P ₂ O ₅ (kg/ha)	25.4	Olsen's method (Olsen <i>et. al.</i> , 1954)
Available K ₂ O (kg/ha)	313.2	Flame photometric method (Jackson, 1973)
Fe (mg/kg)	13.45	DTPA extractable by AAS method (Lindsay & Norvell, 1978)
Mn (mg/kg)	2.85	
Zn (mg/kg)	1.76	
Cu (mg/kg)	1.37	

3.3 CROPPING HISTORY

The field RRS Kaul was situated near the Dhandh-Kaithal-Hisar Road inside the campus. The field having the facility of tubewell water and the cropping history of the field showed that the mostly the field was left fallow and during 2015-16, only moong crop was sown (Table 4).

Table 4. Cropping history of the experimental field at RRS, Kaul

Year	<i>Kharif</i>	<i>Rabi</i>	<i>Summer</i>
2014-15	Fallow	Wheat	Fallow
2015-16	Moong	Wheat	Fallow
2016-17	Fallow	Wheat	Fallow
2017-18	Fallow	Wheat (Experimental crop)	Fallow
2018-19	Fallow	Wheat (Experimental crop)	Fallow

3.4 TREATMENT DETAILS

Main plot treatments

Variety (V):

V₁: WH 1080

V₂: WH 1025

V₃: WH 1142

V₄: WH 711

Sub-plot treatments

Nutrient sources (N):

N₁: Control

N₂: 100% RDF

N₃: 50% RDF + 50% RDF through FYM

N₄: 50% RDF + 50% RDF through vermicompost

N₅: 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers
(seed treatment)

Note:

- (i) Well decomposed FYM @ 15 t/ha and vermicompost @ 5 t/ha are applied at 10-15 days before sowing as per treatment
- (ii) RDF (N:P₂O₅:K₂O) @ 150:60:60 Kg/ha applied through urea, DAP and MOP as per treatment (1/3 N and full P and K as basal at sowing and remaining N in two equal splits at first and second irrigation).
- (iii) Biofertilizers (seed treatment)
 - (a) NFB: Liquid formulation (1×10^9 cfu/ml) of *Azotobacter chroococcum* treated with seed (250 mL formulation diluted to 2.5 litres with water for seeds to be sown in 1 ha).
 - (b) PSB: Liquid formulation (1×10^7 cfu/ml) of *Bacillus sp.* treated with seed (125 ml formulation diluted to 2.5 litres with water for seeds to be sown in 1 ha).
- (iv) Only recommended dose of nitrogen (RDN) was applied through FYM and vermicompost.

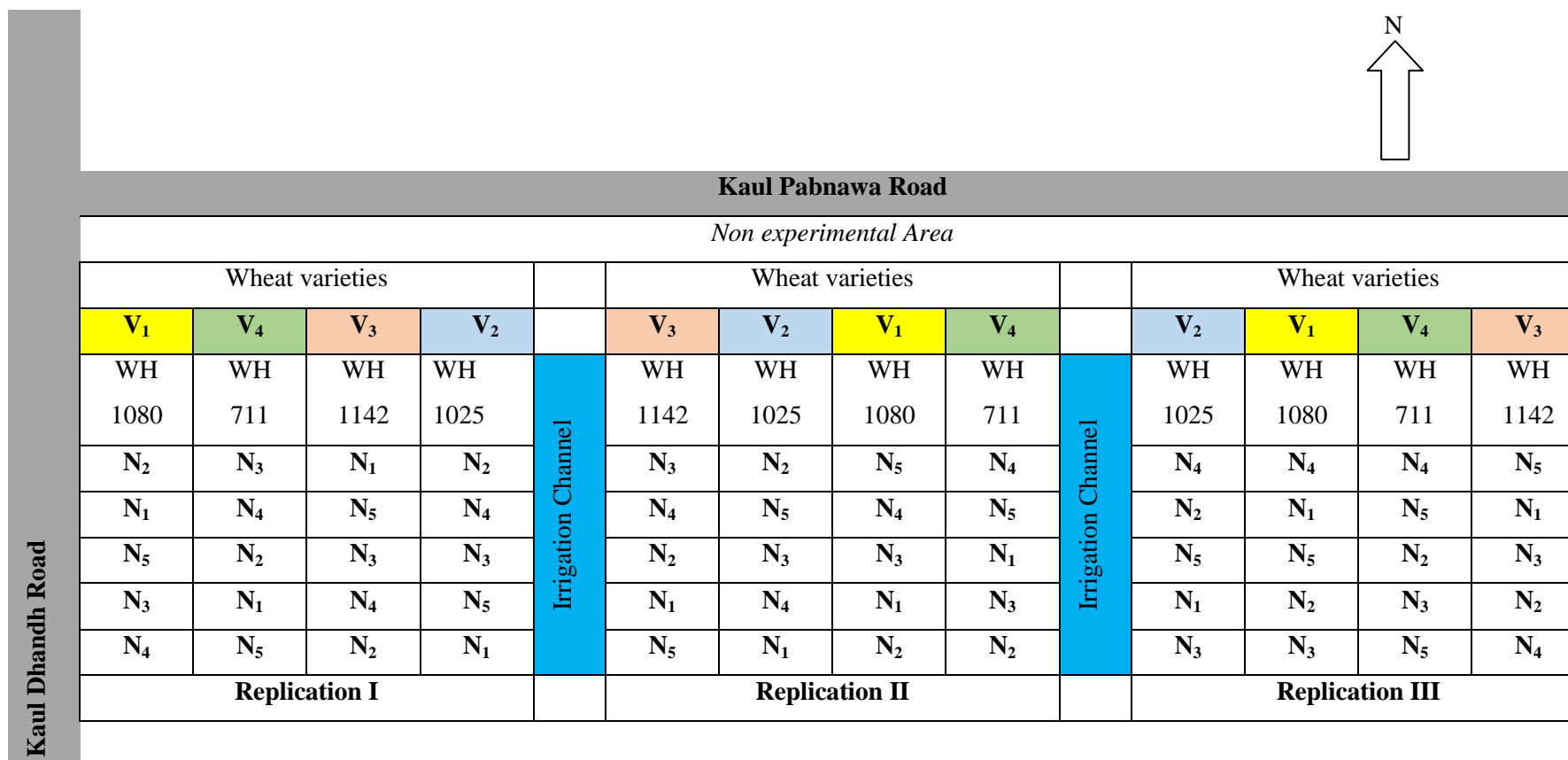
3.5 Layout of the experiment

The field layout of the experiment during 2017-18 and 2018-19 was same. The net plot size was 4 m x 4 m. Two border rows were discarded due to border effect. The whole field was laid out into 20 plots per replication (Fig. 3). There were total 60 plots and each treatment was randomized with equal opportunity to get the plot number starting from 1-60. The number of rows per plot was 20. The layout of the various treatments was presented in (Figure 3).

Table 5. General characteristics of wheat varieties

S. No.	Varieties	Varieties release year	Recommended area & condition	Main characteristics	Maturity days	Grain characteristics	Yield (q/ha)	Other characteristics
1.	WH 1080	2011	Rainfed & low input	Medium height	Approx 110-115	Medium in size, protein content (12.5%) and high Fe and Zn content in grain	Average: 32.5 Potential: 44.4	Resistant to lodging, drought and all rust
2.	WH 1025	2010	Rainfed & low input	Semi-dwarf	Approx 140-150	Bold shining grain and good chapatti making quality	Average: 27.5 Potential: 38	Drought tolerant and rust resistant
3.	WH 1142	2015	Early sown, restricted irrigation & medium input condition	Tall and semi erect growth habit	Approx 140	Medium in size and good protein content (12.1%)	Average: 48.1 Potential: 62.5	Drought tolerant and resistant to yellow rust
4.	WH 711	2002	Timely sown, high fertility soil & irrigated condition	Dwarf and high yielding	Approx 145	Shining, amber hard grains and good for chapatti making	Average: 57.15 Potential: 59.5	Lodging resistant, moderately resistant to rust & karnal bunt

Source: Jindal *et al.* (2021)



Nutrient sources (N):

- N₁: Control
- N₂: 100% RDF
- N₃: 50% RDF + 50% RDF through FYM
- N₄: 50% RDF + 50% RDF through vermicompost
- N₅: 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)

Plant geometry:

- Row to row spacing : 20 cm
- Net plot size : 4 m x 4 m

FIG. 3: LAYOUT OF THE EXPERIMENT

3.6 AGRONOMIC PRACTICES AND INTER-CULTURAL FIELD OPERATIONS

The different agronomic practices were carried out during both the years are presented in the (Table 6).

Table 6. Agronomic practices and inter-cultural operations during the experiments

Sr. No.	Agronomic practices	DAS	Year	
			2017-18	2018-19
(i)	Pre-sowing irrigation	-	10.11.2017	18.11.2018
(ii)	Preparatory tillage operations (Harrowing, cultivator and planking)	-	18.11.2017	24.11.2018
(iii)	Sowing	-	19.11.2017	25.11.2018
(iv)	Application of fertilizer (N, P & K)	-	19.11.2017	25.11.2018
(v)	First irrigation	21	09.12.2017	15.12.2018
(vi)	Weeding & hoeing-spray of herbicide	35	23.12.2017	29.12.2018
(vii)	Second irrigation	60	17.01.2018	23.01.2019
(viii)	Third irrigation	80	06.02.2018	12.02.2019
(ix)	Harvesting	145	12.04.2018	18.04.2019
(x)	Threshing	153	20.04.2018	26.04.2019

3.6.1 Pre sowing irrigation

Pre-sowing irrigation was applied to the field on 10.11.2017 and 18.11.2018 during 2017-18 and 2018-19.

3.6.2 Field preparation

Preparatory tillage operations like cross harrowing was done to make the soil pulverized and to cut the weed plants germinated after pre-sowing operation. After harrowing, planking was done on 18.11.2017 and 24.11.2018 during 2017-18 and 2018-19, respectively also to make the field levelled and to break the large size soil particles.

3.6.3 Seed rate, seed treatment, sowing date and spacing

Sowing was done with the help of tractor drawn seed-cum-fertilizer drill on 19.11.2017 and 25.11.2018 during 2017-18 and 2018-19, respectively. The seed of wheat variety (WH 1080, WH 1025, WH 1142 and WH 711) was procured from Directorate of Farms, CCS HAU, Hisar. The class of the seed was certified. The treated seeds were sown keeping 20 cm between row-row with a recommended seed rate of 100 kg/ha. Seedling depth should be around 5 cm.

3.6.4 Fertilizer application

Fertilizers were applied as per the recommended dose of fertilizer. Urea, DAP and MOP was applied as the source of N, P and K. 1/3 N and full P and K as basal at sowing and remaining N in two equal splits at first and second irrigation.

3.6.5 Irrigation

First, second and third irrigation was applied at 21(09.12.2017 & 06.02.2018), 60 (15.12.2018 & 12.02.2019) and 80 (06.02.2018 & 12.02.2019) DAS with the canal water during 2017-18 and 2018-19, respectively.

3.6.6 Weeding and hoeing

Weed flora was diverse, among grassy weed the presence of *Phalaris minor* (Mandusi/Kanki), *Polypogon monspiliensis* (Lomar ghas) and *Poa annua* (Poa grass) and in broadleaf weed population of *Chenopodium album* (bathua), *Rumex dentatus* (Jangali palak), *Coronopus didymus* (Pitpapra), *Anagallis arvensis* (Krishnaneel), *Medicago denticulata* (Maina), *Melilotus indica* (Senji/Metha) and *Malva parviflora* (Malva/Sonchal) was dominant weed during 2017-18 and 2018-19. One post-emergence spray of herbicide (2, 4 D-E or Weed Mar 38EC @ 500 gm a.i./ha or 1315 ml/ha) was applied at 35 days after sowing to control the broad leaf weeds during both the years. Grassy weed was controlled with pre-emergence spray of Pendimethalin (Stomp 30EC) @ 1500 gm a.i./ha or 4950 g or ml/ha) at 3 DAS and one post emergence spray of Fenoxaprop-ethyl (Puma Super 10EC) @ 120 gm a.i./ha or 1200 ml/ha at 30 DAS during both year of study.

3.6.7 Harvesting

Harvesting of crop was done at physiological maturity. The whole plant dried and appeared yellow to brown in colour. The grain was put under tooth so as to observe the hardness of the grains. The border rows were cut first and the produce left as non-experimental produce. The harvested produce was knotted into bundles and left for drying in the respective plots for threshing.

3.6.8 Threshing

Threshing was done with the mini-thresher available at Regional Rice Research Station, Kaul. The bundles left in the plots were threshed and the grains yield were collected in the polythenes bags.

3.7 OBSERVATIONS RECORDED

3.7.1 GROWTH STUDIES

3.7.1.1 Plant population

In each plot one metre row length was marked and plant population with in this area was counted at 30 DAS.

3.7.1.2 Plant height

The plant height was measured from the base of the plant i.e. ground level to the top of the main shoot of the randomly selected five tagged plants in each net plot of all replications at 30, 60, 90, 120 DAS and at harvest. An average value for each plot was computed and expressed in centimetres.

3.7.1.3 LAI (Leaf area index)

The leaf area index is calculated by dividing the leaf area per plant by land area occupied by the plant. Leaf area was measured with the help of leaf area metre.

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Ground area (cm}^2\text{)}}$$

3.7.1.4 LAD (Leaf area duration)

Leaf area duration is the integral part of leaf area index over a growth period and expressed in days. Leaf area duration of a crop is a measure of its ability to produce leaf area on unit area of land over a time period.

$$\text{LAD} = \frac{\text{LAI}_1 + \text{LAI}_2}{2} \times (t_2 - t_1)$$

Where,

LAD = Leaf area duration between time t_2 and t_1

LAI₁ = Leaf area index at time t_1

LAI₂ = Leaf area index at time t_2

3.7.1.5 Dry matter accumulation

Dry matter accumulation was recorded at 30, 60, 90, 120 DAS and at harvest. At each sampling five plants were uprooted randomly from each plot. After cutting roots, above ground biomass was first air dried and then oven dried at 70°C till a constant weight was obtained. Average dry weight was recorded and expressed in g/plant

3.7.1.6 Shoot length (cm)

Five plants were taken from each plot randomly at 90DAS. Length of these shoot was measured and average length (cm) of shoot was worked out.

3.7.2 PHENOLOGICAL STUDIES

3.7.2.1 Days taken to 50% heading

It is the number of days in which 50% of the plant attained the heading phase. In each plot 50 plants were tagged and days to heading in first 25 plants in each plot were recorded separately which gave days to 50% heading.

3.7.2.2 Days taken to 50% anthesis

It is the number of days in which 50% of the plant attained the anthesis phase. In each plot 50 plants were tagged and days to anthesis in first 25 plants in each plot were recorded separately which gave days to 50% anthesis.

3.7.2.3 Panicle emergence rate (PER)

Panicle emergence rate indicates the rate at which panicle emerges from the leaf sheath. As panicle emerges due to force of inter-nodal elongation, this parameter is helpful in moisture stress studies. It expresses as length increases per time.

$$\text{PER} = \frac{P_2 - P_1}{t_2 - t_1}$$

Where,

P₁ = Length of emerged panicle at time t_1

P₂ = Length of emerged panicle at time t_2

3.7.2.4 Leaf production rate (LPR)

Leaf production rate can be estimated by counting the number of leaves on five tagged plants at periodical intervals (30-60 DAS). It is expressed as number of leaves/day.

$$\text{LPR} = \frac{L_{n2} - L_{n1}}{(t_2 - t_1)}$$

Where,

L_{n1} = Number of leaves at times t_1

L_{n2} = Number of leaves at times t_2

3.7.3 YIELD ATTRIBUTES AND YIELD

3.7.3.1 Number of effective tillers/m²

Effective tillers were estimated at the time of maturity and enumerated for one square metre area. The tillers having the ear head were considered as effective tillers.

3.7.3.2 Spike length (cm)

Five representative spikes were harvested from marked rows. The spike length (cm) was measured from the base to the top of the spike. Average length of spikes expressed in cm

3.7.3.3 Number of grains/spike

Five plants were tagged for estimation of grain per ear head. The ear heads were taken and the grain per ear head were counted and recorded in data sheet.

3.7.3.4 Grain weight/spike

Five plants were tagged for estimation of grain weight per spike. The spike was taken and the grain were counted and weighed and recorded in data sheet.

3.7.3.5 Test weight

A composite sample of grains was taken from the produce of each net plot and 1000-grains were counted at random with the help of automatic seed counter and weighed. The weight of 1000-grain was recorded as test weight for each plot.

3.7.3.6 Biological yield

The weight of the harvested and thoroughly sun dried above and below ground produce of each plot was recorded separately before threshing and expressed as kg/ha.

3.7.3.7 Grain yield

The plot wise threshing was done and the yield was taken in large size polythene bags, which were weighed in the field on spot. The plot yield was then converted to kg/ha as per the standard procedure.

3.7.3.8 Straw yield

Straw yield was worked out by subtracting the grain yield from total biological yield of net plot area and expressed in kg/ha.

3.7.3.9 Harvest index

The harvest index (HI) was calculated by using following formula (Singh and Stoskopf, 1971).

$$\text{HI (\%)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

3.7.4 QUALITY PARAMETERS

3.7.4.1 Protein content in grains

Protein content in grain was calculated by using following formula (Jones, 1941).

$$\text{Protein content in grain (\%)} = \text{N content in grain} \times 6.25$$

3.7.4.2 Starch content

Extraction:

Starch was extracted by the method of Cerning and Guilbot (1973).

Procedure:

Took 500 mg of the sample and 25 ml of ethanol (80%) was added in a round bottomed flask. The flask was connected to a condenser and kept on a heating mantle for 30 minutes with occasional stirring. The extract was cooled and centrifuged at 800 rpm for 30 min. The supernatant was collected. This procedure was repeated twice, by taking 25 ml 80% ethanol. Then the supernatant was discarded and sugar free extract was taken.

Estimation:

The starch from sugar free pellets was estimated by the method of Clegg (1956). Five ml water was added to aforesaid residue of the test material and while stirring 6.5 ml of 52% perchloric acid was stirred continuously for 15 min. To this 20 ml water was added and centrifuged. The supernatant was settled in a 100 ml volumetric flask. Five ml water was added to the residue and repeated the extraction with 52% perchloric acid, stirring occasionally for 30 minute. The contents of the tube were washed into a volumetric flask containing the test extract and made it to 100 ml with water. It was then filtered discarding first 5 ml of filtrate. A suitable aliquot of the extract was used for glucose estimation using anthrone reagent by the method of Yemm and Willis (1954).

$$\text{Starch} = \text{Glucose} \times 0.9$$

3.7.5 CHEMICAL ANALYSIS

3.7.5.1 Plant analysis

Nutrient concentration

3.7.5.1 Sampling and preparation of plant samples

The plant samples for nutrient analysis were collected at harvesting, and grain and straw were washed thoroughly with distilled water. The grain and straw were then kept in paper bags and dried in hot air oven at 90°C for 4 hours. The dried grain and straw were finely ground in a 'Wiley Mill' to fine powder. This fine powder was again dried in oven at 60°C

for a couple of hours and stored in desiccators till the samples were used for chemical analysis.

3.7.5.2 Estimation of nitrogen

The estimation of total nitrogen was done by digesting the samples with concentrated H₂SO₄ and digestion mixture in micro Kjeldhal's assembly as given by Jackson (1973).

Table 7. Chemical studies and method of estimation in plant

S. No.	Nutrient	Method of estimation	References
1.	N (%)	Modified Kjeldahl's method	Jackson (1973)
2.	P (%)	Di-acidic digestion	Johnson and Ulrich (1959)
		Vandomolybdo-phosphoric yellow colour method	Jackson (1973)
3.	K (%)	Flame photometer method	Jackson (1973)

3.7.5.3 Digestion of plant sample for phosphorus and potassium determination

Powdered plant samples were digested with diacid mixture (HNO₃ + HClO₄ in 3:1 ratio) after predigesting with concentrated nitric acid till colourless white precipitate was obtained. The precipitate was dissolved in 6 N HCl and filtered. The filtrate was made up to 100 ml using distilled water.

3.7.5.4 Estimation of phosphorus

The phosphorus content in the plant acid extract was estimated by Vanadomolybdo-Phosphoric yellow colour method as suggested by Johnson and Ulrich, (1959) and Jackson (1973). The intensity of yellow colour was taken at 470 nm in Elico spectrophotometer model CL24.

3.7.5.5 Estimation of potassium

Potassium concentration in the plant acid extract was estimated by using the Flame Photometer method. Reading was taken in Elico Flame photometer; model C-140 after digesting the samples with diacid mixture as suggested by Jackson (1973).

3.7.6.1 Nutrient uptake

The uptake of nitrogen, phosphorus and potassium was computed from their concentration in grain and straw using following relationship:

$$\text{Nutrient uptake by grain or straw (kg/ha)} = \frac{\text{Nutrient concentration in grain or straw (\%)} \times \text{grain or straw yield (kg/ha)}}{100}$$

The total nutrient uptake was worked out by adding the uptake by grain and straw.

3.7.6.2 Nutrient balance sheet or Nutrient removal ratio

Nutrient balance is the ratio of nitrogen uptake by grain to nitrogen applied. It is expressed in kg/kg.

$$\text{Nutrient balance sheet of nitrogen (kg/kg)} = \frac{\text{Nitrogen uptake by grain (kg)}}{\text{Total nitrogen applied (kg)}}$$

3.7.6.3 Nutrient use efficiency (AE, PE & AR)

3.7.6.3.1 Agronomic efficiency (AE)

Agronomic efficiency is the additional grain yield produced due to application of nutrients over unfertilized control per unit of nutrients applied. It is expressed in kg/kg

$$\text{Agronomic efficiency (AE)} = \frac{\text{GYn} - \text{GYc}}{\text{Na}}$$

Where,

GYn = Grain or economic yield with nutrient

GYo = Grain or economic yield without nutrient

Na = Nutrient applied

3.7.6.3.2 Physiological efficiency (AE)

Physiological efficiency is the additional biological yield produced due to application of nutrients over unfertilized control per unit of additional nutrient uptake over unfertilized control. It is expressed in kg/kg

$$\text{Physiological efficiency (PE)} = \frac{\text{BYn} - \text{BYo}}{\text{NUn} - \text{NUo}}$$

Where,

BYn = Biological yield with nutrient

BYo = Biological yield without nutrient

NUa = Nutrient uptake with nutrients

NUo = Nutrient uptake without nutrients

3.7.6.3.3 Recovery efficiency (RE)

Recovery efficiency is the additional nutrient uptake over unfertilized control per unit nutrient applied. It is expressed in per centage.

$$\text{Recovery efficiency (RE)} = \frac{\text{NUn} - \text{NUo} \times 100}{\text{Na}}$$

Where,

NUn = Nutrient uptake with nutrients

NUo = Nutrient uptake without nutrients

Na = Nutrient applied

3.7.7 SOIL NUTRIENT STATUS BEFORE AND AFTER COMPLETION OF EXPERIMENT

After harvest of wheat, soil samples from each experimental plot were collected at 0-30 cm depth to determine organic carbon, available N, P, K, Fe, Mn, Zn and Cu as per methods listed in (Table 3).

3.7.8 ECONOMIC ANALYSIS

3.7.8.1 Total Cost of cultivation (₹/ha)

The expenses incurred for all the cultural operations from preparatory tillage to threshing including the cost of inputs viz. seeds, fertilizers, organic manures (FYM and vermicompost), nitrogen fixing biofertilizer and phosphate solubilizing biofertilizer etc. applied commonly or as per treatment was calculated on the basis of prevailing market prices.

3.7.8.2 Gross returns (₹/ha)

The gross realization in terms of rupees per hectare was worked by multiplying the wheat grain and straw yield from RDF treatment with prevailing market price.

3.7.8.3 Net returns (₹/ha)

Net return of each treatment was calculated by deducting the total cost of cultivation from the gross returns.

$$\text{Net returns (₹/ha)} = \text{Gross returns} - \text{Total cost of cultivation}$$

3.7.8.4 Benefit cost ratio (BCR)

The benefit cost ratio was calculated with the help of following formula:

$$\text{BCR} = \frac{\text{Gross returns (₹/ha)}}{\text{Total cost of cultivation (₹/ha)}}$$

3.7.9 STATISTICAL ANALYSIS

Statistical analyses of the individual data of various parameters studied in the experiments were carried out as per split plot design. Analysis of variance was worked out using standard statistical procedures as described by Panse and Sukhatme (1961). Standard error of mean (SE_m±), critical difference (CD) at 5% probability and coefficient of variation (%) were worked out for the interpretation of the results. The design of the experiment was split plot design. In split plot design, multiple splits can be assigned easily. In the present study, there were two factors, (A) variety (main plot); (B) nutrient sources (sub-plot). The statistical analysis was carried with the help of OPSTAT developed by Sheoran *et al.* (1998). The significance of treatment effects were computed with the help of 'F' (variance ratio) test and to judge the significance of differences between means of two treatments, critical difference (CD) at 5% was worked out as described by Cochran and Cox (1957) and Gomez, A. P (1983) as follows:

$$\text{C.D.} = \sqrt{\frac{2 \times \text{Mean square error}}{n}} \times 't'$$

Where,

C.D. = Critical difference

n = Number of observations of that factor for which CD is to be calculated at 5%

't' = Value of Fisher's table (Fisher, 1935) for error degree of freedom at 5% level of significance

The software estimated the critical difference at 5% based on the procedure given by Panse and Sukhatme (1961).

Table 8. Analysis of variance (ANOVA) for split plot with factor A with v levels in main plots and factor B with n levels in sub-plots will be as follows

Sources of Variation	Degree of freedom (d.f.)	Sum of square (SS)	Mean sum square (MS)	Computed F
Replication (r)	r-1	RSS	RMS	RMS/EMS (a)
Main-plot factor (A)	v-1	ASS	AMS	AMS/EMS (a)
Error (a)	(r-1) (v-1)	ESS (a)	EMS (a)	
Sub-plot factor (B)	n-1	BSS	BMS	BMS/EMS (b)
V×N	(v-1) (n-1)	ABSS	ABMS	ABMS/EMS (b)
Error (b)	v(r-1) (n-1)	ESS (b)	EMS (b)	
Total	rvn-1	TSS		

CHAPTER-III

RESULTS

In this chapter, the results of the present investigation entitled “Performance of different varieties of wheat (*Triticum aestivum* L.) under integrated nutrient management system” have been presented

4.1 Growth parameters

4.1.1 Plant population

Mean plant stand was recorded at 30 DAS (Table 9). Variety WH 1142 produced significantly higher mean number of plants per metre row length than all other varieties in 2017-18 whereas it was at par with WH 711 in 2018-19. Increase in plant population in WH 711 was also significant over WH 1080 and WH 1025 in both years. The mean plant population of WH 1025 was significantly lower than all other varieties except over WH 1080 in 2018-19. The mean plant population at 30 DAS was found significantly higher in 100% RDF over all the nutrient sources during both the year of study.

The interaction between varieties and nutrient sources was non-significant in both years.

Table 9. Effect of varieties and integrated nutrient management system on mean plant population/m² row length in wheat

Treatments	Plant population per metre row length	
	2017-18	2018-19
Varieties (V)		
WH 1080	46.4	48.0
WH 1025	45.4	47.2
WH 1142	47.6	49.5
WH 711	47.0	48.9
SEm□	0.11	0.26
C.D. (p = 0.05)	0.37	0.9
Nutrient sources (N)		
Control	42.7	43.2
100% RDF	49.8	52.2
50% RDF + 50% RDF through FYM	45.5	47.9
50% RDF + 50% RDF through vermicompost	47.2	48.7
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	47.7	49.9
SEm±	0.18	0.21
C.D. (p = 0.05)	0.53	0.6
Interaction (V×N)	NS	NS

4.1.2 Plant height

Mean plant height of wheat was recorded at 30, 60, 90, 120 DAS and at harvest (Table 10). Varieties differed significantly for plant height except at 60 DAS in 2017-18. Plant height of WH 1142 was at par with WH 711 at 30 DAS in both years and at 120 DAS and at harvest in 2017-18 where as it was significantly higher than WH 711 at 90 DAS in both years and at 60 DAS, 120 DAS and at harvest in 2018-19 and over all other varieties at all stage in both years. WH 711 attained significantly more plant height than WH 1080 and WH 1025 at all growth stages except at 60 DAS in 2018-19 and at 90 DAS in 2017-18. Plant height of WH 1080 was significantly more than WH 1025 at 60 DAS, 120 DAS and at harvest in 2018-19. Plant height was found significantly higher with 100% RDF over all other nutrient sources at all stages during both years of study.

The interaction between varieties and nutrient sources didn't significantly alter wheat mean plant height over the course of the two research years (Table 10).

4.1.3 Leaf area index

Mean leaf area index was recorded at 30, 60, 90 and 120 DAS and for each stage leaf area index (LAI) was calculated (Table 11). Leaf area index was significantly higher of WH 1142 over all the varieties during both years. All treatments of nutrient application resulted in significantly higher leaf area index over control at all growth stages in both years (Table. 12). At all the growth stages except 30 DAS, 100% RDF attained significantly higher LAI than all other treatments of nutrient application in both years. Application of 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) resulted in significantly higher LAI than 50% RDF + 50% RDF through FYM at 60 DAS, 90 DAS and 120 DAS in both years and over 50% RDF + 50% RDF through vermicompost at 60 DAS and 90 DAS in 2018-19 and at 120 DAS in both years.

The interaction between varieties and nutrient sources significantly alter wheat mean leaf area index over the course of the two research years (Table 11).

4.1.4 Leaf area duration

The data pertaining effect of integrated nutrient management system on leaf area duration in wheat at 30, 60, 90 and 120 DAS are presented in (Table 12). The data clearly revealed that the mean leaf area duration was found significantly higher in variety WH 1142 (9.80 and 10.10) over all the varieties during 2017-18 at 30 and 60 DAS. Same trend has been seen during 2018-19. The data clearly revealed that the mean leaf area duration was found non-significant in variety WH 1142 over all the varieties during 2017-18 at 90 and 120 DAS, while as its significantly higher in variety WH 1142 (162.37 and 131.47) over all the varieties during 2018-19. The data clearly revealed that the mean leaf area duration was found

Table 10. Effect of varieties and integrated nutrient management system on mean plant height at 30, 60, 90, 120 DAS and at harvest in wheat

Treatments	Plant height (cm)									
	30 DAS		60 DAS		90 DAS		120 DAS		At harvest	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)										
WH 1080	20.6	22.0	43.0	44.6	80.0	81.0	94.8	94.8	96.8	97.8
WH 1025	20.0	20.6	41.3	43.6	78.7	80.4	94.0	92.5	96.4	95.2
WH 1142	22.4	23.1	44.8	46.3	82.2	83.6	96.1	99.8	98.3	101.3
WH 711	21.8	22.8	43.2	45.3	80.9	81.9	95.5	97.1	97.7	99.3
SEm±	0.29	0.37	0.21	0.23	0.36	0.24	0.26	0.14	0.24	0.27
C.D. (p = 0.05)	1.03	1.31	0.76	0.81	1.26	0.86	0.92	0.5	0.84	0.95
Nutrient sources (N)										
Control	19.1	19.4	40.2	40.7	74.9	75.1	90.3	91.3	93.4	94.1
100% RDF	23.4	24.2	46.1	48.3	83.1	85.7	98.7	99.6	100.8	102.6
50% RDF + 50% RDF through FYM	20.2	21.6	42.1	44.3	80.8	81.2	94.3	95.4	96.7	97.4
50% RDF + 50% RDF through vermicompost	21.2	22.5	43.1	45.3	81.3	82.8	95.4	96.5	97.3	98.2
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	22.1	22.8	43.9	46.3	82.1	83.6	96.6	97.4	98.3	99.6
SEm±	0.22	0.24	0.17	0.21	0.23	0.26	0.22	0.24	0.26	0.26
C.D. (p = 0.05)	0.64	0.71	0.49	0.62	0.67	0.75	0.62	0.68	0.75	0.74
Interaction (V×N)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 11. Effect of varieties and integrated nutrient management system on mean leaf area index at 30, 60, 90 and at 120 DAS in wheat

Treatments	Leaf area index (LAI)							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)								
WH 1080	0.64	0.68	4.62	4.75	5.63	5.73	2.68	2.78
WH 1025	0.61	0.65	4.28	4.52	5.42	5.6	2.52	2.57
WH 1142	0.68	0.72	5.13	5.22	6.23	6.29	3.12	3.2
WH 711	0.66	0.7	4.91	4.97	5.95	6.03	2.85	3.05
SEm±	0.00	0.00	0.05	0.01	0.04	0.04	0.01	0.02
C.D. (p = 0.05)	0.01	0.01	0.17	0.05	0.14	0.13	0.02	0.05
Nutrient sources (N)								
Control	0.58	0.63	4.41	4.6	5.45	5.49	2.58	2.65
100% RDF	0.71	0.75	4.92	5.15	6.03	6.23	2.91	3.13
50% RDF + 50% RDF through FYM	0.62	0.67	4.74	4.78	5.78	5.86	2.78	2.84
50% RDF + 50% RDF through vermicompost	0.65	0.69	4.78	4.84	5.85	5.92	2.81	2.91
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.67	0.71	4.82	4.95	5.91	6.05	2.87	2.97
SEm±	0.04	0.06	0.02	0.03	0.03	0.03	0.01	0.01
C.D. (p = 0.05)	0.13	0.18	0.07	0.07	0.09	0.09	0.03	0.04
Factor (N) at same level of V	0.01	0.01	0.16	0.15	0.19	0.20	0.07	0.08
Factor (V) at same level of N	0.02	0.02	0.21	0.14	0.21	0.21	0.06	0.09

Table 12. Effect of varieties and integrated nutrient management system on leaf area duration at 30, 60, 90 and at 120 DAS in wheat

Treatments	Leaf area duration (days)							
	0-30 DAS		30-60 DAS		60-90 DAS		90-120 DAS	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)								
WH 1080	9.28	9.24	80.04	79.88	157.64	157.3	128.42	128.50
WH 1025	8.84	8.92	78.44	78.34	156.18	155.87	127.20	126.94
WH 1142	9.80	10.10	83.87	84.38	160.59	162.37	131.05	131.47
WH 711	9.52	9.78	81.29	82.48	159.19	159.38	129.81	130.06
SEm±	0.04	0.03	0.66	0.40	0.95	0.82	1.11	0.29
C.D. (p = 0.05)	0.13	0.10	2.33	1.41	NS	2.90	NS	1.02
Nutrient sources (N)								
Control	8.70	8.40	77.55	77.40	151.65	151.35	122.10	121.65
100% RDF	9.75	10.05	83.55	84.00	162.29	163.2	132.30	132.60
50% RDF + 50% RDF through FYM	9.30	9.45	80.4	80.85	158.10	158.55	129.60	129.90
50% RDF + 50% RDF through vermicompost	9.45	9.75	81.15	81.75	159.45	159.75	130.50	130.65
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	9.60	9.90	81.9	82.35	160.50	160.8	131.10	131.40
SEm±	0.05	0.06	0.33	0.59	0.82	0.86	0.50	0.77
C.D. (p = 0.05)	0.13	0.18	0.96	1.72	2.37	2.50	1.45	2.23
Interaction (V×N)	NS	NS	NS	NS	NS	NS	NS	NS

significantly higher in 100% RDF (9.75, 83.55, 162.29 and 132.30) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources ($V \times N$) didn't significantly alter wheat leaf area duration over the course of the two research years (Table 12).

4.1.5 Dry matter accumulation (g/plant)

Dry matter accumulation per plant in wheat at 30, 60, 90, 120 DAS and at harvest was recorded (Table 13). There was consistent increase in dry matter accumulation from 30 DAS up to harvest. Variety WH 1142 produced the highest dry matter at all growth stage in both years. It was at par with WH 711 at 60 DAS in 2017-18 and at harvest in both years and significantly higher at all other growth stages. WH 1142 accumulated significantly more dry matter than WH 1025 at all growth stages (except at 60 DAS, 120 DAS and harvest in 2018-19) and over WH 1080 at 30 DAS and WH 1025 were on par for dry matter accumulation at all growth stages in both years. All treatments of nutrient application resulted in significantly higher dry matter accumulation than control treatment at all growth stages in both years (Table 14). Application of 100% RDF through inorganic source resulted in significantly higher dry matter accumulation at all growth stages than all other treatments of nutrient application in both years. Application of 50% RDF + 50% through FYM + 50% through vermicompost + biofertilizers also resulted in significantly more dry matter accumulation than application of 50% RDF + 50% RDF through FYM at 30 DAS, 60 DAS, 90 DAS and 120 DAS in both years and also over 50% RDF + 50% RDF through vermicompost at 30 DAS in both years and 60 DAS in 2018-19.

The interaction between varieties and nutrient sources significantly alter wheat mean dry matter accumulation over the two research years.

4.1.6 Shoot length (cm)

The data pertaining effect of the integrated nutrient management system on mean shoot length in wheat at 90 DAS are presented in (Table 14). The data revealed that the mean shoot length was found significantly higher in variety WH 1142 (77.4 cm) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the mean shoot length was found significantly higher in 100% RDF (78.4 cm) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19. The interaction between varieties and nutrient sources ($V \times N$) did not significantly alter the wheat mean shoot length over the course of the two research years.

4.2. Phenological parameters

4.2.1 Days taken to 50% heading

The data pertaining effect of the integrated nutrient management system on mean days taken to 50% heading in wheat are presented in (Table 15).

Table 13. Effect of varieties and integrated nutrient management system on mean dry matter accumulation (g/plant) at 30, 60, 90, 120 DAS and at harvest in wheat

Treatments	Dry matter accumulation (g/plant)									
	30 DAS		60 DAS		90 DAS		120 DAS		At harvest	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)										
WH 1080	2.57	2.79	10.94	11.22	14.35	14.43	20.88	21.18	24.65	24.87
WH 1025	2.51	2.71	10.71	10.86	14.18	14.18	20.25	20.45	24.15	24.33
WH 1142	2.88	2.99	11.44	11.69	15.1	15.77	21.7	22.12	25.15	25.96
WH 711	2.77	2.83	11.12	11.48	14.54	14.94	21.3	21.54	24.79	25.2
SEm±	0.03	0.03	0.1	0.13	0.07	0.08	0.25	0.31	0.15	0.28
C.D. (p = 0.05)	0.09	0.11	0.36	0.47	0.23	0.27	0.89	1.11	0.54	0.97
Nutrient sources (N)										
Control	2.32	2.42	9.72	9.92	13.21	13.34	18.12	18.21	23.14	23.29
100% RDF	3.22	3.34	11.78	12.12	15.23	15.98	22.75	23.08	25.87	26.21
50% RDF + 50% RDF through FYM	2.48	2.59	11.12	11.32	14.56	14.71	21.12	21.45	24.43	24.92
50% RDF + 50% RDF through vermicompost	2.57	2.67	11.21	11.43	14.76	14.93	21.35	21.52	24.85	25.12
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	2.83	3.12	11.43	11.76	14.94	15.18	21.83	22.34	25.12	25.91
SEm±	0.09	0.07	0.09	0.11	0.08	0.14	0.22	0.11	0.24	0.32
C.D. (p = 0.05)	0.25	0.21	0.26	0.31	0.22	0.4	0.63	0.33	0.7	0.93
Factor (N) at same level of V	NS	0.43	0.55	0.67	0.46	0.81	1.33	0.76	1.44	1.93
Factor (V) at same level of N	NS	0.40	0.58	0.73	0.45	0.76	1.42	1.25	1.37	1.91

Table 14. Effect of varieties and integrated nutrient management system on mean shoot length (cm) at 90 DAS

Treatments	Shoot length (cm)	
	2017-18	2018-19
Varieties (V)		
WH 1080	75.0	75.7
WH 1025	74.2	74.8
WH 1142	77.4	78.3
WH 711	76.6	77.2
SEm±	0.57	0.57
C.D. (p = 0.05)	2.01	2.02
Nutrient sources (N)		
Control	70.5	70.7
100% RDF	78.4	79.8
50% RDF + 50% RDF through FYM	76.1	76.6
50% RDF + 50% RDF through vermicompost	76.6	77.1
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	77.4	78.1
SEm±	0.62	0.66
C.D. (p = 0.05)	1.79	1.91
Interaction (V×N)	NS	NS

The data revealed that days taken to 50% heading was found significantly minimum in variety WH 1025 (87.2) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data that the mean days taken to 50% heading was found significantly minimum in control (79.2) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alter mean days taken to 50% heading over the two research years (Table 15).

4.2.2 Days taken to 50% anthesis

The data pertaining effect of the integrated nutrient management system on mean days taken to 50% anthesis in wheat are presented in (Table 15). The data revealed that days taken to 50% anthesis was found significantly minimum in variety WH 1025 (92.6) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the mean days taken to 50% anthesis was found significantly minimum in control (84.2) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alter mean days taken to 50% anthesis over the course of the two research years (Table 15).

4.2.3 Panicle emergence rate

The data pertaining effect of integrated nutrient management system on mean panicle emergence rate in wheat are presented in (Table 15). The data clearly revealed that panicle emergence rate was found non-significant in varieties during 2017-18. Same trend has been seen during 2018-19. The data clearly revealed that the mean panicle emergence rate was found non-significant in nutrient sources during 2017-18, whereas its was found significantly higher in 100% RDF (0.16) during 2018-19 over all other nutrient sources.

The interaction between varieties and nutrient sources (V×N) did not significantly alter mean panicle emergence rate over the two research years (Table 15).

4.2.4 Leaf production rate

The data pertaining effect of integrated nutrient management system on mean leaf production rate in wheat at 30-60 days interval are presented in (Table 15). The data revealed that mean leaf production rate was found significantly maximum in variety WH 1142 (0.54) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the mean leaf production rate was found significantly maximum with application of 100% RDF (0.58) over all the nutrient sources during 2017-18. Similar trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alter mean leaf production rate over the two research years (Table 15).

4.3 Yield attributes and yields

4.3.1 Number of effective tillers/m²

The data pertaining effect of the integrated nutrient management system on mean number of effective tillers/m² in wheat are presented in (Table 16). The data clearly revealed that the mean number of effective tillers/m² was found significantly higher in variety WH 1142 (357.6) over all the varieties during 2017-18. Similar trend has been seen during 2018-19. The data clearly revealed that the mean number of effective tillers/m² was found significantly higher in 100% RDF (362.1) over all the nutrient sources during 2017-18. Similar trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alters mean number of effective tillers/m² in wheat over the course of the two research years (Table 16).

4.3.2 Spike length (cm)

The data pertaining effect of the integrated nutrient management system on mean spike length in wheat are presented in (Table 17). The data revealed that the mean spike length was found significantly higher in variety WH 1142 (11.2 cm) over all the varieties during 2017-18. Similar trend has been seen during 2018-19. The data revealed that the mean spike length was found significantly higher in 100% RDF (11.2 cm) over all the nutrient sources during 2017-18. Similar trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alters wheat mean spike length over the two research years.

4.3.3 Number of grains/spike

The data pertaining effect of integrated nutrient management system on mean number of grains/spike in wheat are presented in (Table 16). The data clearly revealed that the mean number of grains/spike was found significantly higher in variety WH 1142 (51.2) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data clearly revealed that the mean number of grains/spike was found significantly higher in 100% RDF (52.3) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alters wheat mean number of grains/spike over the course of the two research years.

4.3.4 Grain weight/spike (g)

The data pertaining effect of the integrated nutrient management system on mean grain weight/spike in wheat are presented in (Table 16). The data revealed that the mean grain weight/spike was found significantly higher in variety WH 1142 (3.2 g) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the mean grain weight/spike was found significantly higher in 100% RDF (3.4 g) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alter wheat mean grain weight/spike over the two research years.

4.3.5 Test weight (g)

The data pertaining effect of the integrated nutrient management system on mean test weight in wheat are presented in (Table 16). The data revealed that the mean test weight was found significantly higher in variety WH 1142 (40.9 g) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the mean test weight was found significantly higher in 100% RDF (41.8 g) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alters wheat mean test weight over the two research years.

4.3.6 Grain yield (kg/ha)

The data pertaining effect of the integrated nutrient management system on mean grain yield in wheat are presented in (Table 17 and Fig. 4 & 5). The data revealed that the mean grain yield was found significantly higher in variety WH 1142 (4866 kg/ha) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the mean grain yield was found significantly higher in 100% RDF (4736 kg/ha) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

Table 15. Effect of varieties and integrated nutrient management system on phenological parameters of wheat

Treatments	Phenological parameters							
	Days taken to 50% heading		Days taken to 50% anthesis		Panicle emergence rate		Leaf production rate (30-60 days interval)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)								
WH 1080	89.4	89.8	94.8	95.6	0.14	0.14	0.50	0.57
WH 1025	87.2	87.6	92.6	93.4	0.13	0.13	0.49	0.55
WH 1142	93.9	94.3	98.6	99.3	0.15	0.14	0.54	0.57
WH 711	91.4	91.9	96.4	97.2	0.15	0.14	0.53	0.57
SEm±	0.24	0.24	0.24	0.33	0.01	0.00	0.00	0.00
C.D. (p = 0.05)	0.84	0.85	0.84	1.15	NS	NS	0.01	0.01
Nutrient sources (N)								
Control	79.2	78.3	84.2	83.2	0.13	0.11	0.43	0.41
100% RDF	94.9	95.7	101.2	102.4	0.17	0.16	0.58	0.64
50% RDF + 50% RDF through FYM	91.9	92.3	95.2	96.5	0.13	0.13	0.50	0.57
50% RDF + 50% RDF through vermicompost	92.8	93.7	97.4	98.4	0.14	0.14	0.51	0.60
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	93.8	94.5	99.9	101.2	0.15	0.15	0.54	0.61
SEm±	0.50	0.50	0.53	0.55	0.01	0.00	0.00	0.00
C.D. (p = 0.05)	1.52	1.52	1.52	1.60	NS	0.01	0.01	0.01
Factor (N) at same level of V	3.10	3.10	3.10	3.30	NS	NS	0.02	0.02
Factor (V) at same level of N	2.90	2.90	2.90	3.10	NS	NS	0.02	0.02

The interaction between varieties and nutrient sources (V×N) significantly alter wheat mean grain yield over the two research years (Table 18 and Table 19). Significantly maximum grain yield was recorded in interaction between 100% RDF through inorganic source and WH 1142 (5283 and 5298 kg/ha) in 2017-18 and 2018-19 respectively. Whereas, significantly minimum grain yield (3455 and 3463 kg/ha) was recorded in interaction between control and WH 1025 during 2017-18 and 2018-19.

4.3.7 Straw yield (kg/ha)

The data pertaining effect of the integrated nutrient management system on mean straw yield in wheat are presented in (Table 17 and Fig 4 & 5). The data revealed that the mean straw yield was found significantly higher in variety WH 1142 (7820 kg/ha) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the mean straw yield was found significantly higher in 100% RDF (7652 kg/ha) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alters the wheat mean straw yield over the two research years (Table 20 and Table 21). Significantly maximum straw yield was recorded with interaction between 100% RDF through inorganic source and WH 1142 (8358 and 8428 kg/ha) in 2017-18 and 2018-19 respectively. Whereas, significantly minimum straw yield (6211 and 6311 kg/ha) was recorded with interaction between control and WH 1025 during 2017-18 and 2018-19.

4.3.8 Harvest index (%)

The data pertaining effect of integrated nutrient management system on mean harvest index in wheat are presented in (Table 17). Mean harvest index was found non-significant in wheat varieties and nutrient sources during 2017-18 and 2018-19 respectively.

The interaction between varieties and nutrient sources (V×N) didn't significantly alter the wheat mean harvest index over the two research years.

4.4 Effect of integrated nutrient management system on quality parameters of different varieties of wheat

4.4.1 Protein content in grain (%)

The data pertaining effect of the integrated nutrient management system on mean protein content in grain in the wheat are presented in (Table 22). The data revealed that the mean protein content in grain was found significantly higher in variety WH 1142 (11.71%) over all other varieties during 2017-18. Same trend has been seen during 2018-19. Among nutrients sources the mean protein content in grain was found significantly higher in 100% RDF (11.83%) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

Table 16. Effect of varieties and integrated nutrient management system on mean yield attributes of wheat

Treatments	Yield attributes									
	Number of effective tillers/m ²		Spike length (cm)		Number of grains/spike		Grain weight/spike (g)		Test weight (g)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)										
WH 1080	344.9	351.3	10.2	10.4	49.1	50.6	2.9	3.1	39.8	39.8
WH 1025	328.2	337.4	9.3	9.5	40.8	42.1	2.2	2.4	38.1	38.4
WH 1142	357.6	368.2	11.2	11.3	51.2	52.9	3.2	3.4	40.9	41.6
WH 711	349.5	359.1	10.8	11.0	50.4	51.6	3.1	3.3	40.2	40.3
SEm±	0.64	1.38	0.14	0.14	0.36	0.17	0.02	0.01	0.13	0.16
C.D. (p = 0.05)	2.26	4.88	0.50	0.50	1.28	0.61	0.06	0.05	0.47	0.55
Nutrient sources (N)										
Control	332.1	341.2	9.6	9.7	43.1	44.5	2.8	2.9	38.4	38.7
100% RDF	362.1	371.5	11.2	11.5	52.3	53.7	3.4	3.6	41.8	42.1
50% RDF + 50% RDF through FYM	334.1	342.7	10.2	10.4	46.3	47.8	2.6	2.8	38.7	38.9
50% RDF + 50% RDF through vermicompost	345.9	353.4	10.3	10.5	48.2	49.4	2.7	2.9	39.7	39.8
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	351.0	361.1	10.6	10.7	49.3	50.9	2.9	3.2	40.2	40.5
SEm±	1.24	1.41	0.19	0.19	0.35	0.38	0.04	0.03	0.22	0.2
C.D. (p = 0.05)	3.59	4.07	0.54	0.54	1.02	1.08	0.11	0.1	0.62	0.58
Factor (N) at same level of V	7.30	8.55	1.11	1.11	2.15	2.20	0.22	0.20	1.27	1.20
Factor (V) at same level of N	6.80	8.73	1.08	1.08	2.22	2.03	0.21	0.18	1.20	1.17

Table 17. Effect of varieties and integrated nutrient management system on mean yield of wheat

Treatments	Yields					
	Grain yield (kg/ha)		Straw yield (kg/ha)		Harvest index (%)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)						
WH 1080	4716	4734	7438	7504	38.96	38.86
WH 1025	3595	3609	6530	6593	35.83	35.68
WH 1142	4866	4877	7820	7911	38.64	38.49
WH 711	4795	4818	7487	7565	38.94	38.93
SEm±	12.0	13.8	16.1	19.6	0.19	0.19
C.D. (p = 0.05)	42.2	48.7	56.9	69.2	NS	NS
Nutrient sources (N)						
Control	4388	4400	7018	7105	38.47	38.47
100% RDF	4736	4758	7652	7719	38.50	38.45
50% RDF + 50% RDF through FYM	4407	4420	7118	7209	38.50	38.36
50% RDF + 50% RDF through vermicompost	4440	4457	7272	7360	37.93	37.74
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	4494	4513	7535	7574	37.63	37.5
SEm±	17.7	18.2	23.9	26.5	0.22	0.22
C.D. (p = 0.05)	51.2	52.7	69.1	76.8	NS	NS
Interaction (V×N)	Sig	Sig	Sig	Sig	NS	NS

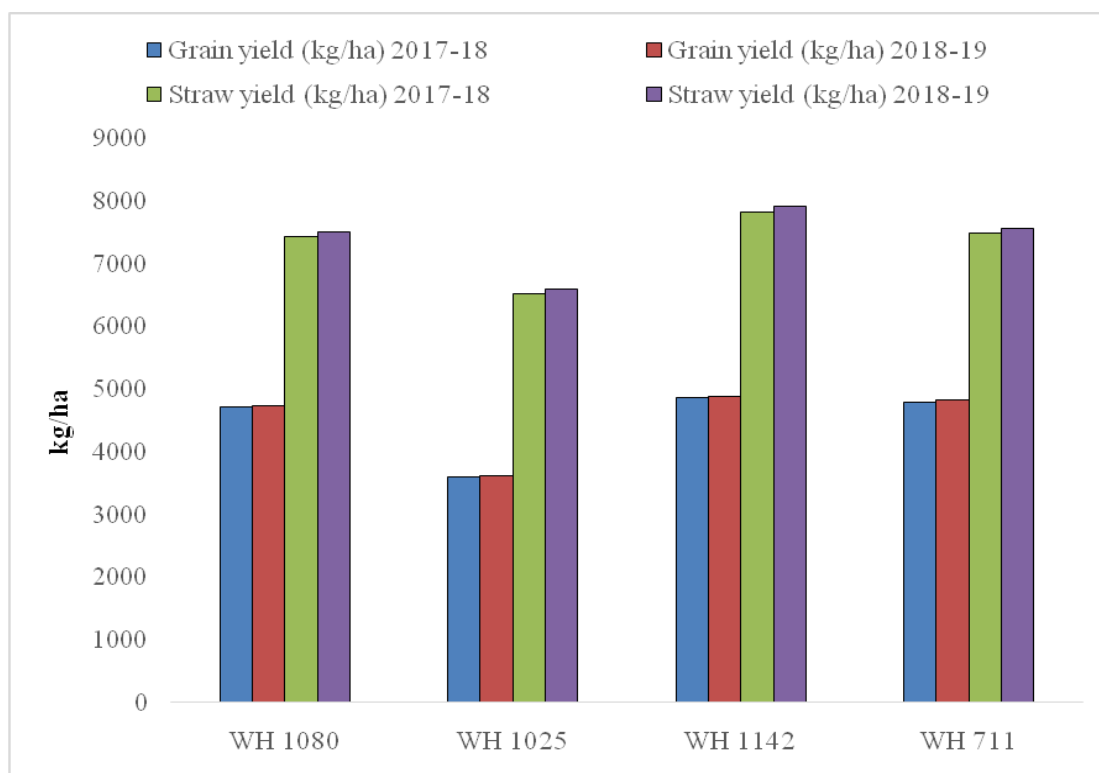


Fig 4. Grain and straw yield (kg/ha) of different varieties of wheat during 2017-18 & 2018-19

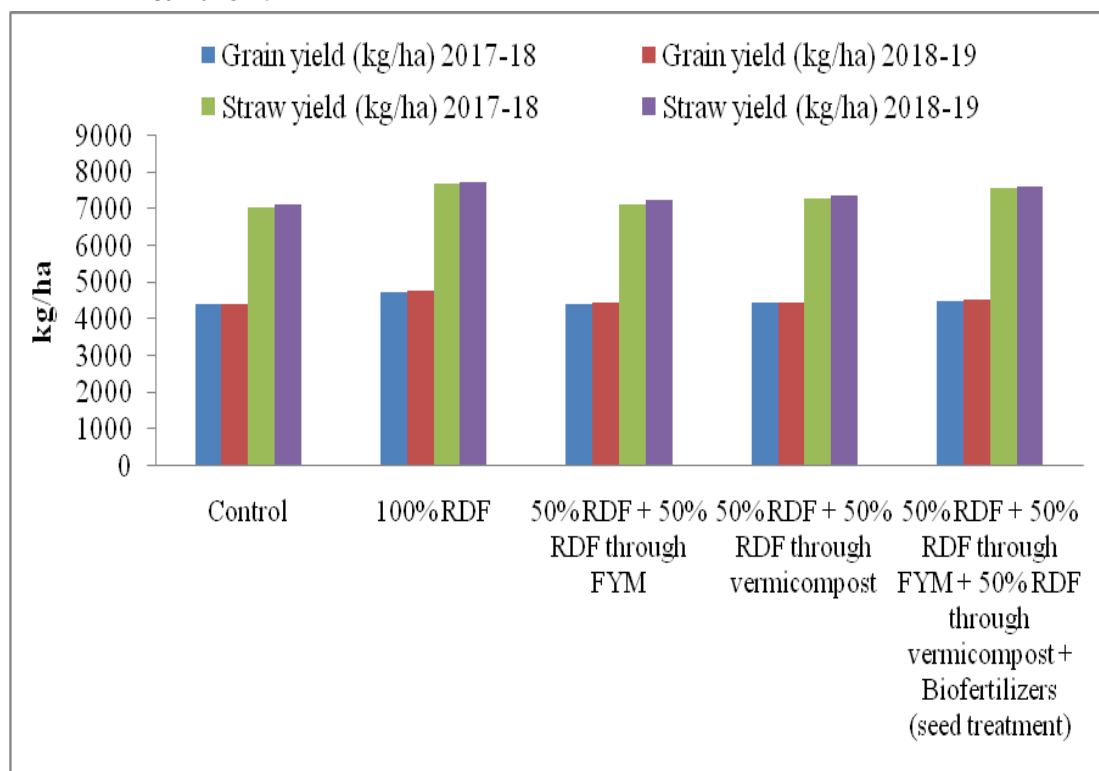


Fig 5. Grain and straw yield (kg/ha) of different nutrient sources in wheat during 2017-18 & 2018-19

Table 18. Interaction effect of varieties and nutrient sources on mean grain yield (kg/ha) of wheat in 2017-18

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	4631	3445	4786	4692	4388
100% RDF	4903	3638	5283	5121	4736
50% RDF + 50% RDF through FYM	4655	3619	4684	4670	4407
50% RDF + 50% RDF through vermicompost	4685	3631	4738	4706	4440
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	4708	3641	4838	4789	4494
Mean	4716	3595	4866	4795	
	SEm±		CD at 5%		
Factor (N) at same level of V	26.7		105.2		
Factor (V) at same level of N	33.8		100.6		

Table 19. Interaction effect of varieties and nutrient sources on mean grain yield (kg/ha) of wheat in 2018-19

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	4636	3463	4796	4704	4400
100% RDF	4919	3652	5298	5161	4758
50% RDF + 50% RDF through FYM	4669	3630	4697	4683	4420
50% RDF + 50% RDF through vermicompost	4703	3643	4748	4732	4457
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	4741	3655	4848	4809	4513
Mean	4734	3609	4877	4818	
	SEm±		CD at 5%		
Factor (N) at same level of V	30.9		108.9		
Factor (V) at same level of N	35.4		105.8		

Table 20. Interaction effect of varieties and nutrient sources on mean straw yield (kg/ha) of wheat in 2017-18

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	7158	6211	7423	7280	7018
100% RDF	7739	6733	8358	7777	7652
50% RDF + 50% RDF through FYM	7242	6437	7481	7312	7118
50% RDF + 50% RDF through vermicompost	7385	6608	7654	7442	7272
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	7665	6662	8185	7626	7535
Mean	7438	6530	7820	7487	
	SEm±		CD at 5%		
Factor (N) at same level of V	36.1		142.0		
Factor (V) at same level of N	45.7		135.8		

Table 21. Interaction effect of varieties and nutrient sources on mean straw yield (kg/ha) of wheat in 2018-19

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	7251	6311	7506	7354	7105
100% RDF	7796	6789	8428	7861	7719
50% RDF + 50% RDF through FYM	7332	6510	7581	7412	7209
50% RDF + 50% RDF through vermicompost	7485	6678	7754	7522	7360
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	7655	6678	8285	7676	7574
Mean	7504	6593	7911	7565	
	SEm±		CD at 5%		
Factor (N) at same level of V	43.9		158.4		
Factor (V) at same level of N	51.4		153.3		

The interaction between varieties and nutrient sources (V×N) was non-significant for mean protein content in grain over the two research year.

4.4.2 Starch content in grain (%)

The data pertaining effect of the integrated nutrient management system on mean starch content in grain in wheat are presented in (Table 22). The data revealed that the mean starch content in grain was found significantly higher in variety WH 1142 (62.05%) over all other varieties during 2017-18 whereas, it was non-significant during 2018-19. Among

nutrient sources mean starch content in grain was significantly higher in 100% RDF (63.48%) over all the nutrient sources during 2017-18. Similar trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) was non-significant for mean starch content in grain during 2017-18 and 2018-19.

4.5 Nutrient content, uptake and efficiencies

4.5.1 N, P and K content in grain (%)

The data pertaining effect of the integrated nutrient management system on mean N, P and K content in grain at harvest in the wheat are presented in (Table 23). The data revealed that the mean N content in variety WH 1142 was at par with varieties WH 1025 and WH 1080 in 2017-18 and with WH 711 during 2018-19. Mean P content in variety WH 1142 was at par with variety WH 1025 during 2017-18 and with varieties WH 711 and WH 1080 during 2018-19. Mean K content in variety WH 1142 was at par with varieties WH 711 and WH 1080 during 2017-18 but it was non-significant for K during 2018-19. Among nutrient sources, application of 100% RDF gives higher N and P content in grain during 2017-18 over all nutrient sources and at par with 50% RDF + 50% RDF through vermicompost and 50% RDF +50% RDF through FYM + 50% RDF through vermicompost + biofertilizers for P content during 2018-19. Mean K content in grain with application of 100% RDF was higher over control, 50% RDF + 50% RDF through FYM and 50% RDF + 50% RDF through vermicompost and at par with 50% RDF +50% RDF through FYM + 50% RDF through vermicompost + biofertilizers during 2017-18, while its was higher over all nutrient sources during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alters the mean N, P and K content in grain over the two research year.

4.5.2 N, P and K content in straw (%)

The data pertaining effect of the integrated nutrient management system on mean N, P and K content in straw at harvest in the wheat are presented in (Table 24). The data revealed that the mean N, P and K content in straw didn't differ significantly however variety WH 1142 (0.45, 0.15 and 1.67%) contain highest over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the mean N, P and K content in straw didn't differ significantly however 100% RDF (0.46, 0.15 and 1.71%) contain highest over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19 for mean N and P content in straw however, K content in straw significantly higher with 100% RDF over all nutrient sources during both the years.

The interaction between varieties and nutrient sources (V×N) was non-significant for mean N, P and K content in straw over the two research year.

4.5.3 N, P and K uptake by grain (kg/ha)

The data pertaining effect of the integrated nutrient management system on mean N, P and K uptake by grain in wheat are presented in (Table 25). Mean N, P and K uptake by

grain was found significantly higher in variety WH 1142 (83.1, 25.0 and 23.2 kg/ha) over all the varieties during 2017-18. Same trend has been seen during 2018-19. Mean N, P and K uptake by grain was found significantly higher with application of 100% RDF (86.7, 25.9 and 23.4 kg/ha) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) was non-significant for mean N, P and K uptake by grain over the two research years.

4.5.4 N, P and K uptake by straw (kg/ha)

The data pertaining effect of the integrated nutrient management system on mean N, P and K uptake by straw in wheat are presented in (Table 26). Mean N, P and K uptake by straw was found significantly higher in variety WH 1142 (35.5, 11.5 and 130.4 kg/ha) over all the varieties during 2017-18. Same trend has been seen during 2018-19. Mean N, P and K uptake by straw was found significantly higher with application of 100% RDF (35.3, 11.6 and 130.9 kg/ha) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) was non-significant for mean N, P and K uptake by straw over the two research years.

Table 22. Effect of varieties and integrated nutrient management system on mean protein and starch content (%) in wheat

Treatments	Protein content (%)		Starch content (%)	
	2017-18	2018-19	2017-18	2018-19
Varieties (V)				
WH 1080	11.2	11.5	61.1	62.1
WH 1025	10.7	10.8	60.3	61.6
WH 1142	11.7	12.1	62.1	63.1
WH 711	11.5	11.7	61.6	62.9
SEm±	0.05	0.09	0.28	0.39
C.D. (p = 0.05)	0.19	0.32	0.99	NS
Nutrient sources (N)				
Control	10.7	10.9	60.1	61.3
100% RDF	11.8	12.1	63.5	64.8
50% RDF + 50% RDF through FYM	11.0	11.2	60.6	61.8
50% RDF + 50% RDF through vermicompost	11.2	11.5	60.8	61.9
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	11.5	11.7	61.3	62.4
SEm±	0.08	0.11	0.35	0.37
C.D. (p = 0.05)	0.24	0.31	1.01	1.08
Interaction (V×N)	NS	NS	NS	NS

4.5.4 Nitrogen balance sheet/removal ratio of nitrogen (kg/kg)

The data pertaining effect of the integrated nutrient management system on mean nutrient balance sheet of nitrogen in wheat are presented in (Table 27). The data revealed that mean nutrient balance sheet of nitrogen was found significantly higher in variety WH 1142 (0.60 kg/kg) over all the varieties during 2017-18. Same trend has been seen during 2018-19. Mean nutrient balance sheet of nitrogen was found significantly higher with application of 100% RDF (0.62 kg/kg) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) were non-significantly alters the mean nutrient balance sheet of nitrogen over the two research years.

Table 23. Effect of varieties and integrated nutrient management system on mean N, P and K content (%) in wheat grain

Treatments	Nutrient content in grain (%)					
	N		P		K	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)						
WH 1080	1.65	1.73	0.51	0.52	0.47	0.48
WH 1025	1.56	1.65	0.50	0.51	0.44	0.47
WH 1142	1.71	1.84	0.51	0.53	0.48	0.48
WH 711	1.69	1.82	0.51	0.52	0.47	0.48
SEm±	0.02	0.02	0.00	0.00	0.00	0.00
C.D. (p = 0.05)	0.07	0.07	0.01	0.01	0.02	NS
Nutrient sources (N)						
Control	1.48	1.57	0.41	0.42	0.41	0.42
100% RDF	1.83	1.94	0.55	0.56	0.49	0.51
50% RDF + 50% RDF through FYM	1.56	1.63	0.52	0.54	0.47	0.48
50% RDF + 50% RDF through vermicompost	1.67	1.78	0.53	0.55	0.47	0.48
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	1.73	1.87	0.53	0.55	0.48	0.49
SEm±	0.02	0.02	0.00	0.00	0.01	0.00
C.D. (p = 0.05)	0.05	0.05	0.01	0.01	0.01	0.01
Factor (N) at same level of V	0.11	0.11	0.02	0.02	0.03	0.03
Factor (V) at same level of N	0.11	0.11	0.02	0.02	0.03	0.02

Table 24. Effect of varieties and integrated nutrient management system on mean N, P and K content (%) in wheat straw

Treatments	Nutrient content in straw (%)					
	N		P		K	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)						
WH 1080	0.44	0.46	0.14	0.14	1.56	1.64
WH 1025	0.43	0.44	0.13	0.14	1.47	1.54
WH 1142	0.45	0.47	0.15	0.16	1.67	1.72
WH 711	0.45	0.46	0.14	0.15	1.59	1.67
SEm±	0.00	0.01	0.00	0.00	0.01	0.01
C.D. (p = 0.05)	0.01	0.02	0.00	0.01	0.03	0.02
Nutrient sources (N)						
Control	0.42	0.42	0.13	0.13	1.45	1.48
100% RDF	0.46	0.48	0.15	0.16	1.71	1.76
50% RDF + 50% RDF through FYM	0.43	0.45	0.13	0.14	1.47	1.57
50% RDF + 50% RDF through vermicompost	0.44	0.46	0.14	0.14	1.58	1.68
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.45	0.47	0.15	0.15	1.65	1.71
SEm±	0.00	0.00	0.00	0.00	0.01	0.01
C.D. (p = 0.05)	0.01	0.01	0.01	0.01	0.04	0.03
Interaction (V×N)	NS	NS	NS	NS	NS	NS

Table 25. Effect of varieties and integrated nutrient management system on mean N, P and K uptake (kg/ha) by wheat grain

Treatments	Nutrient uptake by grain (kg/ha)					
	N		P		K	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)						
WH 1080	78.0	81.9	23.9	24.7	22.2	22.73
WH 1025	56.2	59.4	18.0	18.5	15.9	16.89
WH 1142	83.1	89.6	25.0	25.9	23.2	23.56
WH 711	81.0	87.5	24.5	25.2	22.7	23.17
SEm±	0.40	0.40	0.20	0.20	0.20	0.10
C.D. (p = 0.05)	1.30	1.60	0.80	0.50	0.60	0.35
Nutrient sources (N)						
Control	65.0	69.2	18.1	18.3	18.2	18.5
100% RDF	86.7	92.5	25.9	26.7	23.4	24.4
50% RDF + 50% RDF through FYM	69.0	72.3	22.9	23.8	20.7	21.1
50% RDF + 50% RDF through vermicompost	74.3	79.6	23.4	24.4	21.0	21.6
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	77.8	84.5	24.0	24.7	21.7	22.3
SEm±	0.80	0.50	0.30	0.30	0.30	0.20
C.D. (p = 0.05)	2.30	1.50	0.80	0.80	0.80	0.70
Interaction (V×N)	NS	NS	NS	NS	NS	NS

Table 26. Effect of varieties and integrated nutrient management system on mean N, P and K uptake by wheat straw (kg/ha)

Treatments	Nutrient uptake by straw (kg/ha)					
	N		P		K	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)						
WH 1080	32.4	34.4	10.2	10.7	115.8	122.8
WH 1025	27.8	28.7	8.6	9.1	96.1	101.5
WH 1142	35.5	37.2	11.5	12.3	130.4	135.9
WH 711	33.4	34.9	10.4	11.1	119.1	126.2
SEm±	0.50	0.40	0.10	0.10	0.40	0.20
C.D. (p = 0.05)	1.90	1.40	0.30	0.30	1.50	0.90
Nutrient sources (N)						
Control	29.2	30.0	9.1	9.5	101.8	105.3
100% RDF	35.3	36.9	11.6	12.4	130.9	136.0
50% RDF + 50% RDF through FYM	30.8	32.3	9.3	10.0	104.7	113.3
50% RDF + 50% RDF through vermicompost	32.2	34.0	10.0	10.5	115.0	123.8
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	34.0	35.9	10.9	11.5	124.4	129.6
SEm±	0.30	0.30	0.10	0.10	0.60	0.70
C.D. (p = 0.05)	0.90	1.00	0.30	0.20	1.90	2.00
Interaction (V×N)	NS	NS	NS	NS	NS	NS

4.5.5 Use efficiency of nitrogen (AE, PE and AR)

4.5.5.1 Agronomic efficiency of nitrogen (kg/kg)

The data pertaining effect of the integrated nutrient management system on mean agronomic efficiency of nitrogen (kg/kg) in wheat are presented in (Table 28). The data revealed that the mean agronomic efficiency of nitrogen was found significantly higher in variety WH 1142 (9.11 kg/kg) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the mean agronomic efficiency of nitrogen was found significantly higher in 100% RDF (8.24 kg/kg) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) were non-significantly alters the wheat mean agronomic efficiency of nitrogen (kg/kg) over the two research years.

4.5.5.2 Physiological efficiency of nitrogen (kg/kg)

The data pertaining effect of the integrated nutrient management system on mean physiological efficiency of nitrogen (kg/kg) in wheat are presented in (Table 28). The data revealed that the mean physiological efficiency of nitrogen was found significantly higher in variety WH 1142 (85.7 kg/kg) over all the varieties during 2017-18. Declining trend has been seen during 2018-19. The data revealed that the mean physiological efficiency of nitrogen was found significantly higher in 100% RDF (99.45 kg/kg) over all the nutrient sources during 2017-18. Declining trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) were non-significantly alters the wheat mean physiological efficiency of nitrogen (kg/kg) over the two research years.

4.5.5.3 Recovery efficiency of nitrogen (%)

The data pertaining effect of the integrated nutrient management system on mean recovery efficiency of nitrogen in wheat are presented in (Table 28). The data revealed that the mean recovery efficiency of nitrogen was found significantly higher in variety WH 1142 (25.40%) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the mean recovery efficiency of nitrogen was found significantly higher in 100% RDF (27.21%) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) was non-significantly alters the wheat mean recovery efficiency of nitrogen over the two research years.

Table 27. Effect of varieties and integrated nutrient management system on mean nitrogen balance sheet in wheat (kg/kg)

Treatments	Nitrogen balance sheet (kg/kg)	
	2017-18	2018-19
Varieties (V)		
WH 1080	0.55	0.52
WH 1025	0.40	0.37
WH 1142	0.60	0.55
WH 711	0.58	0.54
SEm±	0.08	0.07
C.D. (p = 0.05)	0.19	0.18
Nutrient sources (N)		
Control	-	-
100% RDF	0.62	0.58
50% RDF + 50% RDF through FYM	0.48	0.46
50% RDF + 50% RDF through vermicompost	0.53	0.50
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.56	0.52
SEm±	0.05	0.05
C.D. (p = 0.05)	0.13	0.12
Interaction (V×N)	NS	NS

4.6 Nutrient status of soil at harvest

4.6.1 Soil organic carbon (%)

The data pertaining effect of the integrated nutrient management system on mean organic carbon content in soil at harvest are presented in (Table 29). The data revealed that mean organic carbon content in soil at harvest didn't differ significantly over all the varieties during 2017-18 and 2018-19. The data revealed that the mean organic carbon in soil at harvest was found significantly higher in 50% RDF through inorganic sources + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (0.48%) over all the nutrient sources during 2017-18, whereas it was at par with 50% RDF + 50% RDF through vermicompost and highly significantly over control, 100% RDF and 50% RDF + 50% RDF through FYM.

The interaction between varieties and nutrient sources (V×N) was significant for mean organic carbon in soil at harvest over the two research years.

4.6.2 Available N, P and K (kg/ha)

The data pertaining effect of the integrated nutrient management system on mean available N, P and K in soil at harvest are presented in (Table 29). The data revealed that mean available N, P and K in soil at harvest was found significantly higher in variety WH 1142 (133.8, 26.1 and 330.2 kg/ha) over all the varieties during 2017-18. Same trend has been seen during 2018-19.

Table 28. Effect of varieties and integrated nutrient management system on mean use efficiency of nitrogen in wheat

Treatments	Use efficiency of nitrogen					
	Agronomic efficiency (kg/kg)		Physiological efficiency (kg/kg)		Recovery efficiency (%)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)						
WH 1080	8.11	8.89	80.20	71.82	18.25	21.55
WH 1025	2.63	2.73	38.10	36.79	10.00	11.43
WH 1142	9.11	9.85	85.70	79.87	25.40	27.50
WH 711	8.63	9.45	81.80	72.23	22.62	24.59
SEm±	2.59	2.47	19.10	17.23	6.16	6.43
C.D. (p = 0.05)	6.47	6.17	47.60	43.09	15.40	16.07
Nutrient sources (N)						
Control	-	-	-	-	-	-
100% RDF	8.24	9.05	66.93	61.35	27.21	29.09
50% RDF + 50% RDF through FYM	6.05	6.80	99.45	94.46	14.05	16.82
50% RDF + 50% RDF through vermicompost	6.27	7.05	83.54	75.40	16.52	18.86
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	6.63	7.42	77.21	67.37	20.98	22.44
SEm±	0.88	0.90	13.01	13.24	5.27	4.91
C.D. (p = 0.05)	2.19	2.25	32.52	33.11	13.17	12.27
Interaction (V×N)	NS	NS	NS	NS	NS	NS

The data revealed that the mean available N, P and K in soil at harvest was found significantly higher in 100% RDF (139.3, 29.2 and 335.1 kg/ha) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alters the wheat mean available N, P and K in soil at harvest over the two research years.

4.6.3 Available Fe, Mn, Zn and Cu (mg/kg)

The data pertaining effect of the integrated nutrient management system on mean available Fe, Mn, Zn and Cu in soil at harvest are presented in (Table 30). The data revealed that mean DTPA-extractable available Fe, Mn, Zn and Cu in soil at harvest was found significantly higher in variety WH 1142 (15.96, 3.66, 2.23 and 1.56 mg/kg) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the mean DTPA-extractable available Fe, Mn, Zn and Cu in soil at harvest was found significantly higher in 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (16.81, 3.91, 2.41 and 1.61 mg/kg) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

The interaction between varieties and nutrient sources (V×N) significantly alters the wheat mean DTPA-extractable available Fe, Mn, Zn and Cu in soil at harvest over the two research year.

4.7 Effect of varieties and integrated nutrient management system on economics of different varieties of wheat

4.7.1 Gross returns (₹/ha)

The data pertaining effect of the integrated nutrient management system on gross returns in wheat are presented in (Table 31 and Fig. 6 & 7). The data revealed that gross returns in wheat was found higher in variety WH 1142 (141946 Rs./ha) over all the varieties during 2017-18. Same trend has been seen during 2018-19. The data revealed that the gross returns in wheat were found higher in 100% RDF (138391 Rs./ha) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19.

4.7.2 Cost of cultivation (₹/ha)

The data pertaining effect of the integrated nutrient management system on cost of cultivation in wheat are presented in (Table 31 and Fig. 6 & 7). The data revealed that cost of cultivation in all wheat varieties (88664 and 88919 Rs./ha) remain same during 2017-18 and 2018-19. Among the nutrient sources cost of cultivation in wheat was found minimum in control (83247 Rs./ha) during both year of study. Maximum cost of cultivation was incurred with 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) (100925 Rs./ha) during both year of study while minimum cost of cultivation incurred with control (81247 Rs./ha) during both year of study.

Table 29. Effect of varieties and integrated nutrient management system on mean available organic carbon, N, P and K content in soil at harvest in wheat

Treatments	Available nutrient in soil at harvest							
	Soil organic carbon (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)								
WH 1080	0.44	0.46	125.8	128.4	24.4	26.9	323.9	327.9
WH 1025	0.44	0.46	117.0	120.9	22.9	24.3	321.7	326.0
WH 1142	0.45	0.46	133.8	135.2	26.1	28.3	330.2	335.8
WH 711	0.45	0.46	127.5	131.4	25.0	27.0	326.1	331.6
SEm±	0.00	0.00	0.30	0.40	0.10	0.10	0.70	1.30
C.D. (p = 0.05)	NS	NS	0.90	1.30	0.50	0.50	2.30	4.40
Nutrient sources (N)								
Control	0.41	0.42	114.2	116.7	20.1	21.3	321.2	324.2
100% RDF	0.43	0.44	139.3	141.2	29.2	32.1	335.1	341.2
50% RDF + 50% RDF through FYM	0.45	0.46	121	124.2	23.1	24.5	319.7	324.5
50% RDF + 50% RDF through vermicompost	0.46	0.48	125	128.3	24.3	26.4	323.4	328.3
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.48	0.49	130.7	134.5	26.2	28.8	327.8	333.4
SEm±	0.00	0.00	0.40	0.40	0.10	0.10	0.90	0.90
C.D. (p = 0.05)	0.01	0.01	1.30	1.30	0.30	0.30	2.70	2.50
Factor (N) at same level of V	0.01	0.01	2.59	2.64	0.70	0.70	5.47	5.50
Factor (V) at same level of N	0.01	0.01	2.44	2.61	0.76	0.76	5.26	6.31

Table 30. Effect of varieties and integrated nutrient management system on mean available Fe, Mn, Zn and Cu (mg/kg) content in soil at harvest in wheat

Treatments	Available DTPA-Extractable Micronutrients (mg/kg)							
	Available Fe		Available Mn		Available Zn		Available Cu	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)								
WH 1080	14.41	15.25	3.13	3.26	2.04	2.11	1.42	1.48
WH 1025	13.50	14.50	2.94	3.10	1.83	1.96	1.35	1.41
WH 1142	15.96	17.30	3.66	3.79	2.23	2.37	1.56	1.59
WH 711	14.32	15.83	3.38	3.50	2.17	2.24	1.46	1.51
SEm±	0.10	0.14	0.02	0.02	0.01	0.01	0.01	0.01
C.D. (p = 0.05)	0.35	0.48	0.08	0.08	0.03	0.05	0.02	0.02
Nutrient sources (N)								
Control	12.76	13.23	2.51	2.61	1.65	1.71	1.31	1.36
100% RDF	13.91	14.52	2.81	2.87	1.83	1.93	1.38	1.41
50% RDF + 50% RDF through FYM	14.12	15.71	3.43	3.62	2.17	2.27	1.41	1.48
50% RDF + 50% RDF through vermicompost	15.13	16.41	3.72	3.83	2.26	2.37	1.52	1.58
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	16.81	18.71	3.91	4.12	2.41	2.57	1.61	1.67
SEm±	0.11	0.11	0.02	0.02	0.01	0.01	0.01	0.01
C.D. (p = 0.05)	0.33	0.32	0.05	0.05	0.03	0.03	0.02	0.02
Factor (N) at same level of V	0.68	0.69	0.10	0.10	0.06	0.06	0.04	0.05
Factor (V) at same level of N	0.68	0.74	0.12	0.12	0.06	0.07	0.04	0.05

4.7.3 Net returns (₹/ha)

The data pertaining effect of the integrated nutrient management system on net returns in wheat are presented in (Table 31 and Fig 6 & 7). The data revealed that net returns in wheat was found higher in variety WH 1142 (53282 Rs./ha) over all the varieties during 2017-18. Same trend has been seen during 2018-19. Whereas minimum net returns was recorded in variety WH 1025 during 2017-18 (20571 Rs./ha) and 2018-19 (23360 Rs./ha). Among different nutrient source net returns in wheat was found higher in 100% RDF (51227 Rs./ha) over all the nutrient sources during 2017-18. Same trend has been seen during 2018-19. Whereas, minimum net returns was recorded in 50% RDF + 50% RDF through vermicompost treatment during 2017-18 (28901 Rs./ha) and 2018-19 (31386 Rs./ha), respectively.

4.7.4 Benefit cost ratio (BCR)

The data pertaining effect of the integrated nutrient management system on benefit cost ratio in wheat are presented in (Table 31 and Fig 6 & 7). The data revealed that benefit cost ratio was found higher in variety WH 1142 (1.60) over all the varieties during 2017-18. Same trend has been seen during 2018-19. Whereas, minimum benefit cost ratio was obtained in variety WH 1025 (1.23 and 1.26) during 2017-18 and 2018-19. Among nutrient source highest benefit cost ratio was recorded in 100% RDF (1.59) over all the nutrient sources during both year of study. Whereas, minimum benefit cost ratio was recorded in 50% RDF + 50% RDF through vermicompost (1.28 and 1.31) during 2017-18 and 2018-19, respectively.

Table 31. Effect of varieties and integrated nutrient management system on economics of wheat production

Treatments	Gross returns (₹/ha)		Cost of cultivation (₹/ha)		Net returns (₹/ha)		Benefit cost ratio (BCR)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Varieties (V)								
WH 1080	136753	140414	88664	88919	48089	51495	1.54	1.58
WH 1025	109235	112279	88664	88919	20571	23360	1.23	1.26
WH 1142	141946	145738	88664	88919	53282	56828	1.60	1.64
WH 711	138605	142473	88664	88919	49943	53558	1.56	1.60
Nutrient sources (N)								
Control	118636	121578	83247	83721	35390	37857	1.43	1.45
100% RDF	138391	142188	87164	88169	51227	54019	1.59	1.61
50% RDF + 50% RDF through FYM	128763	132317	90546	91311	38217	41006	1.42	1.45
50% RDF + 50% RDF through vermicompost	130312	133969	101410	102583	28901	31386	1.28	1.31
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	132909	136381	99077	100544	33831	35837	1.34	1.36

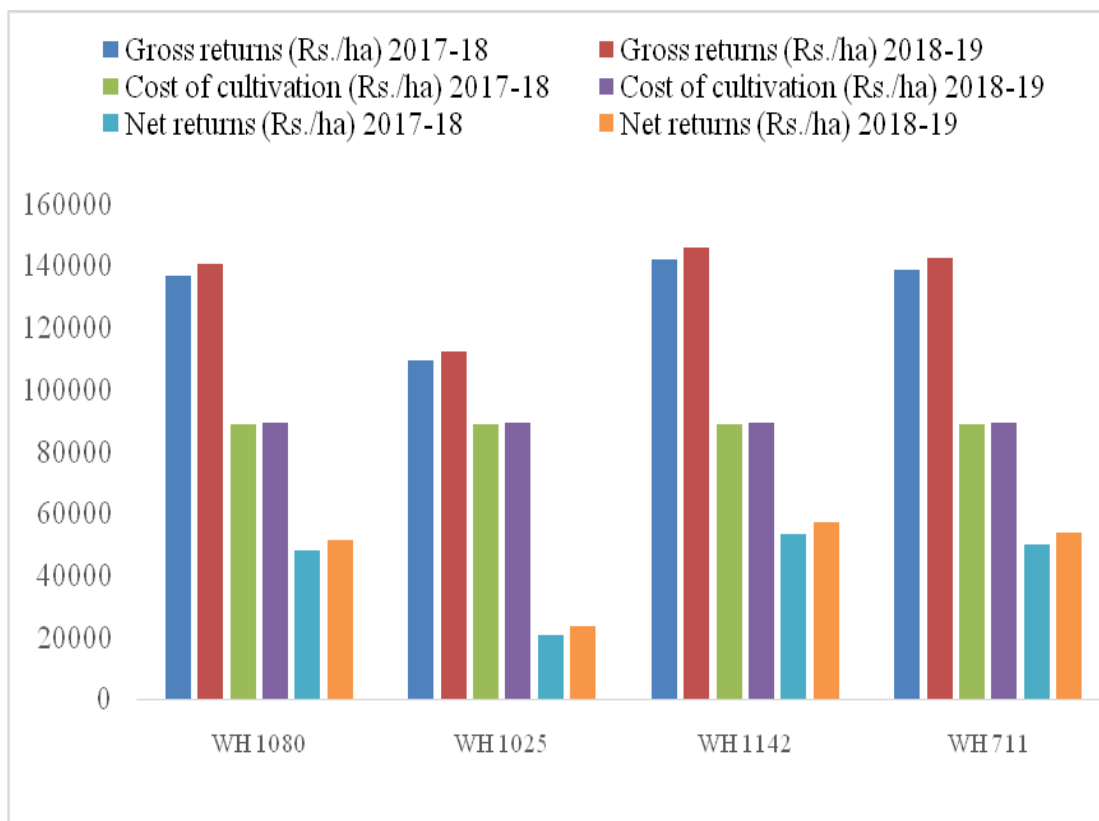


Fig. 4: Economic of different varieties of wheat during 2017-18 and 2018-19

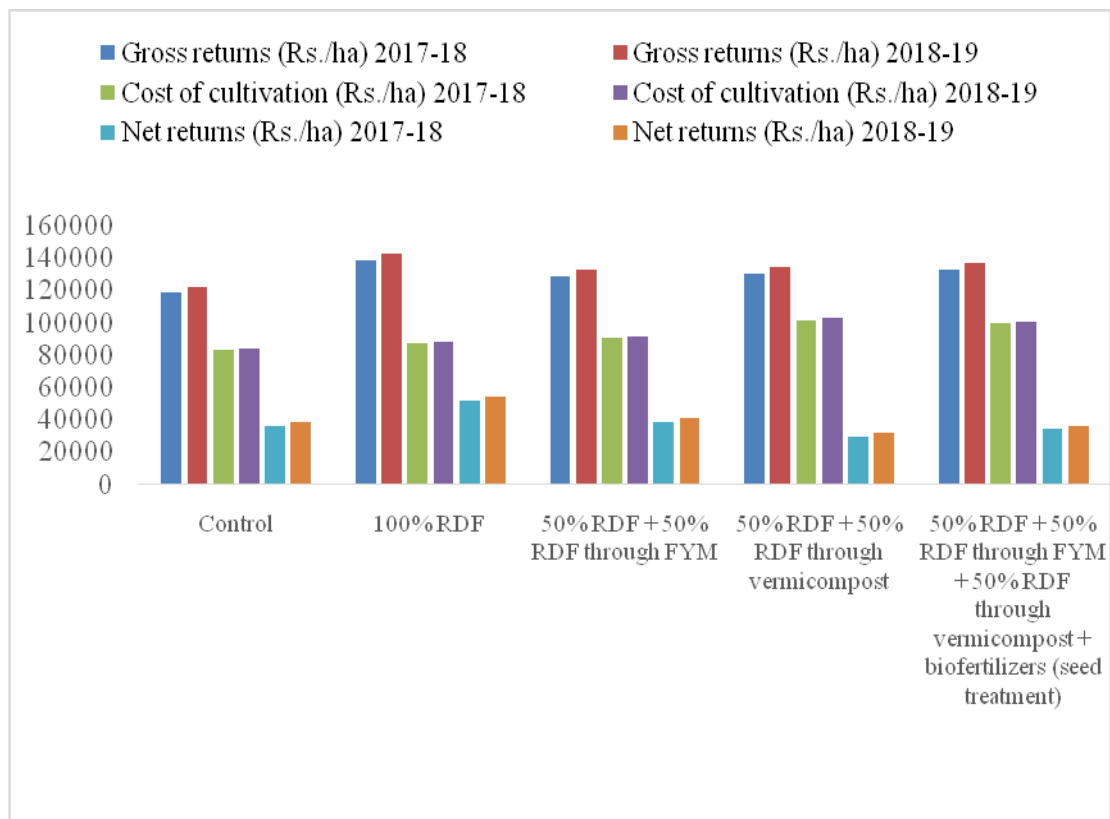


Fig. 5: Economic of different nutrient sources during 2017-18 and 2018-19 in wheat

CHAPTER-V

DISCUSSION

In this chapter, the results of the present investigation entitled as “**Performance of different varieties of wheat (*Triticum aestivum* L.) under integrated nutrient management system**” are discussed to know how the different treatments affected the various parameters associated with the crop under investigation. The results achieved during the study are discussed under the following headings: -

5.1 Growth, phenology, yield attributes and yields

5.2 Quality of wheat, nutrient content and uptake and nutrient status of the soil at harvest

5.3 Economics

5.1.1 Growth

Significantly higher mean plant population, plant height, shoot length, leaf area index, leaf area duration and dry matter accumulation were recorded in variety WH 1142 over WH 1080 WH 1025 and WH 711 (Table 9 to Table 14) during both year of study. The mean plant population of WH 1142 at 30 DAS was significantly increased to 4.9%, 2.6% and 1.3% over varieties WH 1025, WH 1080 and WH 711 during 2017-18 and 4.9%, 3.1% and 1.2% during 2018-19, respectively. The mean plant height of WH 1142 at 30, 60, 90, 120 DAS and at harvest significantly increased to 12.0%, 8.5%, 4.4%, 2.2% and 2.0% during 2017-18 and 12.1%, 6.2%, 4%, 7.9% and 6.4% during 2018-19 respectively over variety WH 1025. Similar trend were seen over varieties WH 1080 and WH 711 during both year of study. Significant increase in mean leaf area index (11.5%, 19.9%, 14.9%, 23.8% and 10.8%, 15.5%, 12.3% and 24.5%) and mean leaf area duration (10.9%, 6.9%, 2.8%, 3.0% and 13.2%, 7.7%, 4.2 %, 3.6%) in variety WH 1142 at 30, 60, 90 and at 120 DAS over WH 1025 during 2017-18 and 2018-19, respectively. Similar trend has been seen over varieties WH 1080 and WH 711 during both year of study. Significantly higher mean dry matter accumulation per metre row length in wheat variety WH 1142 in tune of 14.7%, 6.8%, 6.5%, 7.2% and 4.2% during 2017-18 and 10.3%, 7.6%, 11.2%, 8.2% and 6.7% during 2018-19 respectively over variety WH 1025. Varieties WH 1080 and WH 711 followed the similar trend during both year of study. Significantly longer mean shoot length was observed in variety WH 1142 in tune of 4.3%, 3.2% and 1.0% and 4.7%, 3.4% and 1.4% over varieties WH 1025, WH 1080 and WH 711 during 2017-18 and 2018-19 respectively. The performance of variety WH 1142 over WH 1025, WH 1080 and WH 711 in term of all growth attributes is achieved due to high genetic potential. These results are in line with findings of Hazari *et al.* (2019), Kumar *et al.* (2018), Singh *et al.* (2021), Manschadi and Soltani (2021), Kumar *et al.* (2019), Khatik *et al.*

(2021), Singh *et al.* (2013), Chauhan *et al.* (2020), Hiltbrunner and Liedgens (2008) and Wang *et al.* (2021).

Among nutrient sources 100% RDF through inorganic sources significantly increase the mean plant population per metre row length, plant height, shoot length, leaf area index, leaf area duration and dry matter accumulation over other nutrient combination during 2017-18 and 2018-19, respectively (Table 10 to Table 15). Mean plant population per metre row length with application of 100% RDF through inorganic sources at 30 DAS was increased to 16.6%, 9.5%, 5.5% and 4.4% in 2017-18 and 20.8%, 9.0%, 7.2% and 4.6% in 2018-19 over control, 50% RDF + 50% RDF through FYM, 50% RDF + 50% RDF through vermicompost and 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment). Significantly higher mean plant height (22.5%, 14.7%, 10.9%, 9.3, 7.9% and 24.7%, 18.7%, 14.1%, 9.1%, 9.0%) and dry matter accumulation per plant (38.8%, 21.2%, 15.3%, 25.6%, 11.8% and 38.0%, 22.2%, 19.8%, 26.7%, 12.5%) with application of 100% RDF through inorganic sources in 2017-18 and 2018-19 over control at 30, 60, 90, 120 DAS and at harvest respectively. Application of 100% RDF through inorganic sources recorded significantly higher mean LAI (22.4%, 11.6%, 10.6%, 12.8% and 19%, 12%, 13.5%, 18.1%) and LAD (12.1%, 7.7%, 7.0%, 8.35% and 19.6%, 8.5%, 7.8%, 9.0%) at 30, 60, 90 and 120 DAS over control during both year of study. This might be attributed to quick release of nutrients in sufficient quantity by fertilizers during early stage of plants when nutrients are required for proper root growth and establishment. Availability of nutrient particularly nitrogen to wheat crop at peak demand provide favourable condition to increase more amino acid and carbohydrate synthesis which is ultimate product of photosynthesis process. The development of more sink attributed due to quick release of nutrient through chemical sources, which help in distribution and translocation of photosynthate to sink which leads to higher growth attribute in wheat crop (Zaki *et al.*, 2012). These findings are akin to those of Pandey *et al.* (2009), Kakraliya *et al.* (2017), Akhtar *et al.* (2018) and Reddy Tummala *et al.* (2018).

Among integrated approach 50% RDF through inorganic source + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers gives higher mean plant population, plant height, leaf area index, leaf area duration, dry matter accumulation and shoot length over control, 50% RDF through inorganic source + 50% RDF through FYM, 50% RDF through inorganic source + 50% RDF through vermicompost (Table 10 to Table 15). This might be attributed due to supply of both macro and micronutrients to plants through FYM and vermicompost during the entire growth period. Besides, FYM and vermicompost also help improve physical, chemical and biological properties of soil which favour better plant growth and development. Organic source of plant nutrients releases adsorbed ions slowly for the entire growth period resulting in better nutrient availability for proper growth of crop

plants. Besides, they also add organic matter to the soil which increases microbial flora in rhizosphere which makes plants nutrients in available form to plants. Seed treatment with biological nitrogen fixation and phosphate solubilizing bacteria improve seed vigour and germination of wheat (Brar *et al.*, 2015). Similar results were also reported by Singh *et al.* (2011), Kumar *et al.* (2015), Mondal *et al.* (2015), Kakraliya *et al.* (2017), Saleemi *et al.* (2017), Akhtar *et al.* (2018), Rani and Sharma (2018), Reddy Tummala *et al.* (2018) and Mangaraj *et al.* (2022).

5.1.2 Phenological parameter

Phenological events can affect the growth and yield of the crop (Table 16). Significantly more mean number of days taken to 50% heading (93.9 days) and 50% anthesis (98.6 days) were recorded in variety WH 1142 and while minimum mean number of days taken for 50% heading and 50% anthesis was recorded in WH 1025 (87.24 and 92.62 days respectively), during 2017-18. Same trend has been seen 2018-19. Longer duration in variety WH 1142 is due to genetic constituent of the cultivar. Significantly higher mean leaf production rate (LPR) recorded in the variety WH 1142 (0.54 leaf/day), whereas minimum was observed in the WH 1025 (0.49 leaf/day) during 2017-18 respectively and same trend has been seen during 2018-19. Higher mean LPR was due to more number of leaf productions and higher value of mean LAI which is inherent property of variety. The differential response to various phenophases (in days) might also be partially attributed to their genetic difference which have reflected in the form of different number of days to reach a particular phenophase and different response to environmental conditions (Suleiman *et al.*, 2014). The results are in close vicinity with the findings of Raza *et al.* (2018), Hazari *et al.* (2019), Awulachew (2019), Gemechu *et al.* (2019), Legesse *et al.* (2019), Chauhan *et al.* (2020), Joshi *et al.* (2022) and Ajay *et al.* (2022). Significantly more number of days taken to 50% heading (94.9 days) and 50% anthesis (101.2 days) were seen with 100% RDF and during 2017-18 respectively (Table 15). Significantly higher panicle emergence rate (length increase per time) and leaf production rate (leaf/day) were recorded with 100% RDF (0.17 and 0.58 respectively) in 2017-18. Same trend has been seen during 2018-19. This is due to continuous supply of macronutrients (N, P and K) during crop growth stage. Among integrated approach 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) perform better in all yield attributes parameter over control, 50% RDF + 50% RDF through FYM and 50% RDF + 50% RDF through vermicompost. The integrated approach balanced the supply of macro and micronutrients, improve soil health and supply nutrients for entire duration of crop slowly through organic in conjugation with chemical fertilizers which quickly release the nutrient and meet the balanced demand by crop. The higher value of growth attributes like length of panicle, leaf area index and leaf area duration have cumulative

effect on higher PER and LPR. These findings are akin to those of Mondal *et al.* (2015), Redda and Abay (2015), Khan *et al.* (2016) and Singh *et al.* (2018).

5.1.3 Yield attributes

Significantly higher mean number of effective tillers/m², spike length, number of grains/spike, grains weight/spike, and 1000-grain weight was recorded in variety WH 1142, whereas minimum value of above yield attributes were observed in WH 1025 during 2017-18 and same trend has been seen during second year (Table 16). Percentage increase in variety WH 1142 over variety WH 1025 were 8.9%, 25.4%, 43.9%, 19.4% and 7.4% respectively during 2017-18 for mean number of effective tillers/m², spike length, number of grains/spike, grains weight/spike, and 1000-grain weight. Same trend has been seen during 2018-19 (Table 16). The differences in yield attributes traits were due to genetic variability. The high yielding varieties developed by plant breeders have genetic potential of producing higher yield attributes (Krishna and Veetil, 2022). The variety WH 1142 having highest yield potential which give superiority over WH 711, WH 1080 and WH 1025. These findings are akin to those of Alam *et al.* (2013), Singh *et al.* (2013), Doring *et al.* (2015), Kumar *et al.* (2015), Kumar *et al.* (2018), Tahir *et al.* (2018), Khan *et al.* (2019), Singh *et al.* (2020), Khatik *et al.* (2021), Kumari *et al.* (2021), Manschadi and Soltani (2021) and Singh *et al.* (2021). Significantly higher mean number of effective tillers/m², spike length, number of grains/spike, grains weight/spike, and 1000-grain weights were recorded in 100% RDF during both years. Percentage increase in treatment receiving 100% RDF over control was 9.0%, 21.3%, 23.9%, 16.7% and 8.8% for mean number of effective tillers/m², spike length, grains/spike, number of grains weight/spike, and 1000-grain weight respectively during 2017-18. Similar trend has been seen during 2018-19 (Table 16). Minimum yield attributes recorded from control treatment during 2017-18 and 2018-19. Quick availability of nitrogen through chemical sources resulted in stimulatory impact on number of tillers in wheat through production of cytokines and rapid multiplication of synthesized carbohydrates which results into rapid increase in volume of protoplasm, number of cell and accumulation of more carbohydrate and its partitioning resulted in more mean number of effective tillers/m², spike length, number of grains/spike, grains weight/spike and 1000-grain weight (Dhiman *et al.* 2019). Among integrated combination, treatment receiving 50% RDF + 50% RDF through FYM and 50% RDF + 50% RDF through vermicompost perform better yield attributes over 50% RDF + 50% RDF through FYM and 50% RDF + 50% RDF through vermicompost. Integrated approach leads to supply of nutrients throughout the growth period leads more favourable environment around rhizosphere, synthesis of amino acid, protein, carbohydrate and other important organic constituent of cell leading to higher value of yields attributes. These findings are akin to those of El-Sirafy *et al.* (2006), Gupta and Aggarwal (2008), Pandey *et al.* (2009), Behera and Rautaray. (2010), Singh *et al.* (2011), Mane *et al.* (2014), Hasim *et al.*

(2015), Mayer *et al.* (2015), Bhatt *et al.* (2016), Argal *et al.* (2017), Kakraliya *et al.* (2017), Molla *et al.* (2018), Tahir *et al.* (2018), Arif *et al.* (2019) and Walia and Patidar. (2021).

5.1.4 Yields

Significantly higher mean of grain yield, straw yield and harvest index were calculated in variety WH 1142 during both years whereas lowest mean of grain yield, straw yield and harvest index were recorded in variety WH 1025 during both the years (Table 17). Significantly higher percentage of mean grain yield and straw yield (35.4% and 19.8%) were observed in variety WH 1142 over variety WH 1025 during 2017-18. Same trend has been seen during 2018-19. The increase in grain yield, straw yield and harvest index of wheat was due to significantly higher plant population, plant height, dry matter accumulation, leaf area index, leaf area duration, shoot length, days taken to 50% heading, days taken to 50% anthesis, panicle emergence rate, leaf production rate, number of effective tillers/m², number of grains/spike, grains weight/spike, spike length and 1000-grain weight etc. Because of genetic variation, different varieties of crop may differ in growth and development behaviour and response to different management practices (Singh *et al.* 2010). The results are in close vicinity with the findings of Alam *et al.* (2013), Singh *et al.* (2013), Doring *et al.* (2015), Khavse *et al.* (2015), Kumar *et al.* (2015), Hazari *et al.* (2019), Kumar *et al.* (2019), Chauhan *et al.* (2020), Gupta *et al.* (2020), Khatik *et al.* (2021), Kumari *et al.* (2021), Manschadi and Soltani (2021), Joshi *et al.* (2022) and Sirohi *et al.* (2022). The grain yield and straw yield were significantly increased in 100% RDF through inorganic sources during both years over all other nutrient sources (Table 17). Balanced application of fast releasing nutrient might have contributed to higher growth, phenological and yield attributes for higher yields of wheat crop. Mineralisation of nutrient takes place after 7-8 days of application, more number of sink is developed and more accumulation of carbohydrate takes place which gives more production of dry matter (Bhattacharyya *et al.* 2016). The results are in close vicinity with the findings of El-Sirafy *et al.* (2006), Hasim *et al.* (2015), Molla *et al.* (2018) and Hammad *et al.* (2020). Among integrated system, treatment receiving 50% RDF + 50% RDF through FYM + 50% through vermicompost + biofertilizers (seed treatment) resulted in significantly higher yields over 50% RDF + 50% RDF through FYM or 50% RDF + 50% RDF through vermicompost. Judicious use of chemical nutrient, organic nutrient and biofertilizers, supply of nutrients in early stage through inorganic source, and at later stage of crop growth through organic section and biofertilizers solubilise through release of organic acid which might have prevented the immobilization of nutrient. Organic source also improve soil physical and biological health. They supply balanced amount of macro and micro-nutrient throughout the crop growth stage. The results are in close vicinity with the findings of Gupta and Aggrawal. (2008), Kumar *et al.* (2015), Mayer *et al.* (2015), Khan *et al.* (2017), Verma *et al.* (2017) and Kalhapure *et al.* (2020). Significantly maximum mean grain and straw yield was

recorded with interaction between WH 1142 and 100% RDF through inorganic sources during both year of study (Table 18, 19, 20 & 21). This may be due to high genetic potential of wheat varieties and quick supply of nutrient through inorganic fertilizers. Harvest index didn't differ significantly due to interaction between varieties and nutrient sources during both years of study (Table 17). These results are supported by the finding of Gashaw *et al.* (2013), Swain *et al.* (2014), Kandil *et al.* (2016), Zhang *et al.* (2020) and Kumar *et al.* (2021).

5.2.1 Quality

Significantly higher mean protein and starch content in grain were observed in variety WH 1142 in both years (Table 22). Whereas, lowest value of mean protein and starch content was recorded in variety WH 1025 during both the years of study this may be due to the genetic property of variety to uptake more nitrogen and synthesize more protein and carbohydrate over other variety. These findings are akin to those of Hiltbrunner and Liedgens. (2008), Gashaw *et al.* (2013), Gerba *et al.* (2013), Doring *et al.* (2015), Widodo *et al.* (2015), Arif *et al.* (2019) and Gemechu *et al.* (2019).

Application of 100% RDF through inorganic sources resulted in significantly higher protein (10.4%) and starch (5.6%) content in grain during both years over control treatment (Table 22). Among integrated nutrient management system, treatment receiving 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) resulted in significantly higher protein and starch content over 50% RDF + 50% RDF through FYM and 50% RDF + 50% RDF through vermicompost. It may be due to increased uptake of nitrogen, phosphorus, and sulphur by grain and straw and their total uptake from organic and inorganic sources. Nitrogen is an integral part of protein, and phosphorus is structural component of certain co-enzymes involved in protein synthesis. Sulphur is a constituent of three amino acids viz. methionine, cysteine and cystine, which are the building blocks of protein (Ramesh *et al.* 2005). Sulphur also helps in conversion of these amino acids into high quality protein. Starch is an insoluble, non-structural carbohydrate composed of α -glucose polymers. It is synthesized by plants to store energy in a dense, osmotically inert form. Higher the interception of solar radiation during photosynthesis more is the synthesis of starch by wheat plant during day time. The higher value of growth and phenological attributes gives favourable condition for starch formation. The results are in close vicinity with the findings of Gashaw *et al.* (2013), Gerba *et al.* (2013), Singh, 2017, Dereje *et al.* (2019) and Hammad *et al.* (2020).

5.2.2 Nutrient studies

5.2.2.1 Nutrient content and uptake by grain and straw at harvest

Among the varieties, the significantly higher mean nitrogen, phosphorus and potassium content and uptake by grain and straw were recorded in WH 1142 over WH 1025 in both years (Table 23 to 26). WH 1142 took up higher percentage of mean nitrogen (9.1%,

6.6%, 47.7% and 27.6%), phosphorus (2.2%, 11.4%, 38.3% and 33.4%) and potassium (7.5, 13.3, 45.4 and 35.7%) content and uptake by grain and straw over WH 1025 during 2017-18. Similar trend was seen during 2018-19. This may be due to inherent ability of cultivar to absorb more nutrients. Due to robust root hair growth and high yielding nature of modern or dwarf cultivar the nutrient removal by crop is higher over the traditional variety. These findings are akin to those of Rodgers and Barneix (1988), Singh and Arora (2001), Buchi *et al.* (2016), Daba (2017), Khan *et al.* (2017), Arif *et al.* (2019), Tahir *et al.* (2020), Khatik *et al.* (2021) and Manschadi and Soltani (2021).

Among the different nutrient sources, the significantly higher nitrogen, phosphorus and potassium content and uptake by grain and straw were recorded in 100% RDF over the control treatment in both years (Table 23 to 26). This may be due to quick supply of available plant nutrients to plants through inorganic fertilizers. The more availability of nutrients in the soil leads to higher uptake by wheat crop. These findings are akin to those of Rodgers and Barneix (1988), Shafi *et al.* (2012) and Buchi *et al.* (2016). Among integrated system treatment application of 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) resulted in gives significantly higher nitrogen, phosphorus and potassium content and uptake by grain and straw over 50% RDF + 50% RDF through FYM or 50% RDF + 50% RDF through vermicompost in both years. This might be due to enhance roots cation exchange capacity and increased the NPK absorption by wheat crop. Further organic sources continuously supply the plant nutrient throughout the life cycle of wheat crop. Wheat crop absorb more nutrient even in the low water availability in soil from organic sources, because these improve physical and biological properties of soil. These findings are akin to those of Verma *et al.* (2016) and Khan *et al.* (2017).

5.2.2.2 Nitrogen removal ratio and use efficiency of nitrogen

Among the varieties, the significantly higher mean nitrogen removal ratio, agronomic efficiency of nitrogen, physiological efficiency of nitrogen and recovery efficiency of nitrogen by wheat crop were recorded in variety WH 1142 over the variety WH 1025 during 2017-18 and 2018-19 (Table 27 & 28). Significantly higher percentage of mean nitrogen removal ratio (50.0% and 48.6%), agronomic efficiency of nitrogen (246.4% and 260.8%), physiological efficiency of nitrogen (124.9 and 117.1%) and recovery efficiency of nitrogen (154.0% and 140.6%) were recorded in WH 1142 over the variety WH 1025 during 2017-18 and 2018-19. This may be due to cumulative effect of higher grain and straw yield and higher content and uptake of nutrient by grain and straw of cultivar due to his genetic potential. The results are in close vicinity with the findings of Gill *et al.* (2004), Buchi *et al.* (2016) and Daba (2017).

Among the different nutrient sources, significantly higher percentage of mean nitrogen removal ratio (29.2% and 26.1%), agronomic efficiency of nitrogen (36.2% and

33.1%), and recovery efficiency of nitrogen (93.7% and 72.95%) by wheat crop were in 100% RDF over the treatment receiving 50% RDF + 50% RDF through FYM treatment during both year (Table 27 & 28). Significantly higher percentage of mean physiological efficiency of nitrogen (48.6% and 54%) was obtained 50% RDF + 50% RDF through FYM over the treatment receiving 100% RDF. This may be due to the higher grain and straw yield and higher content and uptake of nutrient by grain and straw at harvest. The results are in close vicinity with the findings of Singh and Arora. (2001), Jahan *et al.* (2018), Faizly *et al.* (2020), Lu *et al.* (2020) and Darjee *et al.* (2022).

5.2.3 Nutrient status of soil at harvest

5.2.3.1 Organic carbon and available N, P and K in soil at harvest

Among the varieties, the significantly higher mean available N, P and K content in soil at harvest were recorded in variety WH 1142 over the variety WH 1025 during 2017-18 and 2018-19, respectively, which is higher than the initial status of soil (Table 29). Significantly higher percentage of mean organic carbon in soil at harvest was recorded in WH 1142 over the variety WH 1025 in both years but difference was non significant (Table 29). This may be due to varietal trait. These findings are akin to those of Alam *et al.* (2013), Kumar *et al.* (2018), Daba (2017), Arif *et al.* (2019), Manschadi and Soltani (2021), Singh and Verma (2021) and Ndjadi *et al.* (2016). Mean higher percentage of available N (24.1% and 25.4%), P (2.8% and 11.4%) and K (5.4% and 7.2%) was recorded in WH 1142 over initial status of soil. This might be attributed due to rapid mineralization of N, P and K through applied inorganic fertilizers. Among the different nutrient sources, significantly higher percentage of mean available N (29.2% and 31.0%), P (15.0% and 26.4%) and K (7.0% and 8.9%) in soil at harvest was recorded in 100% RDF over the initial status of soil during 2017-18 and 2018-19, respectively (Table 29). This might be due to the rapid mineralization of plant nutrients applied through fertilizers. Significantly higher percentage of mean organic carbon (17.1 and 19.5%) in soil at harvest was recorded in 50% RDF through inorganic sources + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) over initial status of soil during 2017-18 and 2018-19, respectively (Table 29). This might be due to the fact that FYM and vermicompost contain macro and micronutrients and supply only 70% of contained nutrients to first crop. The results are in close vicinity with the findings of Bhattacharyya *et al.* (2007), Bhatt *et al.* (2016), Bharali *et al.* (2017), Datta *et al.* (2018) and Darjee *et al.* (2022).

5.2.3.2 DTPA-extractable available Fe, Mn, Zn and Cu in soil at harvest

Among the varieties, the significantly higher mean available Fe, Mn, Zn and Cu content in soil at harvest were recorded in variety WH 1142 over initial status during 2017-18 and 2018-19 respectively (Table 30). Variety WH 1142 resulted in higher mean available Fe (18.7% and 28.6%), Mn (28.4% and 33.0%), Zn (26.7% and 34.7%) and Cu (13.9% and

16.1%) over initial status in soil during 2017-18 and 2018-19, respectively. This might be varietal trait and its genetic potential to uptake nutrient from soil and its availability after uptake in soil at harvest. The results are in close vicinity with the finding of Alam *et al.* (2013), Kumar *et al.* (2018), Daba (2017), Arif *et al.* (2019), Manschadi and Soltani (2021), Singh and Verma (2021) and Ndjadi *et al.* (2016). Among different nutrient sources, the significantly higher mean available Fe (25.0% and 39.1%), Mn (37.2% and 44.6%), Zn (36.9% and 46.0%) and Cu (17.5% and 21.9%) content in soil at harvest were recorded in 50% RDF through inorganic sources + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) over the initial status during 2017-18 and 2018-19 respectively (Table 30). Organic sources provide all micronutrients with macronutrients in the soil. The results are in close vicinity with the findings of Abbasi and Yousra. (2012), Rathod *et al.* (2013), Rutkowska *et al.* (2014), Dhaliwal *et al.* (2021) and Singh and Saini (2022).

5.3 Effect on economics

The mean gross return, net return and BCR were maximum for variety WH 1142 (141946 Rs./ha, 53282 Rs./ha and 1.60), whereas lowest mean gross return, net return and BCR were recorded in variety WH 1025 (109235 Rs./ha, 20571Rs./ha and 1.23) during 2017-18 and similar trend has been seen during 2018-19 (Table 31). This might be due to higher grain and straw yield in variety WH 1142 and lowest in variety WH 1025 during both the years. The variety WH 1142 earned 159% and 143% net return over variety WH 1025 during 2017-18 and 2018-19, respectively (Table 31). The results are in close vicinity with the findings of Singh *et al.* (2010), Alam *et al.* (2013), Singh *et al.* (2013), Kumar *et al.* (2015), Khan *et al.* (2019), Gemechu *et al.* (2019) and Khatik *et al.* (2021). Application of 100% RDF resulted in highest mean gross return, net return and BCR (138391 Rs./ha, 51227 Rs./ha and 1.59) respectively over all other nutrient sources during 2017-18 and same trend has been seen during 2018-19. Among nutrient sources the lowest cost of cultivation (83247 and 83721 Rs./ha) was incurred by control treatment while maximum cost cultivation incurred with 50% RDF + 50% RDF through vermicompost (101410 and 102583 Rs./ha) during 2017-18 and 2018-19 (Table 31). The lowest cost of cultivation in control treatment is attributed by no application of input like fertilizers and pesticides while maximum with 50% RDF + 50% RDF through vermicompost due higher cost of vermicompost and their higher rate of application. The results are in close vicinity with the findings of Gupta and Aggarwal (2008), Shah and Kumar (2014), Kumar *et al.* (2015), Verma *et al.* (2015), Dawlatzai *et al.* (2016), Chaudhry *et al.* (2017), Parewa *et al.* (2019), Paik *et al.* (2020) and Tanwar *et al.* (2022).

CHAPTER-VI

SUMMARY AND CONCLUSION

In the present chapter the results of the present study entitled “Performance of different varieties of wheat (*Triticum aestivum* L.) under integrated nutrient management system” have been summarized on the basis of results as under:-

6.1 Growth

- 6.1.1 Variety WH 1142 registered higher mean plant population at 30 DAS, plant height, LAI, LAD, dry matter accumulation and shoot length of wheat at all growth stages in compare to all varieties during 2017-18 and 2018-19.
- 6.1.2 Application of 100% RDF resulted in significantly higher mean plant population (30 DAS), plant height and dry matter accumulation (30, 60, 90, 120 DAS and at harvest), LAI and LAD (30, 60, 90 and 120 DAS), and shoot length in compare to control, 50% RDF + 50% RDF through FYM, 50% RDF + 50% RDF through vermicompost and 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) during 2017-18 and 2018-19.
- 6.1.3 Application of 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) resulted in higher growth parameters over 50% RDF + 50% RDF through FYM and 50% RDF + 50% RDF through vermicompost during 2017-18 and 2018-19.

6.2 Phenological parameter

- 6.2.1 Variety WH 1142 took more mean number of days to 50% heading and 50% anthesis over all other varieties during both year of study. Application of 100% RDF took more number of days 50% heading and 50% anthesis over control, 50% RDF + 50% RDF through FYM, 50% RDF + 50% RDF through vermicompost and 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) during 2017-18 and 2018-19.
- 6.2.2 Control treatment recorded minimum numbers of days 50% heading and 50% anthesis over all other nutrient sources during 2017-18 and 2018-19.
- 6.2.3 Mean panicle emergence rate (PER) was non-significant during 2017-18 and 2018-19 in varieties and nutrient sources.
- 6.2.4 Mean leaf production rate (LPR) of WH 1142 was higher over all the varieties during 2017-18 and 2018-19.
- 6.2.5 Percentage increase in mean LPR in 100% RDF over control treatment was 34.9% 2017-18 and 56.1% in 2018-19. Mean PER was non-significant in 2017-18 and it was significantly higher with 47.7% over control treatment in 2018-19.

- 6.2.6 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) gives good result over 50% RDF + 50% RDF through FYM and 50% RDF + 50% RDF through vermicompost in phenological studies during 2017-18 and 2018-19.

6.3 Yield attributes and yields parameters

- 6.3.1 Variety WH 1142 produced higher mean number of effective tillers/m², number of grains/spike, grain weight/spike; spike length and 1000-grain weight respectively over all varieties during 2017-18 and similar trend was reported in 2018-19.
- 6.3.2 Significantly higher mean number of effective tillers/m², number of grains/spike, grain weight/spike, spike length and 1000-grain weight was recorded in 100% RDF over all other nutrient sources during 2017-18. Similar trend has been seen during 2018-19.
- 6.3.3 Application of 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) significantly increased mean yield attributes over 50% RDF + 50% RDF through FYM and 50% RDF + 50% RDF through vermicompost during 2017-18 and 2018-19.
- 6.3.4 Mean grain yield and straw yield were significantly higher in WH 1142 respectively over all other varieties during 2017-18 and similar trend was observed in 2018-19.
- 6.3.5 Significantly higher mean grain yield and straw yield were recorded in treatment receiving 100% RDF over the all nutrient sources during 2017-18 and similar trend has been seen during 2018-19.
- 6.3.6 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) resulted significantly higher mean grain and straw yield over 50% RDF + 50% RDF through FYM and 50% RDF + 50% RDF through vermicompost during 2017-18 and 2018-19.
- 6.3.7 The mean harvest index of wheat was not significantly influenced by varieties and nutrient sources during 2017-18 and 2018-19.
- 6.3.8 Significantly higher mean grain yield and straw yield was recorded in interaction between variety WH 1142 and 100% RDF through inorganic sources during 2017-18 and 2018-19. The interaction effect of varieties and nutrient sources on harvest index was found to be non-significant during 2017-18 and 2018-19.

6.4 Quality

- 6.4.1 Significantly higher mean protein and starch content in grain was recorded in variety WH 1142 (11.7% and 62.1%) and lowest in variety WH 1025 (10.7% and 60.3%) during 2017-18. Similar trend is observed during 2018-19.
- 6.4.2 Significantly higher mean protein and starch content in grain were reported in treatment receiving 100% RDF (11.8% and 63.5%), whereas lowest in control

treatment (10.7% and 60.1%) during first year of studies and similar trend has been seen during second year of study.

- 6.4.3 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) gives significantly higher mean protein and starch content in grain over 50% RDF + 50% RDF through FYM and 50% RDF + 50% RDF through vermicompost during 2017-18 and 2018-19.

6.5 Nutrient content, uptake and efficiencies at harvest

- 6.5.1 Among all the varieties, the significantly higher mean N, P and K content in grain (1.7%, 0.51% and 0.48%) and straw (0.45%, 0.15% and 1.67%) at harvest were recorded in variety WH 1142 during 2017-18. Similar trend has been observed in 2018-19. Among all the varieties, the significantly lowest mean N, P and K content in grain (1.56%, 0.50% and 0.44%) and straw (0.43%, 0.13% and 1.47%) at harvest were recorded in variety WH 1080 during 2017-18. Similar trend has been observed in 2018-19.
- 6.5.2 Among different nutrient sources, significantly higher mean N, P and K content in grain (1.83%, 0.55% and 0.49%) and straw (0.46%, 0.15% and 1.71%) at harvest were recorded in 100% RDF during 2017-18. Similar trend has been observed in 2018-19. Among different nutrient sources, significantly lowest mean N, P and K content in grain (1.48%, 0.41% and 0.41%) and straw (0.42%, 0.35% and 1.45%) at harvest were recorded in control treatment during 2017-18. Similar trend has been observed in 2018-19.
- 6.5.3 Significantly higher mean N, P and K uptake by grain (86.7, 25.9 and 23.4 kg/ha) and straw (35.3, 11.6 and 130.9 kg/ha) at harvest were recorded in 100% RDF during 2017-18. Similar trend has been observed in 2018-19. Significantly lowest mean N, P and K uptake by grain (65.0, 18.1 and 18.2 kg/ha) and straw (29.2, 9.1 and 101.8 kg/ha) at harvest were recorded in control treatment during 2017-18. Similar trend has been observed in 2018-19.
- 6.5.4 Significantly highest mean nitrogen removal ratio was recorded in variety WH 1142 (0.60 and 0.55 kg/kg) and lowest in variety WH 1025 (0.40 and 0.37 kg/kg) during during 2017-18 and 2018-19. Among nutrient sources significantly highest mean nitrogen removal ratio was recorded in 100% RDF (0.62 and 0.58 kg/kg) and lowest in 50% RDF + 50% RDF through FYM (0.48 and 0.46 kg/kg) during 2017-18 and 2018-19.
- 6.5.5 Significantly highest mean agronomic use efficiency (9.1 and 9.8 kg/kg), physiological efficiency (85.7 and 79.9 kg/kg) and recovery efficiency (25.4 and 27.5%) were recorded in variety WH 1142 during 2017-18 and 2018-19.

6.5.6 Significantly highest mean agronomic use efficiency (8.24 and 9.05 kg/kg) and mean recovery efficiency (27.21 and 29.09%) were recorded in 100% RDF during 2017-18 and 2018-19, respectively. However, significantly highest mean physiological efficiency (99.4 and 94.5 kg/kg) was recorded in 50% RDF + 50% RDF through FYM during 2017-18 and 2018-19.

6.6 Nutrient status of soil at harvest

6.6.1 Among different varieties significantly higher mean available organic carbon, available N, available P and available K in soil at harvest were recorded in variety WH 1142 (0.45%, 133.8 kg/ha, 26.1 kg/ha and 330.2 kg/ha) during 2017-18 and similar trend has been reported in 2018-19. Significantly lowest mean available organic carbon, available N, available P and available K in soil at harvest were recorded in variety WH 1025 (0.44%, 117 kg/ha, 22.9 kg/ha and 321.7 kg/ha) during 2017-18. Similar trend has been reported in 2018-19.

6.6.2 Significantly higher mean available N, P and K in soil at harvest were recorded in treatment comprising 100% RDF (139.3, 29.2 and 335.1 kg/ha) over all other treatment during 2017-18 and similar trend has been reported in 2018-19.

6.6.3 Significantly higher mean available organic carbon content in soil at harvest was reported in treatment comprising 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) during 2017-18 (0.48%) and 2018-19 (0.49%).

6.6.4 Among different varieties significantly higher mean available Fe, Mn, Zn and Cu in soil at harvest were recorded in variety WH 1142 (15.96, 3.66, 2.33 and 1.56 mg/kg, respectively) and among nutrient sources it was recorded with 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) (16.81, 3.91, 2.41 and 1.61 mg/kg, respectively) during 2017-18. Similar trend has been during 2018-19.

6.7 Economics

6.7.1 All varieties have equal mean cost of cultivation (88664 and 88919 Rs./ha) during 2017-18 and 2018-19, respectively.

6.7.2 Highest mean gross return, net returns and BCR (141946 Rs./ha, 53282 Rs./ha and 1.60) incurred in wheat variety WH 1142 during 2017-18. Similar trend has been seen during 2018-19.

6.7.3 Lowest mean gross return, net returns and BCR (109235 Rs./ha, 20571 Rs./ha and 1.23) incurred in variety WH 1025 during 2017-18. Similar trend has been seen during 2018-19.

6.7.4 Maximum mean gross return and net returns (138391 Rs./ha and 51227 Rs./ha) was recorded with 100% RDF during 2017-18 and similar trend has been seen in 2018-19.

Among various nutrient sources lowest mean gross return and cost of cultivation (118636 and 83247 Rs./ha) were incurred in control treatment. While lowest mean net return (28901 Rs./ha) and BCR (1.28) recorded in 50% RDF + 50% RDF through vermicompost during 2017-18 and similar trend has been seen during 2018-19.

6.7.5 Maximum mean cost of cultivation (101410 Rs./ha) was incurred in treatment 50% RDF + 50% RDF through vermicompost during 2017-18 and similar trend has been seen during 2018-19.

6.7.6 Among integrated approach most efficient system is treatment receiving 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) in term of mean gross return (132909 and 136381 Rs./ha) and in term of mean net returns with 50% RDF + 50% RDF through FYM (38217 and 41006 Rs./ha) during 2017-18 and 2018-19 respectively.

Conclusion

Variety WH 1142 with application of 100% RDF through inorganic sources produced the highest mean grain yield and offered highest mean gross income, net return and BCR. This was followed by variety WH 711 with 100% RDF through inorganic sources during 2017-18 and 2018-19. Highest N, P, K content and uptake by grain and straw at harvest was obtained in variety WH 1142 over varieties WH 1080, WH 1025 and WH 711 and with 100% RDF among other nutrient sources. Maximum available mean organic carbon and DTPA-extractable micronutrient (Fe, Mn, Zn and Cu) was recorded with application of 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment).

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Appendix I

Interaction effect of varieties and nutrient sources on dry matter accumulation at 30 DAS in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	2.52	2.12	2.63	2.41	2.42
100% RDF	3.27	3.38	3.10	3.61	3.34
50% RDF + 50% RDF through FYM	2.28	2.73	2.99	2.38	2.59
50% RDF + 50% RDF through vermicompost	2.75	2.52	2.99	2.41	2.67
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	3.12	2.81	3.20	3.34	3.12
Mean	2.52	2.43	3.21	3.11	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.07		0.43		
Factor (V) at same level of N	0.14		0.40		

Appendix II

Interaction effect of varieties and nutrient sources on dry matter accumulation at 60 DAS in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	8.86	9.29	10.87	9.86	9.72
100% RDF	11.06	11.18	12.23	12.64	11.78
50% RDF + 50% RDF through FYM	11.74	10.96	11.35	10.45	11.12
50% RDF + 50% RDF through vermicompost	11.68	10.40	10.79	11.98	11.21
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	11.34	11.74	11.95	10.70	11.43
Mean	10.72	9.98	11.12	10.97	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.23		0.55		
Factor (V) at same level of N	0.19		0.58		

Appendix III

Interaction effect of varieties and nutrient sources on dry matter accumulation at 60 DAS in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	10.09	8.77	10.96	9.86	9.92
100% RDF	11.54	12.04	12.25	12.65	12.12
50% RDF + 50% RDF through FYM	11.63	10.73	11.32	11.59	11.32
50% RDF + 50% RDF through vermicompost	11.51	11.01	11.81	11.41	11.43
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	11.30	11.76	12.11	11.87	11.76
Mean	10.98	10.13	11.32	11.14	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.30		0.67		
Factor (V) at same level of N	0.24		0.73		

Appendix IV

Interaction effect of varieties and nutrient sources on dry matter accumulation at 90 DAS in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	12.08	12.90	14.17	13.68	13.21
100% RDF	14.86	14.43	16.27	15.36	15.23
50% RDF + 50% RDF through FYM	14.55	14.78	15.22	13.69	14.56
50% RDF + 50% RDF through vermicompost	15.01	14.34	15.00	14.70	14.76
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	15.25	14.45	14.84	15.24	14.94
Mean	13.92	14.12	15.14	14.56	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.14		0.46		
Factor (V) at same level of N	0.15		0.45		

Appendix V

Interaction effect of varieties and nutrient sources on dry matter accumulation at 90 DAS in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	12.08	12.90	14.17	13.68	13.21
100% RDF	14.86	14.43	16.27	15.36	15.23
50% RDF + 50% RDF through FYM	14.55	14.78	15.22	13.69	14.56
50% RDF + 50% RDF through vermicompost	15.01	14.34	15.00	14.70	14.76
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	15.25	14.45	14.84	15.24	14.94
Mean	13.92	14.12	15.14	14.56	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.17		0.81		
Factor (V) at same level of N	0.26		0.76		

Appendix VI

Interaction effect of varieties and nutrient sources on dry matter accumulation at 120 DAS in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	18.89	16.44	20.42	16.73	18.12
100% RDF	21.27	22.18	22.98	24.57	22.75
50% RDF + 50% RDF through FYM	20.93	20.52	21.22	21.81	21.12
50% RDF + 50% RDF through vermicompost	20.90	20.56	21.77	22.17	21.35
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	22.43	21.53	22.13	21.23	21.83
Mean	20.95	20.23	22.12	21.34	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.57		1.33		
Factor (V) at same level of N	0.46		1.42		

Appendix VII

Interaction effect of varieties and nutrient sources on dry matter accumulation at 120 DAS in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	18.37	15.55	20.02	18.91	18.21
100% RDF	22.77	23.10	23.66	22.79	23.08
50% RDF + 50% RDF through FYM	21.27	20.37	22.20	21.97	21.45
50% RDF + 50% RDF through vermicompost	22.44	20.65	21.05	21.95	21.52
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	21.07	22.57	23.67	22.07	22.34
Mean	21.34	20.45	22.92	21.75	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.70		0.76		
Factor (V) at same level of N	0.38		1.25		

Appendix VIII

Interaction effect of varieties and nutrient sources on dry matter accumulation at harvest in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	24.40	22.09	22.59	23.48	23.14
100% RDF	25.43	25.00	27.23	25.83	25.87
50% RDF + 50% RDF through FYM	23.70	24.12	25.30	24.60	24.43
50% RDF + 50% RDF through vermicompost	24.74	23.75	25.26	25.67	24.85
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	24.97	25.77	25.37	24.38	25.12
Mean	24.84	24.34	25.75	25.12	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.34		1.44		
Factor (V) at same level of N	0.46		1.37		

Appendix IX

Interaction effect of varieties and nutrient sources on dry matter accumulation at harvest in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	23.77	21.24	24.88	23.26	23.29
100% RDF	26.30	24.42	27.22	26.90	26.21
50% RDF + 50% RDF through FYM	24.07	26.07	24.97	24.57	24.92
50% RDF + 50% RDF through vermicompost	24.91	25.12	25.52	24.92	25.12
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	25.31	24.82	27.21	26.31	25.91
Mean	25.23	24.67	26.11	25.62	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.62		1.93		
Factor (V) at same level of N	0.64		1.91		

Appendix X

Interaction effect of varieties and nutrient sources on leaf area index (LAI) at 30 DAS in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	0.57	0.53	0.63	0.6	0.58
100% RDF	0.70	0.67	0.75	0.73	0.71
50% RDF + 50% RDF through FYM	0.62	0.58	0.66	0.64	0.62
50% RDF + 50% RDF through vermicompost	0.64	0.63	0.67	0.66	0.65
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.67	0.65	0.7	0.68	0.67
Mean	0.64	0.61	0.68	0.66	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.01		0.01		
Factor (V) at same level of N	0.01		0.02		

Appendix XI

Interaction effect of varieties and nutrient sources on leaf area index (LAI) at 30 DAS in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	0.62	0.58	0.68	0.65	0.63
100% RDF	0.74	0.71	0.79	0.77	0.75
50% RDF + 50% RDF through FYM	0.67	0.63	0.71	0.69	0.67
50% RDF + 50% RDF through vermicompost	0.68	0.67	0.71	0.70	0.69
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.71	0.69	0.74	0.72	0.71
Mean	0.68	0.65	0.72	0.70	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.01		0.01		
Factor (V) at same level of N	0.01		0.02		

Appendix XII

Interaction effect of varieties and nutrient sources on leaf area index (LAI) at 60 DAS in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	4.34	4.14	4.73	4.44	4.41
100% RDF	4.86	4.55	5.24	5.04	4.92
50% RDF + 50% RDF through FYM	4.69	4.24	5.20	4.85	4.74
50% RDF + 50% RDF through vermicompost	4.50	4.21	5.25	5.18	4.78
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	4.74	4.29	5.23	5.04	4.82
Mean	4.62	4.28	5.13	4.91	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.11		0.16		
Factor (V) at same level of N	0.07		0.21		

Appendix XIII

Interaction effect of varieties and nutrient sources on leaf area index (LAI) at 60 DAS in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	4.53	4.44	4.78	4.65	4.60
100% RDF	5.02	4.66	5.51	5.41	5.15
50% RDF + 50% RDF through FYM	4.73	4.52	5.02	4.85	4.78
50% RDF + 50% RDF through vermicompost	4.58	4.47	5.37	4.92	4.84
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	4.90	4.50	5.39	5.01	4.95
Mean	4.75	4.52	5.21	4.97	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.03		0.15		
Factor (V) at same level of N	0.05		0.14		

Appendix XIV

Interaction effect of varieties and nutrient sources on leaf area index (LAI) at 90 DAS in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	5.31	5.18	5.82	5.49	5.45
100% RDF	5.77	5.53	6.53	6.29	6.03
50% RDF + 50% RDF through FYM	5.56	5.33	6.26	5.96	5.78
50% RDF + 50% RDF through vermicompost	5.76	5.47	6.20	5.96	5.85
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	5.76	5.55	6.31	6.04	5.91
Mean	5.63	5.41	6.22	5.95	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.09		0.19		
Factor (V) at same level of N	0.07		0.21		

Appendix XV

Interaction effect of varieties and nutrient sources on leaf area index (LAI) at 90 DAS in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	5.30	5.16	5.86	5.63	5.49
100% RDF	5.94	5.82	6.71	6.46	6.23
50% RDF + 50% RDF through FYM	5.77	5.57	6.09	6.03	5.86
50% RDF + 50% RDF through vermicompost	5.70	5.59	6.46	5.92	5.92
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	5.96	5.86	6.32	6.08	6.05
Mean	5.73	5.60	6.29	6.02	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.08		0.20		
Factor (V) at same level of N	0.07		0.21		

Appendix XVI

Interaction effect of varieties and nutrient sources on leaf area index (LAI) at 120 DAS in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	2.48	2.28	2.88	2.68	2.58
100% RDF	2.74	2.64	3.24	3.04	2.91
50% RDF + 50% RDF through FYM	2.71	2.51	3.10	2.80	2.78
50% RDF + 50% RDF through vermicompost	2.66	2.58	3.28	2.71	2.81
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	2.79	2.59	3.11	2.99	2.87
Mean	2.68	2.52	3.12	2.84	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.01		0.07		
Factor (V) at same level of N	0.02		0.06		

Appendix XVII

Interaction effect of varieties and nutrient sources on leaf area index (LAI) at 120 DAS in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	2.60	2.27	2.97	2.78	2.65
100% RDF	2.96	2.82	3.49	3.27	3.13
50% RDF + 50% RDF through FYM	2.62	2.41	3.22	3.11	2.84
50% RDF + 50% RDF through vermicompost	2.88	2.59	3.15	3.04	2.91
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	2.86	2.75	3.20	3.07	2.97
Mean	2.78	2.57	3.20	3.05	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.03		0.08		
Factor (V) at same level of N	0.03		0.09		

Appendix XVIII

Interaction effect of varieties and nutrient sources on days taken to 50% heading in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	81.3	65.5	85.4	84.7	79.2
100% RDF	92.7	92.9	97.9	96.0	94.9
50% RDF + 50% RDF through FYM	91.2	91.8	94.8	89.8	91.9
50% RDF + 50% RDF through vermicompost	91.4	92.4	95.2	92.2	92.8
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	90.6	93.7	96.2	94.6	93.8
Mean	89.4	87.2	93.9	91.5	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.5		3.1		
Factor (V) at same level of N	1.0		2.9		

Appendix XIX

Interaction effect of varieties and nutrient sources on days taken to 50% heading in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	80.4	64.6	84.5	83.9	78.3
100% RDF	93.5	93.6	98.7	96.7	95.7
50% RDF + 50% RDF through FYM	91.6	92.2	95.2	90.2	92.3
50% RDF + 50% RDF through vermicompost	92.3	93.3	96.1	93.1	93.7
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	91.4	94.5	97.0	95.4	94.5
Mean	89.8	87.7	94.3	91.9	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.5		3.1		
Factor (V) at same level of N	1.0		2.9		

Appendix XX

Interaction effect of varieties and nutrient sources on days taken to 50% anthesis in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	81.3	81.4	86.8	87.4	84.2
100% RDF	99.2	99.1	104.3	102.3	101.2
50% RDF + 50% RDF through FYM	96.1	91.8	99.1	94.0	95.2
50% RDF + 50% RDF through vermicompost	97.1	96.0	99.8	96.8	97.4
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	100.4	94.8	102.9	101.3	99.9
Mean	94.8	92.6	98.6	96.4	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.5		3.1		
Factor (V) at same level of N	1.0		2.9		

Appendix XXI

Interaction effect of varieties and nutrient sources on days taken to 50% anthesis in wheat (2018-19)

Nutrient sources (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	80.3	80.4	85.7	86.4	83.2
100% RDF	100.4	100.3	105.5	103.5	102.4
50% RDF + 50% RDF through FYM	97.4	93.1	100.4	95.3	96.5
50% RDF + 50% RDF through vermicompost	98.1	97.0	100.8	97.8	98.4
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	101.8	96.2	104.3	102.7	101.2
Mean	95.6	93.4	99.3	97.2	96.4
	SEm±		CD at 5%		
Factor (N) at same level of V	0.7		3.3		
Factor (V) at same level of N	1.0		3.1		

Appendix XXII

Interaction effect of varieties and nutrient sources on leaf production rate in wheat (2017-18)

Nutrient sources (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	0.40	0.44	0.50	0.38	0.43
100% RDF	0.54	0.43	0.62	0.72	0.58
50% RDF + 50% RDF through FYM	0.49	0.51	0.50	0.50	0.50
50% RDF + 50% RDF through vermicompost	0.52	0.51	0.50	0.50	0.51
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.54	0.53	0.56	0.53	0.54
Mean	0.50	0.48	0.54	0.53	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.01		0.02		
Factor (V) at same level of N	0.01		0.02		

Appendix XXIII

Interaction effect of varieties and nutrient sources on leaf production rate in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	0.42	0.40	0.41	0.41	0.41
100% RDF	0.63	0.63	0.65	0.64	0.64
50% RDF + 50% RDF through FYM	0.56	0.56	0.57	0.59	0.57
50% RDF + 50% RDF through vermicompost	0.61	0.55	0.61	0.62	0.60
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.62	0.61	0.62	0.59	0.61
Mean	0.57	0.55	0.57	0.57	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.01		0.02		
Factor (V) at same level of N	0.01		0.02		

Appendix XXIV

Interaction effect of varieties and nutrient sources on number of effective tillers/m² in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	330	315	349	334	332
100% RDF	355	339	366	390	362
50% RDF + 50% RDF through FYM	337	323	355	321	334
50% RDF + 50% RDF through vermicompost	343	332	356	353	346
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	360	333	362	349	351
Mean	345	329	359	350	
	SEm±		CD at 5%		
Factor (N) at same level of V	1.4		7.3		
Factor (V) at same level of N	2.3		6.8		

Appendix XXV

Interaction effect of varieties and nutrient sources on number of effective tillers/m² in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	340	320	359	346	341
100% RDF	368	353	377	388	372
50% RDF + 50% RDF through FYM	340	329	364	339	343
50% RDF + 50% RDF through vermicompost	352	341	366	356	353
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	357	344	376	368	361
Mean	351	337	368	359	
	SEm±		CD at 5%		
Factor (N) at same level of V	3.1		8.6		
Factor (V) at same level of N	2.9		8.7		

Appendix XXVI

Interaction effect of varieties and nutrient sources on spike length (cm) in wheat (2017-18)

Nutrient sources (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	9.1	8.4	10.7	10.3	9.6
100% RDF	12.4	9.9	11.6	11.1	11.2
50% RDF + 50% RDF through FYM	10.0	9.0	10.9	10.8	10.2
50% RDF + 50% RDF through vermicompost	9.8	9.3	11.5	10.8	10.3
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	9.9	10.1	11.2	11.1	10.6
Mean	10.2	9.3	11.2	10.8	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.32		1.11		
Factor (V) at same level of N	0.36		1.08		

Appendix XXVII

Interaction effect of varieties and nutrient sources on spike length in wheat (2018- 19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	8.9	9.2	10.6	10.2	9.70
100% RDF	12.8	9.6	12	11.5	11.5
50% RDF + 50% RDF through FYM	10.1	9.5	11	10.9	10.4
50% RDF + 50% RDF through vermicompost	9.8	9.8	11.5	10.8	10.5
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	10.3	9.6	11.6	11.5	10.8
Mean	10.4	9.5	11.3	11.0	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.32		1.11		
Factor (V) at same level of N	0.36		1.08		

Appendix XXVIII

Interaction effect of varieties and nutrient sources on number of grains/spike in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	39.8	39.8	48.8	44.1	43.1
100% RDF	59.6	41.4	52.6	55.6	52.3
50% RDF + 50% RDF through FYM	45.1	41.9	49.8	48.4	46.3
50% RDF + 50% RDF through vermicompost	49.3	41.5	52.0	49.9	48.1
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	51.5	39.4	52.6	53.9	49.3
Mean	49.1	40.8	51.1	50.4	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.8		2.2		
Factor (V) at same level of N	0.7		2.2		

Appendix XXIX

Interaction effect of varieties and nutrient sources on number of grains/spike in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	45.0	39.2	47.9	45.9	44.5
100% RDF	58.7	45.8	55.7	54.8	53.7
50% RDF + 50% RDF through FYM	46.8	40.7	53.9	49.9	47.8
50% RDF + 50% RDF through vermicompost	52.9	41.5	52.5	50.9	49.4
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	49.4	43.1	54.6	56.3	50.9
Mean	50.6	42.1	52.9	51.6	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.4		2.2		
Factor (V) at same level of N	0.7		2.0		

Appendix XXX

Interaction effect of varieties and nutrient sources on grain weight/spike (g) in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	2.33	2.24	3.35	3.09	2.75
100% RDF	3.78	2.63	3.60	3.63	3.41
50% RDF + 50% RDF through FYM	2.67	1.94	2.94	2.78	2.58
50% RDF + 50% RDF through vermicompost	2.73	2.15	3.03	2.92	2.71
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	3.15	2.23	3.18	3.08	2.91
Mean	2.93	2.24	3.22	3.10	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.04		0.22		
Factor (V) at same level of N	0.07		0.21		

Appendix XXXI

Interaction effect of varieties and nutrient sources on grain weight/spike (g) in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	2.43	2.34	3.45	3.19	2.85
100% RDF	4.01	2.86	3.83	3.86	3.64
50% RDF + 50% RDF through FYM	2.85	2.12	3.12	2.96	2.76
50% RDF + 50% RDF through vermicompost	2.93	2.35	3.23	3.12	2.91
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	3.42	2.50	3.45	3.35	3.18
Mean	3.13	2.43	3.41	3.30	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.03		0.20		
Factor (V) at same level of N	0.06		0.18		

Appendix XXXII

Interaction effect of varieties and nutrient sources on 1000-grain weight (g) in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	39.0	35.4	40.1	39.2	38.4
100% RDF	41.2	39.6	44.0	42.3	41.8
50% RDF + 50% RDF through FYM	38.3	36.9	40.1	39.5	38.7
50% RDF + 50% RDF through vermicompost	39.8	39.9	39.6	39.4	39.7
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	40.6	38.6	40.7	40.8	40.2
Mean	40.2	38.4	41.3	40.7	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.30		1.27		
Factor (V) at same level of N	0.41		1.20		

Appendix XXXIII

Interaction effect of varieties and nutrient sources on 1000-grain weight (g) in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	39.5	37.3	40.1	38.0	38.8
100% RDF	42.1	41.0	44.8	40.4	42.1
50% RDF + 50% RDF through FYM	38.7	36.8	40.6	39.5	38.9
50% RDF + 50% RDF through vermicompost	38.8	37.7	40.9	41.7	39.8
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	39.9	39.0	41.4	41.8	40.5
Mean	39.9	38.3	41.4	40.5	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.35		1.20		
Factor (V) at same level of N	0.39		1.17		

Appendix XXXIV

Interaction effect of varieties and nutrient sources on nitrogen content in wheat grain (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	39.5	37.3	40.1	38.0	38.8
100% RDF	42.1	41.0	44.8	40.4	42.1
50% RDF + 50% RDF through FYM	38.7	36.8	40.6	39.5	38.9
50% RDF + 50% RDF through vermicompost	38.8	37.7	40.9	41.7	39.8
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	39.9	39.0	41.4	41.8	40.5
Mean	39.9	38.3	41.4	40.5	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.35		1.20		
Factor (V) at same level of N	0.39		1.17		

Appendix XXXV

Interaction effect of varieties and nutrient sources on nitrogen content in wheat grain (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	1.51	1.20	1.64	1.59	1.48
100% RDF	1.80	1.78	1.89	1.85	1.83
50% RDF + 50% RDF through FYM	1.53	1.51	1.62	1.58	1.56
50% RDF + 50% RDF through vermicompost	1.72	1.68	1.59	1.69	1.67
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	1.71	1.67	1.80	1.74	1.73
Mean	1.65	1.53	1.72	1.69	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.04		0.11		
Factor (V) at same level of N	0.04		0.11		

Appendix XXXVI

Interaction effect of varieties and nutrient sources on nitrogen content in wheat grain (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	1.58	1.27	1.75	1.70	1.57
100% RDF	1.94	1.92	1.98	1.94	1.94
50% RDF + 50% RDF through FYM	1.51	1.49	1.79	1.75	1.63
50% RDF + 50% RDF through vermicompost	1.80	1.76	1.74	1.84	1.78
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	1.85	1.81	1.94	1.88	1.87
Mean	1.81	1.73	1.91	1.82	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.04		0.11		
Factor (V) at same level of N	0.04		0.11		

Appendix XXXVII

Interaction effect of varieties and nutrient sources on phosphorus content in wheat grain (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	0.41	0.39	0.44	0.41	0.41
100% RDF	0.55	0.54	0.54	0.56	0.55
50% RDF + 50% RDF through FYM	0.52	0.52	0.52	0.52	0.52
50% RDF + 50% RDF through vermicompost	0.53	0.52	0.53	0.53	0.53
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.53	0.53	0.54	0.53	0.53
Mean	0.48	0.47	0.51	0.49	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.01		0.02		
Factor (V) at same level of N	0.01		0.02		

Appendix XXXVIII

Interaction effect of varieties and nutrient sources on phosphorus content in wheat grain (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	0.40	0.38	0.46	0.42	0.42
100% RDF	0.57	0.56	0.55	0.56	0.56
50% RDF + 50% RDF through FYM	0.54	0.53	0.54	0.54	0.54
50% RDF + 50% RDF through vermicompost	0.55	0.54	0.55	0.54	0.55
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.55	0.55	0.55	0.55	0.55
Mean	0.52	0.51	0.52	0.52	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.01		0.02		
Factor (V) at same level of N	0.01		0.02		

Appendix XXXIX

Interaction effect of varieties and nutrient sources on potassium content in wheat grain (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	0.41	0.37	0.43	0.44	0.41
100% RDF	0.48	0.51	0.49	0.50	0.49
50% RDF + 50% RDF through FYM	0.48	0.42	0.49	0.50	0.47
50% RDF + 50% RDF through vermicompost	0.50	0.48	0.47	0.45	0.47
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.50	0.45	0.50	0.48	0.48
Mean	0.46	0.44	0.49	0.47	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.01		0.03		
Factor (V) at same level of N	0.01		0.03		

Appendix XXXX

Interaction effect of varieties and nutrient sources on potassium content in wheat grain (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	0.41	0.40	0.44	0.42	0.42
100% RDF	0.52	0.50	0.53	0.51	0.51
50% RDF + 50% RDF through FYM	0.47	0.47	0.48	0.49	0.48
50% RDF + 50% RDF through vermicompost	0.51	0.47	0.48	0.49	0.48
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.49	0.50	0.48	0.49	0.49
Mean	0.48	0.45	0.49	0.48	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.01		0.03		
Factor (V) at same level of N	0.01		0.02		

Appendix XXXXI

Interaction effect of varieties and nutrient sources on soil organic carbon (%) in soil at harvest in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	0.40	0.41	0.42	0.41	0.41
100% RDF	0.43	0.45	0.43	0.43	0.43
50% RDF + 50% RDF through FYM	0.44	0.44	0.48	0.43	0.45
50% RDF + 50% RDF through vermicompost	0.46	0.45	0.45	0.48	0.46
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.47	0.47	0.49	0.50	0.48
Mean	0.41	0.41	0.41	0.41	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.00		0.01		
Factor (V) at same level of N	0.00		0.01		

Appendix XXXXII

Interaction effect of varieties and nutrient sources on soil organic carbon (%) in soil at harvest in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	0.40	0.41	0.43	0.44	0.42
100% RDF	0.46	0.43	0.43	0.45	0.44
50% RDF + 50% RDF through FYM	0.46	0.47	0.45	0.46	0.46
50% RDF + 50% RDF through vermicompost	0.47	0.48	0.49	0.50	0.48
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	0.50	0.51	0.50	0.47	0.49
Mean	0.45	0.44	0.46	0.45	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.00		0.01		
Factor (V) at same level of N	0.00		0.01		

Appendix XXXXIII

Interaction effect of varieties and nutrient sources on available nitrogen (kg/ha) in soil at harvest in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	117.5	98.8	123.3	117.3	114.2
100% RDF	143.8	131.2	145.6	136.6	139.3
50% RDF + 50% RDF through FYM	122.2	112.0	130.0	120.0	121.0
50% RDF + 50% RDF through vermicompost	118.2	119.7	129.7	132.4	125.0
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	127.6	123.3	140.5	131.5	130.7
Mean	129.0	121.0	138.0	131.0	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.57		2.59		
Factor (V) at same level of N	0.83		2.44		

Appendix XXXXIV

Interaction effect of varieties and nutrient sources on available nitrogen (kg/ha) in soil at harvest in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	118.1	106.3	120.7	121.7	116.7
100% RDF	141.4	126.1	150.2	147.2	141.2
50% RDF + 50% RDF through FYM	122.4	120.1	132.1	122.1	124.2
50% RDF + 50% RDF through vermicompost	125.6	126.3	134.5	126.8	128.3
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	134.5	125.7	138.6	139.2	134.5
Mean	127.3	119.3	136.4	131.2	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.83		2.64		
Factor (V) at same level of N	0.87		2.61		

Appendix XXXXV

Interaction effect of varieties and nutrient sources on available phosphorus (kg/ha) in soil at harvest in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	16.6	17.4	23.6	22.8	20.1
100% RDF	29.5	25.8	31.0	30.5	29.2
50% RDF + 50% RDF through FYM	24.8	22.6	23.6	21.6	23.1
50% RDF + 50% RDF through vermicompost	22.8	23.8	25.8	24.8	24.3
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	28.3	24.8	26.3	25.3	26.2
Mean	24.2	23.1	26.1	25.2	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.32		0.70		
Factor (V) at same level of N	0.25		0.76		

Appendix XXXXVI

Interaction effect of varieties and nutrient sources on available phosphorus (kg/ha) in soil at harvest in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	21.5	17.0	24.8	22.0	21.3
100% RDF	30.9	28.1	33.8	35.6	32.1
50% RDF + 50% RDF through FYM	25.9	23.7	25.9	22.7	24.5
50% RDF + 50% RDF through vermicompost	24.9	25.9	27.9	26.9	26.4
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	31.1	27.0	29.1	28.1	28.8
Mean	26.2	24.1	28.2	27.2	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.31		0.70		
Factor (V) at same level of N	0.25		0.76		

Appendix XXXXVII

Interaction effect of varieties and nutrient sources on available potassium (kg/ha) in soil at harvest in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	318.7	319.7	323.7	322.7	321.2
100% RDF	333.4	327.1	345.4	334.5	335.1
50% RDF + 50% RDF through FYM	315.6	318.6	328.2	316.6	319.7
50% RDF + 50% RDF through vermicompost	324.4	320.4	323.4	325.4	323.4
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	327.2	322.7	330.2	331.2	327.8
Mean	322.8	319.7	329.1	325.5	
	SEm±		CD at 5%		
Factor (N) at same level of V	1.46		5.47		
Factor (V) at same level of N	1.77		5.26		

Appendix XXXXVIII

Interaction effect of varieties and nutrient sources on available potassium (kg/ha) in soil at harvest in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	324.3	309.9	334.7	328.0	324.2
100% RDF	345.2	336.5	347.4	335.6	341.2
50% RDF + 50% RDF through FYM	319.4	322.7	329.9	326.0	324.5
50% RDF + 50% RDF through vermicompost	324.6	326.7	330.1	331.8	328.3
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	326.0	334.1	336.9	336.7	333.4
Mean	325.6	323.5	333.2	329.1	
	SEm±		CD at 5%		
Factor (N) at same level of V	2.81		5.50		
Factor (V) at same level of N	2.01		6.31		

Appendix XXXXIX

Interaction effect of varieties and nutrient sources on available DTPA-extractable Fe (mg/kg) in soil at harvest in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	11.87	11.80	14.96	12.43	12.76
100% RDF	13.93	12.07	16.03	13.63	13.91
50% RDF + 50% RDF through FYM	14.83	12.55	14.67	14.44	14.12
50% RDF + 50% RDF through vermicompost	15.26	14.66	16.04	14.57	15.13
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	16.15	16.45	18.08	16.55	16.81
Mean	14.81	13.78	16.21	14.32	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.22		0.68		
Factor (V) at same level of N	0.23		0.68		

Appendix XXXXX

Interaction effect of varieties and nutrient sources on available DTPA-extractable Fe (mg/kg) in soil at harvest in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	12.07	12.29	15.90	12.66	13.23
100% RDF	14.21	14.15	15.46	14.25	14.52
50% RDF + 50% RDF through FYM	16.10	14.56	16.04	16.15	15.71
50% RDF + 50% RDF through vermicompost	17.07	14.42	17.17	16.97	16.41
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	16.77	17.07	21.90	19.09	18.71
Mean	14.71	13.71	16.61	15.31	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.30		0.69		
Factor (V) at same level of N	0.24		0.74		

Appendix XXXXXI

Interaction effect of varieties and nutrient sources on available DTPA-extractable Mn (mg/kg) in soil at harvest in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	2.69	2.00	2.78	2.57	2.51
100% RDF	2.51	2.49	3.27	2.97	2.81
50% RDF + 50% RDF through FYM	3.21	3.21	3.65	3.66	3.43
50% RDF + 50% RDF through vermicompost	3.42	3.63	4.16	3.67	3.72
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	3.81	3.37	4.44	4.02	3.91
Mean	2.91	2.71	3.41	3.12	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.05		0.10		
Factor (V) at same level of N	0.04		0.12		

Appendix XXXXXII

Interaction effect of varieties and nutrient sources on available DTPA-extractable Mn (mg/kg) in soil at harvest in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	2.47	2.27	3.05	2.67	2.61
100% RDF	2.40	2.51	3.53	3.04	2.87
50% RDF + 50% RDF through FYM	3.41	3.42	3.85	3.79	3.62
50% RDF + 50% RDF through vermicompost	3.75	3.74	4.03	3.79	3.83
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	4.24	3.57	4.47	4.20	4.12
Mean	3.21	3.06	3.79	3.48	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.05		0.10		
Factor (V) at same level of N	0.04		0.12		

Appendix XXXXXXIII

Interaction effect of varieties and nutrient sources on available DTPA-extractable Zn (mg/kg) in soil at harvest in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	1.60	1.42	1.81	1.76	1.65
100% RDF	1.67	1.61	2.08	1.96	1.83
50% RDF + 50% RDF through FYM	2.28	1.78	2.32	2.31	2.17
50% RDF + 50% RDF through vermicompost	2.32	2.11	2.36	2.25	2.26
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	2.31	2.21	2.57	2.55	2.41
Mean	2.12	1.91	2.32	2.23	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.02		0.06		
Factor (V) at same level of N	0.02		0.06		

Appendix XXXXXXIV

Interaction effect of varieties and nutrient sources on available DTPA-extractable Zn (mg/kg) in soil at harvest in wheat (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	1.90	1.56	2.04	1.35	1.71
100% RDF	2.04	1.75	1.95	1.97	1.93
50% RDF + 50% RDF through FYM	2.12	2.06	2.44	2.45	2.27
50% RDF + 50% RDF through vermicompost	2.15	2.11	2.62	2.60	2.37
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	2.36	2.29	2.81	2.82	2.57
Mean	2.09	1.93	2.33	2.24	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.03		0.06		
Factor (V) at same level of N	0.02		0.07		

Appendix XXXXXV

Interaction effect of varieties and nutrient sources on available DTPA-extractable Cu (mg/kg) in soil at harvest in wheat (2017-18)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	1.20	1.23	1.45	1.37	1.31
100% RDF	1.31	1.27	1.56	1.37	1.38
50% RDF + 50% RDF through FYM	1.36	1.40	1.54	1.34	1.41
50% RDF + 50% RDF through vermicompost	1.55	1.37	1.60	1.57	1.52
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	1.65	1.50	1.65	1.64	1.61
Mean	1.43	1.37	1.59	1.48	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.01		0.04		
Factor (V) at same level of N	0.01		0.04		

Appendix XXXXXVI

Interaction effect of varieties and nutrient sources on available DTPA-extractable Cu (mg/kg) in soil at harvest (2018-19)

Nutrient source (N)	Varieties (V)				
	WH 1080	WH 1025	WH 1142	WH 711	Mean
Control	1.36	1.18	1.51	1.39	1.36
100% RDF	1.36	1.30	1.55	1.43	1.41
50% RDF + 50% RDF through FYM	1.45	1.45	1.55	1.47	1.48
50% RDF + 50% RDF through vermicompost	1.58	1.57	1.61	1.55	1.58
50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment)	1.64	1.58	1.74	1.72	1.67
Mean	1.48	1.42	1.62	1.52	
	SEm±		CD at 5%		
Factor (N) at same level of V	0.01		0.05		
Factor (V) at same level of N	0.02		0.05		

Appendix XXXXXVII
Cost of cultivation of wheat during 2017-18 and 2018-19

S.No.	Particular		Actual expenditure (₹ ha)	
			2017-18	2018-19
1.	Preparatory tillage		5582/ha	5582/ha
2.	Pre-sowing irrigation		874/ha	874/ha
3.	Labour (male/female)		300/day	350/day
4.	Sowing		2255/ha	2255/ha
5.	Ridging		232/ha	232/ha
6.	Seed (kg)	40 kg	2223/ha	2223/ha
7.	Nutrient source			
	a) Nitrogen (urea)	50 kg	268 (5.36/kg)	268 (5.36/kg)
	b) Phosphate(DAP)	50 kg	1150 (23/kg)	1150 (23/kg)
	c) Potassic (MOP)	50 kg	800 (16/kg)	800 (16/kg)
	d) Vermicompost		4000/t	4000/t
	e) FYM (q)		300/t	300/t
	f) Biofertilizers (seed treatment)			
	<i>Azotobacter chroococcum</i>	250 ml	150/ha	150/ha
	<i>Bacillus sp.</i>	150 ml	225/ha	225/ha
8.	Fertilizer application		353/ha	576/ha
9.	Irrigation		2774/ha	2774/ha
10.	Hoeing/weeding			
	a) Chemical		968/ha	968/ha
11.	Plant protection		1230/ha	1230/ha
12.	Harvesting		4483/ha	4483/ha
13.	Threshing		6076/ha	6076/ha
14.	Miscellaneous		1235/ha	1545/ha
15.	Interest on working capital (@ 4.5%)		1257/ha	1257/ha
16.	Management charges (@ 10% of variable cost)		2919/ha	2919/ha
17.	Risk factor (@ 10% of variable cost)		2919/ha	2919/ha
18.	Transportation		1218/ha	1643/ha
19.	Rental value of land per season		45000	45000
20.	Prevailing market price			
	a) Grain		1840/q	1975/q
	b) Straw		575/q	600/q

Appendix XXXXXVIII

Rating of available organic carbon, N, P, K and DTPA extractable micronutrient in soil

S. No.	Available nutrient	Rating in soil at harvest		
		Low	Medium	High
1.	Organic carbon (%)	<0.50	0.50-0.75	>0.75
2.	Nitrogen (kg/ha)	<280	280-560	>560
3.	Phosphorus (kg/ha)	<10	12-24.6	>24.6
4.	Potassium (kg/ha)	<108	108-280	>280
DTPA extractable critical range of available cationic micronutrient (mg/kg)				
1.	Iron (Fe)	2.5-4.5		
2.	Manganese (Mn)	2.0		
3.	Zinc (Zn)	0.4-1.2		
4.	Copper (Cu)	0.2		

Source: Basu, 2011(Methods manual soil testing in India, DAC, Ministry of Agriculture, GOI)

Appendix XXXXXIX

Chemical composition of farmyard manure and vermicompost

S. No.	Organic manures	Chemical composition			
		N (%)	P (%)	K (%)	Organic carbon (%)
1.	Farmyard manure	0.52	0.24	0.47	15.2
2.	Vermicompost	1.57	0.53	0.61	23.1

ABSTRACT

Title of Thesis : **Performance of different varieties of wheat (*Triticum aestivum* L.) under integrated nutrient management system**

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Admission number : 2016A06D

Title of Degree : Doctor of Philosophy (Agronomy)

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Year of award of Degree : 2022

Major Subject : Agronomy

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Number of words in Abstract : 592

Keywords : Growth, economics, nutrient management, varieties and yield.

A field experiment was carried out during winter 2017-18 and 2018-19 at RRS, Kaul, Haryana. The experiment comprising of 4 level of varieties in main plots (WH 1080, WH 1025, WH 1142 and WH 711) and 5 levels of nutrient combination in subplots (Control, 100% RDF, 50% RDF + 50% RDF through FYM, 50% RDF + 50% RDF through vermicompost and 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) was carried out in split plot design with three replications. The soil of the experimental plot was clay loam in texture and slightly alkaline in reaction with pH 7.9 and EC of 0.27 dS/m. The soil was low in available nitrogen (107.8 kg/ha), high in available phosphorus (25.4 kg/ha), high in available potassium (313.2 kg/ha), copper (1.37 mg/kg), iron (13.45 mg/kg), manganese (2.85 mg/kg) and zinc (1.76 mg/kg) before sowing. The objective of experiment was effect of varieties and nutrient sources on growth attributes, yields and yield attributes, quality, nutrient content by wheat, nutrient uptake by wheat, available OC, N, P, K, Fe, Mn, Zn and Cu in soil at harvest, nitrogen removal ratio, nitrogen use efficiency and most profitable nutrient sources and varieties. Significantly higher mean plant population, plant height, LAI, LAD, dry matter accumulation and shoot length were recorded in variety WH 1142 and 100% RDF, respectively. Days taken to 50% heading and 50% anthesis was shorter in variety WH 1025 and in control treatment among nutrient sources. Yield attributes viz. mean number of effective tillers/m², spike length (cm), number of grains/spike, grains weight/spike (g) and 1000-grain weight were significantly higher in wheat variety WH 1142 and in nutrient sources with 100% RDF. Mean protein and starch content in grain is significantly influenced by application of 100% RDF. WH 1142 gives significantly higher mean grain yield of 4866 kg/ha and 4877 kg/ha, respectively during 2017-18 and 2018-19 over other varieties (WH 1080, WH 1025 and WH 711). Significantly higher mean grain (4736 and 4758 kg/ha) and straw yield (7652 and 7719 kg/ha) were recorded in 100% RDF during 2017-18 and 2018-19, respectively over other nutrient sources. Application of 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) resulted in significantly higher grain and straw yield over other integrated approach. Among interaction effect significantly higher grain and straw yield were recorded in WH 1142 × 100% RDF during 2017-18 and 2018-19. Mean N, P and K content and uptake by grain and straw was significantly higher in variety WH 1142, which is followed by variety WH 711, WH 1080 and WH 1025 during 2017-18 and 2018-19. Available mean N, P and K content in soil at harvest were increased in plot receiving 100% RDF as compared to initial status. However significant increase in available mean organic carbon and DTPA-extractable Fe, Mn, Zn and Cu in soil at harvest recorded in treatment receiving 50% RDF + 50% RDF through FYM + 50% RDF through vermicompost + biofertilizers (seed treatment) over initial status of soil. Use efficiency (AE, PE and RE) of nitrogen was significantly higher in 100% RDF, due to higher uptake by crop and higher yields. Highest mean net return (53282 and 56828 Rs./ha) were incurred with variety WH 1142 and among nutrient sources with 100% RDF (51227 and 54019 Rs./ha) during 2017-18 and 2018-19. The higher BCR of wheat was recorded in variety WH 1142 (1.60 and 1.64) over all other varieties and among nutrient sources in 100% RDF (1.59 and 1.61) during 2017-18 and 2018-19.

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List of publication

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I, hereby, declare that all the information given in the resume is true to the best of my knowledge.

Dated:

(Aniket Diwedi)

Place:

UNDERTAKING OF THE COPY RIGHT

I, **Aniket Diwedi** Admission No. **2016A06D** undertake that I give copy right to the Chaudhary Charan Singh Haryana Agricultural University, Hisar of my thesis entitled **“Performance of different varieties of wheat (*Triticum aestivum* L.) under integrated nutrient management system”**.

I also undertake that patent, if any, arising out of the research work conducted during the program shall be filed by me only with due permission of the competent authority of Chaudhary Charan Singh Haryana Agricultural University, Hisar-125004, India.

(ANIKET DIWEDI)
Signature of the Student