# Effect of doses and sources of nutrients on growth, yield and quality of timely sown irrigated wheat (*Triticum aestivum* L .)

Thesis

**Submitted to the**

**Sardar Vallabhbhai Patel University of Agriculture & Technology,**

**Meerut-250110, U.P., India**

**BY**


**SHIKHAR VERMA**
**Id. No. - 4813**


**IN PARTIAL FULFILMENT OF THE REQUIREMENTS**

**FOR THE DEGREE OF**

**MASTER OF SCIENCE**

**IN**

**AGRICULTURE (AGRONOMY)**

**SEPTEMBER, 2021**

# *ACKNOWLEDGMENT*

*I feel ecstasy to express my profound regards, deepest sense of gratitude and heartfelt devotion to reverend advisor Dr. N. S. Rana, Professor, Agronomy, and chairman advisory committee Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, for his ingenious, precious and pragmatic counsel along with his valuable guidance, concrete suggestions, constructive criticisms and untiring efforts during the course of investigation and preparation of the manuscript. Words simply may not prove sufficient enough to express my feeling to him for his generosity and sympathy as the Chairman of my advisory committee for which I will be indebted to him forever.*

*I feel profoundly delighted to express my deep sense of gratefulness to advisory committee members, Dr. Adesh Singh, Assistant Professor, Agronomy, Dr. B. P. Dhyani, Professor, Soil Science and Agricultural Chemistry, and Dr. Bhim Singh, Associate Professor (Statistics), for their valuable suggestions, everlasting help, and ever encouraging attitude. A word of appreciation goes to the faculty members of Agronomy Department Dr. Vivek, Dr. R. K. Naresh, Dr. R. B. Yadav, Dr. Mukesh Kumar, Dr. P.K. Singh and Dr. K.G. Yadav, Dr. Raj Vir Singh for their generous help and encouragement at various stages of research. I am also thankful to Dr. U.P. Sahi to provide laboratory for chemical analysis and technical staff, Sh. Sunder for their unconditional support during the experimentation. I wish to express her whole hearted appreciation to all scientists and faculty members of Svpua&t for their kind help and cooperation rendered during my study and research.*

*I am grateful to the Dean Post Graduate studies, Dean College of Agriculture, Director of Agriculture Experiment station and Head Agronomy for providing necessary facilities for smooth conduct of the experiments.*

*Most factiously warmest thanks and appreciation goes to my intimate colleagues, seniors and juniors viz. Vivek, Vikash, Mausmi, Sandeep, Shekhar, Sachin, Durgesh, Satya, Rahul, Mohit, Bal veer, Lali, Dimple, for the affable assistance, arduous affection and cheerful company rendered by them during the course of study.*

*I am overwhelmed with rejoice, my profound sense of veneration and gratitude to my beloved parents Sh. Rakesh Verma and Smt. Susheela Verma and my uncle Dr. Ram Pravesh who have always been my role models, for their every help, love, affection, encouragement.*

*The help rendered by the regional staff of IFFCO, New Delhi, located at Meerut in providing the research material is gratefully acknowledged. Finally, I owe everything to "ALMIGHTY GOD" to shower blessings so my efforts reach the destination.*

*Author is highly grateful to SAMAJ KALYAN SCHOLORSHIP, Government of Uttar Pradesh for financial assistance during course of investigation.*

Meerut — SHIKHAR VERMA

*September,2021* — *(Author)*

**Dr. N.S. Rana**
**Professor**

**Department of Agronomy**
**Sardar Vallabhbhai Patel**
**University of Agri. &Tech.,**
**Meerut–250 110 (U.P.)**

# CERTIFICATE

This is to certify that the thesis entitled **"Effect of doses and sources of nutrients on growth, yield and quality of timely sown irrigated wheat (*Triticum aestivum* L.)"**submitted in partial fulfillment of the requirements for the degree of **Master of Science** with major in **Agronomy** and minor in **Soil Science and Agricultural Chemistry** of the College of Post Graduate Studies, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, is a record of *bona-fide* research carried out by **Mr. Shikhar Verma, Id. No. 4813**, under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the investigation and source of literature have been duly acknowledged.

**(N.S. Rana)**
Chairman
Advisory Committee

# CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Mr. Shikhar Verma, Id. No.4813,** a candidate for the degree of **Master of Science** in Agriculture with major in **Agronomy** and minor in **Soil Science and Agricultural Chemistry**, agree that the thesis entitled "**Effect of doses and sources of nutrients on growth, yield and quality of timely sown irrigated wheat (*Triticum aestivum* L.)"** may be submitted by **Mr. Shikhar Verma,** in partial fulfillment of the requirements for the degree.

**(N. S. Rana)**
Chairman
Advisory Committee

| | | |
|---|---|---|
| **( B. P. Dhyani )**<br>**Member** | **( Adesh Singh )**<br>**Member** | **( Bhim Singh )**<br>**Member** |

## Abbreviations used

| | | | | | |
|---|---|---|---|---|---|
| % | : | Per cent | S. No. | : | Serial number |
| a.i. | : | Active ingredient | B:C ratio | : | Benefit Cost ratio |
| Wt. | : | Weight | P=0.05 | : | Significant at 5 % probability |
| $^{0}$C | : | Degree Celsius | NS | : | Non-significant |
| mm | : | Millimeter | SEm ± | : | Standard error of mean |
| cm | : | Centimeter | CD | : | Critical difference |
| cm$^{2}$ | : | Square centimeter | Max. | : | Maximum |
| m | : | Meter | Min. | : | Minimum |
| m$^{2}$ | : | Square meter | N | : | Nitrogen |
| Day$^{-1}$ | : | Per day | P | : | Phosphorus |
| DAS | : | Days after sowing | K | : | Potash |
| df | : | Degree of freedom | S | | Sulphur |
| ds m$^{-1}$ | : | Deci siemens per meter | Fe | | Iron |
| *et al.* | : | et allii; (co-authors) | OC | | Organic Carbon |
| *etc.* | : | et cetera (and others) | EC | | Electrical conductivity |
| Fig. | : | Figure | pH | : | Per cent of hydrogen ions |
| g | : | Gram | BD | | Bulk density |
| ha | : | Hectare | S$^{-1}$ | : | Per second |
| ha$^{-1}$ | : | Per hectare | LAI | : | Leaf area index |
| m ha | : | Million hectares | CGR | : | Crop growth rate |
| *i.e.* | : | Id east (that is) | RGR | : | Relative growth rate |
| µ | : | Micro | NAR | : | Net assimilation Rate |
| m t | : | Million tonnes | *Viz.* | : | Videlicot (Sl/ 1g) namely |
| kg | : | Kilogram | RH | : | Relative humidity |
| RDF | : | Recommended dose of fertilizer | RDN | : | Recommended dose of nutrient |

# CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# 1. INTRODUCATION

Wheat (*Triticum aestivum* L.) is one of the most important staple food crops in the world, as it provides 21% of the food calories and 20% of the protein to more than 4.5 billion people. The world acreage under wheat crop accounts 216.18 million ha producing 763.6 million metric tonnes with an average of 3530 kg $ha^{-1}$ **(USDA report, 2020)**. In India, it covers 29.32 million ha producing 103.6 million metric tonnes, one third of the total food grain production, with an average productivity of 3530 kg $ha^{-1}$ **(USDA report, 2020)**. The current world population of 7.7 billion is expected to reach 9.7 billion by 2050. India is the second most populous country (1.3 billion) after China (1.41 billion) and expected to surpass that of China touching a peak 1.7 billion by 2050 **(The UN World Population Prospects: The 2019 Revision)**. Accordingly, wheat is likely to continue to be vital in ensuring food security across the globe.

Uttar Pradesh is India's biggest wheat-growing state with 9.65 million hectares (36.6%), 26.87 million tonnes (39.3%), and a productivity of 2785 kg $ha^{-1}$ **(Anonymous, 2019).** Wheat productivity in the state however, is significantly lower than in Punjab (4.3 tonnes $ha^{-1}$) and Haryana (4 tonnes $ha^{-1}$) due to late sowing following the harvest of long-term rice varieties and sugarcane, poor seed replacement rate, lack of quality seed, imbalanced fertilization, unscientific water management and poor mechanization, among other factors. Wheat sowing in western Uttar Pradesh is delayed till the end of December, and in some cases into the first week of January, resulting in substantial yield reductions. Farmers attempt to compensate for delayed planting by applying excessive fertilizers, particularly nitrogen, while ignoring yield physiology in limited conditions.

Fertilizers (urea, DAP & MOP) play important role in maximizing crop yield and hence farmers in general apply a high dose of chemical fertilizers during wheat production to harvest high grain yields. Heavy use of chemical fertilizers has manifold environmental impacts including degradation of soil fertility, organic matter absorption, decreased water holding capacity, nutrient mobilization and uptake by root as reported by **Xiao *et al*. (2019).** Similarly, Fertilizer being a major determinant of yield has gained much attention in research since long time. The research has achieved high productivity; Nonetheless, the nutrient utilization efficiency is low. The efficiency of nutrient usage of N, P and K still stands at 30-35%, 18-20%, and 35-40%, respectively as reported by **Subhramanian *et al*. (2015).** Low fertilizer use efficiency not only increases the cost of production but also poses some significant environmental issues. Moreover, quite volatile global market has resulted higher fertilizer price. Considering all these facts we need to establish an efficiency-centered fertilizer management practice.

Shortage of arable land, limited water and nutrient resources necessitates increase in resource use efficiency without sacrificing production through effective use of modern technologies **(Nader and Shahraki, 2013).** In the context Nanotechnology is dedicated to improving the fertilizer use efficiency. Over the last few years, various nano-sized fertilizers or smart delivery-based fertilizers with surface coating of nanoparticles have received due attention. Owing to their smaller scale, high specific surface area, high surface energy and high solubility, nanoparticles attain their unique properties. The specific properties can be beneficially used to increase the quality of nutrient usage. Fertilizers and nutrients contained in nano porous materials, covered with a thin polymer coating, or distributed as nanoscale particles or emulsions **(Rai *et al*., 2012)** are known as Nano-fertilizers. Nano-particles under 100 nm in size can be employed as fertilizer for successful nutrient management, in addition to the added benefit of stress tolerating strength.

Foliar fertilizer administration is credited with the advantages of rapid and efficient nutrient utilization, elimination of leaching losses, fixing, and modulation of nutrient uptake by plants as reported by **Manonmani and Srimathi (2009).** Similarly, **Narang *et al*. (1997)** advocated that foliar application of fertilizers is more effective than soil application due to better plant utilization and lower cost per unit area. Additionally, enhanced photosynthetic rate and improved transfer of these nutrients from the leaves to the developing grains.

Biofertilizers are live microorganisms with the ability to mobilize plant nutrients in the soil. They are a low-cost, capital-intensive, non-bulk, and environmentally friendly way to increase production **(Kloepper *et al*., 1989).** *Azotobacter* is a biofertilizer that plays an important part in the nitrogen cycle in nature, binding atmospheric nitrogen that is unavailable to plants and releasing it in the form of ammonium ions that are available to plants in the soil, fixing an average of 20 kg N $ha^{-1}$ each year **(Dilworth *et al*., 1988).** *Azotobacter* along with phosphate solubilizing bacteria and Potash mobilizing bacteria increases the grain yield (10-12%) of wheat as well as increases the availability of micronutrients such as Fe, Mn, Zn etc. in the soil and thus, the combined application of biofertilizers may be regarded as beneficial for the growth and yield of wheat as reported by **Noreen and Noreen (2014).**

In order to replace commercial chemical fertilizers, the application of bio-stimulants fertilizer is of great importance. Seaweed Extract is a new generation, highly effective natural organic fertilizer that promotes growth, yield and enhances the resistance to biotic and abiotic stress of many crops. In addition to having low production costs, extracts derived from seaweed are biodegradable, non-toxic, non-polluting and non-hazardous to humans, animals and birds, unlike chemical fertilizers **(Dhargalkar and Pereira, 2005).** Wheat nutrient absorption is thought to be improved by using extracts of *Kappaphycus alvarezii* and *Gracilaria edulis*. This could be owing to the presence of various organic chemicals and a natural chelating component (i.e. anitol), which help the plant mobilize fixed nutrients in usable form. It also contains a lot of potassium and phosphorus as reported by **Shah *et al*. (2013).**

Excessive use of chemical fertilizers adversely affected the environment and soil health. Therefore, balanced and integrated application of nano nutrients, biofertilizers, bio-stimulants and inorganic fertilizers should be a key factor in order to achieve improved and sustainable soil fertility and crop yield. Keeping in mind the foregoing facts, the present study, entitled “Effect of doses and sources of nutrients on growth, yield and quality of timely sown irrigated wheat (*Triticum aestivum* L .)” was conducted with the following objectives:-

1. To study the effect of nutrient sources and doses on growth, yield and quality of wheat,
2. To find out the effect of nutrient management options on nutrient content and uptake by wheat, and
3. To assess economic feasibility of different nutrient management practices for wheat.

# 2. REVIEW OF LITERATURE

Considerable research has been done on input and management practices in wheat. But there is dearth of information on the response to nano based materials, Biofertilizers and Bio-stimulants. Therefore, an effort has been made to review the work done on use of prevalent nano nutrient, biofertilizer and bio-stimulant sources in wheat / cereals in relation to growth and development of the crop under pertinent conditions. Accordingly, the work done in India and abroad pertaining to the proposed study has been reviewed and accounted here under:

## 2.1 EFFECT OF NPK-FERTILIZERS

Most of the Indian soils are deficient in nitrogen, low to medium in phosphorus and medium to rich in potassium. All the primary nutrients being either the constituents of metabolically active compounds or activator of vital enzyme systems play a vital role in the growth, yield and quality of crops. Crop yield is a function of productive tillers plant$^{-1}$ and yield plants$^{-1}$ which in turn are decided by germination, emergence, tillering, mortality and growth of the plants. Effect of NPK on various growth and yield parameters as observed and reported by the researches is as follows:

### 2.1.1 On crop growth

**Kumar *et al*. (2010)** reported that the application of nitrogen in three split doses (1/3 before sowing + 1/3 after first irrigation + 1/3 at spike initiation) recorded significantly taller plants, more dry matter accumulation and higher LAI followed by N applied in two splits (1/2 before sowing + 1/2 after first irrigation) and therefore also increased yield by 9.9% over the later. Further, **Amal *et al*., (2011)** reported that foliar fertilizer of urea and potassium caused significant stimulatory effect on growth parameters, however, foliar feeding with urea 2% + potassium 2% gave the highest significant values for all growth characters at 65, 90 and 115 days after sowing and also for yield and its components i.e. plant height, number of spikes $m^{-2}$, weight of spikes $m^{-2}$ as well as grain, straw and biological yield.

**Gul *et al.* (2011)** studying the effect of foliar application of nitrogen, potassium and zinc on wheat cultivars found that Ghazanive-98 recorded highest emergence (309 $m^2$) and number of tillers (527 $m^{-2}$) with 0.5% N, 0.5% K and 0.5% Zn spray twice as against respective lowest emergence of 130 $m^{-2}$ and 263 tillers $m^{-2}$ in control plot. Similarly, **Surendar *et al.* (2013)** also found that the basal application of 25 kg $ha^{-1}$ nitrogen with foliar spray of urea 2% and 0.1 ppm brassinolide significantly responded to growth attributes viz., Leaf area index, Crop growth rate, Relative growth rate, Net assimilation rate and Specific leaf weight and resulting higher accumulation of total dry matter and increased yield. Similarly, a field experiment was conducted by **Jat *et al*. (2013)** and they noticed that at 90 days after sowing, plant height, number of tillers and dry matter accumulation was maximum with application of 120, 60 and 60 kg $ha^{-1}$ of N, $P_2O_5$ and $K_2O$. Further, plant height increased with an increase in fertilizer dose. **Singh and Kushwaha (2013)** also concluded that application of increased rate of fertilizes enhanced the growth attributes *viz.* plant height and dry matter production in all the stages of wheat plant. Highest plant height and dry matter (g $plant^{-1}$) was recorded with the application of 100 % NPK compared to those observed in lower levels of fertilization.

**Dash *et al.* (2015)** Observed significant increase in plant population with balanced fertilization i.e. application of N, P, K, S, B and Zn attributed to better germination and seedlings establishment under Gwalior conditions. Further, **Patra *et al.* (2018)** conducted an experiment to evaluate the effect of different nitrogen levels on late sowing wheat and found that plant height, dry matter accumulation, leaf area index, crop growth rate & number of effective tillers increased significantly with increase in nitrogen dose up to 150 kg $ha^{-1}$.

### 2.1.2 Yield attributes and yield

**Malghani *et al*. (2010)** observed that application of 175:150:125 kg N, $P_2O_5$, $K_2O$ $ha^{-1}$ increased grain yield (5168 Kg $ha^{-1}$) of wheat by 51.58% over control (2502 Kg $ha^{-1}$), followed by 75:50:125, 100:75:50, 125:100:75, 150:125:100 and 200:150:125 Kg N, $P_2O_5$, $K_2O$ $ha^{-1}$. Further **Saini *et al.* (2010)** reported that recommended dose of fertilizer might have supplied nutrients to crop in optimum and balanced proportion required for its better growth and development, thereby leading to higher grain yield**.** While working on wheat. **Ghanshyam *et al*. (2010)** found that the application of fertilizers at 75% RDF being at par with 100% RDF increased the grain and straw yield of wheat significantly over 50% RDF in both the seasons. Application of 75% RDF to wheat recorded 18.8 and 18.9% higher grain yield of wheat during respective seasons over 50% RDF. According to **Guixia *et al*. (2010),** an application of S, Zn, and S+ Zn in addition to NPK improved the yield attributing characters, grain, straw and biological yields compared to NPK alone. Increase of 7.2, 5.4 and 9.0% in number of effective tillers $m^{-2}$, 5.8, 4.6 and 6.8% in grains $ear^{-1}$, 11.5, 8.8 and 12.38% in grain weight $ear^{-1}$ and 5.1, 3.8 and 6.1% in 1000-grain weight was observed on pooled basis with NPK+S, NPK + Zn and NPK +S + Zn over NPK alone, respectively.

**Asghar *et al.* (2010)** studied the impact of NPK on wheat grain yield. The highest wheat grain yield (5168 kg $ha^{-1}$) was obtained by them with 175-150-125 kg of NPK $ha^{-1}$. The increasing trend in yield with increasing level of NPK was also reported in the study. Further **Gul *et al.* (2011)** conducted an experiment to study the effect of nitrogen on productivity of the different varieties of the wheat and found higher spikes $m^{-2}$ (286), grains $spike^{-1}$ (38.55) and thousand grains weight (44.67 g) which resulted in maximum grain yield (3308 kg $ha^{-1}$) with N-rate 150 kg $ha^{-1}$. Resulted of an experiment on wheat by **Malghani *et al*. (2012)** revealed highest grain yield of 5168 Kg $ha^{-1}$ with an application of 175:150:125 NPK kg $ha^{-1}$ establishing

51.6% increase over control (2502 kg $ha^{-1}$). Accordingly, **Sharma and Shahwany (2014)** showed that application of 100% NP increased the spike length, number of spike $m^{-2}$, 1000- grain weight, biological yield, grain yield and harvest index significantly by 13.48, 25.14, 12.28, 20.72, 44.58 and 20.03 %, respectively over control. Further **Jat *et al*. (2013)** revealed that application of 120:60:60 kg N, $P_2O_5$ and $K_2O$ $ha^{-1}$ resulted in highest number of grains per ear, ear weight and test weight of wheat, which were statistically close with 80:40:40 kg $ha^{-1}$ N, $P_2O_5$, $K_2O$ and both were significantly higher than 80:40:0 kg N, $P_2O_5$ and $K_2O$ $ha^{-1}$ fertilizer dose. Further, **Patra *et al.* (2018)** while evaluating the effect of different nitrogen levels on late sown wheat, suggested that all the yield attributes, grain yield and biological yield were significantly increased with increasing the nitrogen dose up to 150 kg $ha^{-1}$.

### 2.1.3 Nutrient uptake and nutrient content

Nutrient content and uptake have been found to exhibit large variation in response to nutrient management practices under various agro-ecological conditions. They are derived by soil fertility status, nutrient applications, absorption and assimilation capability of crop plants. **Jat *et al.* (2013)** studied the nutrient content and uptake pattern by wheat. Uptake of N, K, S and Zn with an application of 9 kg Zn $ha^{-1}$ was highest. Uptake of N, S, K and Zn in grain was 49.3, 50, 51.4 and 53.7% and in straw 44.08, 50, 41.8 and 48.2% higher with the dose over control, respectively. Significant response of wheat to Zn could be directly attributed to an enhanced availability of Zn in soil at a level below where the optimum requirement of crop was fulfilled. This showed that enhancement in Zn levels not only increased the yields but also increased the nutrient concentration and ultimately their uptake.

**Sheoran *et al.* (2015)** reported that nitrogen, phosphorus and potassium uptake by grain and straw in wheat, increased significantly with the increase in each successive dose of nitrogen up to the level of 200 mg $kg^{-1}$ soil and highest uptake of NPK by grain were 149.56, 57.59, and 40.87 mg $pot^{-1}$, respectively.

### 2.1.4 Quality parameters

**Kumar and Dhar (2010)** conducted an experiment on sandy loam soil and observed that 120:26:50 kg N, $P_2O_5$, $K_2O$ $ha^{-1}$ showed superiority over 60:13:25 NPK in terms of quality of wheat. The uptake of N, P and K also exhibited similar trend to both direct and residual fertility to different nutrient management practices applied to crop. According to **Hameeda *et al.* (2010)** application of medium and high fertilizer levels exhibited similar grain protein content. Similar trends were recorded for low and medium fertilizer levels. Higher percentage of grain protein (10.89%) were obtained from high NPK levels (105:75:75 kg $ha^{-1}$) and it differed significantly from low NPK (35:25:25 kg $ha^{-1}$) which has the lowest grain protein content (9.88%). Further to these findings, **Jat *et al*. (2013)** observed that significantly increased protein content with increase in application of fertilizer especially nitrogen. The maximum protein content was observed with treatment having higher application of N, $P_2O_5$ and $K_2O$ @ 120, 60 and 60 kg $ha^{-1}$ and this value was significantly higher than the treatment supplied with 80, 40 and 00 kg $ha^{-1}$ N, $P_2O_5$ and $K_2O$ $ha^{-1}$.

**Bhaduri *et al.* (2013)** proposed that nitrogen is the most important nutrient to have pronounced effect on quality parameters and showed significantly higher degree of correlation, followed by phosphorus and potassium. It implies that higher nutrient status of soil improved the nutrient uptake as well as quality of wheat grain. Moreover, **Youssef *et al.* (2013)** found that the protein content in wheat grains was increased with increasing N levels up to 288 kg N $ha^{-1}$ in presence of 53 kg $P_2O_5$ $ha^{-1}$ as well as 120 kg $K_2O$ $ha^{-1}$. This treatment recorded the highest values for protein content in wheat grains and total chlorophyll content.

### 2.1.5 Soil properties

**Meena *et. al.* (2012)** reported that integrated use of fertilizer NPK and FYM, improved soil physical health as revealed by a significant decrease in soil bulk density (BD) and an increase in water holding capacity (WHC) vis-à-vis soil fertilizer treatments or unfertilized control. During the years of experimentation soil BD decreased from 1.50 mg $m^{-3}$ in NPK to 1.40 mg $m^{-3}$ in NPK + FYM + ID plots. Moreover, a field experiment was conducted by **Jat *et al*. (2013)** at Varanasi in Inceptisol, had sandy loam texture, particle density 2.68 mg $m^{-3}$, bulk density 1.35 Mg $m^{-3}$, pH (1:2.5, soil: water) 7.3, electrical conductivity 0.27 dS $m^{-1}$, organic carbon 4.3 g $kg^{-1}$ and available nitrogen 184.6 kg, phosphorus 14.2 kg and potassium 153.7 kg $ha^{-1.}$.They observed that the level of available nutrients significantly increased with each successive increase in fertilizer levels in soil. The higher content of available N, P and K, was observed with 120:60:60 as compared with application @ 80: 40:00 kg of N, $P_2O_5$ and $K_2O$ $ha^{-1}$. Amount of added fertilizers determines the availability of nutrients to the crop and its content in post-harvest soil. The study revealed that crop sown on 20 November with application of 120:60:60 kg $ha^{-1}$ of N, $P_2O_5$ and $K_2O$ had maximum height and number of tillers.

**Sharma *et al.* (2015)** reported that with application of 50% NPK + 50% FYM; organic carbon content (0.87%), cation exchange capacity (13.80 C mol $kg^{-1}$) and available Nitrogen (746.4 kg $ha^{-1}$) and Phosphorus (48.3 kg $ha^{-1}$) were statistically different from that with control. Suggesting that crop yield and soil properties may be improved significantly by application of organic with inorganics for longer time. Hence, instead of using chemical fertilizer alone, the integrated use could be more effective and sustainable for environment and agriculture.

### 2.1.6 Cost and returns

**Singh *et al.* (2010)** reported that 100% recommended dose of NPK through fertilizers gave significantly higher net return over control and it was statistically at par with 75% recommended dose of NPK. Further **Jabran *et al*. (2011)** obtained maximum net returns of 67,033 ha$^{-1}$ annum$^{-1}$ was obtained with complete SSNM treatment (N 150, P 60, K 120, S 40, B 5, Mn 20, Zn 25 in rice followed by N 150, P 60, K 120 in wheat) in rice-wheat system, which was 31,681 and 16,905 ha$^{-1}$ annum$^{-1}$ higher over those of farmer's practice and state recommended fertilizer doses. Maximum wheat grain (4891.67 kg ha$^{-1}$) was obtained from field sprayed with fertilizer nitrogen (N), phosphorus (P) and potassium (K) @ 12.5, 7.85 and 5.25 kg ha$^{-1}$ at grain development stage.

**Kumar and Thenua (2012)** found that gross returns, net returns and B:C ratio were higher in treatment receiving 150 kg N ha$^{-1}$, while lowest values of these parameters were recorded in control treatment. Similarly, **Mauriya *et al.* (2013)** recorded variations in the cost of cultivation under different treatments due to variable cost of macro and micro-nutrients. Grain and straw yields were the major factors which caused differences in gross and net returns. Maximum net returns of 67,033 ha annum$^{-1}$ were obtained with complete SSNM treatment (nitrogen 150, Phosphorus 60, potassium 120, sulphur 40, Boron 5 manganese 20 and zinc 25 kg in rice followed by nitrogen 150, Phosphorus 60 and potassium 120 kg in wheat) in rice–wheat system, which was 31,681 and 16,905 ha annum$^{-1}$ higher over those of farmer's practice and state recommended fertilizer doses.

In a field experiment, **Singh and Kushwah (2013)** found that net monetary returns and return rupee$^{-1}$ invested were significantly more with 100 % NPK in comparison to their lower levels. Higher monetary returns could be ascribed to higher gross monetary returns with moderate cost of cultivation. Increase in returns rupee$^{-1}$ was due to higher value of gross return compared to low cost of cultivation.

## 2.2 Effect of nano material on crop plant

Nano-fertilizers are the most recent and technologically advanced sources of providing minerals to crops. Some nano materials, such as silica nano-particle and chelated nano-fertilizer, are more effective than conventional fertilizers. Silver coated nano-fertilizer, Nanorockphosphate, hydroxyapatite and titanium nanoparticles, gypsum nano-fertilizers, zeolite based nitrogen nano-fertilizers, and others are known to increase NUE by way of mobility, release pattern, surface area, content in grain, and reduce loss (leaching, denitrification, fixation) of inorganic fertilizer (NPK) when used alone or in combination as advocated by **Liu and Lal (2015) and Liang *et al*. (2013).**

### 2.2.1 EFFECT OF NANO-N & Zn -FERTILIZERS

Nano fertilizers have emerged as a trailblazer in agricultural research. They are highly useful for scientific nutrient management in precision agriculture as they supply nutrients in the amounts and at the rates that plants require among the various stages of growth and development. There are limited arable lands and water supplies, the agriculture can only develop with higher resource usage efficiency with least of damage to the production bed through the proper application of contemporary technologies. Nanofertilizers are very important tools in agriculture to improve crop growth, yield and quality parameters with increased nutrient use efficiency, reduced wastage of fertilizers and low cost of cultivation. **Rameshaiah *et al.* (2015)** reported an increase in nutrient use efficiency (NUE) by 3 times with use of nano-fertilizer. Effect of nano-materials has been reported by several workers under different conditions as follows.

### 2.2.2 On crop growth

**Prasad *et al*. (2012)** conducted an experiment to examine the effects of nano-scale zinc oxide particles on plant growth and development in Chennai and results showed that the nano-scale zinc oxide particles resulted in an increase in germination percentage, seedling vigor, plant height, chlorophyll content and initiation of flowering in peanut. Further, **Dhoke *et al*. (2013)** conducted a research to study the effect of nano-particles on mung and reported that the growth and development of mung seedlings were more pronounced when treated with the ZnO, FeO and ZnFeCu-oxide nano-particle suspensions which promoted root and shoot length as well as biomass accumulation when compared with the control. Similarly, **Kumar *et al.* (2014)** also reported that application of nano-gypsum and rock phosphate tagged with urea at the rate of 3 kg $ha^{-1}$ in wheat significantly increased tillers $m^{-2}$, dry matter accumulation and the days taken to 50% flowering, physiological maturity and harvest maturity than control and other treatments in comparison.

**Reazaei and Abbasi (2014)** studied application of mineral fertilizer of zinc, chelate of zinc and nano-chelate of zinc in cotton revealed significant increasing height, fresh weight, and dry weight in treatments with nano-chelate and chelate of zinc. Similarly, **Ghahremani *et al*. (2014)** conducted a greenhouse experiment to investigate the effects of different concentrations i.e. 0.1, 0.2, 0.4 and 0.6 % of nano-calcium and nano-potassium chelate fertilizers on quantitative and qualitative characteristics of basil and reported that nano calcium and nano potassium significantly increased basil dry matter and leaf area than control.

**Ajirloo *et al*. (2015)** working with Nano–K fertilizer and N bio-fertilizer in tomato (*Lycopersicon esculentum* L.) concluded that application of Nano-K fertilizer and nitrogen bio-fertilizer significantly increased all the crop growth parameters *viz*. plant height, stem diameter, leaf area and fruit weight. An increase in growth parameters like plant height, leaf number, fresh and dry weight of savory plant with use of nano-zinc has been reported by **Vafa *et al.* (2015).** Similarly, **Benzon *et al*.**

**(2015)** obtained a good response of rice to nano-fertilizers (N>1.2%; $P_2O_5$>0.001%; $K_2O$>0.0001%) as its growth *viz.* plant height and tillers was significantly enhanced by all combination treatments except for that applied with nano-fertilizer only. The full recommended dose of conventional and nano-fertilizer (FRR-CF+FRR-NF) resulted in significant increase in plant height and number of tillers than control and other treatments in comparison.

**Aziz *et al*. (2016)** evaluating the effect of nano chitosan-NPK fertilizer application in the foliar form on wheat plants obtained significant increase in all growth variables *viz*. shoot length, fresh weight, dry weight and leaf area of wheat crop and a significant reduction in days taken to 50 % ear head stage, days to physiological maturity and days to harvesting with the ratio of 23.5 % (130 days compared with 170 days for yield production from date of sowing) when sprayed with nano chitosan – NPK fertilizers. Further, **Manikandan and Subramanian (2016)** evaluated the response of maize plants to the zeolite based nitrogen nano-fertilizers (nano-zeolite possesses extensive surface area and its coating or blending with the conventional nitrogenous fertilizers can regulate the release of nitrogen) and conventional fertilizers in two greenhouse experiments and reported that the response was more pronounced in Alfisols than Inceptisol besides concomitant significant increase in plant height, root length and leaf area. However, the increase in dry matter accumulation for nano-zeolite urea treatment as foliar application was found to be at par with application of conventional urea.

### 2.2.3 On yield and yield attributes

Alike, growth and development yield and yield attributes of various crops have been reported to exhibit variations under the influence of nano-sources of plant-nutrients. The yield of wheat with high amount urea fertilizer was 2.31 % lower than that with low amount nano-synergism fertilizer (10 kg $ha^{-1}$). Similarly, rice grain yield was improved significantly (11.3%) after applying slow- release nano fertilizer over normal fertilizers as reported by **Wu *et al.* (2013).** Similarly, **Suriyaprabha (2012)** also recorded higher values of yield parameters under nano-fertilizers treated plants compare to bulk nutrient sources. Further, **Kumar *et al.* (2014)** working at Pant Nagar with nano-fertilizers of gypsum and rock phosphate (3 kg $ha^{-1}$) in wheat crop opined that yield parameters and yield obtained at 50% RDF with nano- materials was statistically similar with 100% RDF without nano-materials.

**Reazaei and Abbasi (2014)** conducting their work on mineral fertilizer of zinc, chelate of zinc and nano chelate of zinc in cotton reported that application of zinc chelate and specially the nano-chelate of zinc resulted in significant increase in yield of cotton attributed to increase in yield attributes like number of bolls per plant and mean weight of 20 bolls. Similarly, in pear-millet, **Tarafdar *et al*. (2014)** reported a significant increase in the grain yield to the extent of 37.7% owing to the use of nano zinc fertilizer than control. Similarly, significant increase in number of fruits per plant, fruit weight, fruit diameter and fruit yield tomato with application of nano-zinc has been advocated by **Ajirloo *et al.* (2015)**.

**Benzon *et al*. (2015)** led an experiment to determine the effects of nano- fertilizer on growth, development, yield and chemical properties of rice. The results revealed that the full recommended rate of conventional and nano-fertilizer enhanced the grain yield and yield attributes *viz*. chlorophyll content, number of reproductive tillers, panicles, panicle weight, total grain weight (unpolished-17.5%, polished - 20.7%), total shoot dry weight and harvest index than control and other treatments in comparison. **Farnia and Omidi (2015)** recorded favorable effect of nano- Zinc chelate and nano-biofertilizer on yield and yield components of maize namely 100-grain weight, number of rows per cob, number of grains per cob and harvest index in comparison to control and other treatments Moreover, **Janmohammadi *et al.* (2016)**

found that the application of nanofertilizers improved fertilizer use efficiency and significantly increased the grain yield and straw yield of barley.

**Drostkar *et al.* (2016)** opined that foliar spray of NPK nano-fertilizers increased the yield and yield components in chickpea as a result of increased growth, hormone activity and enhancement of metabolic process, increase in flowering and grain formation. **Aziz *et al*. (2016)** while evaluating the effects of nano chitosan- NPK fertilizer application in the foliar form on wheat revealed a significant increase in spike length, 1000-grain weight, number of grains per spike, grain yield, straw yield and harvest index of the wheat in comparison to control and normal NPK fertilized crop.

**2.2.4 On nutrient uptake and nutrient content**

Nutrient sources and levels are known to have significant effect on nutrient content and uptake by crops. **Fan *et al.* (2012)** conducting an experiment to investigate the effects of combined application of nitrogen fertilizer and nano-carbon on nitrogen use of soil and rice cv Changbai 10 observed significant increase in nitrogen uptake with combined application of nitrogen fertilizer and nano-carbon fertilizers.

**Adhikari *et al*. (2014)** studying the efficacy of different nano Rock Phosphate, taking maize as a test crop with five treatments (control, NK (100%), NPK (100%), NK (100%) + 60 kg $P_2O_5$) Nano rock phosphate (Nano RP) through Udaipur Nano RP (34% $P_2O_5$) and Udaipur nano RP (31% $P_2O_5$) revealed that the total P content and its uptake were higher (0.65% and 40.29 kg $ha^{-1}$) in SSP treated plant, which was closely followed by Udaipur nano RP 34 % (0.63 % and 38.29 kg $ha^{-1}$) over the control (0.60 % and 27.82 kg $ha^{-1}$). The SSP treated plants had significantly highest apparent P recovery (47.98 %) which was comparable to Udaipur nano RP (34% $P_2O_5$), whereas the Udaipur nano RP (31% $P_2O_5$) had the lowest. The additional

N and K uptake by the plant was also observed with application of P sources, which ranged from 16.5 kg $ha^{-1}$ to 37.2 kg $ha^{-1}$ and 27.9 kg $ha^{-1}$ to 64.7 kg $ha^{-1}$ under different Phosphorus treatments. These results showed almost similar utilization of Phosphorus from nano RP and SSP while yield response was marginally lower with the later.

**Kumar *et al.* (2014)** studied the effect of nano-fertilizers of gypsum and rock phosphate (3 kg $ha^{-1}$) on wheat and observed significant increase in nutrient uptake with 50% RDF with nano- materials which was at par with 100% RDF without nano-materials. Further, **Manikandan and Subramanian (2016)** also estimated the response of maize plants to the zeolite-based nitrogen nano-fertilizers and conventional fertilizers in two greenhouse experiments of two distinct soil textures (Inceptisol – Periyanayakkan palayam soil series – clay loam and Alfisols - Iregur soil series- sandy loam) and concluded that the nutrient uptake was significantly higher with nano-zeolite urea than conventional urea.

**2.2.5 On quality parameters**

**Ghafari and Razmjoo (2013)** conducted an experiment to evaluate the effects of foliar application of nano-iron oxide (2 and 4 g $L^{-1}$ 8 g $L^{-1}$ ) and iron sulphate (4 and 8 g $L^{-1}$ ) on quality of bread wheat (*Triticum aestivum* L.) and observed significantly higher grain carbohydrate yield besides chlorophyll, grain protein and iron contents with application of 8 g $L^{-1}$ iron sulphate followed by application of 2 g $L^{-1}$ of nano-iron oxide than control plots in comparison. Similarly, **Ramesh *et al.* (2014)** reported significant increase in chlorophyll and protein content with low concentration nano-ZnO treated sample in wheat crop whereas no changes were recorded with respect to bulk-ZnO and bulk and nano-$TiO_2$ treated samples. Further, **Manikandan and Subramanian (2016)** evaluated the zeolite-based nitrogen nano- fertilizers on maize crop in two greenhouse experiments of two distinct soil textures (Inceptisol –

Periyanayakkan palayam soil series – clay loam and Alfisols - Iregur soil series-sandy loam) and reported that the crude protein content was significantly higher for nano-zeolite urea treatment in comparison to conventional urea.

### 2.2.6 Soil properties

**De Rosa *et al*. (2010)** advocated that Nano-fertilizers are known to improve the nutrient use efficiencies as a result of the large surface area and small size of the nano material's that allow sustained release, enhanced interaction and efficient uptake of nutrients for crop fertilization. **Du *et al*. (2011)** noticed that ZnO NPs were no longer retained in the soil for longer period and dissolved in the soil, leaving no significant change in soil chemical properties at the end of crop growth period. Similarly, **Liu *et al.* (2015)** confirmed a high Zn bio-availability in ZnO NPs-spiked soil to maize as they observed significant positive correlations with ZnO NPs dose, indicating the Zn in plants is at least partly from ZnO NPs.

### 2.2.7 Cost and returns

Economic viability/feasibility of any technology/practices drives its adoption at the end clientele and thus, is worked out. In the current scenario inputs use have been escalating at a faster rate in comparison to outputs thus narrowing down the profit margin at the end of farms. Nano-materials/sources can only be adopted if they reduce the cost incurred on nutrient management in crops. **Kumar *et al.* (2014)** while working with effect nano-fertilizers of gypsum and rock phosphate in wheat at Pantnagar assessed the economic fairness of the nutrient sources. They reported that B:C ratio was almost similar with use of conventional fertilizer (100%) and 50% of conventional fertilizer conjugated with nano sources.

## 2.3 Effect of Biofertilizers

Liquid biofertilizers are unique formulations comprising desired microorganisms, their nutrients, and cell protectant chemicals and additives that improve cell survival during seed or soil application. The population of *Rhizobium* sp., *Azospirillum* sp., and PSB up in the produced liquid inoculants was known to be $10^8$ cells per ml of liquid biofertilizers. Because the cell count in liquid biofertilizers is large, each seed receives thousands of cells.

### 2.3.1 Crop growth

**Minaxi *et al*. (2013)** reported significant increase in growth, yield and nutrient uptake of wheat plants with both strains of Phosphate Solubilizing Bacteria (BAM-4, BAM-12) that interacted positively with Arbuscular Mycorrhiza fungi towards all growth parameters. A remarkable enhancement of seed yield was recorded notably by 92.8%. Similarly, **Singh *et al.* (2013)** reported that seed inoculation with *Azotobacter* and *Azospirillum* significantly increased the plant height, dry matter of wheat over no inoculation. However, both were at par with respect to fore-mentioned parameters. Also, **Shirinzadeh *et al*. (2013)** reported that plant height was significantly increased by seed priming with plant growth promoting rhizobacteria (*Azotobacter* & *Azospirillum*). Further, In a two-year study in Meerut, ***Jat et al.* (2018)** found that seed inoculation with NPK-Biofertilizer increased plant height and dry matter by 18.17 %, 17.75 %, and 42.80 %, 39.76 %, respectively, as compared to RDF.

### 2.3.2 Yield attributes and yield

**Yadav *et al*. (2011)** showed that the biofertilizers, united application of *Azotobacter* and *Azospirillum* induced significantly more productive tillers spikes$^{-1}$ and dry weight plant$^{-1}$ of barley followed up by *Azotobacter* and *Azospirillum* as individual, against minimal in control during both the years. On mean base, the maximum grain yield (50.95 q ha$^{-1}$) was achieved under mixed application of *Azotobacter* + *Azospirillum* followed up by individual application of *Azotobacter*

(43.22 q $ha^{-1}$), *Azospirillum* (48.15 q $ha^{-1}$), and in control (45.24 q $ha^{-1}$), respectively. Similarly, **Shirinzadeh *et al*. (2013)** reported that seed priming with plant growth promoting rhizobacteria (*Azotobacter* & *Azospirillum*), affected spike length, number of spikes per area, grains per spike, 1000-grain weight and grain yield, significantly. **Bahadur *et al*. (2013**) also studied different nutrient management options involving carrier based *Azotobacter* and PSB biofertilizers in Rice-Wheat system and observed that application of organic manures integrated with RDF and biofertilizers (PSB + *Azotobacter*) produced more grain yield (3-3.5 t $ha^{-1}$) of wheat which was at par to 125% recommended dose of fertilizers (3-3.5 t $ha^{-1}$). They also reported favorable effects of biofertilizers on various yield attributing parameters of wheat. Further **Dibakar *et al*. (2014)** also observed that grain yield of wheat was increased due to the application of phosphorus in combination with PSB. The highest grain yield was obtained with application of 50% phosphorous with PSB and VAM in wheat. The increase in grain yield with 50% P + PSB + VAM found significantly superior to 100% phosphorus application. Similarly, **Chand *et al*. (2014)** assessed the effect of INM module on wheat. The results revealed that an application of NPK @ 120:60:40 kg $ha^{-1}$ with seed treatment of *Azotobacter* @ 200 g $10^{-1}$ kg seed and PSB @ 2.5 $kg^{-1}$ mixed with 60 kg FYM applied in soil before sowing improved the grain yield of wheat by 29.3% followed by 18.1% with application of NPK @ 120:60:40 kg $ha^{-1}$ with seed treatment of *Azotobacter* @ 200 g $10^{-1}$ kg seed compared to farmers practice *Azotobacter* and PSB inoculation, being at par, caused significant improvement in the growth and yield attributes over control in wheat. Further, ***Jat et al.* (2018)** revealed that seed inoculation with NPK-Biofertilizer increased yield attributes such as effective tiller, grain per spike, 1000 grain weight, and grain yield considerably over no inoculation in two years of wheat experimentation.

### 2.3.3 Nutrient uptake

**Minaxi *et al*. (2013)** reported that nitrogen and phosphorus contents in wheat were higher in all biofertilizers (PSB + *Azotobacter*) treatments than control. Seed inoculation with PSB in combination with rock phosphate increased total P uptake, but significant increase was observed when PSB and AM (*Glomus etunicatum*) were inoculated together. However, P concentration in shoots differed among biofertilizers treatments. The maximum increase in N (145%) and P (171%) content was observed with treatment of PSB + *Azotobacter* amended with AM + Tri calcium phosphate than control at 45 and 110 DAS in wheat. similarly, **Kaur and Reddy (2014)** observed that stimulatory effects of PSB on P uptake was more pronounced when wheat seeds were inoculated with PSB and applied in combination with rock phosphate during two years field study after harvest of wheat crop. Futher, **Jat *et al.* (2018)** found that stimulatory effect of NPK-biofertilizer on N,P,K uptake when seed treatment of wheat done with NPK-biofertilizer and applied in combination of FYM resulted significant uptake of NPK over RDF during two year of investigation after harvest of crop.

### 2.3.4 Quality parameters

**Bahrani *et al*. (2010)** reported that *Azotobacter* + *Mycorrhiza* treatment increased grain protein by 13% over control. Similarly, **Thalooth *et al*. (2012)** noticed that biofertilizers inoculation increased crude protein content, while the least values were observed with un inoculated barley plants. Further, **Jat *et al.* (2018)** reported that Protein content of wheat recorded highest (10.18%) when the crop was inoculated with NPK- biofertilizer which was significantly superior in comparison to (7.42%) in control and (8.50%) with Recommended NPK.

### 2.3.5 Soil biological properties

**Nath *et al*. (2011)** reported that dehydrogenase activity has been found to be increased significantly in soils due to application of organic and inorganic fertilizers along with biofertilizers treatment. Substitution of 25% N P fertilizers by way of enriched compost (2 tonnes $ha^{-1}$) with biofertilizers (*Azotobacter* + PSB) promoted higher level of dehydrogenase activity (152.94 µg TPF $g^{-1}$ $24^{-1}$ h) over 100% NPK fertilizer plot (64.63 µg TPF $g^{-1}$ $24^{-1}$ h) after harvesting of wheat. Further **Minaxi *et al*. (2013)** also reported that number of PSB population was significantly higher in dual seed inoculation of two bacterial strains (*Pseudomonas flueroscens* BAM-4 and *Burkholderia cepacia* BAM-12) with AM fungi than single inoculation with AM fungi in wheat by recording higher number of PSB population (4.25 x $10^6$ cells $g^{-1}$) after harvest of wheat at 110 DAS. Similarly, **Bahedur *et al*. (2013)** evaluated the effect of carrier based biofertilizers of *Azotobacter* and PSB in wheat in combination with chemical fertilizers and organic manures. They counted maximum bacterial population (94.0 x$10^5$ $g^{-1}$ soil) & *Azotobacter* counts (51.5 x $10^2$ $g^{-1}$ soil) with application of NPK + FYM at 5 t $ha^{-1}$ + PSB and maximum PSB count (42.0 x $10^2 g^{-1}$ soil) with application of NPK + PSB. Further, **Kaur and Reddy (2014**) studied the effect of PSB ( *Pantoea cypripedia* and *Psedomonas placoglossicida*) inoculation on soil biological properties and reported that inoculation of both PSB significantly increased acid phosphatase, alkaline phosphate and dehydrogenase enzyme activities compared to control after harvest of wheat. They also reported maximum PSB population with *Pseudomonas placoglossicida* inoculation (9.3 x $10^7$ cfu $g^{-1}$ soil) along with Rock phosphatase compared to un-inoculated treatment (0.3 x $10^7$ cfu $g^{-1}$ soil) after harvest of wheat. Further, **Jat *et al.* (2018)** found that when seed inoculation of wheat done with NPKbiofertilize showed significant increase in population of bacteria, fungi, actinomycetes in both the year of investigation over control and RDF at Meerut.

### 2.3.6 Cost and return

**Chand *et al*. (2014)** studied the effect of application of biofertilizers (*Azotobacter* + PSB) to wheat and reported highest net returns (Rs.50,390 ha$^{-1}$) with seed treatment of *Azotobacter* @ 20 g kg$^{-1}$ seed and PSB @ 2.5 kg$^{-1}$ mixed with 60 kg FYM applied in soil before sowing as compared to farmers practice (Rs.43,650). The highest B:C ratio was recorded in seed treatment with *Azotobacter* and soil application of PSB (3.30) in comparison to the control (2.65). Also, **Behera and Rautaray (2010)** revealed that maximal net returns were collected from 100% NPK succeeded by biofertilizers + 50% NPK. Net returns were observed least under the unfertilized control treatment. Further, **Yadav *et al*. (2011)** showed that maximum net income was 43678 ha$^{-1}$ and B:C ratio was 2.2 under mixed application of *Azotobact*er + *Azospirillum* succeeded by single application of *Azotobacter* (40443 and 2.09) and *Azospirillum* (39411 and 1.95) against control (37267 and 1.82), respectively. Further, **Jat *et al.* (2018)** reveled that higher net return was Rs 88307 ha$^{-1}$ and B:C ratio of (3.77%) with seed inoculation by NPK-biofertilizer against no inoculation (Control) Rs 59202 ha$^{-1}$ with B:C ratio of (2.85%) respectively.

## 2.4 Effect of Biostimulants

In recent years, marine bioactive substances extracted from marine algae are used as supplement to the inorganic fertilizer. These substances recently, gained importance as foliar spray for many crops, which enhances yield and quality of crops due to presence of chemical complex polysaccharide compounds like laminarian, fucoidan, alginate, beneficial nutrients and growth hormones like cytokinin, auxins, betains, and sterols which promote plant growth. Many chemical components of seaweed extracts and their modes of action remain unknown, but it is possible that these components exhibit synergistic activity **(Fornes *et al.*, 1995).** Realizing the potential use of seaweed sap for enhancing the productivity of crops, *Kappaphycus alvarezii* has proven potentiality as a foliar biostimulants to increase productivity of many crops across varied agro ecological locations for research, development and commercialization. After four decades of introduction, *Kappaphycus* is now being recognized as the most widely cultivated commercial seaweed.

### 2.4.1 Crop growth

Sea weed extracts possess several growth hormones besides macro and micro nutrients which influenced the different parameters of growth in wheat / cereals. Application of *Kappaphycus alvarezii* & *Gracilaria edulis* sap increased plant height of wheat with increase in concentration of seaweed sap and maximum was recorded with 7.5% K sap and 5% G sap, which were 12.06 and 8.45% higher over control respectively **(Sevov *et al.*, 2013).** Similarly, **Pramanick *et al*. (2014)** noticed that application of 15% *Kappaphycus alvarezii* and *Gracilaria edulis* extract accelerate the growth attributes of rice. Further, **Trivedi *et al.* (2018)** investigated the effect of the application of *Kappaphycus alvarezii* sea weed extract on maize and found an increase in growth attributes over control. Similarly, **Jat *et al.* (2018)** while investigating in wheat found that application of Bio-stimulant-L @ 625 ml $ha^{-1}$ with RDF attained higher plant height, dry matter accumulation, no. of tiller over RDF.

### 2.4.2 Yield attributes and yield

Yield is the final economic product which is the resultant of growth and development of the crop**. Shah *et al*. (2013)** observed that foliar application of either 7.5% *Kappaphycus alvarezii* or 5% *Gracilaria edulis* sap significantly influenced the yield and yield attributes of wheat by 19.7 and 13.2% respectively over control. Similarly, **Pramanick *et al*. (2014)** observed that Foliar application of either 15% *Kappaphycus alvareziior or Gracilaria edulis* sap thrice along with RDF increased rice grain yield by 41.5 and 35.0% and the yield of straw by 53.7 and 45.7% respectively over control. Further in rice also, **Devi and Mani (2015)** reported that foliar application of either 15% K sap or G sap with RDF increased grain yield by 11.8 and 9.6%, respectively over control. Similarly **Pal *et al.,(*2015)** reported that foliar application of either K sap or G sap (2.5, 5, 10 and 15%) along with recommended dose of chemical fertilizer produced significantly higher yield of rice in comparison to control (RDF+ water spray). Further **Singh *et al., (*2015b)** found that increasing the concentration of K sap gradually increased the grain and straw yield of rice up to 10% K sap concentration and then declined, whereas increasing the concentration of G sap gradually increased the grain and straw yield of rice up to 15% concentration, and It was also found that a crop receiving with 50 % RDF and sprayed with either 2.5 % K sap or G sap yielded the same amount of rice grain and straw as a crop receiving 100 % RDF. Further, **Jat *et al.* (2018)** reported that application of Bio-stimulant-L@ 625 ml $ha^{-1}$ with RDF increased yield and yield attribute viz. ear length, grain per spike, 1000 grain weight over RDF in wheat crop.

### 2.4.3 Nutrient uptake

Application of seaweed sap increased the nutrient uptake by plants. It is due to presence of some organic constituents in the sea weed sap, which chelates the trace elements, and improves the efficiency of nutrient uptake **(Strik and Van Staden, 2006).** Foliar application of seaweed sap along with RDF in rice increased N, P and K uptake with increasing concentration of seaweed sap and maximum was recorded with 15% G sap and K sap along with 100% RDF and lowest uptake were recorded with the application of water spray + RDF as reported by **Pal *et al. (*2015).** It is possible that the presence of marine bioactive compounds in seaweed sap boosts stomatal absorption efficiency in treated plants over control plants as reported by **Mancuso *et al.* (2006)**. In the same vein as the previous investigation, **Popko *et al.* (2018)** reported that application amino acids based biostimulants at different doses contributed to the increase of the nutrients content in grains, in particular copper (ranging 31–50%), as well as sodium (35–43%), calcium (4.3–7.9%) and molybdenum (3.9–16%). In rice total nitrogen, phosphorus, potassium and sulphur uptake increased with increasing concentration of sap up to 10% K sap, further uptake of total N, P, K, and S was reduced as the sap content increased as reported by **Singh *et al.* (2015b).** Due to the presence of biostimulants, nutrient uptake increased with seaweed application, and their promotive effects boosted root proliferation and establishment, allowing plants to mine more nutrients from further away and deeper soil horizons in a balanced ratio. Furthermore, SLF modulates bio physiological activity, resulted in a sustained increase in photosynthetic activity. Further**, Jat *et al.* (2018)** Investigating in wheat found that foliar application of Bio-stimulant-L @ 625 ml $ha^{-1}$ with RDF increased nutrient uptake of N, P and K in wheat crop over RDF.

### 2.4.4 Quality parameters

Significantly increase in the grain quality at recommended doses of bio-stimulants. **Shah, M.T. Zodape *et al.* (2013)** studied the impact of foliar sprays of *Kappaphycus alvarezii* and *Gracilaria edulis* sap on growth and yield response of wheat var. 'GW 496'. At different stages of the crop, three foliar sprays of both saps were sprayed at rates of 2.5, 5.0, 7.5, and 10.0% (v/v), with water as a control. Grain yield was observed to be improved by 19.74 and 13.16%, respectively, for plants receiving 7.5 and 5.0% concentrations of *K. alvarezii* and *G.edulis* sap, compared to control. The increase in the number of spikes, spike weight, spike length, and 100 seed weight were all credited with increasing yield. *K. alvarezii* sap, applied foliarly at 7.5%, increased nutrient content in grains from 7.91% (K) to 31.82% (S), whereas

*G. edulis* sap enhanced nutrient content from 5.72% (N) to 37.54% (S). Further, **Singh *et al.*, *(*2016a)** reported that application of Biozyme (Seaweed extract) significantly increased protein content in wheat grain, which could be attributed to a promotive effect on root development, resulting in increased nutrient uptake, particularly those essential as ingredients in protein synthesis (nitrogen, phosphorus, and sulphur).

### 2.4.5 Soil properties

Intensive crop cultivation mostly leads to nutrient depletion of the soil reservoir all over the world as reported by **Shaaban *et al. (*2004, 2007, 2008).** The antagonistic effect of soil micro and macro nutrients affects the availability of some plant nutrients for plant roots **(Aulakh and Malhi 2005).** Application of seaweed extract enhances the moisture holding capacity of the soil as well as nutrient status in soil **(Mohanty *et al.*, 2013),** because seaweed extract trigger the growth of beneficial microbes and secretion of substances which aggregate the soil particles. In maize crop application of seaweed sap positively influenced, soil available P and K at harvest as found by **Singh *et al. (*2015c).** With increasing sap concentration up to 10% K sap, available soil nitrogen, phosphorous, and potassium content fell in rice, while additional increases in sap concentration slightly enhanced available N, P, K, and S in soil as reported by ***Singh* (2015).** Further**, Jat *et al.* (2018)** analyzed soil after harvest of wheat crop, found that foliar application of Bio-stimulant-L @ 625 ml $ha^{-1}$ with RDF have better availability of nutrient and microbial activity is soil as compare to RDF.

### 2.4.6 Cost and returns

Bio-stimulants application enhances productivity with better quality and profitability as well as higher monetary return. In rice, **Pramanick *et al.* (2014)** observed that over traditional rice production methods, foliar application of seaweed extract combined with the recommended dose of fertilizer (RDF) boosted net monetary return and B:C ratio. Similarly, **Singh *et al.* (2015)** reported that net return and B:C ratio increased with increasing concentration of seaweed sap up to 10% K sap thereafter (i.e.15% K sap) it declined significantly. Similarly, Crop fertilized with 50% RDF and sprayed with 2.5% K or G sap fetched the same net return and B:C ratio as control (100 % RDF alone). This may be concluded that productivity of crops can be further boosted up by application of seaweed. Further, **Jat *et. al. (*2018)** while investigating in wheat found that foliar application of Bio-stimulant-L @ 625 ml $ha^{-1}$ with RDF have better B:C ratio (3.44) as compared to RDF (3.20).

The particulars of experimental materials used and techniques adopted during the course of investigation entitled "**Effect of doses and sources of nutrients on growth, yield and quality of timely sown irrigated wheat (*Triticum aestivum* L.)**" are described in this chapter.

### 3.1 Experimental site and Location

The experiment was conducted at crop research Centre of the University located in Indo-Gangetic plains of Western Uttar Pradesh. At $29^0$ 5′ 34″ N latitude, $77^0$ 41′ 58″ E longitudes and at an elevation of 230 meters above the mean sea level. Meerut lies 65 km away from Delhi on the national highway 58 linking New Delhi and Dehradun.

### 3.2 Climate and weather

Meerut enjoys semi-arid and sub-tropical climate with extremely hot summer and cold winter, Minimum and maximum temperature both exhibit a gradual decrease starting from I week of October and reach their minimum in December and January. An increase in the temperature is recorded with effect from I week of February and peak value is noticed in $3^{rd}$ week of May. Occasional frost is also experienced during II fortnight of December and January. The mean weekly minimum temperature records as low as 4.3 $^0$C in $2^{nd}$ week of January. Whereas, mean weekly maximum temperature reaches as high as 36.9 $^0$C in $4^{th}$ Week of April. The area receives mean annual rainfall of 800 mm of which more than 80% is confined to the period of July-September through south-west monsoon. A few winter showers are also received. April and May are the driest months with mean relative humidity of 50 to 55%, whereas high humidity (92%) is recorded in the month of August. Daily observation on temperature, humidity, sunshine hours, rainfall, recorded at meteorological observatory of SVPUA&T Meerut were collected to work out weekly means as presented in Appendix I and depicted in Figure 3.1. The crop experienced lowest (4.9$^0$C) of mean weekly minimum temperature in 4$^{th}$ week of December and highest (38.2$^0$C) in 2$^{nd}$ week of April during 2021. Second week of January was most humid (94.9%), however the driest (22.0%) were month of the crop season was 2$^{nd}$ week of April. The crop received 39.9 mm rain during its period.

### 3.3 Soil of the experiment field

A composite soil sample was drawn from randomly selected samples from 15 cm soil depth before initiating the experiment for analyzing various soil properties. The values obtained are given in Table 3.1. The soil of the experimental site was sandy clay loam in texture, low in available nitrogen and organic carbon, medium in available phosphorus, available potassium and Zinc, moderately alkaline in reaction. Soil samples were collected from each plot after crop harvest as to determine their chemical properties.

### 3.4 Cropping history of the experimental field

The cropping history of the field for last few years was carefully examined before commencement of the present investigation and has been summarized in Table 3.2. Since several years, rice-wheat cropping system has been practiced in experimental field. This study was done in order to know the nature of crop grown on the particular piece of land where the experiment was conducted, which may be helpful in the interpretation and discussion of the results.

### 3.5 Experimental details

The following treatments and experimental design were used to achieve the objective

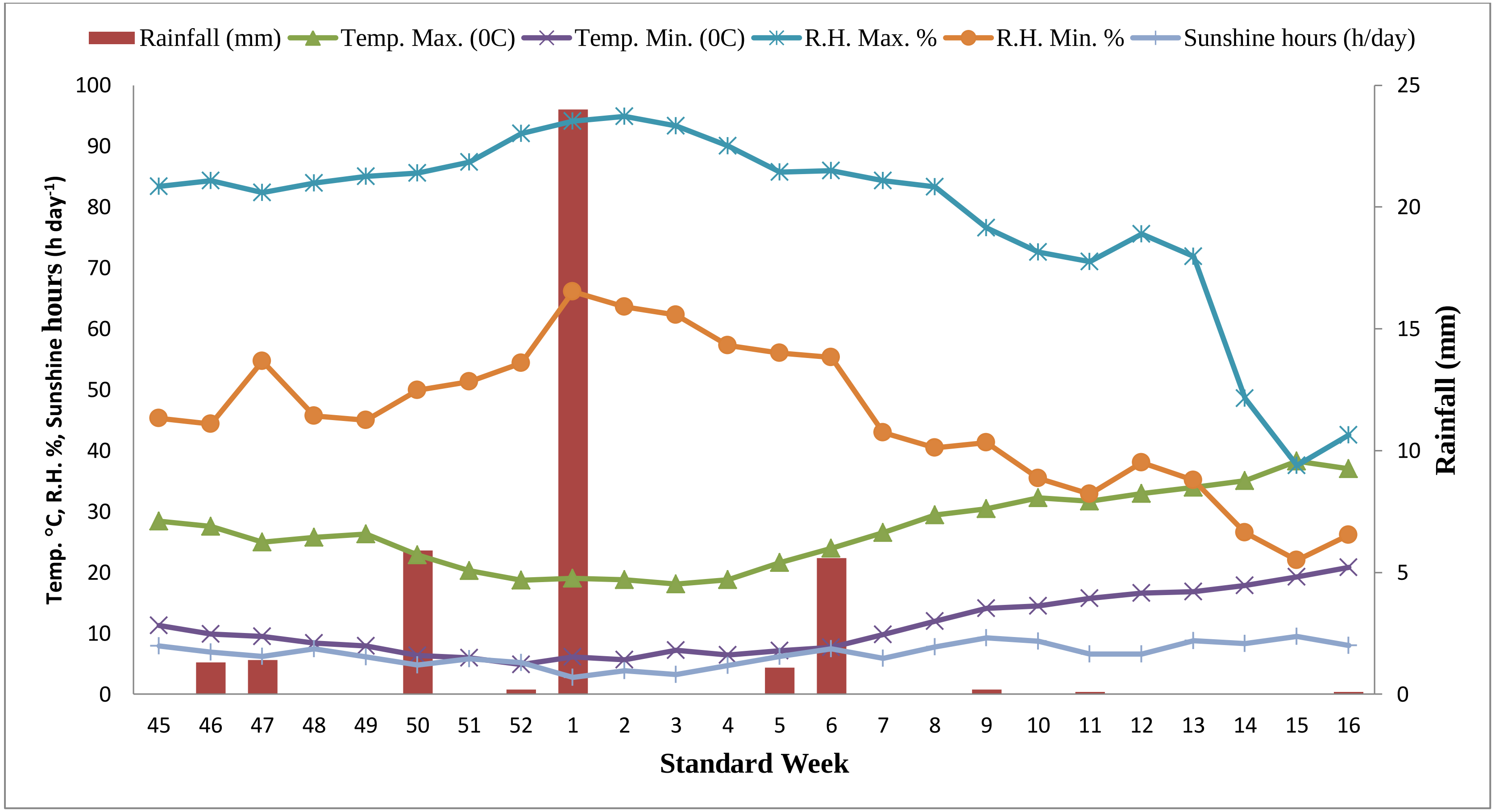



**Fig. 3.1 Mean weakly weather conditions during the experimental season (*rabi* 2020-21)**

**Table 3.1 Physico-chemical properties of the experimental field soil**

| SN | Characteristics | Values | Method followed | Reference |
|---|---|---|---|---|
| **(A)** | Particle size | Percent | Bouyoucos-hydrometer method | Bouyoucos (1965) |
| 1 | Sand | 47.8 | | |
| 2 | Silt | 19.6 | | |
| 3 | Clay | 32.6 | | |
| 4 | Textural class | Sandy clay loam | USDA triangular diagram | Brady and Weil (1996) |
| **(B)** | Physical Characteristics | | | |
| 1 | Bulk density (g $cc^{-1}$) | 1.4 | Core method | Black, (1965) |
| 2 | Particle density (g $cc^{-1}$) | 2.6 | Pycnometer Method | Danielson and Sutherland (1986) |
| 3 | Porosity (%) | 46.1 | Bulk/ particle density | Blake and Hartge (1986) |
| **(C)** | Chemical characteristics | | | |
| 1 | pH (1:2.5 Soil: water) | 7.9 | Glass electrode pH meter | Richard (1954) |
| 2 | EC ($dSm^{-1}$ at $25C^{o}$) 1:2.5 Soil: Water | 0.23 | Solubridge | Richard (1954) |
| 3 | Organic Carbon (%) | 0.40 | Rapid titration method | Walkley and Black (1965) |
| 4 | Available N (kg $ha^{-1}$) | 216.0 | Alkaline potassium permanganate method | Subbiah and Asija (1956) |
| 5 | Available P (kg $ha^{-1}$) | 11.5 | Extraction by 0.5 M $NaHCO_3$ Solution at pH 8.5 (Olsen's method) | Olsen *et al.*, (1954) |
| 6 | Available K (kg $ha^{-1}$) | 250.0 | Extraction with Neutral 1 N ammonium acetate and estimated by flame photometer | Hanway and Heidel (1952) |
| 8 | DTPA extract available Zinc (ppm) | 0.80 | DTPA extractant and estimated on atomic absorption spectrophotometer | Lindsay and Norvell (1978) |
| 9 | Microbial population | | | |
| | Bacteria (No×$10^6$ $cfug^{-1}$) | 0.67 | Serial soil dilution | Rangaswamy (1966) |
| | Fungi(No×$10^4$ $cfug^{-1}$) | 0.46 | | |
| | Actinomycetes(No×$10^3$ cfu $g^{-1}$) | 0.49 | | |

**Table: 3.2 Cropping history of the experimental field**

| Year | Crop | |
|---|---|---|
| | *Kharif* | *Rabi* |
| 2016-17 | Rice | Wheat |
| 2017-18 | Rice | Wheat |
| 2018-19 | Rice | Wheat |
| 2019-20 | Rice | Wheat |
| 2020-21 | Rice | Experimental Wheat crop |

### 3.5.1 Treatments

Treatments (12) comprised levels of NPK (100% and 75%) in combination with NPK (Spray), Nano N/Zn (Spray), Biofertilizer (Seed treatment) and Bio-stimulant (Spray). The treatments were designed in accordance to the objectives of the study as follows (Table 3.3):

**Table: 3.3 Treatment details and their symbols**

| S. No. | Treatments | Symbol |
|---|---|---|
| 1 | Control | $T_1$ |
| 2 | NPK- (150:60:40 kg ha$^{-1}$) | $T_2$ |
| 3 | 100 % NPK + Nano Zn Spray | $T_3$ |
| 4 | 100 % NPK + Bio-stimulant Spray | $T_4$ |
| 5 | 75 % NPK + NPK Consortia | $T_5$ |
| 6 | 75 % NPK + NPK spray | $T_6$ |
| 7 | 75 % NPK + NPK Consortia + Nano N spray | $T_7$ |
| 8 | 75 % NPK + NPK Consortia + NPK spray | $T_8$ |
| 9 | 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant Spray | $T_9$ |
| 10 | 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray | $T_{10}$ |
| 11 | 75 % NPK + NPK Consortia + Nano Zn spray | $T_{11}$ |
| 12 | 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | $T_{12}$ |

### 3.5.2 Experimental design and layout:

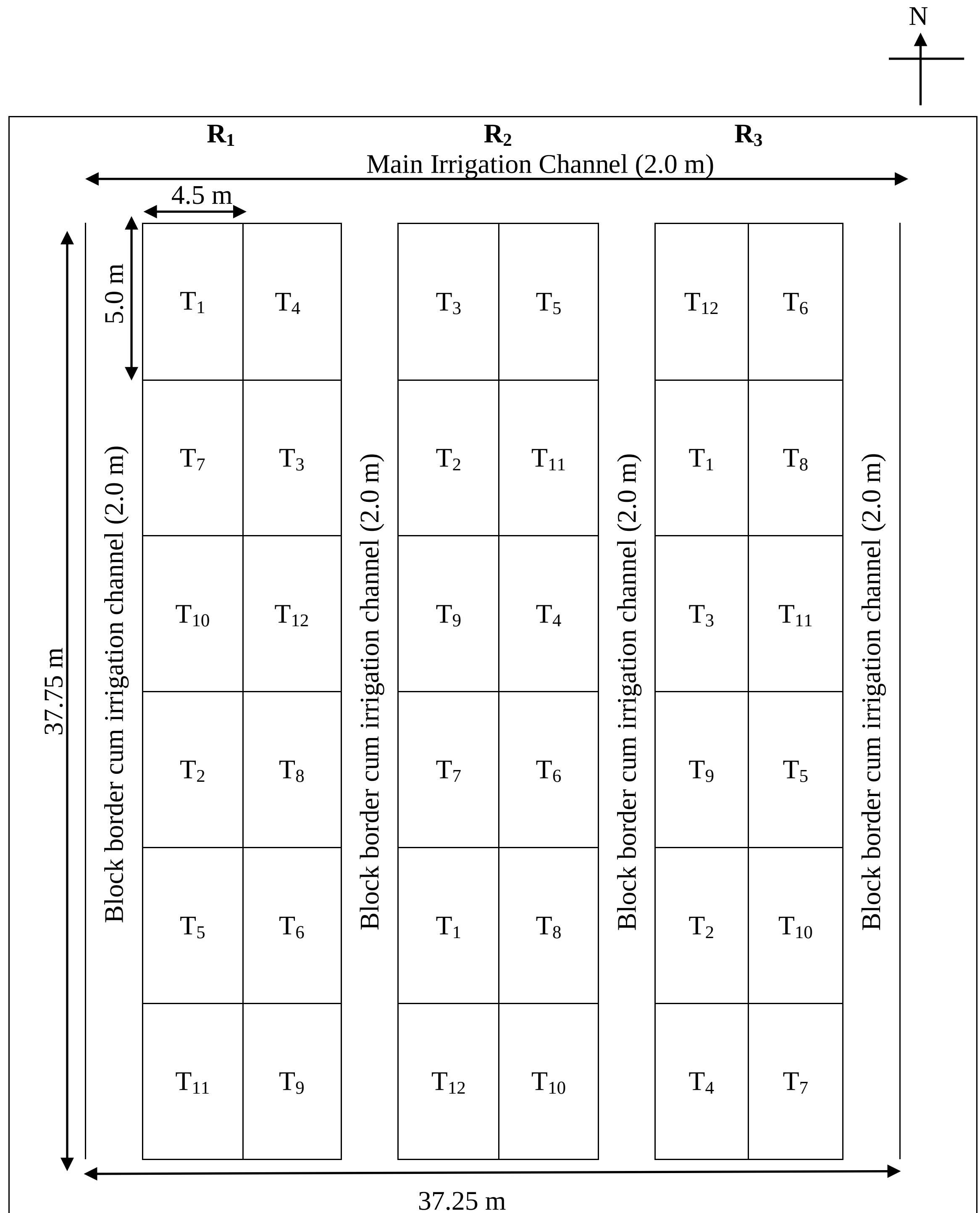
The experiment was laid out in randomized block design (RBD) with three replications. The basic principles of randomized designs were followed.

The lay out plan is depicted in Figure 3.2 and other necessary details are described as follows:

| | | |
|---|---|---|
| a) | Design | : RBD |
| b) | Number of treatments | : 12 |
| c) | Number of replications | : 03 |
| d) | Total no. of plot | : 36 |
| e) | Gross plot size | : 5.0 m X 4.5 m = 22.5 $m^2$ |
| f) | Net plot size | : 4.0 m X 3.15 m = 12.6 $m^2$ |
| g) | Row spacing | : 22.5 cm |
| h) | Sowing method | : Line sowing |
| i) | Total number of rows | : 20 |
| j) | Variety | : HD 2967 |
| k) | Seed rate (kg $ha^{-1}$) | : 100 |
| l) | Recommended NPK dose (kg $ha^{-1}$) | : 150: 60: 40 |
| m) | NPK -(18:18:18) | : 15 g $litre^{-1}$ |
| n) | Bio-stimulant-L | : 625 ml $ha^{-1}$ |
| o) | NPK Consortia- L seed treatment | : 250 ml in 3 litre water 60 $kg^{-1}$ seed |
| p) | Dose of Nano material | : Nano N -@ 4 ml $litre^{-1}$ |
| | | : Bio- Nano Zn -@ 10 ml $litre^{-1}$ |

**3.6 Crop genotype**

The genotype under study belong to *Triticum aestivum* L. which is commonly referred to as bread wheat and grown largely (>87%) in India. The average productivity of wheat was quite low up to 1964-65. Critical observation made by Dr B.P. Pal and Dr. M.S. Swaminathan regarding photo-thermo insensitiveness, dwarfness and input responsiveness of wheat lines in the material developed by Dr N.E. Borlaug laid the foundation for quantum jump in wheat productivity in India




**$T_1$** - Control, **$T_2$**- NPK- (150:60:40), **$T_3$** - 100 % NPK + Nano Zn Spray, **$T_4$** - 100 % NPK + Bio-stimulant spray, **$T_5$** -75 % NPK + NPK Consortia, **$T_6$**-75 % NPK + NPK spray, **$T_7$** -75 % NPK + NPK Consortia + Nano N spray, **$T_8$** -75 % NPK + NPK Consortia + NPK spray, **$T_9$**-75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray, **$T_{10}$** -75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray, **$T_{11}$** - 75 % NPK + NPK Consortia + Nano Zn spray, **$T_{12}$** -75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray

**Fig. 3.2- Layout plan of experimental field**

which finally emerged as green revolution.

### 3.6.1 HD 2967

Wheat Variety 'HD 2967' is a double dwarf variety developed by IARI New Delhi released in 2011 with an average plant height of 101 cm. This has profuse tillering. Ears are medium dense and tapering in shape with white glumes. Its grains are amber, medium bold, hard and lustrous. It is moderately resistant to yellow rust, resistant to brown rust, less susceptible to Karnal bunt and loose smut diseases. It takes about 145 days to mature. Where average yield of 5 t $ha^{-1}$ under irrigated timely sown conditions.

## 3.7 Cultural operations

The cultural operations carried out in the crop are mentioned here in after with a brief account in Table 3.4.

### 3.7.1 Field preparation

The field was irrigated to have optimum moisture level for field preparation and germination. After irrigation the field was ploughed once followed by harrowing twice and planking. Each time, the operations were done by tractor drawn implements. After that, the plots were marked according to the layout plan and dressed properly with spade.

### 3.7.2 Sowing

Certified seed of the wheat variety HD 2967 was sown in lines opened at a distance of 22.5 cm with the help furrow opener as to facilitate 4-5 cm deep placement of seed. As per recommendation for timely sown irrigated wheat 100 kg seed $ha^{-1}$ was used. After sowing the seed, furrow was planked manually to cover seed and have desired compaction to facilitate germination process.

**Table: 3.4 Schedule of cultural operations carried out in the experiment field**

| S. No. | Particulars of operation | Date of operation 2020-21 | Method used |
|---|---|---|---|
| 1 | Pre-sowing irrigation | 23-10-2020 | Tube-well |
| 2 | Field preparation | 03-11-2020 | Tractor drawn disc plough& cultivator |
| 3 | Layout | 04-11-2020 | Manually |
| 4 | Seed treatment by NPK Consortia | 04-11-2020 | Manually |
| 5 | Sowing | 05-11-2020 | Manually |
| 6 | Fertilizer application<br>A. basal application<br>B. N top dressing<br>I-<br>II- | <br>05-11-2020<br><br>07-12-2020<br>31-12-2020 | Manually as per treatments |
| | C. Foliar spray of NPK, nano fertilizers and Bio-Stimulant | 07-12-2020 | Knapsack sprayer as per treatments |
| 7 | Irrigation<br>I-<br>II-<br>III-<br>IV-<br>V- | <br>25-11-2020<br>21-12-2020<br>03-02-2021<br>27-02-2021<br>12-03-2021 | Tube-well |
| 8 | Weed management<br>Hand weeding- I<br>Hand weeding- II | <br>06-12-2020<br>28-12-2020 | Manually |
| 9 | Harvesting | 16-04-2021 | Manually by sickle |
| 10 | Threshing | 19-04-2021 | Pullman Thresher |

### 3.7.3 Fertilizer application

The fertilizer application was done as per treatments (Table 3.5). The recommended dose of NPK was taken as 150: 60: 40 kg ha$^{-1}$ of N, $P_2O_5$ and $K_2O$ respectively where ever required. Nitrogen, phosphorus and potassium were given through urea (46% N), DAP (18 % N & 46% $P_2O_5$) and MOP (60% $K_2O$) respectively.

**Table 3.5 Treatment wise use of sources & time of application**

| Treatment | NPK Consortia | N Splitting | | | Spray | | | |
|---|---|---|---|---|---|---|---|---|
| | | Basal | I Irrigation (Top dressing) | II Irrigation (Top dressing) | NPK | Nano N | Nano Zn | Bio-stimulant-L |
| $T_1$ | - | - | - | - | - | - | - | - |
| $T_2$ | - | 50% | 25% | 25% | - | - | - | - |
| $T_3$ | - | 50% | 25% | 25% | - | - | ✓ | - |
| $T_4$ | - | 50% | 25% | 25% | - | - | - | ✓ |
| $T_5$ | ✓ | 33.3% | 33.3% | 33.3% | - | - | - | - |
| $T_6$ | ✓ | 50% | - | 50% | ✓ | - | - | - |
| $T_7$ | ✓ | 50% | - | 50% | - | ✓ | - | - |
| $T_8$ | ✓ | 50% | - | 50% | ✓ | - | - | - |
| $T_9$ | ✓ | 50% | - | 50% | ✓ | - | - | ✓ |
| $T_{10}$ | ✓ | 50% | - | 50% | ✓ | - | ✓ | ✓ |
| $T_{11}$ | ✓ | 33.3% | 33.3% | 33.3% | - | - | ✓ | - |
| $T_{12}$ | ✓ | 50% | - | 50% | - | ✓ | ✓ | - |

As per the treatments, the status of use of the nutrient sources and their time of application is given in (Table 3.5). Full dose of DAP and MOP were applied as basal while urea was applied in splits i.e. basal (50%), after I (25%) and II irrigation 25% as per treatment. In treatments with 75% NPK and N spray at I irrigation, Urea was applied 50% basal and 50% after II irrigation. In treatments with 75% NPK having no spray of nitrogen, Urea was given in 3 equal splits at basal, after I and II irrigation. Seed treatment by NPK Consortia was done at the rate of 250 ml in 3 litre water / 60 kg seed as per the treatments. NPK- (18:18:18) was sprayed at the rate of 15 g litre$^{-1}$ spray after I irrigation taking 500 l water ha$^{-1}$. Bio-stimulant, Nano-N and Nano Zn were applied at the rate of 625 ml ha$^{-1}$, 4 ml litre$^{-1}$ and 10 ml litre$^{-1}$ respectively in 500 litre of water ha$^{-1}$ as per treatment. Where ever, more than one nutrient were required they all were mixed in same 500 litre of water and sprayed in a single run by hand pressure sprayer fitted with flat fan nozzle. Biofertilizer, bio-stimulant, nano materials were supplied by Indian Farmer's Fertilizer Cooperative Ltd. (IFFCO), New Delhi.

**3.7.3.1 Sources of Nutrients**

**a)** A control treatment is that in which no action was done in respect of nutrient management and it was served as a baseline to compare other treatments.

**b)** **NPK-Granules-** Fertilizers are high performance compound nitrogen-phosphorus- potassium fertilizer including all nutrients required for plant growth. NPK Granules complex fertilizer present in market in different grades. It was applied @ 150:60:40 kg ha$^{-1}$ NPK, full dose of P, K applied and N was applied in splits as per treatments.

**c)** **NPK (18:18:18)-** The NPK complex is a 100% Water soluble fertilizer, containing 18% nitrogen, 18% phosphorus and 18% potassium. It helps to development of roots, seeds and fruits and uniform maturity at the time of harvest. Besides, provides the strength to the crop to withstand under adverse conditions, like insect and disease damage, moisture stress and temperature stress. It was sprayed @ 15 g litre$^{-1}$ in 500 litre as per the treatments.

**d)** **Nano-N & nano-Zn-** Indian Farmer's Fertilizer Cooperative Ltd. (IFFCO) is supplying liquid for use in field crops. It was sprayed Nano N -@ 4 ml litre$^{-1}$ and Bio Nano Zn -@ 10 ml litre$^{-1}$ in 500 litre water each used as per the treatments.

**e)** **NPK Consortia-** It is a liquid bio-fertilizer, is a consortium of Rhizobium, *Azotobector* and *Acetobector*, PSB and KMB is prepared for Nitrogen, Phosphorus and potassium to the crops. It was used for seed treatment @ 250 ml in 3 litre water/ 60 kg seed as per treatments.

**f)** **Biostimulants-** Sagarika a seaweed extract (28% w/w) based growth promoting product, derived from the sap of red & brown algae. Sagarika works as a metabolic bio enhancer, it stimulates internal growth and development processes in plants. It contains inherent nutrients, vitamins, plant growth hormones like auxin, cytokinin and gibberellins, betaines and mannitol etc. Sagarika is available in Liquid and Granular form for application in different crops as soil, root treatment, drip and foliar application method. It was sprayed @ 625 ml $ha^{-1}$ in 500 litre water as per the treatments

**3.7.4 Weed management**

The crop was infested by weeds that are common in wheat in rice–wheat sequence. Therefore, two intercultural operations one at 30 days stage and the other at 50 days stages were performed manually with the help of Khurpi.

**3.7.5 Irrigation**

In general, wheat crop need irrigations at CRI (20-25 DAS), late tillering (40-45 DAS), late jointing (60-65 DAS), booting/flowering (80-85 DAS), milking (90-95 DAS) and Dough stages (110-115 DAS). Sandy clay loamy soils can hold 6 cm of water in wheat root zone, is the optimum depth of irrigation. The crop season had less rainfall than the seasonal distribution. Taking into account the rainfall at late jointing 7/01/2021 (24 mm- 1-7/1/2021), the crop was given 6 cm irrigation under each CRI 25/11/2020 (21 DAS), late tillering 21/12/2020 (47), booting/flowering 03/02/2021 (91), milking 27/02/2021 (115), and dough stages 12/03/2021 (127 DAS). The water was measured by parshall flume.

**3.7.6 Plant protection**

The certified seed was already treated with Bavistin @ 2g $kg^{-1}$of seed which might have checked seed and soil borne pathogens. No diseases appeared in the field and thus measures were also not required.

**3.7.7 Harvesting & threshing**

At maturity, wheat straw/ears/spikelets turn yellow and grain become hard having about 19% moisture. The crop was harvested manually by sickles on 16-04-2021 after attaining maturity. Border and net plot area were harvested separately to facilitate proper recording of observations. After sun drying net plot produce was threshed using plot thresher and winnowed to obtain clean grains.

### 3.8 Observations

The observations on the crop, soil and weather parameters etc. were recorded as follows:

#### 3.8.1 Plant population (No. of population $m^{-2}$)

The number of plants at three marked places each 0.20 m in length from each plot were recorded at 20 DAS and at harvest and expressed as number per $m^{-2}$.

#### 3.8.2 Growth

As to find out the effect of treatments on growth of the crop, observations on plant height, number of tillers and dry matter accumulation were recorded at 30, 60, 90, 120 days after sowing and at harvest as under:

#### 3.8.3 Plant height (cm)

Five plants were tagged randomly in sampling area for recording height. The height was measured in centimeters with the help of meter scale from the ground surface to the tip of fully expanded leaves. Height of all the five plants were summed and averaged to express plant height in centimeters.

#### 3.8.4 Number of tillers $m^{-1}$ row length

Number of tillers were recorded on 3 marked places each 0.20 m length in each plot, averaged and expressed as number $m^{-1}$ row length.

#### 3.8.5 Dry matter accumulation (g $m^{-1}$)

Row length, measuring 0.20 m, was measured at three places randomly and all the plants falling in the row were cut close to the ground and sun dried. The sun dried matter was kept in oven at $70 \pm 2$ $^{0}$C temperature till the constant weight was achieved.

The oven dried weight was recorded, averaged and expressed as dry matter accumulation in gram per metre row length (g $m^{-1}$).

**3.9 Growth indices**

Dry matter accumulation data was used to work out growth behavior of the crop in term of CGR and RGR during 30-60 DAS, 60-90 DAS, 90-120 DAS and 120 DAS-harvest period:

**3.9.1 Crop Growth Rate (g $m^{-2}$ $day^{-1}$)**

Mean crop growth rate of a plant community for a time "t" is defined as the increase in dry weight of plant material per unit area per unit of time. It was calculated from periodic dry matter recorded at different stages with the help of following formula **(Radford, 1967)**

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{A}$$

Where,
$W_1$ = Dry weight of plant (g) per m row length at time $t_1$
$W_2$ = Dry weight of plant (g) per m row length at time $t_2$
A = Land area ($m^2$)

**3.9.2. Relative Growth Rate (RGR) (g $g^{-1}$ $day^{-1}$)**

The relative growth rate of a plant at an instant for a time interval "t" is defined as the increase in dry weight of plant material per unit of material present per unit of time. The mean relative growth rate (RGR) of the crop was calculated by the following formula **(Radford, 1967)**.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where; $W_1$ = Dry weight of plant (g) per m row length at time $t_1$
$W_2$ = Dry weight of plant (g) per m row length at time $t_2$

## 3.10 Yield attributes and yield

### 3.10.1 Number of effective tillers $m^{-2}$

The number of spikes bearing tillers were recorded from 3 places in net plot each 0.20 m length at the time of maturity and expressed as number of effective tillers $m^{-2}$.

### 3.10.2 Ear Length (cm)

Ten ears (spikes) were selected randomly and their length measured. Figures of all the ten spikes were added and sum was divided by 10 to get average spike length. It was recorded in centimetre (cm).

### 3.10.3 Spikelets per spike

Ten ears (spikes) were collected at random from each net plot, their spikelets counted and average was worked out.

### 3.10.4 Grains per spike

Ten spikes selected randomly from each plot and numbers of filled grain per ten spikes and use for nearly length and spikelets per spike, were threshed, the number of grains counted to have number of grains per spike.

### 3.10.5 1000-grain weight (g)

A representative sample from each net plot produce was taken, 1000-grains counted, weighed and expressed in grams (g).

### 3.10.7 Grain yield (q $ha^{-1}$)

The grains obtained after threshing and winnowing of each of the net - plot were weighed in kilograms. The grain yield was further converted on hectare basis and expressed quintals.

$$\text{Grain yield (q ha}^{-1}) = \frac{\text{Net plot grain weight}}{\text{Net plot area (m}^2)} \times 10000$$

### 3.10.9 Straw yield (q $ha^{-1}$)

The straw yield is worked using difference method. Grain yield was subtracted from biological yield as under and expressed in quintal per hectare.

Straw yield (q $ha^{-1}$) = biological yield (q $ha^{-1}$) – grain yield (q $ha^{-1}$)

### 3.10.10 Biological yield (q $ha^{-1}$)

The crop in each net plot was harvested bundled, labeled and sun dried in the field. Bundles were weighted before threshing to record biological yield (grain + straw) per plot and expressed it as quintal $ha^{-1}$ after completion.

### 3.10.11 Harvest Index (%)

Harvest index (HI) the ratio of economic yield to the biological yield was calculated by using the formulae given by **Donald (1962).**

$$\text{HI (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

### 3.11 Plant analysis

Plant samples were collected from each net plot at the harvesting time and oven dried at 70 $\pm 1\ ^{0}$C to the constant weight for analysis of NPK and Zn content. The dried straw samples were crushed by Wiley Mill grinder.

Oxidation of organic material and release of mineral elements was done by digestion of plant sample (straw and seed) as per standard procedure for the nutrients as follows. The content further used for determination of K and Zn.

### 3.11.1 Nitrogen content and uptake

The nitrogen content in samples was determined by modified micro- kjeldahl method (**Jackson,1967)**. The dried samples (0.2g) were digested with 10 ml of $H_2SO_4$ and 1g of catalyst mixture ($K_2SO_4$, $CuSO_4$ and selenium powder) in digestion assembly till the content turns colourless. The digestion material was distilled, and the liberated ammonia was absorbed in (4% Boric acid solution having mixed indicator).

The estimation of nitrogen was done by titrating the distillate with $H_2SO_4$ solution. The value was expressed in percentage on dry weight basis. The total nitrogen was calculated as:

$$\text{Nitrogen content in plant (\%)} = \frac{\text{R (sample titer-blank titer) X Normality of acid X Atomic weight of nitrogen X 100}}{\text{Sample weight (g) x 1000}}$$

Where,

R= Reading

$$\text{N uptake in seed (kg ha}^{-1}\text{)} = \frac{\text{N content in seed (\%) x Seed yield as dry weight (kg ha}^{-1}\text{)}}{100}$$

$$\text{N uptake in straw (kg ha}^{-1}\text{)} = \frac{\text{N content in straw (\%) x Straw yield as dry weight (kg ha}^{-1}\text{)}}{100}$$

Total nitrogen uptake (kg ha$^{-1}$) = Nitrogen uptake in seed + Nitrogen uptake in straw

**3.11.2 Phosphorus content and uptake**

It was determined by Vanadomolybdo-phosphorus acid yellow colour method in acid system, at 470 nm wavelength. The intensity of the yellow colour was measured using spectrophotometer as described by **chapman and parker (1961).** The total P uptake was calculated as follows:

$$\text{P content in plant (\%)} = \frac{\text{C X 100 X Volume of digestant (ml)}}{\text{Wt. of sample (g) X Aliquot (ml) taken X 10000}}$$

Where,
C (ppm) = Concentration of P in aliquot (obtained from standard curve)

$$\text{P uptake in seed (kg ha}^{-1}\text{)} = \frac{\text{P content (\%) in seed x Seed yield as dry weight (kg ha}^{-1}\text{)}}{100}$$

$$\text{P uptake in straw (kg ha}^{-1}\text{)} = \frac{\text{P content in straw (\%) x Straw yield as dry weight (kg ha}^{-1}\text{)}}{100}$$

Total phosphorus uptake (kg $ha^{-1}$) = Phosphorus uptake in seed + Phosphorus uptake in straw

### 3.11.3 Potassium content and uptake

Potassium content of the digested material was estimated by the Flame Photometer. The content was expressed as percent K in seed and straw. Total potassium uptake was calculated as

$$\text{K content in plant (\%)} = \frac{\text{R X Dilution factor}}{10000}$$

Where,

R = Reading on flame photometer

Dilution factor = 0.5 gm digested plant sample dissolved in 100 ml volumetric flask (D. F.-200 times)

$$\text{K uptake in seed (kg ha}^{-1}\text{)} = \frac{\text{K content in seed (\%) x Seed yield as dry weight (kg ha}^{-1}\text{)}}{100}$$

$$\text{K uptake in straw (kg ha}^{-1}\text{)} = \frac{\text{K content in straw (\%) x Straw yield as dry weight (kg ha}^{-1}\text{)}}{100}$$

Total Potassium uptake (kg $ha^{-1}$) = Potassium uptake in seed + potassium uptake in straw

### 3.11.4 Zinc content and uptake

Zinc content of the digested material was estimated by Atomic Absorption Spectro-photometer (AAS) as suggested by **Lindsay and Norvell (1978)**. Ground plant sample weighing 0.5 gram was taken in a 100 ml conical flask. After adding 10 ml of di-acid mixture, the flask was heated on hot plot until the residue became colourless. Thereafter, the mixture was allowed to cool, diluted with distilled water and filtered through Whatman No.1 filter paper. The volume of filtrate was made to 50 ml by adding distill water. Zinc content of the solution was measured with the help of Atomic Absorption Spectrophotometer using hallow cathode lamp (HCL). The zinc content (ppm) as indicated by the AAS based on computed standard curve was recorded and used to work out uptake as under:

Zn in plant sample (ppm) = AAS reading (mg/litre) x dilution

Where,

$$\text{Dilution} = \frac{\text{Final volume (ml)}}{\text{Weight of plant sample (g)}}$$

$$\text{Zn uptake in seed (g ha}^{-1}\text{)} = \frac{\text{Zn content in seed (ppm) x Seed yield as dry weight (g ha}^{-1}\text{)}}{10^{6}}$$

$$\text{Zn uptake in straw (g ha}^{-1}\text{)} = \frac{\text{Zn content in straw (ppm) x Straw yield as dry weight (g ha}^{-1}\text{)}}{10^{6}}$$

Total zinc uptake (g ha$^{-1}$) = Zinc uptake in seed (g ha$^{-1}$) + Zinc uptake in straw (g ha$^{-1}$)

## 3.12 NUTRIENT USE EFFICIENCY (NUE)

Nutrient use efficiency (NUE) shows the ability of crops to absorbs and utilize nutrients in yield. , Agronomic Efficiency (AE), Physiological Efficiency (PE) & Partial Factor Productivity (PFP) as classified by **Craswell and Godwin (1984)** were estimated for the purpose as follows.

### 3.12.1 Agronomic Efficiency (AE) (kg grain yield increase kg$^{-1}$ nutrient applied)

The Agronomic efficiency (AE) indicates improvement in productivity in response to applied nutrient. It is expressed as kg of gain in yield per kg a particular nutrient applied and was calculated using the equation given below:

$$AE = \frac{Y_t - Y_0}{A_t}$$

Where,

AE = Agronomic Efficiency (AE) (kg grain yield increase kg$^{-1}$ nutrient applied)

$Y_t$ = Yield under test treatment (kg $ha^{-1}$)

$Y_o$ = Yield under control (kg $ha^{-1}$)

$A_t$ = Units of nutrient applied in the test treatment (kg $ha^{-1}$)

### 3.12.2 Physiological efficiency (PE) (kg yield increase $kg^{-1}$ nutrient uptake)

The Physiological efficiency (PE) indicates the ability of crop to transform acquired nutrient into economic yield and expressed as kg of grains produced per kg of nutrient absorbed. It was calculated as under:

$$PE = \frac{Y_t - Y_0}{U_t - U_0}$$

Where,

PE = Physiological efficiency (kg yield increase $kg^{-1}$ nutrient uptake)

$Y_t$ = Yield under test treatment (kg $ha^{-1}$)

$Y_o$ = Yield under control (kg $ha^{-1}$)

$U_t$ = Uptake of nutrient in test treatment (kg $ha^{-1}$)

$U_o$ = Uptake of nutrient in control (kg $ha^{-1}$)

### 3.12.3 Partial factor productivity (PFP) (kg of grain $kg^{-1}$ of nutrient applied)

Partial factor productivity indicates productions of a crop in comparison to its nutrient input. It is expressed as kg of grains produced per kg of nutrient applied and was worked out as under:

$$PFP = \frac{Y}{N}$$

Where,

PFP = Partial Factor Productivity (kg of grain $kg^{-1}$of nutrient applied)

Y = Grain yield (kg $ha^{-1}$)

N= Amount of nutrient applied (kg $ha^{-1}$)

### 3.13 Protein content and protein yield

Nitrogen content of grains determined by modified micro-Kjeldahl method was multiplied by 5.73 to get total crude protein content **(AOAC, 1960).**

Grain protein content (%) = Nitrogen content (%) x 5.73

Protein yield was computed as:

$$\text{Protein yield (kg ha}^{-1}\text{)} = \frac{Protein\ content\ \%\ \times grain\ yield\ kg\ ha^{-1}}{100}$$

## 3.14 Soil Properties

Soil sample were taken randomly with the help of soil auger to a depth of 0-15 cm from each plot of the experimental field after the crop harvest as to determine various physico-chemical properties. The samples were dried properly, ground and passed through 2 mm sieve for further analysis as follows.

### 3.14.1 Mechanical/physical study

#### 3.14.1.1 Aggregate stability

Soil sample from 15 cm depth was used for aggregate analysis by the wet sieving method as described by **Cambardella and Elliott *(*1994).**

#### 3.14.1.2 Bulk and particle density

Bulk density was measured using the core-ring method given by **Blake (1965)**. Soil samples were collected using a core sampler (metal cylinder) of 5 cm height and diameter which was pressed into the soil. The cylinder was removed, extracting a sample of known volume of soil followed by recording of moist sample weight. Thereafter sample was dried in an oven at 105°C for 24 hr., till no further changes in weight occurred. Thereby, the oven dried samples were weighed.

$$\text{BD (g cm}^{-3}\text{)} = \frac{\text{Weight of oven dried soil (g)}}{\text{Volume of core sampler (cm}^{3}\text{)}}$$

## 3.15 Chemical study

### 3.15.1 Soil reaction (pH)

Soil pH is the measure of acidity or alkalinity in the soil solution and measured using glass electrode pH meter keeping soil: water in the ratio of 1: 2.5 as described by **Jackson** (**1973**). Soil sample (20 g) was weighed and transferred into 100 ml beaker. To this, 40 ml of distilled water was added and stirred with a glass rod.

Thereafter the mixture was allowed to stand for half an hour with intermittent stirring. The glass electrode was immersed in the soil water suspension in a beaker and pH value was noted with digital pH meter display.

**3.15.2 Electrical conductivity (EC)**

Electrical conductivity (EC) is a measure of the amount of salts present in the soil. Air-dried soil sample (10 g) was taken in a 50 ml beaker and 25 ml of distilled water was added to it. The suspension was stirred at regular interval of 20 to 30 minutes using magnetic stirrer. After one hour of standing soil suspension, E.C was measured with the help of conductivity meter and expressed as $dSm^{-1}$ as presented by **Jackson (1973).**

**3.15.3 Organic carbon (%)**

The Organic carbon content of soil sample was determined by **Walkely and Black (1934)** wet oxidation method. Soil sample of 1 g was taken in a 500 ml Erlenmeyer flask followed by addition of 10 ml of 1 N potassium dichromate solution and 20 ml sulphuric acid. Sample was diluted with 200 ml deionized water and 10 ml of phosphoric acid; 0.2 g ammonium fluoride and 10 drops of diphenylamine indicator were added. Further, sample was titrated with 0.5 N ferrous ammonium sulphate solution until the colour changed from dull green to a turbid blue to brilliant green. Organic carbon content was computed as under.

$$\text{Organic Carbon \%} = \frac{0.003 \times N \times 10 \left(1 - \frac{T}{S}\right) \times 100}{ODW}$$

Where,

N = Normality of $K_2Cr_2O_7$ solution
T = Volume of FeSO4 used in sample titration (ml)
S = Volume of FeSO4 used in blank titration (ml)
ODW = Oven-dry sample weight (g)

**3.15.4 Available nitrogen (kg $ha^{-1}$)**

Available Nitrogen was estimated by alkaline potassium permanganate

($KMnO_4$) method given by **Subbiah and Asija (1956).** The organic matter in soil was oxidized with hot alkaline $KMnO_4$ solution followed by release of ammonia which is distilled and trapped in boric acid mixed indicator solution. The amount of $NH_3$ trapped is estimated by titrating with standard acid. Soil sample of 5 g was taken and transferred to digestion tube. Sample was distilled with 0.32% KMnO4 and 2.5% NaOH followed by heating of sample by passing steady steam and collection of liberated ammonia in conical flask containing 20 ml of 2% boric acid with mixed indicator. Colour changed from pink to green. Thereby, distillate was titrated against 0.02 N sulphuric acid and colour changed to original pink.

$$\text{Available Nitrogen (Kg ha}^{-1}\text{)} = \frac{\text{(A-B)} \times 0.02 \times 14 \times 10^{-3} \times 2.24 \times 10^{6}}{\text{Wt. of soil sample (g)}}$$

A = Volume (ml) of standard sulphuric used for sample titration

B = Volume (ml) of standard sulphuric acid used blank titration

### 3.15.5 Available phosphorus (kg ha$^{-1}$)

The available phosphorus content of the soil was determined by the method as described by **Olsen *et al*. (1954)**. Dried soil sample (2.5 g) containing a pinch of Darco G- 60 was extracted with 50 ml of 0.5 M $NaHCO_3$ (pH 8.5) for 30 minutes. Five ml of filtrate was taken in a 25 ml volumetric flask; 2-3 drops of p- nitrophenol indicator added which resulted in development of yellow color. After that 5N $H_2SO_4$ was added drop by drop until yellow color disappeared to acidify up to 5 pH. Ascorbic acid solution (4ml) was added to the flask and volume was made up. The blue color was obtained, the intensity of blue color which is proportional to phosphate was recorded on the spectrophotometer at a wavelength of 730 nm by using a red filter. The blank was also prepared by adding the entire chemical except for soil. The amount of available phosphorus in soil was expressed in kg ha$^{-1}$as follows:

P in soil (ppm) = ppm P reading from standard curve × [(100/weight of soil in g) ×

(50/10 i.e. dilution factor)]

Available phosphorus (kg ha$^{-1}$) = $P_{(ppm)}$ calculated from standard curve × dilution factor × 2.24

Where,

2.24 = factor to converted ppm into kg ha$^{-1}$

2.24 X $10^6$ is weight of furrow slice

### 3.15.6 Available potassium (kg ha$^{-1}$)

The available potassium content of the soil was determined as described by **Hanway and Heidel (1952).** 5 grams of processed soil was taken in a 150 ml conical flask and extracted with 25 ml of neutral normal ammonium acetate solution. The filtrate was aspirated into the atomizer of the calibrated flame photometer and reading was noted. The amount of available potassium in the soil was calculated and expressed as kg ha$^{-1}$ as under:

Available potassium (kg ha$^{-1}$) = $K_{(ppm)}$ × 5 × 2.24.

Where,

5 = dilution factor ( 5 g dissolved in 25 ml )

2.24 = factor to converted ppm into kg ha$^{-1}$

2.24 X $10^6$ is weight of furrow slice

### 3.15.7 Available Zinc

Available Zn in the soil was extracted by DTPA and Zn, in the extract were determined by Atomic Absorption Spectrophotometer as documented by **Lindsay and Norvell (1978).** Diethylene triamine penta acetic acid (DTPA), a chelating agent, combines with free metal ions in solution and forms soluble complexes. DTPA extractant has the ability to chelate Zn in competition with $Ca^{++}$. Buffering of extractant in a slightly alkaline pH range (7.3) by including soluble $Ca^{++}$, avoids the dissolution of $CaCO_3$ with the release of occluded Zn. Soil sample of 12.5g was taken in a 100 ml iodine value flask followed by addition of 25 ml of the DTPA solution and shake for this mixture for 2 hours on shaker at 70 to 80 oscillation per minute, filter through acid washed distilled water rinsed, whatman No. 1 filter paper and collected the filtrate in plastic bottle. Determined the content of zinc on AAS in ppm as follows.

$$\text{Available (DTPA-extractable) Zn is soil (ppm)} = \frac{A \times B}{C}$$

Where,

A = Concentration in aliquot as read from X-axis of standard curve against the sample reading or sample reading obtained from AAS

B = Volume of DTPA extractant in ml

C = Weight of soil sample in g

**3.16 Biological study**

**3.16.1 Microbial population:**

The population of bacteria, fungi and actinomycetes were counted by serial soil dilution method in the laboratory of Department of Microbiology & Pathology of SVPUA&T at Meerut. Initially as composite sample was drawn from the experimental area determine various soil properties. At harvest, soil samples were collected experiment separated from each net plot for the purpose. The serial dilution technique was employed for isolation and identification of viable Bacteria, Fungi and Actinomycetes count. The media was prepared as used for microflora. Autoclaved and cooled (45°c) medium was poured into sterile Petri plates and then allowed to solidify. One gram of sieved (2 mm) soil was added to 9 ml sterile water and shaking for 15-20 minutes. Serial dilution $10^{-2}$, $10^{-3}$, $10^{-4}$, $10^{-5}$, $10^{-6}$, $10^{-7}$ and $10^{-8}$ were prepared one ml of aliquots of various dilutions were added over cooled and solidified medium in Petri plates and rotated to achieve uniform distribution of spores. The plates were then incubated at 28°C for 3-4 days. Appearance of colonies onto the surface of the medium was observed to count population of Bacteria, Fungi and Actinomycetes using dilution plate technique by employing Martin Rose Bengal agar medium and Ken Knight's agar media, respectively as suggested by **Rangaswamy (1966)**.

### 3.17. Economic Analysis

#### 3.17. 1 Cost of Cultivation

Cost of cultivation refers to the total expenses incurred in cultivating one hectare of a crop. It was worked upon, considering both input and operational expenses incurred in the cultivation. For the wheat, it was calculated based on various input costs, as value of hired human labour, seed, NPK fertilizer, nano fertilizers, biofertilizers, bio-stimulant, inorganic fertilizer, irrigation charges, land revenue and other miscellaneous input. The input prices that prevailed during the period of experimentation were used for computing input cost (Appendix- **XXII**) and the cost incurred in various operations in (Appendix- **XXIII**).

#### 3.17.2 Gross Returns

The monetary returns obtained from marketable produce (grain and straw) were computed by multiplying output quantity and their unit price as follows:

Gross return (Rs $ha^{-1}$) = Return form grains + Return from straw

Monetary return grain (Rs $ha^{-1}$) = Grain yield (q $ha^{-1}$) x minimum support price (Rs /q.)

Monetary return straw (Rs $ha^{-1}$) = Straw yield (q $ha^{-1}$) x local price (Rs /q.)

Minimum support price for grain and local prices for straw are given in Appendix XXIII.

#### 3.17.3 Net Returns

This was worked out by subtracting the total cost of cultivation from their respective gross returns. This value gives actual profit obtained by the farmer as under:

Net Return (Rs $ha^{-1}$) = Gross Return (Rs $ha^{-1}$) – Cost of cultivation (Rs $ha^{-1}$)

### 3.17.4 Benefit: Cost Ratio

Benefit: cost: ratio (BCR) in terms of net return per rupee investment were calculated by using the following formula:

$$\text{B:C} = \frac{\text{Gross return (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs ha}^{-1}\text{)}}$$

## 3.18 Statistical Analysis

Statistical analysis was done with the help of window-based SPSS (Statistical Product and Service Solutions) Version 10.0, SPSS, Chicago, IL. The SPSS technique was used for the analysis of variance to define the statistical significance of treatment effect at 5 % probability level. Further, F- test and significance of difference between treatments was examined by critical difference (CD) as described by **Gomez and Gomez (1984).**

### 3.18.1 Standard error of mean

Standard error of mean was calculated as follows:

$$\text{Standard error of mean (SEm}\pm) = \frac{\sqrt{\text{EMSS}}}{\text{r}}$$

Where;

SEm± = Standard error of mean

EMSS = Error mean sum of square

r = Number of replications on which the observation is based.

### 3.18.2 Critical Difference

The critical difference at 5% level of significance was estimated as below:

$$\text{C. D.} = \text{SEm}(\pm) \times \sqrt{2} \times t_{0.05} \text{ (at error degree of freedom)}$$

Where,

CD = Critical difference

SEm± = Standard error of mean

$t_{0.05}$ = Value of ‘t’ distribution for error degree of freedom at 5 per cent level of significance.

The observations on crop growth, yield attributes, yields, nutrient uptake by wheat and soil health were recorded to study the **"Effect of doses and sources of nutrients on growth, yield and quality of timely sown irrigated wheat (*Triticum aestivum* L.)"** during 2020-21 and subjected to statistical analysis. Treatments means have been given in Tables, depicted in Figures and analysis of variance (ANOVA) in Appendices. The treatments were compared at 5% level of probability using critical difference and explained herein-after.

**4.1 Population Studies**

Plant population of wheat, counted at the initial and harvest stages, differed significantly only at harvest stage under various nutrient management practices (Appendix-II).

Initial plant population, recorded at 20 DAS, varied from 226.1 under control to 256.2 plant $m^{-2}$ under 100 % NPK + Nano Zn spray (Table 4.1). Such differences were however non-significant. The effect of combined application nano fertilizer, bio-stimulant and inorganic fertilizers was not perceptible at this stage as they were not applied by that time (20 DAS), however, seeds were treated with NPK consortia which also not showed any significant effect. Wheat, being an intensive tillering crop, plant population increased manifold at later stages (harvest) where it exhibited significant variations. Crop fertilized with 100 % NPK + Nano Zn spray was having highest plant population at harvest stage being significantly superior over control, 75 % NPK + NPK Consortia, 75 % NPK + NPK spray and RDF but remained at par with other nutrient management practices. Substituting 25% NPK with NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray proved significantly superior over Control, RDF, 75 % NPK + NPK Consortia and 75 % NPK + NPK spray and remained at par with rest of treatments.

**Table 4.1 Effect of doses and sources of nutrients on plant population**

| Treatments | Plant population (No $m^{-2}$) | |
|---|---|---|
| | **20 DAS** | **At harvest** |
| Control | 226.1 | 236.8 |
| NPK- (150:60:40) | 254.5 | 276.9 |
| 100 % NPK + Nano Zn spray | 256.2 | 311.5 |
| 100 % NPK + Bio-stimulant spray | 255.6 | 305.9 |
| 75 % NPK + NPK Consortia | 251.5 | 263.9 |
| 75 % NPK + NPK spray | 247.7 | 281.0 |
| 75 % NPK + NPK Consortia + Nano N spray | 249.5 | 287.6 |
| 75 % NPK + NPK Consortia + NPK spray | 251.8 | 293.1 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 249.7 | 299.6 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 251.6 | 307.8 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 249.2 | 294.2 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 250.6 | 304.6 |
| **SEm±** | **7.4** | **8.5** |
| **CD (p = 0.05)** | **NS** | **25.3** |

### 4.2 Growth and Developmental Studies

#### 4.2.1 Plant height (cm)

Plant height varied significantly under various nutrient management practices at all the stages of growth (Appendix- III).

Plants tended to gain height with advancement in crop age, irrespective of the nutrient management practices up to 120 DAS and then declined slightly at maturity (Table 4.2 & Figure 4.1). Application of nutrients, irrespective of sources and doses resulted in significant increase in plant height at all the growth stages. Further perusal of data revealed that reduction in NPK by 25% reduced plant height significantly at 30 DAS. The effect of Nano fertilizers, Bio-stimulant, and Inorganic fertilizer spray was not perceptible at this stage as they were not applied by that time (30 DAS) and in treatment having reduction of 25% NPK With seed treatment by NPK Consortia showed significant effect over treatment having NPK reduction by 25% at 30 DAS.

**Table 4.2 Effect of doses and sources of nutrients on plant height (cm) at various crop growth stages**

| Treatments | Plant height (cm) | | | | |
|---|---|---|---|---|---|
| | **30 DAS** | **60 DAS** | **90 DAS** | **120 DAS** | **At harvest** |
| Control | 14.1 | 26.5 | 47.0 | 83.4 | 79.4 |
| NPK- (150:60:40) | 19.2 | 32.8 | 74.5 | 103.3 | 100.8 |
| 100 % NPK + Nano Zn spray | 19.4 | 38.9 | 83.8 | 112.4 | 111.1 |
| 100 % NPK + Bio-stimulant spray | 19.6 | 36.6 | 79.1 | 109.6 | 109.2 |
| 75 % NPK + NPK Consortia | 18.6 | 28.3 | 68.2 | 100.3 | 98.1 |
| 75 % NPK + NPK spray | 16.2 | 30.0 | 69.3 | 101.8 | 100.6 |
| 75 % NPK + NPK Consortia + Nano N spray | 18.5 | 32.4 | 76.5 | 103.6 | 102.1 |
| 75 % NPK + NPK Consortia + NPK spray | 18.9 | 33.2 | 76.2 | 105.3 | 104.1 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 17.9 | 33.3 | 76.4 | 105.8 | 103.3 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 18.2 | 38.2 | 81.8 | 111.1 | 110.6 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 18.5 | 32.7 | 78.6 | 105.5 | 104.1 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 17.8 | 35.9 | 79.2 | 107.5 | 106.5 |
| **SEm±** | **0.4** | **1.2** | **2.1** | **2.6** | **2.7** |
| **CD (p = 0.05)** | **1.1** | **3.6** | **6.3** | **7.7** | **7.9** |

At later stages (60, 90, 120 days and at harvest), application of either of Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer spray or their simultaneous use with 100% or 75% NPK increased plant height remarkably over 100% NPK except 75 % NPK + NPK Consortia and 75 % NPK + NPK spray. Crop fertilized with 100 % NPK + Nano Zn spray registered taller plants at all the stages (except 30 DAS) being significantly superior over control, 100 % NPK, 75 % NPK + NPK Consortia, 75 % NPK + NPK spray, 75 % NPK + NPK Consortia + Nano N

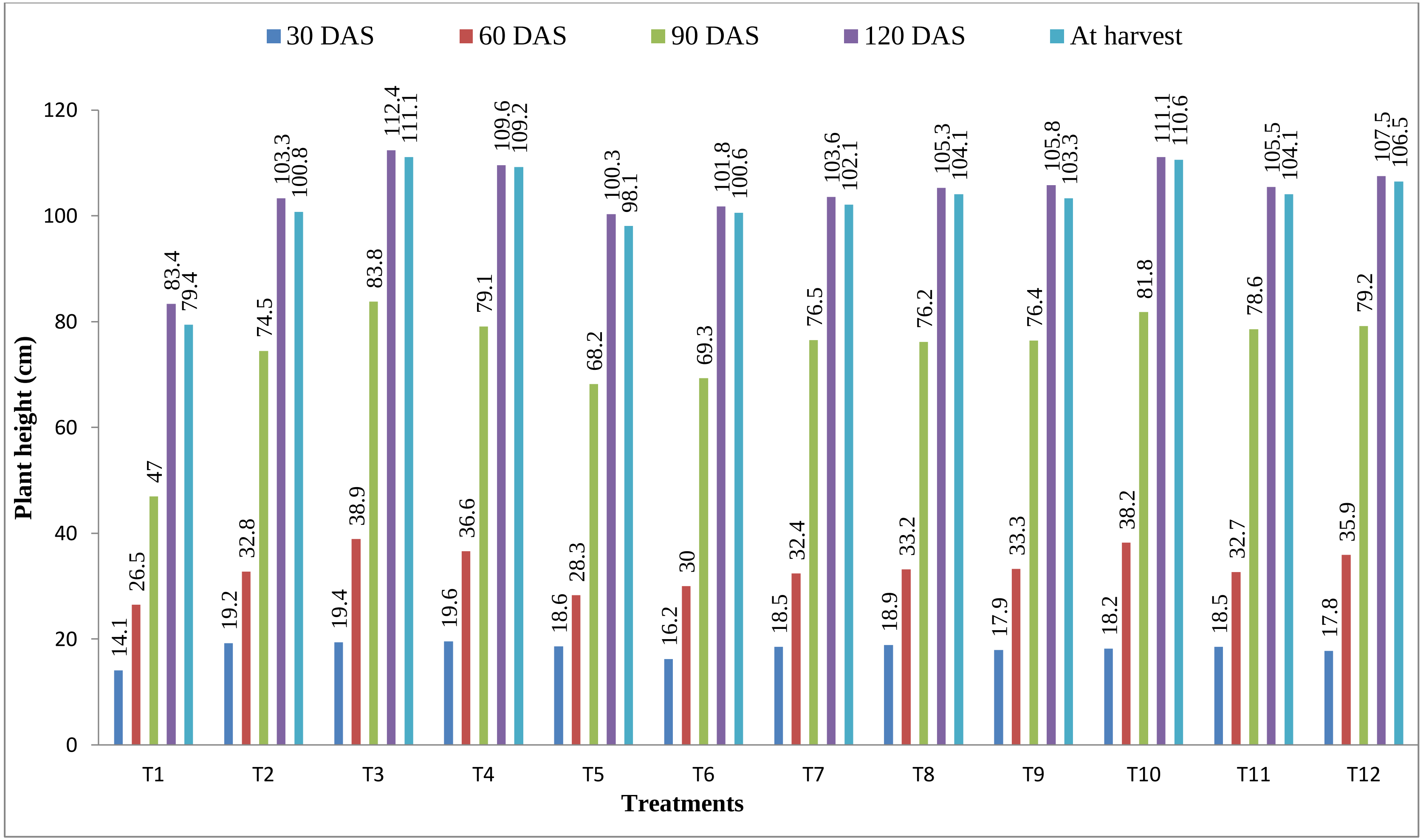



**Fig.4.1 Effect of doses and sources of nutrients on plant height (cm) of wheat at different growth stage**

spray and rest of treatments were at par.

### 4.2.2 Number of tillers $m^{-1}$ row length

The analysis of variance given in Appendix IV revealed that nutrient management options had a significant impact on the number of tillers per meter row length recorded at various crop growth stages.

**Table 4.3 Effect of doses and sources of nutrients on number of tillers $m^{-1}$ row length at various crop growth stages**

| Treatments | Number of tillers $m^{-1}$ row length | | | | |
|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | At harvest |
| Control | 27.1 | 78.8 | 72.5 | 63.0 | 52.5 |
| NPK- (150:60:40) | 34.8 | 94.5 | 85.5 | 73.5 | 62.1 |
| 100 % NPK + Nano Zn spray | 35.4 | 109.4 | 92.4 | 80.4 | 69.7 |
| 100 % NPK + Bio-stimulant spray | 35.4 | 104.4 | 91.4 | 79.4 | 68.4 |
| 75 % NPK + NPK Consortia | 32.9 | 92.9 | 84.9 | 72.9 | 59.2 |
| 75 % NPK + NPK spray | 29.4 | 94.0 | 84.9 | 72.9 | 61.9 |
| 75 % NPK + NPK Consortia + Nano N spray | 31.6 | 96.6 | 86.7 | 74.7 | 63.7 |
| 75 % NPK + NPK Consortia + NPK spray | 31.7 | 96.7 | 88.7 | 76.7 | 65.3 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 32.6 | 97.6 | 88.6 | 76.6 | 65.6 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 31.1 | 108.9 | 91.9 | 79.9 | 68.9 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 32.3 | 96.3 | 87.3 | 75.3 | 65.1 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 31.7 | 102.7 | 90.7 | 78.7 | 67.9 |
| **SEm±** | **0.8** | **3.6** | **3.2** | **2.7** | **2.3** |
| **CD (p = 0.05)** | **2.3** | **10.6** | **9.3** | **8.1** | **6.9** |

Perusal of data on tillering behavior (Table 4.3) of wheat suggested an increase in number of tillers $m^{-1}$ row length upto 60 days stage and a decline there after. During the 30-60 day period, there was a profuse tillering. Application of nutrients irrespective of sources and doses resulted in significant increase in number of tillers at all the crop growth stages over control. Further perusal of the data revealed that 75% NPK with NPK consortia combination recorded in higher number of tillers in comparison to only 75% NPK, at 30 DAS. At later stages (60, 90,120 days and at harvest), application of either of nano fertilizers, bio-stimulant, and inorganic fertilizer spray or their simultaneous use with 100%/75% NPK and NPK Consortia or without NPK-Consortia increased number of tiller $m^{-1}$ over 100% NPK except the treatment having 75 % NPK + NPK Consortia and 75 % NPK + NPK spray. Crop fertilized with 100 % NPK + Nano Zn spray had highest number of tillers at all the stages (except 30 DAS) being significantly superior over control, 75 % NPK + NPK Consortia and 75 % NPK + NPK spray but remained at par with those receiving any combination with 75 and 100% NPK with all other nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizer spray inputs (Nano N + Nano Zn+ NPK-Consortia + Bio-stimulant + NPK spray).

**4.2.3 Dry matter accumulation (g $m^{-1}$)**

At all stages of wheat growth, there was a significant variation in the accumulation of dry matter per meters row length under different nutrient management practices (Appendix- V).

In general, the dry matter accumulation increased progressively and quadratically with the advancement of crop age (Table 4.4 & Figure 4.2). The rate of increase was however, slow up to 30 days and reached its peak between 90 to 120 days and showed a decline further (Table 4.4). Significantly, lowest dry matter accumulation was noted in crop receiving no fertilizer nutrients, irrespective of the stages. At later stages (60, 90, 120 days and at harvest), application of either nano fertilizers, bio-stimulant, and inorganic fertilizer spray or their simultaneous use with 100%/75% NPK with or without NPK-Consortia increased plant dry matter significantly over control**.** Application of 100 % NPK + Nano Zn spray resulted in maximum accumulation of dry matter at all growth stages in compare to 100%/75% RDF with nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizer spray and control. Application of either nano fertilizers or bio-stimulant, in addition to 100% NPK resulted in an increase in dry matter accumulation over 75 % NPK at harvest with any combination of nutrients.

**Table 4.4 Effect of doses and sources of nutrients on dry matter accumulation gram meter per row length at various crop growth stages**

| **Treatments** | **Dry matter accumulation (g m$^{-1}$)** | | | | |
|---|---|---|---|---|---|
| | **30 DAS** | **60 DAS** | **90 DAS** | **120 DAS** | **At harvest** |
| Control | 5.8 | 16.5 | 75.7 | 117.7 | 173.7 |
| NPK- (150:60:40) | 8.4 | 38.7 | 150.1 | 208.1 | 264.6 |
| 100 % NPK + Nano Zn spray | 8.5 | 44.1 | 176.1 | 241.1 | 297.6 |
| 100 % NPK + Bio-stimulant spray | 8.2 | 43.3 | 167.1 | 232 | 293.5 |
| 75 % NPK + NPK Consortia | 7.4 | 31.6 | 136.2 | 198.2 | 260.2 |
| 75 % NPK + NPK spray | 6.3 | 36.9 | 147.8 | 209.8 | 265.8 |
| 75 % NPK + NPK Consortia + Nano N spray | 7.5 | 40.8 | 154.2 | 216.2 | 275.7 |
| 75 % NPK + NPK Consortia + NPK spray | 7.4 | 42.6 | 154.7 | 219.7 | 281.2 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 7.6 | 42.3 | 159.6 | 224.6 | 287.1 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 7.8 | 44.0 | 172.5 | 237.5 | 294.0 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 7.7 | 41.9 | 155.7 | 217.65 | 277.1 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 7.5 | 42.1 | 164.2 | 229.2 | 289.7 |
| **SEm±** | **0.3** | **1.5** | **5.7** | **7.6** | **7.7** |
| **CD (p = 0.05)** | **0.8** | **4.3** | **16.7** | **22.6** | **22.8** |

Among the treatments 100 % NPK + Nano Zn spray accumulated 73.9 % and 12.7 % more dry matter over control and 100% NPK respectively at harvest. The

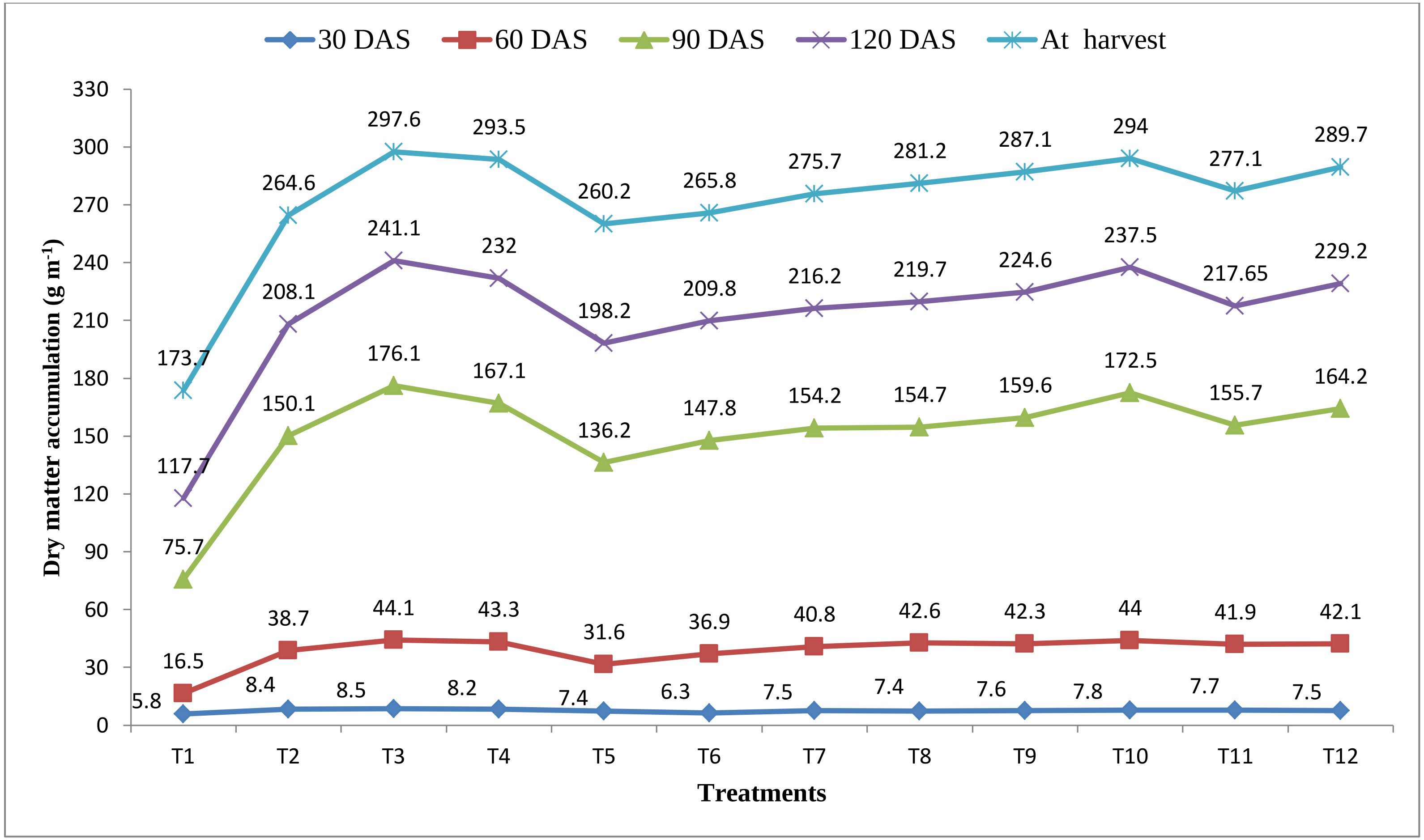



**Fig.4.2 Effect of doses and sources of nutrients on dry matter accumulation g m$^{-1}$ row length row length of wheat at different growth stages**

lowest dry matter accumulation (171.7 g $m^{-1}$) was recorded in unfertilized plot and showed inferiority to rest of the treatments at harvest.

### 4.2.4 Crop growth rate (CGR) g $m^{-2}$ $day^{-1}$

Crop growth rate (CGR), gram in dry matter production per unit land area per unit time was significantly influenced by different nutrient management practices at all the crop growth stages (Appendix –VI).

The data on crop growth rate presented in Table 4.5 and Figure 4.3 indicated significant variations across the stages being highest during 60-90 days period and lower during initial and later phases. Further perusal of the data showed significant increase in crop growth rate with application of nutrients over control at all the stages during 60-90 days period.

**Table 4.5 Effect of doses and sources of nutrients on crop growth rate at various crop growth stages**

| Treatments | crop growth rate (g $m^{-2}$ $day^{-1}$) | | | |
|---|---|---|---|---|
| | 30-60 DAS | 60-90 DAS | 90-120 DAS | 120-Harvest |
| Control | 2.6 | 8.8 | 6.2 | 5.7 |
| NPK- (150:60:40) | 4.5 | 16.5 | 8.6 | 5.8 |
| 100 % NPK + Nano Zn spray | 5.3 | 19.6 | 9.6 | 5.8 |
| 100 % NPK + Bio-stimulant spray | 5.2 | 18.3 | 9.6 | 6.3 |
| 75 % NPK + NPK Consortia | 3.6 | 15.5 | 9.2 | 6.4 |
| 75 % NPK + NPK spray | 4.5 | 16.4 | 9.2 | 5.7 |
| 75 % NPK + NPK Consortia + Nano N spray | 4.9 | 16.8 | 9.2 | 6.1 |
| 75 % NPK + NPK Consortia + NPK spray | 5.2 | 16.6 | 9.6 | 6.3 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 5.1 | 17.4 | 9.6 | 6.4 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 5.4 | 19.0 | 9.6 | 5.8 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 5.1 | 16.9 | 9.2 | 6.1 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 5.1 | 18.1 | 9.6 | 6.2 |
| SEm± | 0.2 | 0.6 | 0.3 | 0.3 |
| CD (p = 0.05) | 0.5 | 1.8 | 1.0 | 0.6 |

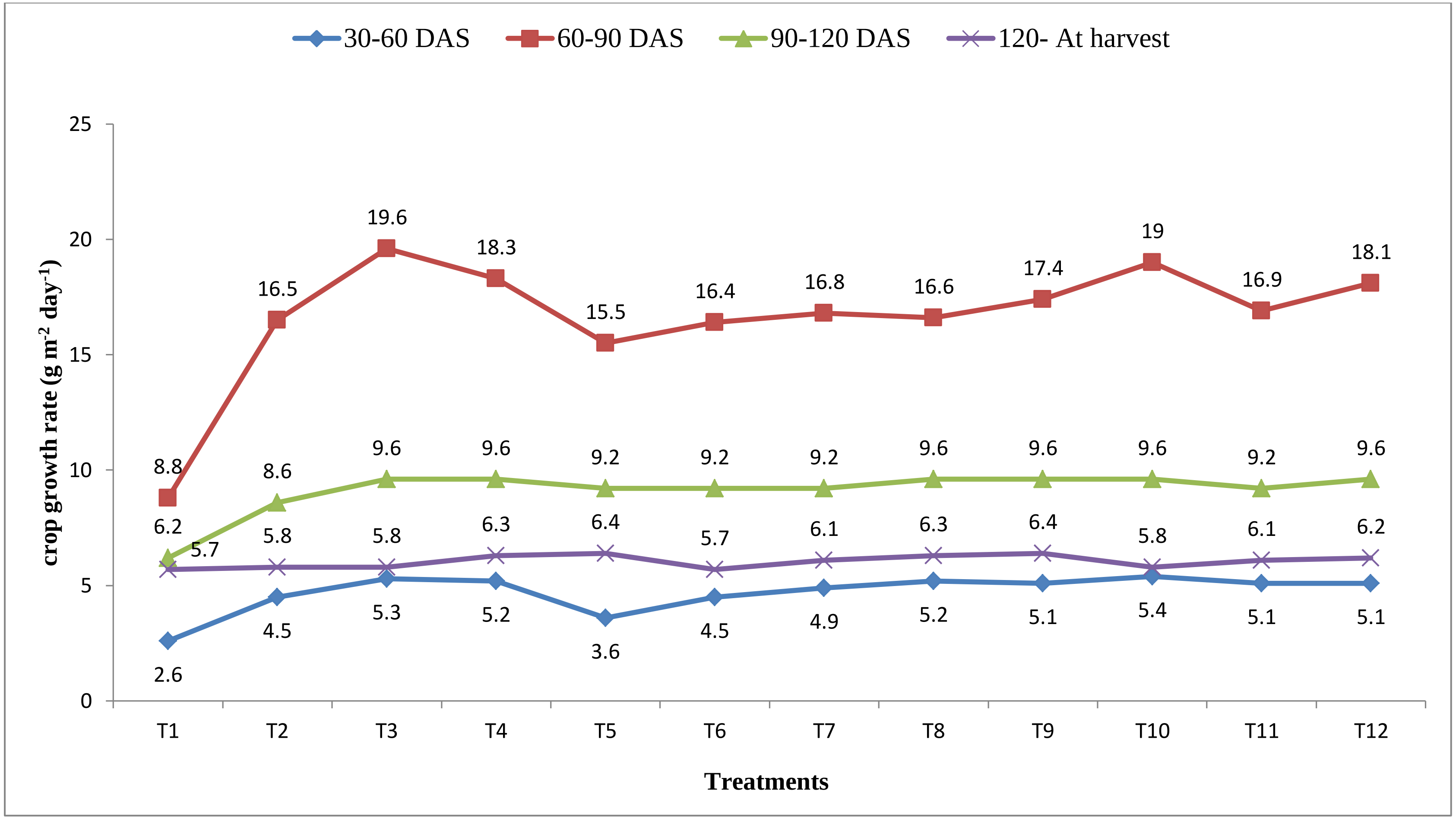



**Fig 4.3 Effect of doses and sources of nutrients on crop growth rate (g m$^{-2}$ day$^{-1}$) of wheat**

The highest crop growth rate during 60-90 DAS period associated with 100 % NPK + Nano Zn spray was significantly higher than other treatments except 100 % NPK + Bio-stimulant spray, 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray, 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray. In comparison to 100% NPK, use of Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer spray with 100 or 75% NPK enhanced crop growth rate remarkably except 75% NPK with Biofertilizer and NPK spray.

**Table 4.6 Effect of doses and sources of nutrients on relative growth rate at various crop growth stages**

| Treatments | Relative growth rate (g $g^{-1}$ $day^{-1}$) | | | |
|---|---|---|---|---|
| | **30-60 DAS** | **60-90 DAS** | **90-120 DAS** | **120-At Harvest** |
| Control | 0.0151 | 0.0121 | 0.0064 | 0.0039 |
| NPK- (150:60:40) | 0.0221 | 0.0186 | 0.0047 | 0.0024 |
| 100 % NPK + Nano Zn spray | 0.0238 | 0.0200 | 0.0045 | 0.0021 |
| 100 % NPK + Bio-stimulant spray | 0.0241 | 0.0195 | 0.0048 | 0.0024 |
| 75 % NPK + NPK Consortia | 0.0212 | 0.0210 | 0.0054 | 0.0027 |
| 75 % NPK + NPK spray | 0.0256 | 0.0201 | 0.0051 | 0.0024 |
| 75 % NPK + NPK Consortia + Nano N spray | 0.0245 | 0.0192 | 0.0049 | 0.0025 |
| 75 % NPK + NPK Consortia + NPK spray | 0.0253 | 0.0187 | 0.0051 | 0.0025 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 0.0249 | 0.0192 | 0.0049 | 0.0025 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 0.0250 | 0.0198 | 0.0046 | 0.0022 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 0.0245 | 0.0190 | 0.0048 | 0.0024 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 0.0250 | 0.0197 | 0.0048 | 0.0024 |
| **SEm±** | **0.001** | **0.001** | **0.0001** | **0.002** |
| **CD (p = 0.05)** | **NS** | **NS** | **NS** | **NS** |

**4.2.5 Relative growth rate (RGR) g $g^{-1}$ $day^{-1}$**

The analysis of variance given in Appendix-VII revealed non-significant

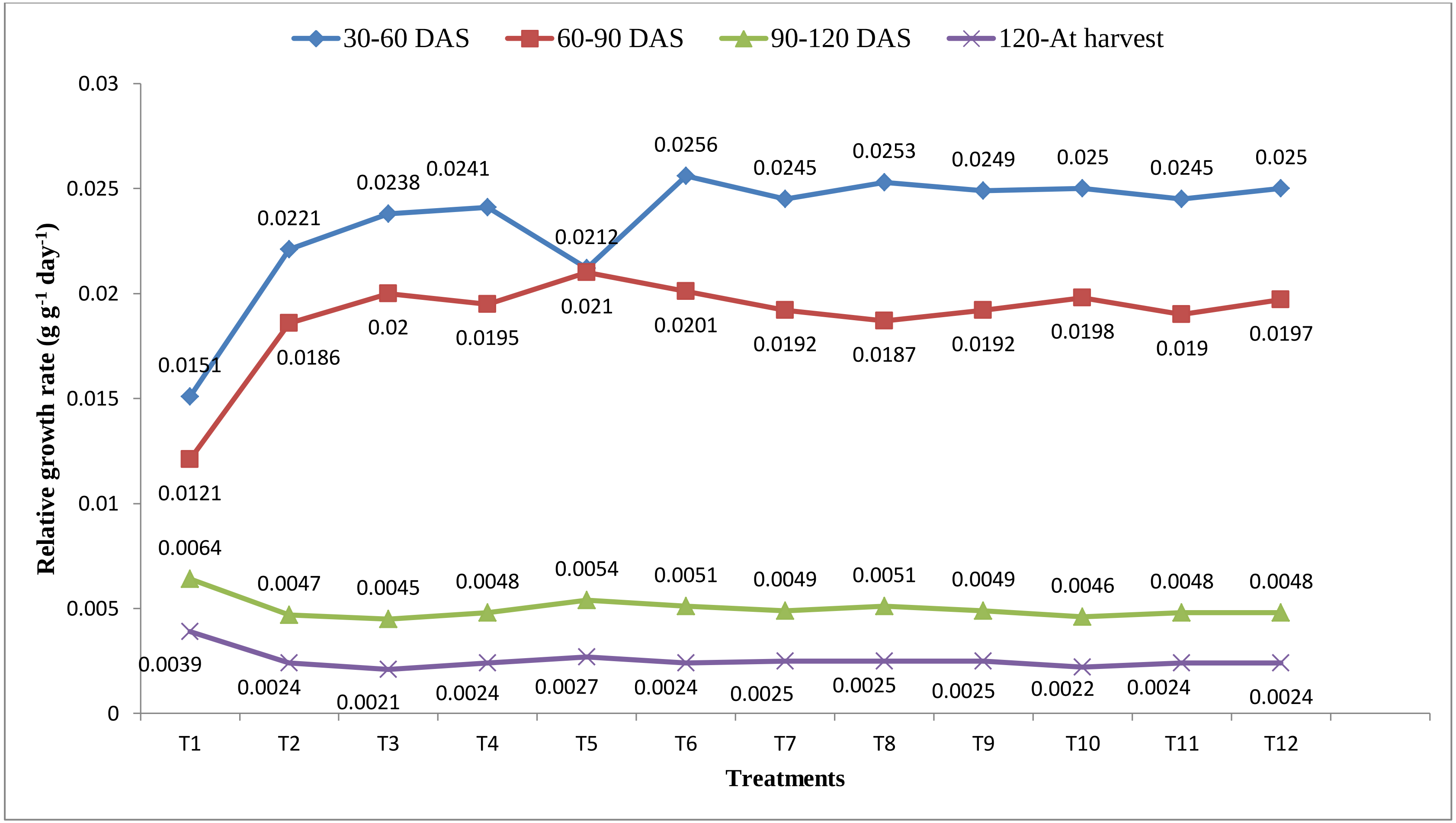



**Fig 4.4 Effect of doses and sources of nutrients on Relative growth rate (g $g^{-1}$ $day^{-1}$) of wheat**

effect of nutrient management practices on relative growth rate i.e. dry matter increase in time initial in relation to initial weight recorded at all growth stages.

Perusal of data in (Table 4.6 and Figure 4.4) revealed that RGR attained maximum value between 60-90 days stage and then declined consistently till the crop maturity. Crop fertilized with 100 % NPK + Nano Zn spray recorded highest growth rate at 60-90 DAS. Lowest value of RGR was recorded in control over rest of the treatments. In comparison to 100% NPK, use of Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer spray with 100% or 75% NPK enhanced relative growth rate increase. Such differences were however non-significant.

## 4.3 Harvest Studies

### 4.3.1 Yield attributes and yield

Nutrient management options exhibited significant effect on yield attributes and yield of wheat *viz*; effective tillers, ear length, spikelet's per spike and grains per spike while non-significant effect was observed in test weight (Appendix- VIII). Attribute wise irrespective is as follows:

#### 4.3.1.1 Effective tillers ($m^{-2}$)

The analysis of variance given in Appendix-VIII revealed significant effect of nutrient management practices on effective tillers ($m^{-2}$) recorded at harvest.

Crop fertilized with various nutrients, their level and sources had significantly higher effective tillers than control (Table 4.7). Application of Nano-Zn and Bio-stimulant in addition to 100% NPK increased effective tillers by 11.8 and 9.9% over 100% of NPK respectively. Further, increase with 75% of NPK with NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray and NPK Consortia +Nano N spray + Nano Zn spray 10.6 and 8.8%. The former was however Crop receiving 75% NPK with NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray increased 10.6%

effective tiller than 100% NPK but at par with 100% NPK + nano Zn / Biostimulant.

Increase in effective tillers with application of Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer spray was significant and in an ascending order of 8.7% (75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray) < 9.8% (100 % NPK + Bio-stimulant spray) < 10.3% (75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray) < 11.4% (100 % NPK + Nano Zn spray) over recommended dose of fertilizer.

**4.3.1.2 Ear length (cm)**

Significant variation was observed in ear length under different nutrient management practices in wheat (Appendix- VIII).

Application of NPK with of nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizer spray, their sources and doses had significantly longer ears in comparison to control (Table 4.7). Additional use of Nano Zn and Bio-stimulant, resulted in respective increase of 18.7 and 17.7% in ear length over 100% NPK. Application of NPK-Consortia + NPK + Bio-stimulant and Zn spray with 75% NPK also registered an increase of 18.7% in ear length over 100 % NPK alone. In the treatment, omission of Nano Zn and substitution of NPK spray with Nano N + omission of Bio-stimulant narrowed down the increase to 15.6 and 16.6% respectively.

Magnitude increase in ear length was significantly affected with combined application of nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizer spray was in an ascending order of 15.6% (75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray) < 16.7% (75 % NPK + NPK Consortia + Nano N spray + Nano Zn spray) < 17.7% (100 % NPK + Bio-stimulant spray) < 18.8% (75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray) / 18.8% (100 % NPK

+ Nano Zn spray) over recommended dose of fertilizer.

#### 4.3.1.3 Spikelet's per spike

Nutrient management options had significant effect on number of spikelet's per spike recorded at harvest (Appendix- VIII).

Various nutrients, their different sources and levels had significantly higher number of spikelet's per spike over control, irrespective of the combinations (Table 4.7). Application of Nano Zn and Bio-stimulant in addition to 100 % NPK resulted an increase of 12.5 and 10.7% over 100% of NPK respectively.

Application of NPK-Consortia + NPK + Bio-stimulant and Zn spray with 75% NPK registered an increase of 11.3% in spikelet's per spike over 100 % NPK alone. In the treatment, omission of Nano Zn and substitution of NPK spray with Nano N + omission of Bio-stimulant narrowed down the increase to 9.5 and 10.7% respectively.

Increase in number of spikelet's per spike with combined application of Nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizer spray was significant in an ascending order of 9.5% (75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray) < 10.7% (75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray) / 10.7% (100 % NPK + Bio-stimulant spray) < 11.3% (75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray) < 12.5% (100 % NPK + Nano Zn spray) over recommended dose of fertilizer.

#### 4.3.1.4 Grains per spike

The analysis of variance given in Appendix- VIII reflected significant effect of nutrient management practices on grains per spike in wheat.

Alike other yield attributes, grains per spike also increased significantly with application of nutrients irrespective of the dose and sources and it ranged from 37.1 with no nutrient application to 48.2 with 100 % NPK + Nano Zn spray however it was equal to 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray (Table 4.7). Crop receiving 100% NPK coupled with spray of Nano Zn and Bio-stimulant spray increased number of grains per spike by 9.0 and 8.8% over 100% NPK.

**Table 4.7 Effect of doses and sources of nutrients on yield attributes**

| **Treatments** | **Yield attributes** | | | | |
|---|---|---|---|---|---|
| | **Effective tillers per m$^2$** | **Ear length (cm)** | **Spikelet's per spike** | **Grains per spike** | **Test weight (g)** |
| Control | 224.0 | 8.1 | 14.1 | 37.1 | 33.5 |
| NPK- (150:60:40) | 272.7 | 9.6 | 16.8 | 44.2 | 37.6 |
| 100 % NPK + Nano Zn spray | 303.7 | 11.4 | 18.9 | 48.2 | 39.2 |
| 100 % NPK + Bio-stimulant spray | 299.3 | 11.3 | 18.6 | 48.1 | 39.0 |
| 75 % NPK + NPK Consortia | 270.0 | 9.8 | 16.5 | 44.9 | 35.5 |
| 75 % NPK + NPK spray | 270.7 | 9.9 | 16.7 | 45.8 | 35.9 |
| 75 % NPK + NPK Consortia + Nano N spray | 278.0 | 10.7 | 16.9 | 46.0 | 38.1 |
| 75 % NPK + NPK Consortia + NPK spray | 287.3 | 10.9 | 17.5 | 46.5 | 38.6 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 287.0 | 11.1 | 18.4 | 47.9 | 38.8 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 301.0 | 11.4 | 18.7 | 48.2 | 39.1 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 281.3 | 10.8 | 17.2 | 46.2 | 38.5 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 296.3 | 11.2 | 18.6 | 48.0 | 38.9 |
| **SEm±** | **8.1** | **0.4** | **0.5** | **1.2** | **1.4** |
| **CD (p = 0.05)** | **23.5** | **1.4** | **1.5** | **3.4** | **NS** |

Application of NPK-Consortia + NPK + Bio-stimulant and Zn spray with 75%

NPK registered an increase of 9.0% in grain per spike over 100 % NPK alone. In the treatment, omission of Nano Zn and substitution of NPK spray with Nano N + omission of Bio-stimulant narrowed down the increase to 8.4 and 8.6% respectively and in the same remained at par with all other treatments involving nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizer spray with NPK (100 or 75%). Increase in grains per spike with application of nano fertilizers, biofertilizers, bio-stimulant, and inorganic fertilizer spray was significant and in an ascending order of 8.4% (75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray) < 8.6% (75 % NPK + NPK Consortia + Nano N spray + Nano Zn spray) < 8.8% (100 % NPK + Bio-stimulant spray) < 9.0% (75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray) / 9.0% (100 % NPK + Nano Zn spray) over recommended dose of fertilizer.

**4.3.1.5 Test weight (g)**

Non-significant variation was observed in test weight (g) under different nutrient management practices (Appendix- VIII).

Test weight ranged from 33.5 g with no nutrient application to 39.2 g with 100 % NPK + Nano Zn spray (Table 4.7). Where with 75% NPK crop receiving NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray recorded highest test weight followed by 100% NPK along with, Bio-stimulant proved better than 100% NPK. Further application of nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizer spray exhibited positive but non-significant effect on test weight.

**4.3.2 Yields**

Grain, straw and biological yields were significantly influenced by different nutrient management practices, while non-significant effect was noticed on harvest index. Information for the parameter is as follows:

### 4.3.2.1 Grain yield (q $ha^{-1}$)

Significant variation was observed in grain yield under different nutrient management options in wheat (Appendix- IX).

Fertilizer application, irrespective of nutrients doses and their sources, increased grain yield significantly over no nutrient application as indicated by data given in Table 4.8 and depicted in Figure 4.5. Application of 100% NPK coupled with spray of Nano Zn and Bio-stimulant increased grain yield by 7.6 q $ha^{-1}$ (15.5%) and 6.7 q $ha^{-1}$ (13.6%) over 100% NPK.

Application of NPK-Consortia + NPK + Bio-stimulant and Zn spray with 75% NPK registered an increase of 6.8 q $ha^{-1}$ (13.8%) in grain yield over 100% NPK alone. In the treatment, omission of Nano Zn and substitution of NPK spray with Nano N + omission of Bio-stimulant narrowed down the increase to 4.4 q $ha^{-1}$ (8.9%) and 5.7 q $ha^{-1}$ (11.6%) respectively.

Increase in grain yield with combined application of nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizer spray was significant and in descending order of 15.5% (100 % NPK + Nano Zn Spray) > 13.8% (75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray) > 13.6% (100 % NPK + Bio-stimulant spray) > 11.6% (75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray) over recommended dose of fertilizer.

### 4.3.1.7 Straw yield (q $ha^{-1}$)

Nutrient management options had significant effect on straw yield (Appendix- IX).

The data given in Table 4.8 and illustrated in Figure 4.5 indicated significant increase in wheat straw yield with application of nutrients. Application of 100% NPK added with spray of nano Zn and Bio-stimulant increased straw yield by 2.6 q $ha^{-1}$ (3.6%) and 1.7 q $ha^{-1}$ (2.3%) over 100% NPK respectively.

**Table 4.8 Effect of doses and sources of nutrients on yield**

| Treatments | Yield (q ha$^{-1}$) | | | |
|---|---|---|---|---|
| | Grain | Straw | Biological | Harvest index |
| Control | 28.3 | 47.9 | 76.2 | 37.1 |
| NPK- (150:60:40) | 49.1 | 71.9 | 121.0 | 40.5 |
| 100 % NPK + Nano Zn spray | 56.7 | 74.5 | 131.2 | 43.2 |
| 100 % NPK + Bio-stimulant spray | 55.8 | 73.6 | 129.4 | 43.1 |
| 75 % NPK + NPK Consortia | 43.5 | 71.1 | 114.6 | 39.9 |
| 75 % NPK + NPK spray | 45.1 | 72.0 | 117.1 | 38.5 |
| 75 % NPK + NPK Consortia + Nano N spray | 49.4 | 72.1 | 121.5 | 40.6 |
| 75 % NPK + NPK Consortia + NPK spray | 52.2 | 71.6 | 123.9 | 42.1 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 53.5 | 71.7 | 125.2 | 42.7 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 55.9 | 73.7 | 129.6 | 43.1 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 50.6 | 71.5 | 122.1 | 41.4 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 54.8 | 72.9 | 127.7 | 42.9 |
| **SEm±** | **1.8** | **2.5** | **4.4** | **1.5** |
| **CD (p = 0.05)** | **5.5** | **7.5** | **13.0** | **NS** |

Application of NPK-Consortia + NPK + Bio-stimulant and Zn spray with 75% NPK registered an increase of 1.8 q ha$^{-1}$ (2.5%) in straw yield over 100% NPK alone. In the treatment, omission of Nano Zn and substitution of NPK spray with Nano N + omission of Bio-stimulant narrowed down the increase to 0.2 q ha$^{-1}$ (0.3%) and 1.0 q ha$^{-1}$ (1.4%) respectively. Crop fertilized with 75% NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray gave higher straw yield 25.8 & 1.8 q ha$^{-1}$ than control and 100% NPK respectively.

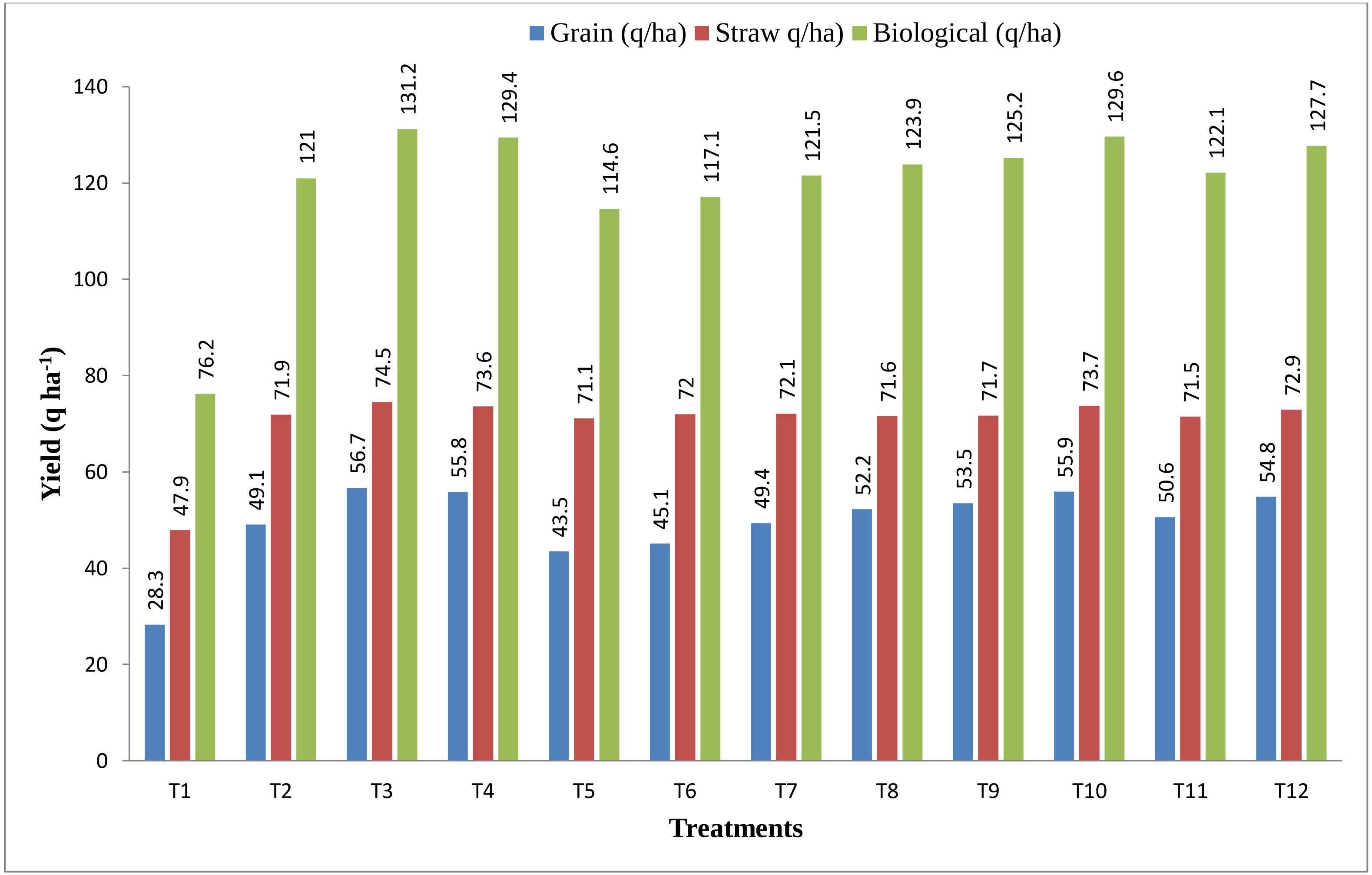



**Fig. 4.5 Effect of doses and sources of nutrients on grain, straw and biological yield of wheat q ha$^{-1}$**

#### 4.3.1.8 Biological yield (q ha$^{-1}$)

Biological yield, total biomass production was affected significantly by nutrient management practices as revealed by analysis of variance presented in Appendix- IX.

Nutrient management practices, irrespective of the nutrients and their sources i.e. nano fertilizers, biofertilizer, bio-stimulant and inorganic fertilizer spray fertilizer increased significantly the biological yield over no nutrient application Table 4.8 and depicted in Figure 4.5. Application of 100% NPK added with spray of Nano Zn and Bio-stimulant spray increased biological yield by 10.2 q ha$^{-1}$ (8.4%) and 8.4 q ha$^{-1}$ (6.9%) over 100% NPK respectively.

Application of NPK-Consortia + NPK + Bio-stimulant and Zn spray with 75% NPK registered an increase of 8.6 q ha$^{-1}$ (7.1%) in biological yield over 100% NPK alone. In the treatment, omission of Nano Zn and substitution of NPK spray with Nano N + omission of Bio-stimulant narrowed down the increase to 4.2 q ha$^{-1}$ (3.5%) and 6.7 q ha$^{-1}$ (5.5%) respectively. Crop fertilized with 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray gave higher yield 53.4 and 8.6 q ha$^{-1}$ than control and 100% NPK.

Increase in biological yield with application of nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizer spray in decreasing order of 8.4% (100 % NPK + Nano Zn spray) > 7.1% (75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray) > 6.9% (100 % NPK + Bio-stimulant spray) > 5.5% (75 % NPK + NPK Consortia + Nano N spray + Nano Zn spray) > 3.5% (75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray) over recommended dose of fertilizer.

#### 4.3.1.9 Harvest index (%)

Harvest index, the ratio of economic yield to biological yield had no significant effect of different nutrient management practices as indicated by the analysis variance presented in Appendix- IX.

Harvest index varied from 37.1% with no nutrient application to 43.2% with application of 100% NPK with Nano Zn spray (Table 4.8). Crop fertilized with 100% NPK with nano Zn recorded highest harvest index (43.2%) followed by 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray (43.1%). Application of NPK along with nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizer spray led to an increase in harvest index over 100% NPK except the treatment having 75% NPK with NPK consortia and NPK spray.

### 4.4 Nutrient content (%) and uptake (kg $ha^{-1}$)

#### 4.4.1 Nitrogen content in grain and straw

The analysis of variance pertaining to the nitrogen content (%) in grain and straw as given in Appendix- X revealed significant effect of nutrient management practices.

The nitrogen content in wheat grains ranged from 1.3 to 2.1% and in straw from 0.19 to 0.62% under different treatments (Table 4.9). The crop fertilized with 100 % NPK + Nano Zn spray had significantly higher nitrogen contents in its components i.e. grain and straw. The Lowest nitrogen content in grain and straw were recorded in crop receiving no fertilizers.It was closely followed by one receiving 75% of NPK along 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray in respect of nitrogen content in grain as well as straw. Application of nano fertilizers, biofertilizer, bio-stimulant and inorganic fertilizer spray with (100%/75%) increased nutrient concentration in comparison to 100% of NPK except treatment having 75 % NPK+ NPK consortia.

#### 4.5.2 Nitrogen uptake in grain and straws

Accumulation of nitrogen in grain, straw and total all differed significantly under the influence of nutrient management practices (Appendix- X).

**Table 4.9 Effect of doses and sources of nutrient on nitrogen content (%), nitrogen uptake and total uptake (kg ha$^{-1}$) in grain and straw**

| Treatment | Nitrogen content (%) | | Nitrogen uptake (kg ha$^{-1}$) | | Total uptake (kg ha$^{-1}$) |
|---|---|---|---|---|---|
| | Grain | Straw | Grain | Straw | |
| Control | 1.3 | 0.19 | 35.4 | 9.1 | 44.5 |
| NPK- (150:60:40) | 1.5 | 0.28 | 73.7 | 20.1 | 93.8 |
| 100 % NPK + Nano Zn spray | 2.1 | 0.62 | 119.1 | 46.2 | 165.3 |
| 100 % NPK + Bio-stimulant spray | 1.9 | 0.60 | 106.0 | 44.2 | 150.2 |
| 75 % NPK + NPK Consortia | 1.4 | 0.28 | 60.9 | 19.9 | 80.8 |
| 75 % NPK + NPK spray | 1.6 | 0.29 | 72.2 | 20.9 | 93.0 |
| 75 % NPK + NPK Consortia + Nano N spray | 1.8 | 0.54 | 88.9 | 38.9 | 127.9 |
| 75 % NPK + NPK Consortia + NPK spray | 1.8 | 0.58 | 94.0 | 41.6 | 135.5 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 1.9 | 0.59 | 101.7 | 42.3 | 144.0 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 2.1 | 0.61 | 117.4 | 45.0 | 162.3 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 1.5 | 0.50 | 75.9 | 35.8 | 111.7 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 2.1 | 0.61 | 115.1 | 44.5 | 159.5 |
| **SEm±** | **0.1** | **0.02** | **3.6** | **1.4** | **5.0** |
| **CD (p = 0.05)** | **0.2** | **0.06** | **10.6** | **4.2** | **14.8** |

In general, the crop accumulated larger amount of nitrogen in grain then in straw irrespective of the treatments (Table 4.9 and Figure 4.6). The crop grown with 100 % NPK + Nano Zn spray accumulated significantly highest amount of nitrogen (165.3 kg ha$^{-1}$) whereas the lowest (44.5 kg ha$^{-1}$) being in crop grown without fertilizer in its grain, straw and total as well. Respective share of grains and straw towards total uptake was 72.1% and 27.9%.

Application of nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizer spray over and above NPK (100/75%) resulted in significant increase in total

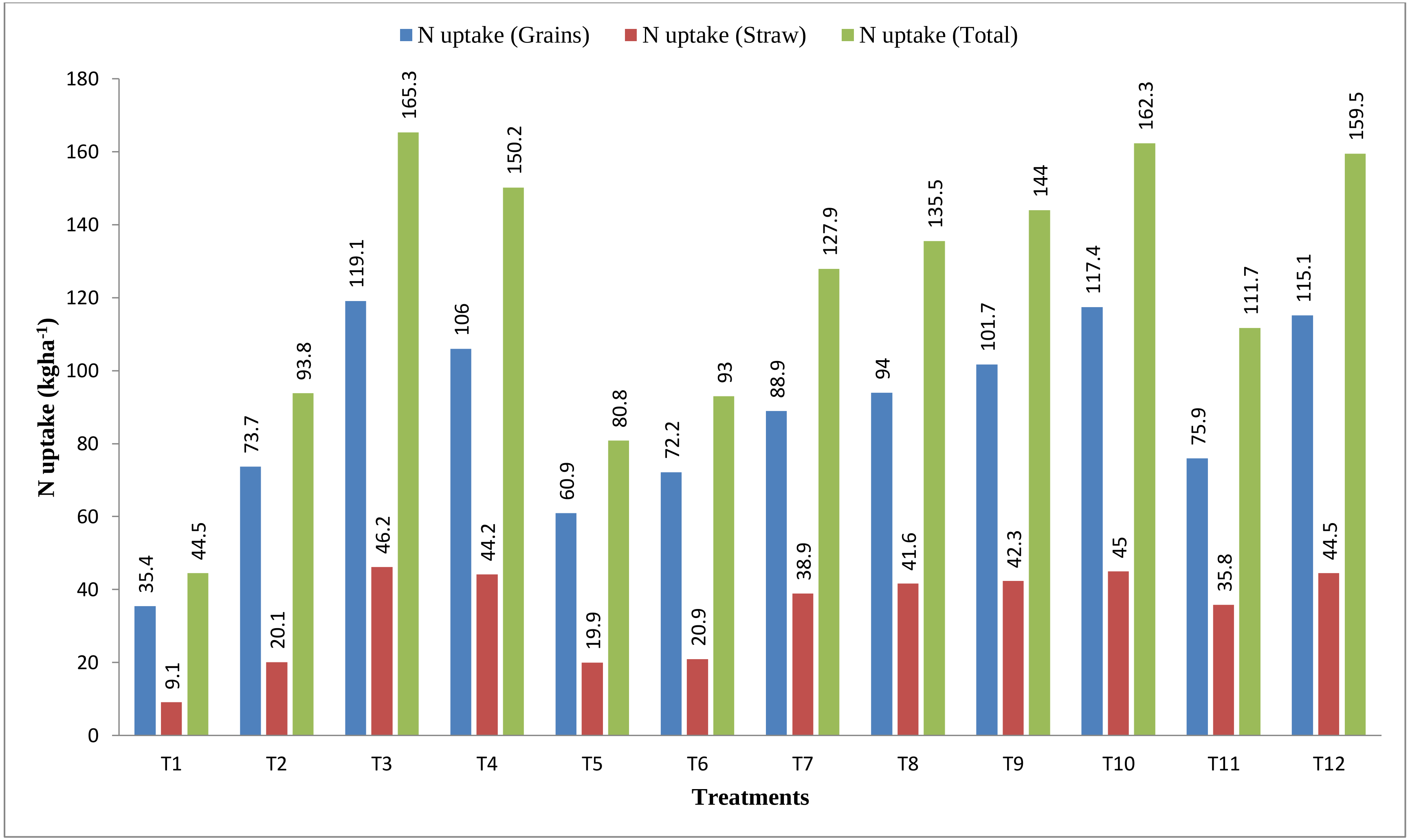



**Fig. 4.6 Effect of doses and sources of nutrients on N uptake (kg ha$^{-1}$) in grains, straw and total uptake of wheat**

Nitrogen accumulation and also in component parts when compared with 100% NPK except treatment having 75 % NPK with NPK Consortia and NPK spray. Differences between treatments having 100 and 75% of NPK with Nano fertilizers, Biofertilizers, Bio-stimulant, and Inorganic fertilizer spray were non-significant though line former resulted in higher uptake.

**4.4.3 Phosphorus content in grain and straw**

Phosphorus content (%) in grain and straw differed significantly under different nutrient management practices (Appendix- XI).

The phosphorus content ranged from 0.10 to 0.26% in grains and 0.07 to 0.13 % in straw under different treatments (Table 4.10). Being lowest in crop grown without nutrient application and highest in crop with 100 % NPK + Nano Zn spray and closely followed by 75 % NPK with NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray. The crop given (75/100%) NPK with Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer spray had significantly higher content in its grain and straw in comparison to 100% NPK except the treatment having only NPK Consortia and NPK spray with 75% NPK.

**4.4.4 Phosphorus uptake in grain and straw**

Phosphorus accumulation in grain, straw and total were affected significantly by nutrient management options as indicated by analysis of variance presented in Appendix- XI.

In general, the crop accumulated larger amount of phosphorus in grains than in straw, irrespective of the treatments (Table 4.10 and Figure 4.7). The crop fertilized with 100 % NPK + Nano Zn spray accumulated significantly highest amount of phosphorus closely related with 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray whereas the lowest being in crop grown without fertilizers in grain, straw and total as well. Respective share of grain and straw towards total uptake was 60.2 & 39.8% in 100% NPK with Nano Zn spray.

**Table 4.10 Effect of doses and sources of nutrients on phosphorus content (%), phosphorus uptake and total uptake (kg ha$^{-1}$) in grain and straw**

| Treatment | Phosphorus content (%) | | Phosphorus uptake (kg ha$^{-1}$) | | Total uptake (kg ha$^{-1}$) |
|---|---|---|---|---|---|
| | Grain | Straw | Grain | Straw | |
| Control | 0.10 | 0.07 | 2.8 | 2.4 | 5.2 |
| NPK- (150:60:40) | 0.18 | 0.08 | 8.8 | 5.8 | 14.6 |
| 100 % NPK + Nano Zn pray | 0.26 | 0.13 | 14.7 | 9.7 | 24.4 |
| 100 % NPK + Bio-stimulant spray | 0.23 | 0.11 | 12.8 | 8.1 | 20.9 |
| 75 % NPK + NPK Consortia | 0.17 | 0.08 | 7.8 | 5.7 | 13.5 |
| 75 % NPK + NPK spray | 0.18 | 0.09 | 7.7 | 6.5 | 14.1 |
| 75 % NPK + NPK Consortia + Nano N spray | 0.17 | 0.08 | 8.4 | 5.8 | 14.2 |
| 75 % NPK + NPK Consortia + NPK spray | 0.22 | 0.1 | 11.5 | 7.2 | 18.7 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 0.18 | 0.09 | 9.6 | 6.5 | 16.1 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 0.25 | 0.12 | 14.0 | 8.8 | 22.8 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 0.20 | 0.08 | 10.1 | 5.7 | 15.8 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 0.17 | 0.1 | 9.3 | 7.3 | 16.6 |
| **SEm±** | **0.007** | **0.004** | **0.4** | **0.3** | **0.7** |
| **CD (p = 0.05)** | **0.022** | **0.011** | **1.2** | **0.8** | **1.9** |

Application of 100 or 75 % of NPK with added Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer spray resulted in significant increase in total phosphorus accumulation and also in component parts when compared with 100% NPK except treatment having NPK Consortia, NPK spray and NPK Consortia + Nano Zn spray with 75 % NPK.

### 4.4.5 Potassium content in grain and straw

The analysis of variance given in Appendix- XII revealed significant effect of nutrient management practices on potassium content (%) of wheat grains and straw.

The potassium content in grains and straw ranged from 0.25 to 0.56% and 0.80

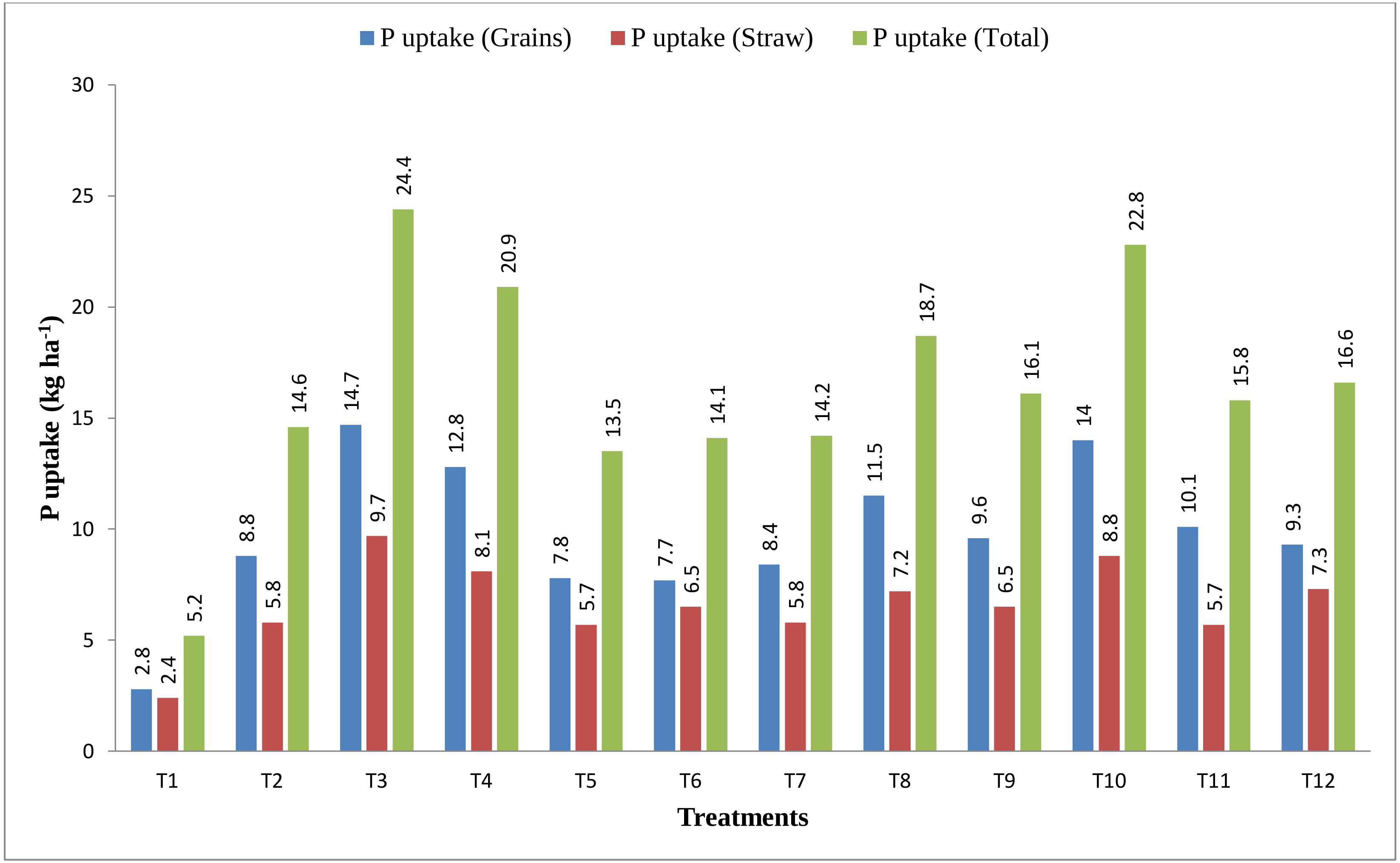



**Fig. 4.7 Effect of doses and sources of nutrients on P uptake (kg ha$^{-1}$) in grains, straw and total uptake of wheat**

to 1.20% respectively under different treatments (Table 4.11). The crop fertilized with 100 % NPK + Nano Zn spray had highest potassium content in its components i.e. grain and straw. Whereas treatment having 75 % NPK with NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray significant over treatment having 100% NPK.

**Table 4.11 Effect of doses and sources of nutrients on potassium content (%), potassium uptake and total uptake (kg ha$^{-1}$) in grain and straw**

| Treatment | Potassium content (%) | | Potassium uptake (kg ha$^{-1}$) | | Total uptake (kg ha$^{-1}$) |
|---|---|---|---|---|---|
| | **Grain** | **Straw** | **Grain** | **Straw** | |
| Control | 0.25 | 0.80 | 7.1 | 38.3 | 45.4 |
| NPK- (150:60:40) | 0.50 | 1.00 | 24.6 | 71.9 | 96.5 |
| 100 % NPK + Nano Zn spray | 0.56 | 1.20 | 31.8 | 89.4 | 121.2 |
| 100 % NPK + Bio-stimulant spray | 0.53 | 1.10 | 29.6 | 81.0 | 110.5 |
| 75 % NPK + NPK Consortia | 0.41 | 0.98 | 17.8 | 69.7 | 87.5 |
| 75 % NPK + NPK spray | 0.43 | 0.99 | 19.4 | 71.3 | 90.7 |
| 75 % NPK + NPK Consortia + Nano N spray | 0.52 | 1.00 | 25.7 | 72.1 | 97.8 |
| 75 % NPK + NPK Consortia + NPK spray | 0.52 | 1.10 | 27.1 | 78.9 | 106.0 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant Spray | 0.54 | 1.10 | 28.9 | 78.9 | 107.8 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray | 0.54 | 1.20 | 30.2 | 88.4 | 118.6 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 0.53 | 1.10 | 26.8 | 78.7 | 105.5 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 0.53 | 1.00 | 29.0 | 72.9 | 101.9 |
| **SEm±** | **0.02** | **0.04** | **1.0** | **2.8** | **3.7** |
| **CD (p = 0.05)** | **0.05** | **0.11** | **2.9** | **8.2** | **11.1** |

### 4.4.6 Potassium uptake in grain and straw

Nutrient management practices had significant effect on potassium accumulation in grain, straw and there by on total uptake by wheat (Appendix- XII).

In general, the crop accumulated larger amount of potassium in straw then in grain irrespective of the treatments (Table 4.11 and Figure 4.8). The crop grown with

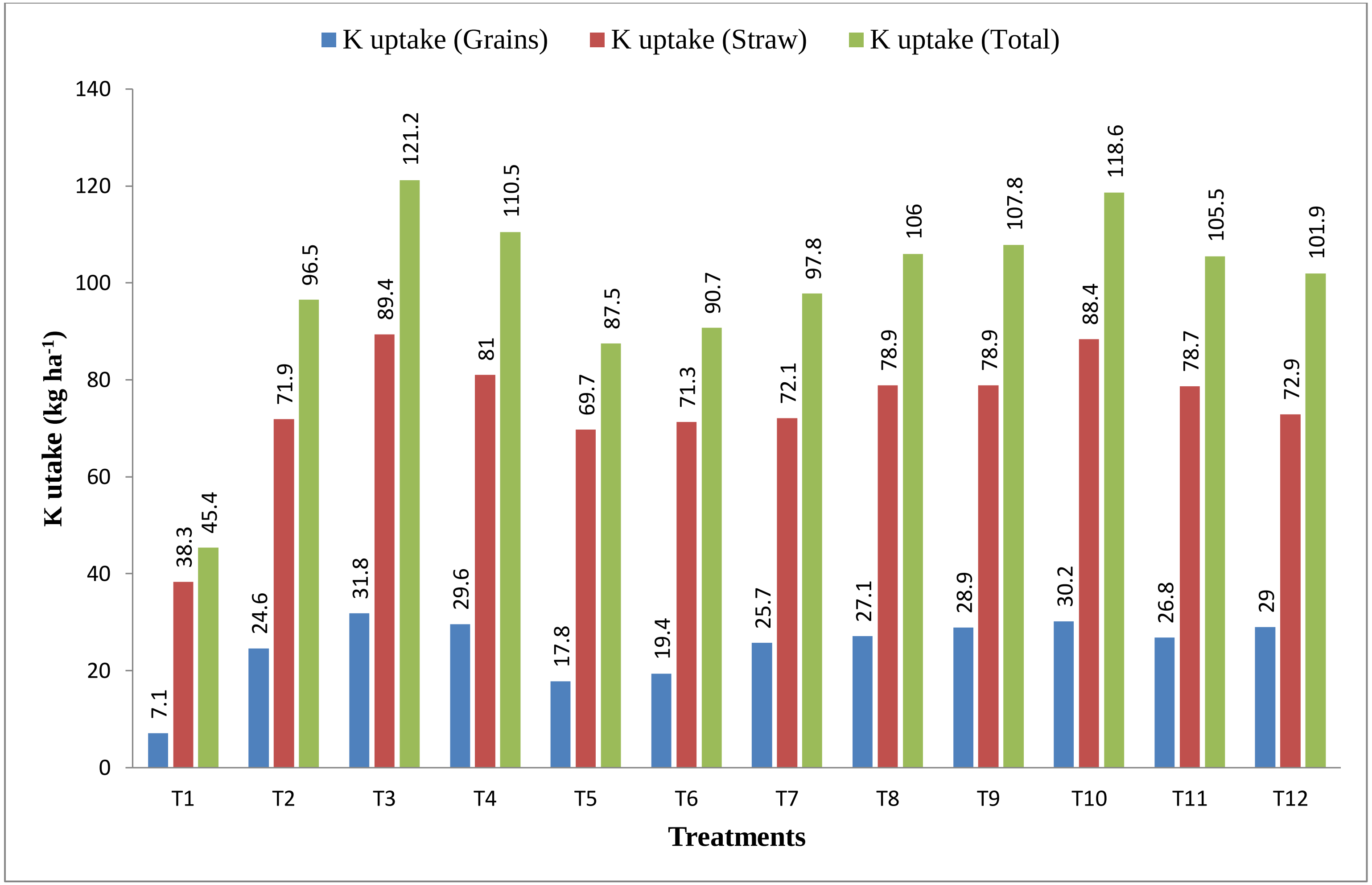



**Fig. 4.8 Effect of doses and sources of nutrients on K uptake (kg ha$^{-1}$) in grains, straw and total uptake of wheat**

100 % NPK + Nano Zn spray accumulated significantly highest amount of potassium whereas the lowest being in crop grown without fertilizer. Respective share of grain and straw towards total uptake was 26.2 & 73.8% with 100% NPK + nano Zn and 15.6 & 84.4 % without fertilizer.

Application of 100 or 75 % of NPK with added Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer spray resulted in significant increase in total potassium accumulation and also in component parts when compared with 100% NPK except treatment having NPK consortia, NPK spray and NPK consortia + nano N spray with 75 % NPK.

**4.4.7 Zinc content in grain and straw**

The analysis of variance pertaining to the zinc content (ppm) in grain and straw as given in Appendix- XIII revealed significant effect of nutrient management practices.

The zinc content in wheat grains ranged from 32.1 to 54.4 ppm and in straw from 24.2 to 33.5 ppm under various treatments (Table 4.12). The highest zinc content in grain (54.4 ppm) and straw (33.5ppm) were recorded with the application of 100 % NPK + Nano Zn spray, being significantly superior over all other treatments except 75% NPK with at least nano Zn spray. All the other treatments where 100 or 75% NPK was supplemented with nano Zinc spray resulted in significant increase in Zinc content over 100% NPK. Application of Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer with (100/75%) increased nutrient concentration statically in comparison to 100% of NPK except treatment having NPK Consortia with 75% NPK.

**4.4.8 Zinc uptake in grain and straw**

Zinc accumulation in grain, straw and total uptake were influenced significantly by nutrient management practices as reflected by analysis of variance presented in Appendix- XIII.

**Table 4.12 Effect of doses and sources of nutrients on zinc content (ppm), zinc uptake and total uptake (g ha$^{-1}$) in grain and straw**

| Treatment | Zinc content (ppm) | | Zinc uptake (g ha$^{-1}$) | | Total uptake (g ha$^{-1}$) |
|---|---|---|---|---|---|
| | Grain | Straw | Grain | Straw | |
| Control | 32.1 | 24.2 | 90.8 | 115.9 | 206.8 |
| NPK- (150:60:40) | 43.5 | 27.1 | 213.6 | 194.8 | 408.4 |
| 100 % NPK + Nano Zn spray | 54.4 | 33.5 | 308.4 | 249.6 | 558.0 |
| 100 % NPK + Bio-stimulant spray | 46.3 | 29.8 | 258.4 | 219.3 | 477.7 |
| 75 % NPK + NPK Consortia | 39.1 | 26.7 | 170.1 | 189.8 | 359.9 |
| 75 % NPK + NPK spray | 45.1 | 26.5 | 203.4 | 190.8 | 394.2 |
| 75 % NPK + NPK Consortia + Nano N spray | 45.2 | 28.6 | 223.3 | 206.2 | 429.5 |
| 75 % NPK + NPK Consortia + NPK spray | 43.9 | 27.9 | 229.2 | 200.0 | 429.2 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 44.4 | 29.2 | 237.5 | 209.4 | 446.9 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 53.4 | 32.1 | 298.5 | 236.6 | 535.1 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 53.1 | 31.7 | 268.7 | 226.7 | 495.3 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 53.3 | 32.4 | 292.1 | 236.2 | 528.3 |
| **SEm±** | **1.7** | **1.1** | **9.1** | **7.7** | **16.8** |
| **CD (p = 0.05)** | **5.0** | **3.2** | **27.0** | **22.8** | **49.7** |

In general, the crop accumulated larger amount of zinc in grains then in straw irrespective of the treatments (Table 4.12 and Figure 4.9). The crop fed with 100 % NPK with Nano Zn spray (558.0 g ha$^{-1}$) accumulated significantly highest amount of zinc whereas the lowest (206.8 g ha$^{-1}$) being in crop grown without fertilizers in grain, straw and total as well. Respective share of grain and straw towards total uptake was 55.2 & 44.8 % in 100 % NPK with Nano Zn spray and 43.9 & 56.1 % in control plot. Application of 100 or 75 % of NPK with added at least nano Zn nutrient resulted significant increase in total zinc accumulation and also in component parts when compared with 100% NPK.

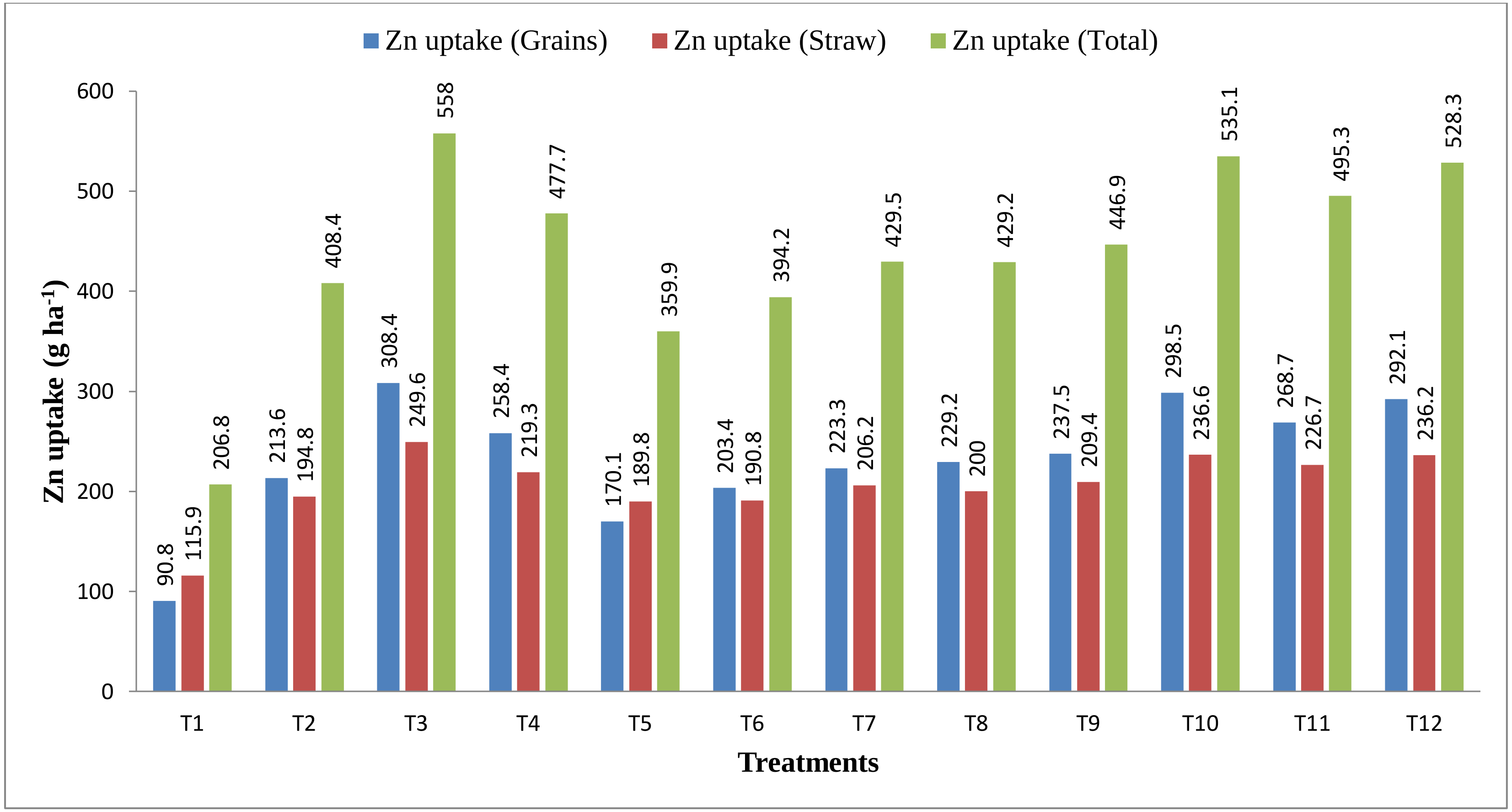



**Fig. 4.9 Effect of doses and sources of nutrients on Zn uptake (g ha$^{-1}$) in grains, straw and total uptake of wheat**

### 4.5 Nutrient Use Efficiency

#### 4.5.1 Agronomic Efficiency (AE, kg grain yield increase $kg^{-1}$ nutrient applied)

Agronomic efficiency of N, P & K was significantly affected by different nutrient management practices as evident from the analysis of variance given in appendix- XIV.

**Table 4.13 Effect of doses and sources of nutrients on agronomic use efficiency**

| **Treatment** | **Agronomic use-efficiency (AE)** | | |
|---|---|---|---|
| | **Nitrogen (N)** | **Phosphorus (P)** | **Potassium (K)** |
| Control | -- | -- | -- |
| NPK- (150:60:40) | 13.8 | 34.6 | 52.0 |
| 100 % NPK + Nano Zn spray | 18.9 | 47.3 | 71.0 |
| 100 % NPK + Bio-stimulant spray | 18.3 | 45.83 | 68.7 |
| 75 % NPK + NPK Consortia | 13.5 | 33.7 | 50.6 |
| 75 % NPK + NPK spray | 14.9 | 37.3 | 56.0 |
| 75 % NPK + NPK Consortia + Nano N spray | 18.7 | 46.8 | 70.3 |
| 75 % NPK + NPK Consortia + NPK spray | 21.2 | 53.1 | 79.6 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 22.4 | 56.0 | 84.0 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 24.5 | 61.3 | 92.0 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 19.8 | 49.5 | 74.3 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 23.5 | 58.8 | 88.3 |
| **SEm±** | **0.7** | **1.8** | **2.7** |
| **CD (p = 0.05)** | **2.1** | **5.3** | **7.9** |

Perusal of data presented in Table 4.13 revealed that there was significant increase in agronomic use efficiency of NPK under different nutrient management practices in comparison to 100% NPK except treatment having NPK Consortia, NPK spray with 75% RDF. Application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray led to higher agronomic efficiency of 24.5 for N, 61.3 for P and 92.0 for K as against 13.8, 34.6 and 52.0 respectively with 100%

NPK. Application of Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer spray individually or simultaneously with 75% of NPK when compared with 100% NPK indicated significant increase in agronomic efficiency except treatment having NPK consortia, NPK spray with 75% NPK.

### 4.5.2 Physiological Efficiency (PE, kg yield increase $kg^{-1}$ nutrient uptake)

Nutrient management practices had significant effect on physiological efficiency of wheat (Appendix XV).

**Table 4.14 Effect of doses and sources of nutrients on physiological use efficiency**

| Treatment | Physiological use-efficiency (PE) | | |
|---|---|---|---|
| | Nitrogen (N) | Phosphorus (P) | Potassium (K) |
| Control | -- | -- | -- |
| NPK- (150:60:40) | 42.2 | 222.1 | 40.7 |
| 100 % NPK + Nano Zn spray | 23.5 | 147.9 | 37.5 |
| 100 % NPK + Bio-stimulant spray | 26.0 | 175.1 | 42.2 |
| 75 % NPK + NPK Consortia | 41.8 | 183.3 | 36.1 |
| 75 % NPK + NPK spray | 34.6 | 188.3 | 37.1 |
| 75 % NPK + NPK Consortia + Nano N spray | 25.3 | 236.0 | 40.3 |
| 75 % NPK + NPK Consortia + NPK spray | 26.2 | 178.0 | 39.4 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 25.3 | 232.1 | 40.4 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 23.4 | 156.9 | 37.7 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 33.2 | 210.1 | 37.1 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 23.0 | 232.8 | 46.9 |
| **SEm±** | **0.9** | **6.8** | **1.4** |
| **CD (p = 0.05)** | **2.7** | **20.1** | **4.1** |

Application of nutrient, irrespective of doses and sources increased physiological efficiency (Table 4.14). In case of physiological N-use efficiency, the application of NPK- (150:60:40) recorded maximum PE (42.2), while minimum (23.0) with 75 % NPK + NPK Consortia + Nano N spray + Nano Zn spray. In case of physiological P-use efficiency, maximum PE (236.0) with 75 % NPK + NPK Consortia + Nano N spray and lowest (147.9) with 100 % NPK + Nano Zn spray. Subjected to physiological potassium use efficiency, application 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray found maximum PE (46.9) and lowest (36.1) in 75 % NPK + NPK Consortia.

### 4.5.3 Partial Factor Productivity (PFP, kg of grain $kg^{-1}$ of nutrient applied)

The analysis of variance given in Appendix- XVI revealed significant effect of nutrient management options on partial factor productivity of N, P and K in wheat crop.

**Table 4.15 Effect of doses and sources of nutrients on partial factor productivity**

| Treatment | Partial factor productivity | | |
|---|---|---|---|
| | Nitrogen (N) | Phosphorus (P) | Potassium (K) |
| Control | -- | -- | -- |
| NPK- (150:60:40) | 32.7 | 81.8 | 122.8 |
| 100 % NPK + Nano Zn spray | 37.8 | 94.5 | 141.8 |
| 100 % NPK + Bio-stimulant spray | 37.2 | 93.0 | 139.5 |
| 75 % NPK + NPK Consortia | 38.7 | 96.7 | 145.0 |
| 75 % NPK + NPK spray | 40.1 | 100.2 | 150.3 |
| 75 % NPK + NPK Consortia + Nano N spray | 43.9 | 109.8 | 164.7 |
| 75 % NPK + NPK Consortia + NPK spray | 46.4 | 116.0 | 174.0 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 47.6 | 118.9 | 178.3 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 49.7 | 124.2 | 186.3 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 45.0 | 112.4 | 168.7 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 48.7 | 121.8 | 182.7 |
| **SEm±** | **1.5** | **3.8** | **5.7** |
| **CD (p = 0.05)** | **4.5** | **11.3** | **16.9** |

The data on PFP given in Table 4.15 indicated significant increase with application of nano fertilizers, biofertilizer, bio-stimulant and inorganic fertilizer spray in comparison to 100% NPK, though of the nutrient Combinations of Nano fertilizers, Biofertilizers, Bio-stimulant, and Inorganic fertilizer spray proved more production then these with 100% NPK. Partial factor productivity ranged from 32.7 to 49.7 for Nitrogen, 81.8 to 124.2 for Phosphorus and 122.8 to 186.3 for Potassium, lowest PFP with 100% NPK and highest PFP with 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray.

**4.6 Protein content (%) and yield kg ha$^{-1}$**

**4.6.1 Protein Content (%)**

The analysis of variance pertaining to the protein content in grain as given in Appendix- XVII revealed significant effect of nutrient management practices.

The protein content in grains ranged from 7.1 to 12.0 % under various treatments (Table 4.16) the lowest being with control and the highest with the application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray. Wheat fertilized with various nutrients, their sources and levels gave significantly higher protein content over control, irrespective of the combinations crop fertilized with 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray recorded highest protein (12.0%). The crop receiving 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray remaining at par 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray ,100 % NPK + Nano Zn spray proved significantly better than 100% NPK either of protein content. Application of Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer spray with (100/75%) increase protein % in comparison to (100%) of NPK except treatment having NPK consortia with 75% NPK.

**4.6.2 protein yield (kg ha$^{-1}$)**

Nutrient management options exhibited significant influence on protein yield of wheat (Appendix- XVII).

**Table 4.16 Effect of doses and sources of nutrients on protein content (%) and protein yield (kg ha$^{-1}$)**

| Treatment | Quality | |
|---|---|---|
| | **Protein (%)** | **Protein (kg ha$^{-1}$)** |
| Control | 7.1 | 202.6 |
| NPK- (150:60:40) | 8.5 | 422.0 |
| 100 % NPK + Nano Zn spray | 11.4 | 649.7 |
| 100 % NPK + Bio-stimulant spray | 10.8 | 607.4 |
| 75 % NPK + NPK Consortia | 8.0 | 348.9 |
| 75 % NPK + NPK spray | 9.1 | 413.4 |
| 75 % NPK + NPK Consortia + Nano N spray | 10.3 | 509.5 |
| 75 % NPK + NPK Consortia + NPK spray | 10.3 | 538.3 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 10.8 | 582.4 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 12.0 | 672.6 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 8.5 | 434.9 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 12.0 | 659.4 |
| **SEm±** | **0.3** | **20.4** |
| **CD (p = 0.05)** | **1.1** | **60.4** |

Alike protein content, protein yield was also highest (672.6 kg ha$^{-1}$) with application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray, while lowest (202.6 kg ha$^{-1}$) with no nutrient Table 4.16. Application of Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer spray in addition to (100%/75%) NPK increased protein yield over 100% NPK except treatment having NPK consortia and NPK spray with 75% NPK. Treatment receiving 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray was at par with 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray, 100 % NPK + Nano Zn spray and significantly superior over 100 % NPK.

## 4.7 Soil fertility

### 4.7.1 Physical properties

#### 4.7.1.2 Bulk density (g cc$^{-1}$)

Nutrient management practices could not leave any significant effect on soil bulk density (Appendix- XVIII).

Perusal of data presented in Table 4.17 indicated that there was a decrease in bulk density due to application of nutrient where as compared to control and it ranged in the various range of 1.43 to 1.51 g cc$^{-1}$ highest being in control plots and lowest in plots receiving 75 % NPK + NPK Consortia + NPK spray. There was definite trend in variation under different treatment.

**Table 4.17 Effect of doses and sources of nutrients on physical properties of soil**

| Treatments | Bulk density (g cc$^{-1}$) | Particle density (g cc$^{-1}$) | Aggregate stability (%) |
|---|---|---|---|
| Control | 1.51 | 2.64 | 56.13 |
| NPK- (150:60:40) | 1.47 | 2.63 | 56.12 |
| 100 % NPK + Nano Zn spray | 1.46 | 2.63 | 57.64 |
| 100 % NPK + Bio-stimulant spray | 1.45 | 2.64 | 56.7 |
| 75 % NPK + NPK Consortia | 1.46 | 2.64 | 55.8 |
| 75 % NPK + NPK spray | 1.44 | 2.63 | 52.2 |
| 75 % NPK + NPK Consortia + Nano N spray | 1.47 | 2.63 | 56.4 |
| 75 % NPK + NPK Consortia + NPK spray | 1.43 | 2.63 | 56.3 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 1.45 | 2.64 | 57.5 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 1.45 | 2.64 | 58.6 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 1.46 | 2.63 | 56.7 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 1.47 | 2.63 | 56.6 |
| **SEm±** | **0.052** | **0.093** | **2.021** |
| **CD (p = 0.05)** | **NS** | **NS** | **NS** |

#### 4.7.1.2 Particle density (g cc$^{-1}$)

No-significant variation was observed in particle density under different nutrient management practices, after harvesting of wheat (Appendix- XVIII).

Perusal of data presented in Table 4.17 indicated that particle density varied from 2.63 to 2.64 g $cc^{-1}$ former being in control plot and the later in plot receiving NPK, nano fertilizers, biofertilizer, bio-stimulant and inorganic fertilizer spray without nutrient management options with change in treatments, the changes in particle density followed as determined.

**4.7.1.3 Aggregate stability (%)**

The analysis of variance given in Appendix- XVIII exhibited non-significant effect of nutrient management practices on aggregate stability also.

Perusal of data presented in Table 4.17 revealed that soil fertilized with higher doses of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray in more value of aggregate stability closely followed by 100 % NPK + Nano Zn spray, while the lowest one received 75 % NPK + NPK Consortia. Variations in aggregate stability were non-significant in either of (75%/100%) NPK.

**4.7.2. Soil chemical properties**

**4.7.2.1. Soil pH**

Soil pH status as analyzed after the crop harvest indicated non-significant variation attributed to nutrient management practices (Appendix- XIX).

The data pertaining Soil pH is presented in Table 4.18. Soil pH did not differ significantly by the nutrient management practices. Numerically the maximum soil pH value (7.8) was observed in control, lowest soil pH (7.5) was recorded with 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray.

**4.7.2.2 EC ($dSm^{-1}$)**

Soil EC status as analyzed after the crop harvest indicated non-significant variation attributed to nutrient management practices (Appendix- XIX).

The data pertaining Soil EC is presented in Table 4.18. Soil EC differed by the nutrient management practices. The maximum soil EC value (0.54) was observed in 100 % NPK + Nano Zn spray. Lowest soil EC (0.48) was recorded in Control plot.

**Table 4.18 Effect of doses and sources of nutrients on organic carbon (%), soil pH and EC**

| Treatments | Organic carbon (%) | Soil pH | EC ($dSm^{-1}$) |
|---|---|---|---|
| Control | 0.38 | 7.8 | 0.48 |
| NPK- (150:60:40) | 0.41 | 7.7 | 0.50 |
| 100 % NPK + Nano Zn spray | 0.42 | 7.7 | 0.54 |
| 100 % NPK + Bio-stimulant spray | 0.47 | 7.6 | 0.52 |
| 75 % NPK + NPK Consortia | 0.42 | 7.7 | 0.49 |
| 75 % NPK + NPK spray | 0.40 | 7.7 | 0.52 |
| 75 % NPK + NPK Consortia + Nano N spray | 0.48 | 7.6 | 0.52 |
| 75 % NPK + NPK Consortia + NPK spray | 0.48 | 7.6 | 0.51 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 0.46 | 7.5 | 0.52 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 0.49 | 7.5 | 0.53 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 0.48 | 7.5 | 0.52 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 0.49 | 7.5 | 0.53 |
| **SEm±** | **0.02** | **0.3** | **0.02** |
| **CD (p = 0.05)** | **0.05** | **NS** | **NS** |

**4.7.2.3 Soil organic carbon (%)**

Soil organic carbon status as analyzed after the crop harvest indicated significant variation attributed to nutrient management practices (Appendix- XIX).

The data pertaining soil organic carbon is presented in Table 4.18. The soil organic carbon did differ significantly by the nutrient management practices. The highest soil organic carbon (0.49%) was recorded in plot having application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray. Lowest organic carbon (0.38) was noticed under no fertilized plot.

**4.6.1 Available nitrogen**

The soil available nitrogen at harvest showed significant effect of nutrient management practices (Appendix- XX).

Perusal of data given in Table 4.19 and Figure 4.10 indicated that the plot receiving of 100 % NPK + Bio-stimulant spray had highest available nitrogen (211.8 kg $ha^{-1}$) after crop harvest closely followed by 75 % NPK + NPK Consortia + Nano Zn spray whereas, the lowest (174.5 kg $ha^{-1}$) was recorded in control plot.

**Table 4.19 Effect of doses and sources of nutrients on chemical properties of soil**

| Treatments | Available nutrients (kg $ha^{-1}$) | | | Available zinc (mg $kg^{-1}$) |
|---|---|---|---|---|
| | Nitrogen | Phosphorus | Potassium | |
| Control | 174.5 | 10.8 | 132.7 | 0.79 |
| NPK- (150:60:40) | 209.2 | 13.1 | 154.8 | 0.8 |
| 100 % NPK + Nano Zn spray | 196.7 | 14.1 | 135.1 | 0.82 |
| 100 % NPK + Bio-stimulant spray | 211.8 | 15.2 | 143.6 | 0.81 |
| 75 % NPK + NPK Consortia | 193.7 | 12.9 | 154.0 | 0.8 |
| 75 % NPK + NPK spray | 205.5 | 12.7 | 151.5 | 0.82 |
| 75 % NPK + NPK Consortia + Nano N spray | 196.6 | 12.7 | 145.8 | 0.82 |
| 75 % NPK + NPK Consortia + NPK spray | 189.0 | 11.4 | 139.2 | 0.84 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 189.5 | 12.1 | 147.8 | 0.83 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 196.2 | 11.1 | 149.1 | 0.86 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 210.9 | 12.2 | 148.6 | 0.87 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 185.0 | 12.0 | 148.4 | 0.85 |
| **SEm±** | **7.0** | **0.4** | **5.2** | **0.029** |
| **CD (p = 0.05)** | **20.5** | **1.3** | **NS** | **NS** |

### 4.6.2 Available phosphorus

The soil available phosphorus at harvest was affected significantly by nutrient management practices as indicated by analysis of variance presented in Appendix-XX.

The data presented in Table 4.19 and Figure 4.10 indicated that the available phosphorus in soil ranged from 10.8 kg $ha^{-1}$ under control to 15.2 kg $ha^{-1}$ in plots

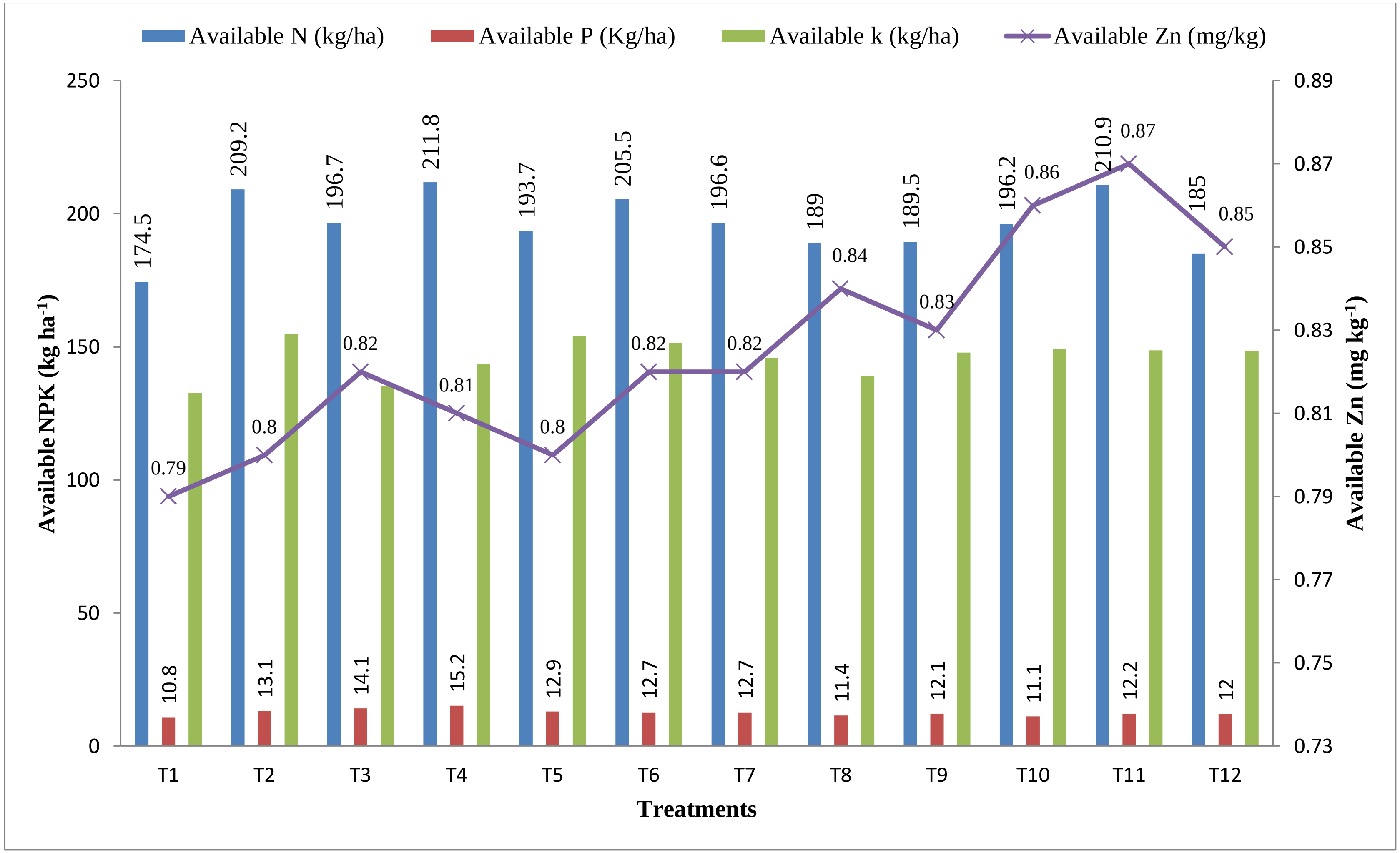



**Fig. 4.10 Effect of doses and sources of nutrients on Soil nutrient status after harvest of wheat**

receiving 100 % NPK + Bio-stimulant spray when tested along with all the Nano fertilizers, Biofertilizers, Bio-stimulant, and Inorganic fertilizer spray.

**4.6.3 Available potassium**

Analysis of variance on residual available soil potassium revealed non-significant effect of nutrient management practices (Appendix- XX).

Perusal of data given in Table 4.19 and Figure 4.10 indicated that available soil potassium, at crop harvest, varied in the range of 132.7 to 154.8 kg $ha^{-1}$ being lowest in control plot and highest in 100% NPK.

**4.6.4 Available zinc**

Like available K. Zn also exhibited non-significant effect of the nutrient management options as indicated by analysis of variance given in Appendix XX.

Perusal of data given in Table 4.19 and Figure 4.10 indicated that soil available zinc ranged in a narrow range from 0.79 to 0.87 mg $kg^{-1}$, the lowest in control plots and higher in plots applied with 75 % NPK + NPK Consortia + Nano Zn spray. Residual zinc content was lower in treatment with 75% NPK in comparison to there being 100% NPK, though the differences were not significant.

**4. Soil biological properties**

**4.6.8 Bacteria (No. × $10^6$ cfu $g^{-1}$)**

Significantly, higher bacterial population was counted in wheat plots fertilized with different nutrient management treatments and their analysis of variance presented in (Appendix- XXI).

The perusal data presented Table 4.20 indicated that the plots receiving different nutrient management practices had higher bacterial count in comparison to control. Application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray recorded highest bacteria (0.78) followed by 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray (0.76) and 75 % NPK + NPK

Consortia +Nano N spray + Nano Zn spray (0.72) while superior to rest of the treatments. Lowest bacteria were recorded (0.65) in control plot.

**Table 4.20 Effect of doses and sources of nutrients on biological properties of soil**

| Treatments | Bacteria (No× $10^6$ cfu $g^{-1}$) | Fungi (No× $10^4$ cfu $g^{-1}$) | Actinomycetes (No× $10^3$ cfu $g^{-1}$) |
|---|---|---|---|
| Control | 0.65 | 0.48 | 0.45 |
| NPK- (150:60:40) | 0.67 | 0.49 | 0.47 |
| 100 % NPK + Nano Zn spray | 0.68 | 0.54 | 0.52 |
| 100 % NPK + Bio-stimulant spray | 0.71 | 0.59 | 0.56 |
| 75 % NPK + NPK Consortia | 0.68 | 0.56 | 0.53 |
| 75 % NPK + NPK spray | 0.66 | 0.49 | 0.46 |
| 75 % NPK + NPK Consortia + Nano N spray | 0.69 | 0.57 | 0.54 |
| 75 % NPK + NPK Consortia + NPK spray | 0.69 | 0.57 | 0.55 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray | 0.76 | 0.64 | 0.61 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 0.78 | 0.67 | 0.63 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 0.7 | 0.58 | 0.56 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 0.72 | 0.59 | 0.58 |
| **SEm±** | **0.025** | **0.021** | **0.02** |
| **CD (p = 0.05)** | **0.075** | **0.062** | **0.059** |

### 4.6.9 Fungi (No× $10^4$ cfu $g^{-1}$)

Application of different nutrient management practices resulted in higher fungi population after harvesting of wheat with their analysis of variance presented in (Appendix- XXI).

Wheat rhizosphere receiving nutrients irrespective of sources and doses had higher fungal production in comparison to control (Table 4.20). Plot receiving 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray (0.67) recorded highest population followed by those given 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray (0.64). Lowest fungi were recorded (0.48) in control plot.

**4.6.10 Actinomycetes (No× $10^3$ cfu $g^{-1}$)**

Like bacteria and fungi, actinomycetes also exhibited significant effect of the nutrient management options as indicated by analysis of variance given in Appendix-XXI.

Data presented in Table 4.20 indicated that under different nutrient management practices actinomycetes count was higher in comparison to control. Plots receiving 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray (0.63) recorded highest actinomycetes followed by 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray (0.61), 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray (0.58) and 100 % NPK + Bio-stimulant spray (0.56). Lowest actinomycetes were recorded in control plot.

**4.9 Economic returns**

**4.9.1 Cost of cultivation**

The data given in the Table 4.21 and Figure 4.11 exhibited variation in cost of cultivation ranged from ₹36750 $ha^{-1}$ for the crop grown without nutrient application to ₹48703 $ha^{-1}$ for the crop grown with 100 % NPK + Nano Zn spray. The cost incurred on 100% NPK, 75% NPK+ NPK consortia, 75% NPK + NPK spray, 75% NPK+ NPK consortia+ nano N spray, 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray, 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray, 75 % NPK + NPK Consortia + Nano Zn spray and 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray ₹6573, 5314, 5813, 6274, 6521, 11051, 10694 and 11074 $ha^{-1}$ respectively over control.

**Table 4.21 Effect of nutrients management on Cost of cultivation, Gross return, Net return and B: C ratio in wheat**

| Treatments | Cost of cultivation (Rs $ha^{-1}$) | Gross return (Rs $ha^{-1}$) | Net return (Rs $ha^{-1}$) | B: C ratio |
|---|---|---|---|---|
| Control | 36750 | 79842 | 43092 | 2.1 |
| NPK- (150:60:40) | 43323 | 132922 | 89598 | 3.0 |
| 100 % NPK + Nano Zn spray | 48703 | 149232 | 100528 | 3.0 |
| 100 % NPK + Bio-stimulant spray | 44241 | 147005 | 102763 | 3.3 |
| 75 % NPK + NPK Consortia | 42064 | 121462 | 79398 | 2.8 |
| 75 % NPK + NPK spray | 42563 | 125072 | 82508 | 2.9 |
| 75 % NPK + NPK Consortia + Nano N spray | 43024 | 133615 | 90590 | 3.1 |
| 75 % NPK + NPK Consortia + NPK spray | 42664 | 138945 | 96280 | 3.2 |
| 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant Spray | 43271 | 141512 | 98240 | 3.2 |
| 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray | 47801 | 147252 | 99450 | 3.0 |
| 75 % NPK + NPK Consortia + Nano Zn spray | 47444 | 135685 | 88240 | 2.8 |
| 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray | 47824 | 144680 | 96855 | 3.0 |
| **SEm±** | ---- | ---- | ---- | ---- |
| **CD (p = 0.05)** | ---- | ---- | ---- | ---- |

**4.9.2 Gross returns**

The data pertaining to gross return are presented in Table 4.21 and Figure 4.11. Gross returns varied from ₹79824 $ha^{-1}$ for the crop raised with no nutrient application to the highest of ₹149232 $ha^{-1}$ from the crop raised 100 % NPK + Nano Zn spray. Crop receiving 100% NPK along with nano-Zn fetched higher gross return by ₹69389 $ha^{-1}$ than control and ₹16310 $ha^{-1}$ higher than 100% NPK.

**4.9.3 Net returns**

Perusal of data presented in Table 4.21 and depicted in Figure 4.11 revealed that higher net returns were fetched with different nutrient management practices in comparison to control. The crop grown with 100 % NPK + Bio-stimulant spray fetched highest net returns of ₹102763 $ha^{-1}$ followed by 100 % NPK + Nano Zn spray ₹100528 $ha^{-1}$. Crop receiving 75 % NPK along with NPK Consortia + NPK spray +

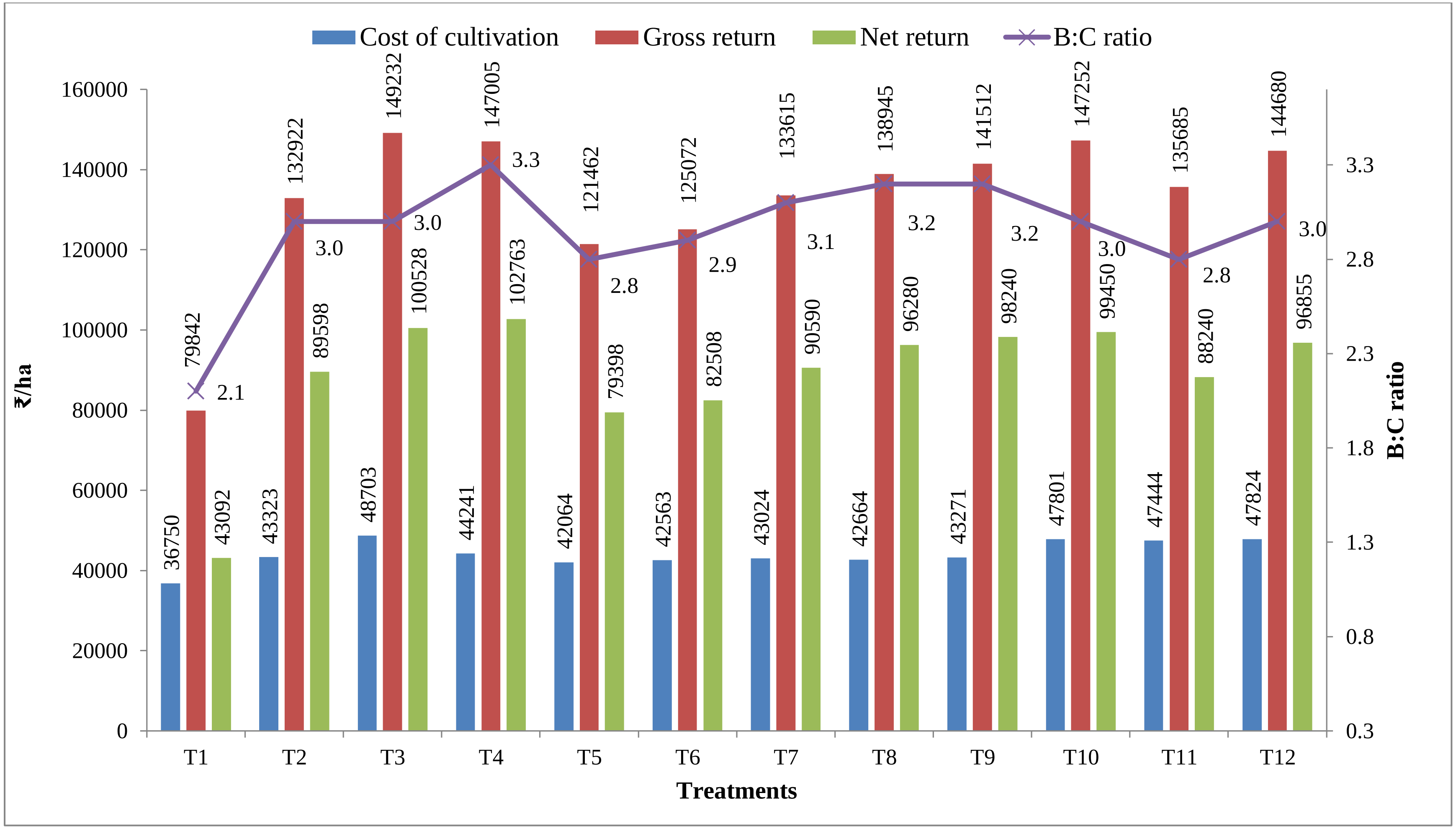



**Fig. 4.11 Economics of wheat affected by different doses and sources of nutrient**

Bio-stimulant spray + Nano Zn spray gave net return higher by ₹56358 $ha^{-1}$ than control and ₹9852 $ha^{-1}$ than 100% NPK.

**4.9.4 B: C ratio**

The data pertaining to B: C ratios are presented in Table 4.21 and depicted in Figure 4.11. The B: C ratio was highest (3.3) in the crop grown with 100 % NPK + Bio-stimulant spray and lowest (2.1) in the crop grown with no fertilizer application. The B:C ratio under the treatments was in the descending order of 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray / 75 % NPK + NPK Consortia + NPK spray > 75 % NPK + NPK Consortia + Nano N spray > 100 % NPK + Nano Zn spray / 100% NPK / 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray / 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray > 75 % NPK + NPK spray > 75 % NPK + NPK Consortia / 75 % NPK + NPK Consortia + Nano Zn spray > control.

The results of the experiment entitled "**Effect of doses and sources of nutrients on growth, yield and quality of timely sown irrigated wheat (*Triticum aestivum* L .)**" conducted at the research farm of Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut from *rabi* 2020-21 have been described in detail in the previous chapter. The significant experimental findings obtained during the course of experimentation are discussed herein with possible explanations and evidences wherever necessary in order to establish the "cause and effect" relationship.

Genotype dictates various plant characters mainly plant height, canopy development, net carbon assimilation and source-sink relationship. Soil and aerial environment particularly temperature, photoperiod and rainfall largely manipulate various plant processes including photosynthesis, respiration, transpiration etc. Agronomic manipulation can go a long way in environmental manifestation to the advantage of crop plants. Yield of a crop is function of crop stand and performance of individual plant. Yield per plant in turn is dependent on the number of effective tillers per unit area, length of ear, number of spikelet's spike$^{-1}$, number of grains spike$^{-1}$ and 1000-grains weight in wheat. Yield formation of a crop depends not only on the size and active duration of photosynthetic system but also upon its dry matter partitioning efficiency between vegetative and reproductive organs. Grain yield thus appear to be result of genotype and environment interactions.

**5.1 Effect of weather**

Favorable environment is a must for expression and realization of genotypic potential of crop plants. Weather variations are the key factors behind seasonal/annual variations in agricultural production. The crop experienced lowest (4.9$^{\circ}$C) of mean weekly minimum temperature in 4$^{th}$ week of December and highest

(38.3°C) in 2nd week of April during 2021. Second week of January was most humid (94.9%), however the driest (22.0%) crop season was the 2nd week of April. The crop received 39.9 mm rain during its period. As such the weather conditions were favorable for growth and development of the wheat crop. When needed water requirement was supplemented through irrigations.

**5.2 Effect of nano nutrients:**

Nutrient's status, transformation and movement in growing medium have profound effect on their absorption and assimilation by crop plants. This in turn affects growth, development and yield formation in crops. Not only this, sources and mode of application i.e: soil /foliar have also significant bearing on nutrient relations in plants. Accordingly, large variations in response of crop plants to nutrient management practices have been reported across various agro-ecological conditions. Nano-sources, for having smaller sizes and larger surface area are known to work efficiently in realizing yield potential of crop plants with higher input use efficiency. Work done on nano-nutrients, that too on wheat is very limited. The result in respect of growth parameters have been discussed in the light of fundamental principles, ancillary observation and work done by other works irrespective of crops.

**5.2.1 On crop growth**

Cell division and cell elongation are the two-fundamental processes behind the growth and development of living beings. But the process requires building materials i.e-protein, carbon and other essential nutrients. Several plant nutrients have been found essential for their involvement in various metabolic activities leading to synthesis of building material. The growth and development of crop plants, thus largely depend upon the availability of nutrients, their absorption and assimilation. Nitrogen plays a vital role in the growth processes as it is an integral part of chlorophyll, proteins, and nucleic acids and is viewed as the central element due to its role in amino acids, purines, DNA and RNA synthesis. Zinc is essential for synthesis of tryptophane, a component of some protein and a compound needed for the production of growth hormones (auxins) such as indole acetic acid (IAA). It is also involved in chlorophyll synthesis enzyme activation and cell membrane integrity.

In the present study sources, doses and mode of application of Nano N and Zn were attempted to observe their effect on growth of plants *viz.* plant height, number of tillers, dry matter accumulation, crop growth rate and relative growth rate recorded at different stages of crop growth. Crop fertilized with 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray remained at par with that receiving 100% NPK along with nano-Zn, but proved significantly better than 100% NPK for having taller plants with higher number of effective tillers, length of spike, number of spikelet's per spike, number of grain per spike and 1000-grains weight and thereby dry matter accumulation. Perusal of the data revealed significant increase in plant height with application of nutrients, irrespective of the treatments at all the crop growth stages. Similar, an increase in plant height with application of NPK with nano-nutrient (NPK) by Mehta S. (2017), with nano-Zn by Munir *et al*. (2018) and Rizwan *et al*. (2019) has also been reported. Significant increase in plant height with application of nano-nutrients might be explained on the basis that Nano Zn stimulates growth hormones (auxins) such as (IAA) involved in chlorophyll synthesis enzyme activation and cell membrane integrity. The resultant higher root biomass made the root system more effective that lead to the higher plant growth and plant height (Ghosh and Malic, 1981). Benzon *et al*. (2015) revealed that plant height was more enhanced when nano-fertilizer was combined with conventional ones due to the reason that nano-fertilizer can either provide nutrients for the plant or aid in the transport or absorption of available nutrients resulting in better crop height.

Crop receiving 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray remained at par with that receiving 100% NPK along with other nutrient combination, but proved significantly better than 100% NPK at harvest. The profuse tillering was due to the fact that nano fertilizer enhanced emergence, more efficient nutrient utilization satisfying nutrient requirement of the crop and increased activity of chloroplast (Hong *et al.*, 2005) & nitrate reductase (Lu *et al.*, 2002).

Dry matter accumulation (DMA), is dependent on size and efficiency of crop canopy towards absorption and utilization of solar radiation. A like, plant height dry-matter accumulation were also higher in crop fed with 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn which remained at par with 100% NPK along with nano nutrient (Zn) and significantly more than 100% NPK and control. It was clearly evident from the data on physico–chemical properties of the soil *viz.* BD, pH, OC, EC and available N, P, K & Zn content represented in Table 4.17 to 4.19. That the crop had higher nutrient content attributed to better root proliferation, improvement in soil aeration and moisture content because of reduction in bulk density. Apart from, increase plant height, no. of tillers (Table 4.2 and 4.3) might have also attributed to it. Besides, the increase in dry matter might be due to cumulative vigorous growth which in turn put forth more photosynthesis surface, chlorophyll formation, biomass and nutrient uptake. Increased CGR and RGR are attributed to higher dry matter accumulation at periodic interval. These results were in corroboration with the findings of Armin *et al*. (2014), Aziz *et al*. (2016), Hafeez *et al*. (2015), Jafarzadeh *et al*. (2013), Benzon *et al*. (2015) Kumar *et al*. (2014) and Mahmoodzadeh *et al*. (2013).

### 5.2.2 Yield attributes and yield

Crop duration is conveniently divided into 2 distinct phases i.e. vegetative and reproductive. Yield formation is greatly influenced by vegetative growth and dry matter partitioning efficiency. Better crop establishment and growth as reflected by higher dry matter accumulation with application 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray and 100 NPK + Nano Zinc spray led to significant improvement in yield attributes and finally the yield over 100 % NPK. A further perusal of the yield attributes and yield (Table 4.7 and 4.8) revealed that the number of effective tillers metre$^{-1}$ row length (301 m$^{-2}$), length of ear (11.4 cm), spikelets per spike (18.6), number of grains per spike (48.2) and 1000-grain weight (39.1) were significantly higher in crop fertilized with 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn there in crop given 100 % NPK and control but remained at par with that receiving 100% NPK along with other nutrient combination i.e. Nano Zn. Such an increase might have been due to favorable soil conditions and resultant vigorous growth (plant height, no. of tillers and dry matter) and attributed to proper nourishment of the plant as also evinced by consequent low mortality as also reported by Kumar *et al.* (2014). Benzon *et al*. (2015) reported synergistic effect of the nano-fertilizers on the efficacy of conventional fertilizer for better nutrient absorption by plant cells resulting to optimal growth of plant parts and metabolic process such as photosynthesis and translocation of photosynthates to the economic parts of the plant. High yields attributed to increased source (leaves) and sink (economic part) strength has been reported by Taiz and Zeiger (2006). Significant increase in crop yields with foliar application of Nano-fertilizers has been advocated by Tarafdar *et al*. (2012).

Application of 75% of NPK with NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray and NPK Consortia +Nano N spray + Nano Zn spray given higher yield of (13.84%) and (11.6%) over RDF respectively (Table 4.8). A significant increase in grain yield with integrated use of nano and inorganic fertilizers was also reported by Mehta (2017). In preceding section, it was well emphasized that nano nutrient (N and Zn) with inorganic fertilizers markedly improved overall growth and yield attributes and finally that increased yield of the crop. As mentioned earlier, nano- fertilizers may have affected these processes through its nutrient transportation capability in terms of penetration and movement of a wide range of nutrients, from roots uptake to foliage penetration and movements within the plant. A number of studies proved the significance of nano-fertilizers. For instance, Sirisena *et al*. (2013) obtained higher grain yield in rice with the application of nano-K fertilizer. This is in agreement with the findings of Liu *et al.* (2009), Harsini *et al.* (2014), Aziz *et al*. (2016), Hafeez *et al*. (2015), Sirisena *et al*. (2013), Jafarzadeh *et al*. (2013), Kumar *et al*. (2014), and Sheikhbaglou *et al*. (2010).

### 5.2.3 On nutrient content and uptake

Nutrient uptake, is largely a function of dry matter yield of components (grain & straw) and partially due to increase in nutrient concentration. Thus, there is a close relationship between the total uptake of nutrient and grain yields and straw yields. Crop fertilized with 100 % NPK + Nano Zn Spray had highest total uptake of nitrogen (165.3 kg $ha^{-1}$), phosphorus (24.4 kg $ha^{-1}$), potassium (121.2 kg $ha^{-1}$) and zinc (558.0 g $ha^{-1}$) against the lowest of 44.5, 5.2, 45.4 kg $ha^{-1}$ and 206.8 g $ha^{-1}$ respectively in crop receiving no fertilizer. The trend was similar for content and uptake in both grain and straw. Further, the grain had more accumulation of N, P and Zn than straw. A reverse pattern was observed in respect of K being more in straw. This was due to increased availability of the nutrients *viz*. N, P & K in readily available form in the soil for quick absorption by the crop. Enhanced uptake and use of nutrients by grain crops with application of a nano- engineered composite consisting of N has been noted by Jinghua (2004). De Rosa *et al*. (2010).

The nutrient content in grain and straw was significantly influenced by nutrient management practices. The content of N, P, K and Zn varied from 1.3 to 2.1%, 0.10 to 0.26%, 0.25 to 0.56% and 32.1 to 54.4 ppm in grain respectively, the highest, being in crop receiving 100 % NPK + Nano Zn Spray and lowest with no nutrient application. Respective content in straw ranged from 0.19 to 0.62%, 0.07 to 0.13%, 0.8 to 1.2% and 24.2 to 33.5 again being the highest with 100 % NPK + Nano Zn spray which was at par with 75% NPK along with other nutrient combination proved significantly better than 100% NPK and lowest with no nutrient application. Favorable effect of NPK on nutrient content of wheat has also been noted by Jhanzab *et al.* (2015), Gupta and Sharma (2006), Adhikari *et al.* (2014), Aziz *et al*. (2008) and Kumar and Pannu (2012). The beneficial effect of nano-nutrient when applied in conjunction with inorganic might have helped in increasing and balancing the availability of essential plant nutrients.

### 5.2.4 Nutrient use efficiency

Nutrient use efficiency (agronomic, partial factor productivity and physiological efficiency) reported in Table 4.13 - 4.15. Observed significant results with the use of nano nutrients. Nutrient use efficiency is dependent upon grain yield, uptake of nutrient and the amount of nutrient applied. Application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray increased nutrient use efficiency significantly in comparison to 100% NPK, control and some other treatments. This might be due to the fact that nano-fertilizers have large surface area and particle size less than the pore size of root and leaves of the plant which can increase penetration into the plant from applied surface and improve uptake and nutrient use efficiency of the nano-fertilizer. Below 100 nm nano-fertilizers makes plant use fertilizers more efficiently, reduces pollution, environmentally friendly, dissolve in water more effectively thus increase its metabolic activities Joseph and Morrison (2006). Similar findings were given by Kumar *et al*. (2014) and Jhanzab *et al*. (2015).

### 5.2.5 Quality studies

The protein yield is largely dependent on grain yield and protein concentration in grain. Quality of wheat in terms of protein content reported in Table 4.16 revealed significant increase with the integrated use of nano (N and Zn) and non-nano fertilizers (NPK).

Crop fertilized with 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray had highest protein content (12.0%) and protein yield (672.6 kg $ha^{-1}$) as against lowest of 7.1% and 202.6 kg $ha^{-1}$ respectively in crop no received fertilizer. Higher nutrient content (Table 4.9), might be due to as with foliar spray of nano nutrient with other nutrient combination easily penetrates (leaves and root) and rapidly translocated in plant system which help to increase protein, sugar content by enhancing the rate of reaction or synthesis process. The results were in accordance with the finding made by Mir *et al*. (2015), Razmjoo (2013) Rajaie and Ziaeyan (2009), and Ghafari and Razmjoo (2013).

### 5.2.6 Cost and returns

The cost of cultivation varied with the treatments for variations in fertilizers input and their application cost and it ranged from ₹36750 $ha^{-1}$ for the crop grown without nutrient application ₹48703 $ha^{-1}$ for the crop that received 100 % NPK + Nano Zn spray. However, the crop raised with 75 % NPK + NPK Consortia + Nano N spray fetched higher net return ₹90590 $ha^{-1}$ B:C ratio was also higher with crop when combined with nano nutrient and other nutrient combination. In term in net return superiority of crop with 75 % NPK + NPK Consortia + Nano N spray might be expressed higher B:C ratio. Variation in cost of cultivation of wheat under different nutrient management options have been reported by Pandey *et al.* (2009), Reddy *et al.* (2009).

### 5.3 Effect of biofertilizer

Liquid biofertilizer are special formulation containing desired microorganisms, their nutrients and cell protectant chemicals and amendments that promote cell survival while application to seed or soil. Thus, liquid bio inoculants are not the usual broth culture from the fermenter or water suspension of the carrier based biofertilizers. Various liquid media have been used for the preparations of liquid bio-inoculants. These media normally consists of carbon, nitrogen and vitamin sources, which promote the growth of bacteria and cell protectant chemicals such as PVP, Glycerol etc.

#### 5.3.1 On crop growth

NPK-consortia constitutes of micro-organisms which are beneficial for better growth and development of crops. Seed inoculation with NPK-consortia significantly influenced all the growth attributes in wheat. Nutrient management practice involving application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray recorded maximum value of growth attributes in wheat in comparison 100% NPK and control plots as given in Table 4.1 & 4.2.

NPK-consortia contain living strains of microorganisms and when mixed with the seed, they colonize in the rhizosphere or in the interiors of plant parts and thus promote growth by increasing the supply or availability of primary nutrients to the host plants. Also, it is well established fact that micro-organisms assimilate atmospheric nitrogen through nitrogenase enzyme in bacterial cells, thus the fixed organic nitrogen in bacterioeds is dissociated and later oxidized to nitrate nitrogen. Due to inoculation of wheat seeds with NPK-consortia, it might have increased the endogenous nitrogen content and better promoted crop growth. In addition to this, *Azotobacter* has ability to produce antifungal, antibodies and similar compounds against pathogens like *Fusarium* and *Alternaria*. Thus, beneficial effects of NPK-consortia inoculation could be attributed to their multiple actions for synthesis of antifungal and antibiotics & growth promoting substances which might have been utilized by the plants in protein synthesis, carbohydrates, starch and other assimilates which led to overall improvement in growth attributes of wheat. Further, inoculation of wheat seeds with NPK-consortia might have increased the P availability by production of organic acids like malic, glyoxalic, succinic, fumaric and citric acid which helps in the solubilization of insoluble phosphorus carriers like calcium and magnesium phosphate. Under the present investigation, distinct superiority of NPK-consortia in improving growth could be ascribed to the better establishment of microorganism population in the rhizosphere besides improving soil quality, with ensured availability of nutrients that enhanced the availability of phosphorus from the soil. Moreover, it has been well emphasized that dual inoculation of beneficial microbes play a vital role in improving three major aspects of yield determination *i.e*. formation of vegetative structure for higher photosynthesis, strong sink strength through development of reproductive structure and production of assimilates to fill economically important sink. Similar research findings have also been reported by Kloepper (1994), Ahemad and Khan (2009) and Kaushik *et al.*, ( 2012).

**5.3.2 Yield attributes and yield**

The inoculation of wheat seeds with NPK-consortia which contain live strains of bacteria & fungi helped improving plant growth and crop productivity. Results revealed that inoculation of wheat by NPK- consortia seed treatment with having 75

% NPK + NPK spray + Bio-stimulant Spray + Nano Zn spray significantly increased the yield attributes & yield of wheat. Application of NPK- consortia significantly increased the number of effective tillers meter$^{-2}$, ear length, grain spike$^{-1}$, test weight, straw and biological yield of wheat as given in Table 4.7 and 4.8.

Pretreatment of seeds with NPK-consortia can play an important role in meeting the nutrient requirement of crops and enhance the soil fertility and crop productivity by fixing atmospheric nitrogen, mobilizing sparingly soluble P and facilitating the release of nutrients through decomposition of crop residues. Also, NPK- consortia i.e. *Azotobacter* and *phosphobacteria* produce growth hormones *viz.* Indole acetic acid and Gibberellins which stimulate the root growth and development. The use of growth stimulating seed inoculants helps to accelerate the uptake of plant nutrients from applied chemical fertilizers by increasing the root growth. In a research study by Malik *et al.*, (2009), Zaidi and Khan (2005).

**5.3.3 On nutrient content and uptake**

Wheat seed inoculation with NPK-consortia improved the absorption and availability of nutrients to crop plants. Results indicated that inoculation of NPK-consortia of wheat + incorporation of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray significantly influenced the nutrient content and uptake in grain and straw of wheat as given in Table 4.9 to 4.12. In a research conducted by Abbasi *et al.,* 2011, they observed that biofertilizer inoculation resulted in three fold increase in uptake of nitrogen and phosphorus by shoots of plant while that of potassium increased by 58%. Moreover, inoculation of wheat seeds with the *Azotobacter* and PSB prior to sowing resulted in higher nutrient content and uptake by crops because *Azotobacter* can be ascribed to the increased specific activities of isocitric and malic dehydrogenase, which is the source of electrons for nitrogen fixation creating a better nutritional environment (Kurtz and Larue, 1975) while PSB solubilizes the native and applied phosphorus (Singh *et al*, 2012). These findings are in confirmation with the results of Mahmoud, 2006, Marozsan, *et al*., (2009), Suke *et al.*, (2011) and Singh *et al.*, (2012a). NPK-biofertilizer inoculation significantly increased the uptake and content of nutrient in wheat which could be attributed to the fixation of nitrogen, better root growth due to increased availability of phosphorus by PSB besides secretion of growth promoting substances especially by *Azotobacter* and *Azospirillum* (Totawat *et al*., 2000). Similar findings have also been reported by Dadarwal *et al*.,(2009) and Balai *et al.*,(2011) and Singh *et al*., (2012a).

**5.3.4 Nutrient use efficiency**

Nutrient use efficiency (agronomic, partial factor productivity and physiological efficiency) reported in Table 4.13-4.15. Observed significant results with the use of biofertilizers i.e. NPK consortia. Nutrient use efficiency is dependent upon grain yield, uptake of nutrient and the amount of nutrient applied. 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray significantly influenced the nutrient use efficiency over RDF. (Parmar and Sindhu, 2013; Kumar *et al*., 2004) and P solubilization by PSB (Afzal *et al*., 2005; Mehrvarz *et al*., 2008; Zaidi and Khan, 2005) also reported that dual inoculation of *Azotobacter* and PSB increased the N and P and K content and uptake in wheat due to their synergistic interaction. It might be due to enhanced activity of nitrogenase and nitrate reductase enzyme in soil for greater BNF by *Azotobacter*. Shabaev *et al*. (2006) found that inoculation with *Azotobacter* + PSB significantly increased the N, P uptake by potato plants over control. The ability of PSB to solubilize insoluble inorganic phosphate compounds such as tricalcium phosphate, dicalcium phosphate etc. in soil due to secretions of various organic acids from root exudates is well known (Mirik et *al*., 2008; Hameed *et al.*, 2008). Barea *et al.* (1976) also reported that P solubilizaiton ability of PSB and growth hormone producing ability of *Azotobacter* indicated considerable influence on nutrient uptake by plants and root biomass. *Azotobacter* and PSB are known to secrete plant growth hormones (Pandey and Kumar, 1989), which might have allowed better root development and acquisition of more N, P and K from soil.

**5.3.5 Microbial population in soil**

Microbial diversity and their richness are the key inputs to our understanding of the role, function and significance of microorganisms in plant nutrient supply. NPK-consortia have positive impact on soil biological properties. Results indicated in the previous chapter showed that inoculation of NPK-consortia significantly improved the activity of dehydrogenase enzyme and microbial population such as bacteria, fungi and actinomycetes in soil as given in Table 4.20. It increased population bacteria> Fungi> actinomycetes with treatment having biofertilizers 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray over 100% RDF. Increased enzymatic activity and population of microbes in the soil might be due to the improvement in the porosity, higher availability of nutrients (especially P) to the plants with better establishment of inoculated microorganisms, which stimulate the indigenous microorganisms. (Shinde and Bangar, 2003). Similar findings were also given by Parewa *et al*., (2014), Abdullahi *et al.,* (2013) and Singh *et al.,* ( 2015). In similar lines, Sushila (1998) also reported that there was increase in the microbial population in rhizosphere of wheat with inoculation of *Azospirillum* and *Azotobacter*. Similar findings were given by Ram and Mir, (2006).

**5.3.6 Quality studies**

The protein yield is largely dependent on grain yield and protein concentration in grain. Quality of wheat in terms of protein content reported in Table 4.16 revealed significant increase with the NPK-Consortia, nano fertilizer and non-nano fertilizers (NPK) combination.

Effect on grain quality in terms of gluten content were observed, in contrast with the findings of some authors which tested the effects of PGPR inoculation in *Triticum* varieties (Pagnani *et al*., 2020). Treatment having 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray / 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray attained highest protein content. Nitrogen being an integral part of protein is expected to enhance this quality parameter. Accumulation of gluten proteins is a complex process involving spatial and temporal regulation. Environmental conditions, such as heat and drought stress, as well as the dose and application timing of nitrogen fertilizers can affect significant changes in gluten composition (Flagella *et al*., 2010; Visioli *et al*., 2018a). However, very little information is available on possible changes in gluten protein composition in response to biofertilizer application. Stępień and Wojtkowiak (2013).

**5.3.7 Cost and returns**

The results revealed that the inoculation of NPK-consortia in wheat significantly increased the value of net returns and benefit cost ratio. The higher net return of 96280 Rs ha$^{-1}$ in 75 % NPK + NPK Consortia + NPK spray and benefit cost ratio of 3.2 was obtained with the inoculation of NPK-consortia in comparison to similar treatments without inoculation of NPK-consortia and control plots as given in Table 4.21. Use of efficient strains of bio-fertilizers is a low cost and environment friendly technology that have an important role in improving the nutrient supply to crops but also reducing the cost of production (Kumar, 2013). These results corroborate the findings of Galal *et al.*,( 2001), Ram and Mir (2006).

## 5.4 Effect of Bio-stimulant

In recent years, marine bioactive substances extracted from marine algae are used as supplement to the inorganic fertilizer. These substances, recently gained importance as foliar spray for many crops, which enhances yield and quality of crops due to presence of chemical complex polysaccharide compounds like laminarian, fucoidan, alginate, beneficial nutrients and growth hormones like cytokinins, auxins, betains, and sterols which promote plant growth. Many chemical components of seaweed extracts and their modes of action remain unknown, but it is possible that these components exhibit synergistic activity Fornes *et al.,* (1995).

Realising the potential use of seaweed sap for enhancing the productivity of crops, *Kappaphycus alvarezii* has proven potentiality as a foliar biostimulant to increase productivity of many crops across varied agro ecological locations for research, development and commercialization. After four decades of introduction, *Kappaphycus* is now being recognised as the most widely cultivated commercial seaweed.

### 5.4.1 on crop growth

Bio-stimulant is a seaweed extract (28% w/w) derived from the sap of red & brown algae which acts as a metabolic bio-enhancer and stimulates the internal growth and development in plants. It is an organic growth promoting product in liquid form which contains inherent nutrients, vitamins, plant growth hormones like auxin, cytokinin, gibberellins, betaines and mannitol etc. are applied by the method of foliar application. Being a soil conditioner, it activates the soil bacteria, especially rhizospheric bacteria that are responsible for better root growth and movement of nutrients. It helps in cell division, internodes elongation and seed development of plants. Foliar application of biostimulant in wheat promoted the root growth, tillering and nutrient uptake. Growth attributes in wheat *viz.,* plant height, number of tillers and dry matter highest when the crop was fed with foliar application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray and 100 % NPK + Bio-stimulant Spray significant over 100% NPK. This could be possibly due to the presence of plant growth hormones *i.e.* IAA, cytokinin and gibberellins in bio-stimulant which led to the enhanced rate of synthesis of protoplasmic protein which increased the cell size and was mainly responsible for the vertical development of plant (Nova and Loomis, 1981). Enhanced fertilizer doses coupled with greater concentration of bio-stimulant increased the nutrient supplying capacity to the wheat plants which in turn resulted in higher growth rate. Similar results were given by Kavitha *et al*., (2008) and Khan *et al.*, (2009). Further, application of bio-stimulant resulted in increased value of crop growth rate (CGR) and relative growth rate (RGR). This might be due to application of bio-stimulant which favored vegetative growth resulting in higher leaf area then the lower leaves of plant which were unable to photosynthesize and start growing below the compensation point (when rate of respiration is higher than photosynthesis) and the photosynthates synthesized by the upper leaves were utilized by themselves thus lowering down the RGR. These findings are in close agreement with those given by Tanaka (1973).

**5.4.2 Yield attributes and yield**

Positive correlation was observed between foliar application of bio stimulant, yield attributes and yields of wheat. Application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn Spray and 100 % NPK + Bio-stimulant Spray significant over 100% NPK produced highest grain and straw yield in wheat. This might be possibly due to the application of bio-stimulant which is a wealthy source of versatile plant nutrients, phytohormones, amino acids and vitamins that enhance the root volume and proliferation, bio-mass accumulation, plant growth, distribution of photosynthates from vegetative part to the developing ear & promotes grain development, reduces chlorophyll degradation and disease occurrence etc. resulting in an overall improved nutrient uptake and higher nutrient use efficiency leading to higher vegetative plant growth & ultimately obtaining higher yield and superior quality of agricultural products. These findings are similar to those given by Staden *et al.*,(1973) khan *et al.* (2009) and Zodape *et al.* (2013).

Yield attributes *viz.*, number of grain spike$^{-1}$, ear length, number of spikelet's spike$^{-1}$ and test weight were found to be positively influenced by the foliar application of Bio-stimulant. Crop given foliar application of Bio-stimulant with 100% NPK, resulted in highest value of yield attributes over same treatment without Bio-stimulant spray. Application of Bio-stimulant provided major crop nutrients which helped in improving the root and shoot growth, plant vigor, more flowering, higher seed setting and greater number of ears. The mineral nutrients present in the bio-stimulant might have increased the photosynthesis process resulting in enhanced supply of available photosynthates with their efficient translocation that resulted in more number of flowers, higher seed setting, increased ear formation and improved grain filling which led to higher yield attributes. These findings are similar to those given by Al Majathoub *et al.* (2004), Xiao *et al.* (2021).

### 5.4.3 On nutrient content and uptake

Application of Bio-stimulant spray had complementary effect on nutrient content and uptake of wheat. Nutrient content and uptake in wheat were positively influenced by foliar application of Bio-stimulant along with application of 100 % NPK which resulted in highest nitrogen, phosphorous and potassium uptake in wheat. Being a good source of plant nutrients, higher amount of nitrogen, phosphorous and potassium were absorbed by plants and thus resulted in improved nutrient content and uptake in wheat. Plant growth promoting rhizobacteria –*Bacillus amyloliquefaciens* & *Azospirillum brasilense* are known to enhance growth and nutrient uptake in crops.

Similar findings were given by Popko *et. al.* (2018), Nguyen *et. al.* (2018) and Nguyen *et .al.* (2019) .

### 5.4.4 Nutrient use efficiency

Seaweed extracts content several macro and micronutrients besides growth hormones which can play significant role on nutrient uptake as well as soil fertility status when applied to the crop. In the present investigation, 100 % NPK + Bio-stimulant Spray, 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray recorded significantly higher nutrient use efficiency over 100 % NPK. Similar finding was reported by Shah *et al.*, (2013) who also observed that the foliar application of *Kappaphycus alvarezii* and *Gracilaria edulis* sap increased nutrient uptake by wheat with increasing concentration of both the sap. Zodape *et al.* (2013) also reported that the foliar spray of 5% concentration of *Kappaphycus alvarezii* sap increased the nutrient uptake in tomato (219 kg N, 28 kg P and 283 kg K $ha^{-1}$) over control and beyond this concentration nutrient up take declined. It may be due to the presence of many organic compounds in seaweed liquid fertilizer which acts as a bio-stimulant that can increase the availability of nutrients in the plant system. As well as the presence of natural chelating compound (*i.e*. manitol) in sap that have increased nutrient availability by better absorption of the chelated compound at leaf levels as reported by Salat (2004). Beside it increased root proliferation and establishment thereby plants cover more volume of soil and fed more nutrients even from distant places and deeper soil horizon uniformly in a balanced proportion. Prasad *et. al*. (2010) and Mancuso *et al.* (2006) reported that the seaweed sap also contain a hormones which might be responsible for increasing nutrient uptake by increasing stomata uptake efficiency.

### 5.4.5 Microbial biomass (Bacteria, fungi and actinomycetes population) in soil

Unless a Bio-stimulant is itself an enzyme, any influence on enzymatic activities as a result of biostimulant application would be driven by changes in microbial or plant activities. Greater enzyme activities can occur through increased enzyme production per unit of microbe or plant Wade *et. Al*. (2021) or by increasing the number of microbes. Treatment having 100 % NPK + Bio-stimulant Spray and 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray resulted increase in bacteria> Fungi> Actinomycetes compared to RDF and control. Thus, the evaluation of microbial biomass and microbial community diversity can further decipher the potential mechanisms and modes of action for soil-applied bio-stimulants. Furthermore, the assessment of microbial communities of soils can allude to soil quality impacts of differing agronomic management practices, providing insight for the influences of said practices on the overall health of the soil Zhang *et al.* (2019). Although costly to conduct, the ability of microbial diversity analysis to infer the biostimulant mechanisms as well as the ecological implications of the application provides a useful parameter for the evaluation of biostimulants.

### 5.4.6 Cost and returns

Seaweed sap application enhances productivity with better profitability as well as higher monetary return mainly due to low cost of seaweed extract. Maximum net return of wheat cultivation was recorded with 100 % NPK + Bio-stimulant Spray alone (₹ 102763 $ha^{-1}$) and with 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant Spray (₹98240 $ha^{-1}$) which was higher than 100% NPK in both cases. Similar, finding were also reported net return and B:C ratio increased with increasing concentration of seaweed sap up to 10 % K sap thereafter (i.e. 15% K sap) it declined significantly. Similarly Crop fertilized to 50% RDF and sprayed to 2.5% K or G sap with much the same net return and B:C ratio as control (100 %

RDF alone) Singh *et al.* (2015) and Pramanick *et al.* (2014).

### 5.5 Effect of inorganic fertilizers

Inorganic fertilizers are rich source of nutrients and need less investment in their storage, transportation and application $kg^{-1}$ of nutrient. Besides, they are readily available and crop responds well to them. However, owning to their escalating cost and increase concern for environment and human health, integration of various sources has become in encases. The extent of substitute / replacement of chemical fertilizers depend upon crop and soils. In the present study attempts were made to substitute / supplement of NPK fertilizers with nano fertilizers, biofertilizer, bio-stimulant and inorganic fertilizer spray. The results obtained have been explained here under:

#### 5.5.1 Growth

Chemical fertilizers play an important role in the growth of crop plants. It was evident from the results that fertilizer levels significantly increased the plant height, number of tillers, and accumulation of dry matter at different growth stages i.e. 30, 60, 90,120 DAS and at harvest (Table 4.1 to 4.4). Results revealed that application of 75% of recommended NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray significantly increased the plant height, number of tillers, CGR, RGR, and dry matter over control but was at par with 100% NPK + other nutrient combinations. Results showed that all the components of plant biomass were favorably influenced by the application of chemical fertilizers. Use of 100 % NPK + Nano Zn Spray proved significantly better than 100% NPK for having tallest plants, highest number of tiller and dry matter accumulation at harvest stage with no fertilized plots as noticed by Mehta (2017). This may be due to the increased availability of nutrients to the growing plant as indicated by nutrient content and uptake (Table 4.9-4.12). The findings corroborate to the findings reported by Suriyaprabha *et al.,* 2012. The results of present investigation are in close conformity with findings of several researchers as Patidar and Mali (2004), Singh (2007) and Singh *et al*. (2012), katyal *et al.* (2002), Kharub and Sharma (2002), and Bandyopadhyay *et al*. (2009).

**5.5.2 Yield attributes and yield**

Sustaining the soil fertility and balanced use of plant nutrients in appropriate amounts is one of the key factors in increasing the crop yield .Grain yield in turn is a reflection of yield attributes namely effective tillers, ear length, grains spike$^{-1}$ and test weight. Results presented in the preceding chapter showed that application of recommended dose of fertilizer led to higher under of yield attributed and yield (Table 4.7-4.8). An application 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn number of effective tillers metre$^{-2}$ (301 m$^{-2}$), length of ear (11.4 cm), spikelets per spike (18.6), number of grains per spike (48.2) and 1000-grain weight (39.1 g ) Respective value for crop fertilized with 100 NPK were 224, 8.1, 37.1 & 33.5. Application of different inorganic fertilizers might have supplied adequate amount of nutrients that helped in the expansion of leaf area which might have accelerated the photosynthesis rate and resulted in increased supply of carbohydrates to the plants. Similar results were also obtained by Jat *et al.* (2014) and Chauhan (2014). When crop raised with 100% NPK + nano Zn significantly increased grain (56.3 q ha$^{-1}$) & straw (71.9 q ha$^{-1}$) yield over 100% NPK. This might be significantly yield attributed with addition of different combination of nutrient. Different combination of fertilizer can either provide nutrient for plant or aid in the transport or utilization of available nutrient in soil and releases the nutrients at a slower rate for a longer period, consequently limiting nutrient loss from the soil resulting in better crop yield (Benzon *et al.,* 2015).

### 5.5.3 Nutrient content and uptake in grain and straw

Nutrient content in plants is governed by nutrient availability, absorption and translocation in plant system. The uptake of a nutrients is further a fertilizer of nutrient content and biomass yield. Nutrient content and uptake both increased significantly with the enhanced doses of fertilizer levels. Crop fertilized with 100% NPK content 1.5% N, 0.18% P, 0.50% K & 43.5 ppm Zn in grains and respective content in straw were 0.28, 0.08, 1.0% and 27.1 ppm. Respective content with crop raised without nutrient application were 1.3, 0.01, 0.25% & 32.1 ppm in grain and 0.19, 0.07, 0.80 & 24.2 ppm in straw Table 4.9- 4.12. Poor contents in control plots were mainly due to lack of application and widespread deficiency of such nutrients in Western Uttar Pradesh (Kumar *et al.,* 2016). Crop fertilized 100% NPK with other nutrient combination i.e. Nano nutrient, Bio-stimulant proved significantly better nutrient content than 100% NPK. It may be due to higher-absorption rate, utilization efficacy, and minimum losses of nano and bio-stimulant nutrient. A reduction in volatilization, denitrification, leaching and fixation losses of NPK has been observed by Haverkamp and Marshall (2009). N, P, K and Zn Nutrient management practice involving application of nano fertilizers, bio-stimulant, and inorganic fertilizer spray, inoculation of wheat, foliar application of other nutrient combination with 75% significantly increased the nutrient content and uptake in grain and straw of wheat over control plots but was at par with 100% NPK with nano Zn and bio-stimulant. Nutrient uptake with NPK application might have been attributed to increased availability of nutrients as noticed by Dhaka and Pathan (2013) and higher biomass yield.

### 5.5.4 Available nutrient in soil after harvest of wheat

Residual soil fertility is an outcome of inherent fertility status, external nutrient applications, removal by crops and other losses. Crop removal is directly related to biomass production. At the sometime, root biomass adds to soil fertility. Microbial population also govern various transformation relation i.e. mineralization and immobilization. Further, nutrients remain in dynamic equalization in different phases i.e. fixed, labile and readily available form. Consequently, manner changes are mixed in availability of soil fertility during short period of crop to the perusal study, availability of nutrient i.e.- available N, P, K & Zn after crop harvest varied among the treatments. Nutrient availability, irrespective of the nutrient, was higher in plots receiving nutrients applications in comparison to control plots. This might have happened going to addition of nutrients from external sources, better root proliferation and favorable conditions for soil microbes increase in nutrient transformations Parmer *et al.* (1998) also opined in increase in adding of nitrogen fixing bacteria with nutrient applications. Further, increase in P and K status of soils might have been attributed to their fixation from added sources from soil solution to exchanges sites/fixations site as advocated by Prasad (1994). Similar observations have been made by Swarup and Wanjari, 2000 and Gogoi, 2011.

### 5.5.5 Microbial biomass (Bacteria, fungi and actinomycetes population) in soil

Microbial population is a good indicator of soil health and governed by various physico-chemical properties of soils. The soil of experimental field had various microbes in an ascending order of Bacteria>Fungi>actinomyces. The results revealed that increasing doses of fertilizer from control to nutrient management practice involving application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray and 100 % NPK + Bio-stimulant increased the bacterial, fungal and actinomycetes population in the rhizosphere. The increase in microbial population might be due to increasing levels of N, P and K that might have increased the root biomass, root exudates and ultimately provided carbon and energy to the soil micro-organisms resulting in the multiplication of microbial population (Geetha and Shivashankar, 1991). Similar results were given by Chand *et al*., 2010 and Parewa *et al*., 2014).

**5.5.6 Cost and returns**

The acceptance of new technology by the farmer's ultimately depends on its economics feasibility. Among the different indicators of monetary efficiency in production system, the economics in terms of net returns has a greater utility and acceptance of technology by the farmers. Economic analyses of different nutrient management options adopted in wheat crop revealed that gross return, net return, and benefit cost ratio were differing among the nutrient management practices. The variations in input and output further led to marked variations in relative returns (Table 4.21). Crop fertilized 100 % NPK + Bio-stimulant Spray recorded highest value for net returns and B:C ratio followed by treatment 100 % NPK + Nano Zn while with 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant Spray recorded highest value for net returns and B:C ratio which was equal to treatment having 75 % NPK + NPK Consortia + NPK spray which was ultimately due to the significant difference in grain & straw yield of wheat crop and cost of fertilizers incurred at different treatments. The crop raised with 100 % NPK + Bio-stimulant Spray fetched net return of ₹ 102763 $ha^{-1}$ being higher by ₹ 13165 $ha^{-1}$ than 100% NPK, ₹ 47047 $ha^{-1}$ than control and with 75 % NPK + NPK Consortia + NPK spray +Bio-stimulant Spray fetched net return of ₹ 98240 $ha^{-1}$ being higher by ₹ 8642 $ha^{-1}$ than 100% NPK ₹ 55148 $ha^{-1}$ than control. It was mainly because of more increase in grain yield and gross income in comparison to increase in cost of cultivation (Dwivedi *et al.,* 2009). Higher B:C ratio might have been attributed to dual advantage i.e. saving in input and additional returns due to higher yield (Pampolino *et al*., 2012). Similar findings were also observed by Kumar *et al*. (2014).

The field experiment entitled "**Effect of doses and sources of nutrients on growth, yield and quality of timely sown irrigated wheat (*Triticum aestivum* L.)**" was conducted to study the effect of nutrient management practices on performance of wheat in a well-drained, sandy clay loam soil, moderately alkaline in reaction during *rabi* 2020-21 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.). The soil was low in organic carbon and available nitrogen but medium in available phosphorus, potassium and Zinc. The treatments (12) *viz.* Control, 100 % NPK, 100 % NPK + Nano Zn , 100 % NPK + Bio-stimulant Spray, 75 % NPK + NPK Consortia, 75 % NPK + NPK, 75 % NPK + NPK Consortia + Nano N, 75 % NPK + NPK Consortia + NPK, 75 % NPK + NPK Consortia + NPK + Bio-stimulant, 75 % NPK + NPK Consortia + NPK + Bio-stimulant + Nano Zn spray, 75 % NPK + NPK Consortia + Nano Zn and 75 % NPK + NPK Consortia + Nano N + Nano Zn were tested in randomized block design with 3 replications. Wheat variety HD 2967 was sown on 5$^{th}$ November, 2020 and harvested on 16$^{th}$ April, 2021. Recommended package of practices, except treatments were adopted. During crop period maximum temperature, minimum temperature and relative humidity ranged from 38.3°C to 18.1°C, 20°C to 4.9°C and 22.0 to 94.9 % respectively with 39.9 mm of rainfall. Salient findings of the investigation are as follows:

1. Growth parameters *viz.* plant height, number of tillers and dry matter accumulation at different growth stage differed significantly under the treatments. Crop fertilized with 75% NPK along with NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray remaining at par with one receiving 100% NPK with other nutrient i.e. Nano Zn and Bio-stimulant proved significantly better than

100% NPK exhibiting better taller plants, higher number of tillers and more dry matter accumulation. Spray of NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray, NPK Consortia +Nano N spray + Nano Zn spray, NPK Consortia + NPK spray + Bio-stimulant Spray and NPK Consortia + NPK spray in combination with 75% NPK increased dry matter accumulation (g $m^{-1}$) by 11.1, 9.5, 8.5 & 6.3 % over 100% NPK, at harvest. Plant height and number of tillers also followed almost similar trend and varied respectively from 79.4 to 111.1 cm and 52.5 to 69.7 $m^{-1}$ row length, lowest being without fertilizer application and highest with 100 % NPK + Nano Zn Spray.

2. Growth indices, namely crop growth rate was significantly affected by different nutrient management practices while relative growth rate remained unaffected. The crop growth rate increased with advancement in crop age upto 90 days and was highest (19.6 g $m^{-2}$ $day^{-1}$) with the application of 100% NPK with nano Zn at 60-90 DAS in comparison to 100% NPK as against 16.5 g $m^{-2}$ $day^{-1}$ with 100% NPK and 8.8 g $m^{-2}$ $day^{-1}$ with control.

3. Yield attributes i.e. effective tiller $m^{-2}$, ear length, number of spikelet's per spike and number of grains per spike recorded at harvest exhibited significant variation under different treatments except for test weight. Crop raised with 75% NPK with NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray remaining at par with treatments having 100% NPK with Nano Zn and Bio-stimulant proved significantly better than 100% NPK had higher number of effective tiller $m^{-2}$ (301.0), length of ear (11.4 cm), number of spikelet's $spike^{-1}$ (18.6), number of grain per spike (48.2) and test weight (39.1 g). The respective lowest of 224.0, 8.1, 14.1, 37.1, and 33.5, was recorded in crop receiving no fertilizer. Further, 100% NPK with Nano Zn and Bio-stimulant increased yield attributes, however it was not significant.

4. Wheat fertilized with various nutrients, their sources and levels gave a significantly higher grain yield over control, irrespective of the combinations. Crop fertilized with 75% of NPK with NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray, NPK Consortia +Nano N spray + Nano Zn spray and NPK Consortia + NPK spray +Bio-stimulant Spray 13.8, 11.6 and 8.9% respectively over 100% of NPK in grain yield. A similar trend was noted in respect of straw and biological yield being respectively 73.6 q $ha^{-1}$ and 129.6 q $ha^{-1}$ in crop given 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray and 47.9 q $ha^{-1}$ and 76.2 q $ha^{-1}$ In crop without fertilizer. Harvest index varied from 37.1 under control to 43.2% under 100 % NPK + Nano Zn Spray among the treatments; however, such variation was non - significant.

5. Nutrient content in grain and straw of wheat differed significantly under different treatments. The content of N, P, K and Zn varied from 1.3 to 2.1%, 0.10 to 0.23 %, 0.25 to 0.56%, and 32.1 to 54.4 ppm in grain, respectively. Respective content in straw ranged from 0.19 to 0.62%, 0.07 to 0.13%, 0.80 to 1.20% and 24.2 to 33.5 ppm. The highest being in crop receiving 100% NPK + nano Zn and lowest with no nutrient application. Further, reducing NPK doses by 25% with Nano fertilizers, Biofertilizer, Bio-stimulant, and Inorganic fertilizer spray reduced or has equal amount nutrient concentration, however it was not-significant.

6. Nutrient Uptake, a function of biomass production and nutrient content also differed significantly under different treatments. The crop fertilized with 100% NPK + nano Zn spray accumulated highest amount of N (165.3 kg $ha^{-1}$), P ( 24.4 kg $ha^{-1}$), K (121.2 kg $ha^{-1}$) and Zn (558.0 g $ha^{-1}$) as against the respective lowest of 44.5, 5.2, 45.4 kg $ha^{-1}$ and 206.8 g $ha^{-1}$, in crop receiving no fertilizer. The crop raised with 75% NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray accumulated 68.5, 8.2, 22.1 kg $ha^{-1}$ and 126.7 g $ha^{-1}$ of N, P, K and Zn respectively

over that raised with 100% NPK. The trend was similar for accumulation in grain and straw.

7. Nutrient use efficiency (agronomic, partial factor productivity and physiological efficiency) was significantly affected by different nutrient management practices. Application of 75% NPK with NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray had Agronomic Efficiency for N, P & K (24.5, 61.3 & 92.0 kg of gain in yield $kg^{-1}$of nutrient applied), Physiological Efficiency for N, P & K (23.4, 156.9 & 37.7 kg of grain $kg^{-1}$ of nutrient absorbed) and Partial Factor Productivity for N, P & K (49.7, 124.2 & 186.3 kg of grain yield $kg^{-1}$ of nutrient applied).

8. Protein content and protein yield in wheat grain differed significantly under the treatments being 12.0% and 672.6 kg $ha^{-1}$ highest in crop fertilized with 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray and lowest of 7.1% and 202.6 kg $ha^{-1}$ in the crop grown without fertilizer where in 100% NPK with nano Zn with protein yield of 649.7 kg $ha^{-1}$. Application of 75% NPK with NPK Consortia + Nano N spray, NPK Consortia + NPK spray, 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray, 75 % NPK + NPK Consortia + Nano Zn spray and 75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray increased protein yield being 87, 116.3, 160.4, 12.9 and 227.4 kg $ha^{-1}$ respectively over 100% NPK.

9. Physico-chemical properties of soil *viz.* bulk density, particle density, aggregate stability soil pH and EC, statistically unaffected by different treatments where biological properties differed significantly due to use of biofertilizers. However, application of nutrient had favorable effect on all the parameters. The plots receiving 75% NPK with NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray had 1.45 g $cc^{-1}$ bulk density, 0.49% organic carbon, 196.2 kg $ha^{-1}$ available

nitrogen, 11.1 phosphorus kg $ha^{-1}$, 149.1 potassium kg $ha^{-1}$, 0.86 mg $kg^{-1}$ zinc, number of bacteria 0.78 × $10^6$ cfu $g^{-1}$ , fungi 0.67 $10^4$ cfu $g^{-1}$ and actinomyces 0.63 $10^3$ cfu $g^{-1}$ against as respective reduce of 1.51, 0.38, 174.5, 10.8, 132.7, 0.79, 0.65,0.48 and 0.45 in control plots.

10. Cost of cultivation was low (₹36750 $ha^{-1}$) in crop receiving no fertilizer and highest (₹48703 $ha^{-1}$) in crop receiving 100% NPK + nano Zn. The crop grown with application of 100% NPK + Zn fetched highest gross return of ₹149232 $ha^{-1}$as against the lowest of ₹79842 $ha^{-1}$under control. Net return was known (₹102763 $ha^{-1}$) highest in crop raised with 100 % NPK + Bio-stimulant Spray with highest B:C ratio of 3.3. Where with 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant Spray + Nano Zn spray net return was (₹99450 $ha^{-1}$) being ₹9852 and 56358 $ha^{-1}$ higher than 100% NPK and control respectively.

**Conclusion**

In view of the foregoing facts, it remains no more obscure that nutrient management practices had a significant and profound effect on growth, development, yield attributes, nutrient content & uptake, yield, nutrient use efficiency, protein (content & yield) and returns in wheat. Application of nano fertilizers, biofertilizers, bio-stimulant and inorganic fertilizer spray individually or simultaneously promoted growth of the crop and enhanced grain yield significantly. Further, nano fertilizers (N, Zn), biofertilizers (NPK-consortia), bio-stimulant, and inorganic fertilizer spray (NPK-18:18:18) have potential to promote growth and yield formation in wheat. Wheat crop fertilized with 75% NPK (112.5:45:30) + NPK Consortia (seed treatment with NPK-consortia 250 ml in 3 litre water 60 $kg^{-1}$ seed) + NPK spray (NPK-18:18:18, 15 g $litre^{-1}$ ) + Bio-stimulant Spray (625 ml $ha^{-1}$) + Nano Zn spray (10 ml $litre^{-1}$) spray after I irrigation taking 500 liter water $ha^{-1}$ resulted in significantly better growth, yield and soil quality. However, the net returns were highest (₹102763 ha$^{-1}$) with 100 % NPK + Bio-stimulant Spray with B:C ratio of 3.3, being higher by ₹ 13165 ha$^{-1}$ than 100% NPK (₹89598 ha$^{-1}$) and ₹59671 ha$^{-1}$ then control (₹43092 ha$^{-1}$). Additional use of Nano Zn spray or Bio-stimulant spray with 100% NPK and NPK-consortia + NPK + Bio-stimulant + Nano Zn spray with 75% NPK increased gross return by ₹16310, 14083 and 14330 ha$^{-1}$ over 100% NPK and ₹69390, 67163 and 67410 ha$^{-1}$ over control respectively. Bio-stimulant spray or Nano Zn spray with 100% NPK registered higher return being comparable with 75% NPK + NPK-consortia + NPK + Bio-stimulant + Nano Zn spray. Soil fertility and microbial population were also almost similar under the treatments. Thus any of the three approaches can be used as per the availability of nutrient sources and cases of application in timely sown irrigated wheat under western-up conditions.

**Future line of work**

The above finding is based on one-year field experimentation. Therefore, in order to arrive at meaningful recommendations, the investigation need to be repeated for one more year. Alternatives for economizing production of Nano fertilizers (N&Zn), Biofertilizers (NPK-consortia), Bio-stimulant, and Inorganic fertilizer spray (NPK-18:18:18) can so a long way in reducing cost of production.

**A.O.A.C. 1960.** Methods of Analysis. Association of official agricultural Chemists, Washington, D.C. 9th edition. **pp.** 15-16**.**

**Abdullahi, R., Sheriff, H.H. and Lihan, S. 2013**. Combine effect of bio-fertilizer and poultry manure on growth, nutrients uptake and microbial population associated with sesame (*Sesamum indicum* L.) in North-eastern Nigeria. *ARPN Journal of Agricultural and Biological Science*, **9**(10): 351-355.

**Adhikari, T., Kundu, S., Meena, V. and Rao, A. 2014.** Utilization of nano rock phosphate by maize (*Zea mays* L.) crop in a vertisol of central India. *Journal of Agricultural Science and Technology*, **4**: 384-394.

**Afzal, A., Ashraf, M., Safeed, A. and Farooq, M. 2005.** Effect of phosphate solubilizing microorganisms on phosphorus uptake, yield and yield traits of wheat (*Triticum aestivum* L.) in Rainfed area. *International Journal of Agricultural Biotechnology*. **7**(2): 207-209.

**Ahemad, M. and Khan, M.S. 2009**. Effect of insecticide-tolerant and plant growth promoting Mesorhizobium on the performance of chickpea grown in insecticide sressed alluvial soils. *Journal of Crop Science and Biotechnology*, **12**: 213-222.

**Ajirloo, A., Shaaban, M. and Motlagh, Z. 2015.** Effect of K Nano-Fertilizer and N Bio- Fertilizer on Yield and Yield Components of Tomato (*Lycopersicon esculentum* L.) *International Journal of Advanced, Biological and Biomedical Research*, **3**(1): 138-14.

**Al Majathoub, M. 2004.** Effect of biostimulants on production of wheat (*Triticum aestivum* L.). *Mediterranean Rainfed Agriculture: Strategies for Sustainability*, CIHEAM, Zaragoza, 147-150.

**Amal G, Ahmed SO and Gomaa AM. 2011.** Bio-Organic Farming of Grain

Sorghum and its Effect on Growth, Physiological and Yield Parameters and Antioxidant Enzymes Activity. *Research Journal of Agriculture and Biological Sciences*. **6**(3): 270-279.

**Anonymous 2019.** Economic Survey of India.

**Armin, M., Akbari, S. and Mashhadi, S. 2014.** Effect of time and concentration of nano-Fe foliar application on yield and yield components of wheat. *International Journal of Biosciences,* **4**(9): 69-75.

**Asghar, M., Baig, M. M. Q., Chaudhary, S., Iqbal, M. F., & Ali, M. A. 2010.** Evaluation of difenoconazole along with macronutrients spray for the control of brown leaf spot (*Bipolaris oryzae*) disease in rice (*Oryza sativa*) crop. *Sarhad Journal of Agriculture*, **35**(1), 1-6.

**Aulakh, M.S. and Malhi, S.S. 2005**. Interactions of nitrogen with other nutrients and water effect on crop yield and quality nutrient use efficiency carbon sequestration and environmental pollution. *Advances in Agronomy*, **86**:342-409.

**Aziz, H. M. M., Hasaneen, M. N. A. and Omer, A. M. 2016.** Nano chitosan-NPK fertilizer enhances the growth and productivity of wheat plants grown in sandy soil. *Spanish Journal of Agricultural Research,* **14**(1): 0902.

**Bahadur, L., Tiwari, D.D., Mishra, J. and Gupta, B.R. 2013.** Nutrient management in rice-wheat sequence under sodic soil. *Journal of the Indian Society of Soil Science,* **61**(4): 341-346.

**Bahrani, A., Pourreza, J. and Hagh Joo, M. 2010.** Response of winter wheat to co-inoculation with *Azotobacter* and *Arburscular Mycorrhizal* Fungi (AMF) under different sources of nitrogen fertilizer. *American-Eurasian Journal of Agriculture and Environmental Science,* **8**(1): 95-103.

**Balai, M. L., Verma, A., Nepalia, V. and Kanthaliye, P.C. 2011.** Productivity and quality of maize (*Zea mays*) as influenced by integrated nutrient management under continuous cropping and fertilization. *The Indian Journal of agricultural Sciences*, **81**: 374-76.

**Bandyopadhyay, K. K., Ghosh, P. K., Hati, K. M., & Misra, A. K. 2009.** Efficient utilization of limited available water in wheat through proper irrigation scheduling and integrated nutrient management under different cropping systems in a Vertisol. *Journal of the Indian Society of Soil Science*, **57**(2), 121-128.

**Barea, J. M., Navaro, E. and Montoya, E. 1976**: Production of plant growth regulators by rhizosphere phosphate-solubilizing bacteria. *Journal of Applied Bacteriology*, **40:** 129-134.

**Barthwal, A., Bhardwaj, A.K., Chaturvedi, S. and Pandiaraj, T. 2013.** Site specific NPK recommendation in wheat (*Triticum aestivum*) for sustained crop and soil productivity in mollisols of Tarai region. *Indian Journal of Agronomy*, **58**(2): 208-214.

**Behera, U.K., and Rautaray,S.K. 2010.** Effect of biofertilizers & chemical fertilizers on productivity & quality parameters of durum wheat (*Triticum turgidum*) on a vertisol of central India. *Archives of Agronomy & Soil Science*, **56**(1): 65-72.

**Benzon, H., Rubenecia, M., Ultra, V. and Lee, S. 2015.** Nano-fertilizer affects the growth, development, and chemical properties of rice. *International Journal of Agronomy and Agricultural Research*, **7**(1): 105-117.

**Bhaduri, D. and Gautam, P. 2013.** Optimization and validation of targeted yield equation fertilizer based doses under in for wheat in tarai region of uttarakhand, india. *Indian Journal Agriculture Research*, **47**(1): 16 - 25.

**Black, C.A. 1965:** Methods of Soil Analysis. Part 1, *American Society of Agronomy*, No 9.

**Blake, G. R., and K.H. Hartge. 1986.** Bulk density. p. 363-375. In A. Klute (ed.) Methods of soil analysis. Part 1. (2nd ed.). *Agronomy Monograph* **9**. ASA and SSSA, Madison, WI.

**Bouyoucos, G. J. 1962.** Hydrometer method improved for making particle size analyses of soils. *Agronomy Journal* **54**: 464-465.

**Brady, N.C. 1996**. The Nature and Properties of Soils. 10th eds. *Prentice Hall of India Pvt. Ltd.*, New Delhi. 501-502.

**Cambardella, C., Elliott, E. 1994.** Carbon and nitrogen dynamics of soil organic matter fractions from cultivated grassland soils. *Soil Science Society of America Journal*,**58**: 123-130.

**Chand, M., Gupta, J. and Roy, N. 2014.** Effect of integrated nutrient management module on wheat yield in Bundelkhand Zone of Uttar pradesh. *Bhartiya Krishi Anusandhan Patrika*, **29**(1): 01-04.

**Chand, S., Somani, L. L. and Bhandari, S. C. 2010.** Effect of fertilizer, farmyard manure (FYM) and biofertilizer on the population of *Azotobacter* and phosphate solubilizing bacteria (PSB) in the soil. *Journal of the Indian Society of Soil Science*, **58**(4):460-463.

**Chapman, D. H., & Parker, F. 1961.** Determination of NPK. *Methods of analysis for soils, plants and water. 1st Ed. California University, Agriculture Division, USA.* ***pp***, 150-179.

**Chauhan, R. S. 2014.** Effect of fertility and weed management on yield, nutrient uptake and economics of wheat. *Annals of Plant and Soil Research*, **16**(4): 304-307**.**

**Craswell, E. T., & Godwin, D. C. 1984.** The efficiency of nitrogen fertilizers applied to cereals grown in different climates (No. REP-3326. CIMMYT.).

**Dadarwal, R. S., Jain, N. K. and Singh, D. 2009.** Integrated nutrient management in baby corn (*Zea mays*). *The Indian Journal of agricultural Sciences,* **79**: 1023-1025.

**Danielson, R. E., & Sutherland, P. L. 1986.** Porosity. Methods of Soil Analysis: Part 1. *Physical and Mineralogical Methods,* **5:** 443-461.

**Dash, A. C. Tomar, G. S. and Katkar, P.H. 2015.** Effect of integrated nutrient management on growth and dry matter accumulation of cluster bean. *Journal of Soils & Crops,* **15**(1): 34-35.

**De Rosa, M. R., Monreal, C., Schnitzer, M., Walsh, R. and Sultan, Y. 2010**. Nanotechnology in fertilizers. *National Nano-technology Journal*, 5: 91.

**Devi, N.L. and Mani, S. 2015.** Effect of seaweed saps *kappaphycus alvarezii* and *gracilaria* on growth, yield and quality of rice. *Indian Journal of science and Technology,* **8**(19).

**Dhaka, B.R. and Pathan, A. R. K. 2013.** Response of wheat to integrated nutrient management in *typicus tipsamment*. *Annals of Plant and Soil Research*, **15**(1): 50-53.

**Dhargalkar, V.K. and Pereira, N. 2005**. Seaweed promising plant of the millennium. *Science and Culture*, 71: 60-66.

**Dhoke, S. K., Mahajan, P., Kamble, R. and Khanna, A. 2013.** Effect of nano-particle suspensions on the growth of mung (*Vigna radiata*) seedlings by foliar spray method. *Nano-technology Development*, **3**(1): 1-5.

**Dhonde, M. B., and Bhakare, B. D. 2008.** Influence of integrated nutrient management on soil properties of vertisols under sorghum-wheat cropping sequence. *Journal Research Acharya N. G. Ranga Agricultural University,* **36**(2 & 3): 1-8.

**Dibakar, M., Rai, R, K., Mishra, S.D., Raja, A., Purakayastha, T. J. and Varghese, E. 2014.** Influence of phosphorous and biofertilizers on Soybean and wheat root growth and properties. *Field crops Research*, **166**: 1-9.

**Dilworth, M.J., Eady, R.R. and Eldridge, M.E. 1988**. The vanadium nitrogenase of *Azotobacter chroococcum.* Reduction of acetylene and ethylene to ethane. *Biochemical Journal*, **249**(3):745–751.

**Donald, C. M. 1962.** In search of yield. *Journal of the Australian Institute of Agricultural Sciences*, 28: 171- 178.

**Drostkar, E., Talebi, R. & Kanouni, H. 2016**. Foliar application of Fe, Zn and NPK nano-fertilizers on seed yield and morphological traits in chickpea under rainfed condition. *Journal of Resources and Ecology*, **4:** 221-228.

**Du, W., Sun, Y., Ji, R., Zhu, J., Wu, J. and Guo, H. 2011.** $TiO_2$ and ZnO nano-particles negatively affect wheat growth and soil enzyme activities in agricultural soil. *Journal of Environmental Monitoring*, **13**: 822-828.

**Dwivedi, B. S., Singh, D., Tiwari, K. N., Swarup, A., Meena, M. C., Majumdar, K. & Yadav, R. L. 2009.** On-farm evaluation of SSNM in Pearl millet-based cropping systems on alluvial soils. *Better crops–India*, **25**.

**Fan, L., Wang, Y., Shao, X., Geng, Y., Wang, Z., Ma, Y. & Liu, J. 2012**. Effects of combined nitrogen fertilizer and nano-carbon application on yield and nitrogen use of rice grown on saline-alkali soil. *Journal of Food, Agriculture & Environment*, **10**(1 part 1): 558-562.

**Farnia, A. and Ghorbani, A. 2015**. Effect of K nano-fertilizer and N bio- fertilizer on yield and yield components of red bean (*Phaseolus vulgaris* L.). *International Journal of Biosciences*, **5**(12): 296-303.

**Flagella, Z., Giuliani, M. M., Giuzio, L., Volpi, C., and Masci, S. 2010**. Influence of water deficit on durum wheat storage protein composition and technological quality. *European Journal Agronomy,* 33:197–207.

**Fornes, F.M., Sanchez-Perales and Guardiola J.L.1995**. Effect of a seaweed extract on citrus fruit maturation, *Acta Horticulturae*, **379**:75-82.

**Galal, Y. G., El-Gandaour, J. A. and El-Akel, F. A. 2001.** Stimulation of wheat growth and N fixation through Azospirillum and Rhizobium inoculation. A field trial with 15N techniques. *Plant Nutrition Food Security and Sustainability of Agro-ecosystems,* 666-667.

**Geetha Kumari, V.L. and Shivashankar, K. 1991**. Studies on organic amendment and $CO_2$ enrichment in ragi/soybean intercropping systems. *Indian Journal of Agronomy*, **36**:202-206.

**Ghafari, H. and Razmjoo, J. 2013.** Effect of foliar application of nano-iron oxidase, iron chelate and iron sulphate rates on yield and quality of wheat. *International Journal of Agronomy and Plant Production*, **4** (11): 2997-3003.

**Ghahremani, A., Akbari, K., Yousefpour, M. and Ardalani, H. 2014**. Effects of Nano- Potassium and nano-calcium chelated fertilizers on qualitative and quantitative characteristics of *Ocimum basilicum. International journal for Pharmaceutical Research Scholars,* **3**: 1-2.

**Ghanshyam, Kumar, S. and Jat R.K. 2010.** Productivity and soil fertility as effected by organic manures and inorganic fertilizers in green gram (*Vigna radiata*)-wheat (*Triticum aestivum* L.). *Indian Journal of Agronomy,* **55**(16):21.

**Ghosh, D. K. and Malic, S. C. 1981**. Effect of fertilizers and spacing on yield and other characters of Black cumin (*Nigella sativa* L.). *Indian Agriculture Journal*, **25**: 191-197.

**Gogoi, B. 2011**. Soil properties and nutrient availability as affected by INM after rainfed cropping sequence. *Indian Journal of Agricultural Research*, **45**: 346-349.

**Gomez, K.A. and Gomez, A.A. 1984.** Statistical procedure for agriculture research 2nd edition Jon Wielly and Sons, New York.

**Guixia, Y. G. & Guang-cai, Z. 2010.** Effect of Sowing Date and Density on Grain Yield and Nutrition Quality and Physiological Index of Winter Wheat. *Journal of Triticeae Crops*, **4:** 20-25.

**Gul, H., Said, A., Saeed, B., Mohammad, F. & Ahmad, I. 2011**. Effect of foliar application of nitrogen, potassium and zinc on wheat growth. *Arpnj Agricultural Bio Science*, **6(4):** 56-59.

**Gupta, V. & Sharma, R. S. 2006**. Effect of integrated nutrient management on productivity and balance of rice–wheat cropping system. *Annals of Plant and Soil Research*, **8**(2): 148-151.

**Hafeez, A., Razzaq, A., Mahmood, T. and Jhanzab, H. M. 2015.** Potential of copper nano-particles to increase growth and yield of wheat. *Journal of Nano science with Advanced Technology*, **1**(1): 6-11.

**Hameed, B., Harini, G., Rupela O. P., Wani, S. P. Reddy, G. 2008.** Growth promotion of maize by phosphate-solubilizing bacteria isolated from composts and macrofauna. *Microbiology Research*, **163**(2): 234-242.

**Hameeda, B. Harini, G. Rupela, OP. Reddy, G. 2010.** Effect of composts or vermicomposts on sorghum growth and mycorrhizal colonization. *African Journal of Biotechnology*, **6**(1):1009–12.

**Hanway,J.J. and Heidel ,H. 1952**. Soil analysis methods as used in Iowa State College Soil Testing Laboratory.

**Harsini, M. G., Habibi, H., & Talaei, G. H. 2014.** Study the effects of iron nano chelated fertilizers foliar application on yield and yield components of new line of wheat cold region of Kermanshah provence. *Agricultural Advances*, ***3***(4), 95-102.

**Hassan, F., Parviz, R. M., Nasser, S. and Amir, F. 2012**. Impact of bulk and nano-sized titanium dioxide ($TiO_2$) on wheat seed germination and seedling growth. *Biological Trace Element Research,* **146**: 101-106.

**Haverkamp RG, Marshall AT 2009**. The mechanism of metal nanoparticle formation in plants: Limits on accumulation. *Journal of Nanoparticle Research,***11**:1453-1463.

**Hong, F., Zhou, J., Liu, C., Yang, F., Wu, C. and Zheng, L. 2005**. Effect of nano titanium oxide on phytochemical reaction of chloroplast of spinach. *Biological Trace Element Research,* **105**(1-3): 269-279.

**Jabran, K., Cheema, Z. A., Farooq, M., & Khan, M. B. 2011.** Fertigation and foliar application of fertilizers alone and in combination with canola extracts enhances yield in wheat. *Crop & Environment,* **2**(1): 42-45.

**Jackson, M.L. 1967.** "Soil chemical Analysis" Prentice Hall of India. *Private Limited,* New Delhi.

**Jackson, M.L. 1973.** "Soil chemical Analysis" Prentice Hall of India. *Private Limited,* New Delhi.

**Jafarzadeh, R., Jami, M. and Hokmabadi, M. 2013**. Response of yield and yield components in wheat to soil and foliar application of Nano Potassium fertilizer. *Journal of crop production research, Environmental stresses in Plant Sciences,* **5**(2): 189-197.

**Janmohammadi, M., Amanzadeh, T., Sabaghnia, N., & Dashti, S. 2016.** Impact of foliar application of nano micronutrient fertilizers and titanium dioxide nanoparticles on the growth and yield components of barley under supplemental irrigation. *Acta Agriculturae Slovenica*, **107**(2): 265-276.

**Jat M L, Satyanarayana T, Majumdar K, Parihar C M, Jat S L, Majumdar K, Satyanarayana T, Pampolino M, Dutta S, Jat M L, Sulewski G and Johnston A M. 2013.** Nutrient Expert for hybrid maize (version 1.1). A decision support tool for providing field specific fertilizer recommendations for tropical hybrid maize. *International Plant Nutrition Institute*, Gurgaon, India.

**Jat, lali. 2018.** Nutrient Management in Wheat (*Triticum aestivum* L.) for Improving Fertilizer Use Efficiency, Productivity and Soil Health in Indo-Gangetic Plains of U.P, Thesis, Ph.D., Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut. 192 P.

**Jat, S.L., Nepalia, V., Chaudhary, J. and Singh, D. 2014.** Effect of nitrogen and weed management on productivity and quality of durum wheat (*Triticum durum*). *Indian Journal of Agronomy*, **59**(2): 281-285.

**Jhanzab, H. M., Razaaq, A., Jilani, G., Rehman, A., Hafeez, A. and Yasmeen, F. 2015**. Silver nano-particles enhance the growth, yield and nutrient use efficiency of wheat. *International Journal of Agronomy and Agricultural Research*, **7**(1): 15- 22.

**Jinghua, G. 2004**. Synchrotron radiation, soft X-ray spectroscopy and nano-materials. *Journal of Nano-technology*, **1**: 193-225.

**Joseph, T. and Morrisson, M. 2006**. Nano forum: Nano-technology in agriculture and food. European Nano-technology Gateway.

**Katyal, V., Gangwar, B. and Gangwar, K.S. 2002.** Yield trends and soil fertility changes in pearl millet (*Pennisetum glacum*)- wheat (*Triticum aestivum*) cropping system under long term integrated nutrient management. *Annals of Agricultural Research* (News series), **23**: 201-205.

**Kaur, G. and Reddy, M.S. 2014.** Influence of P-solubilizing bacteria on crop yield and soil fertility at multi locational sites. *European Journal of Soil Biology*, **61**:35-40.

**Kaushik, M.K., Bishnoi, N.R. and Sumeriya, H.K. 2012.** Productivity and economics of wheat as influenced by inorganic and organic sources of nutrients. *Annals of Plant and Soil Research*, **14**(1): 61-64.

**Kavitha, M. P., Ganesaraja,V. and Paulpandi, V. K. 2008.** Effect of foliar spraying of seaweed extract on growth and yield of rice. *Agriculture Science Digest*, **28**(2):127-129.

**Khan W., Rayirath U, Subramanian S., Jithesh M, Rayorath P., Hodges M.,Critchley A.,Craigie J, Norrie J, Prithiviraj B. 2009** : Seaweed Extracts as Biostimulants of Plant Growth Development. *Journal of Plant Growth Regulation*, **28**(4), 3863.

**Kharub, A.S. and Sharma, V.K. 2002.** Effect of nutrient combinations on wheat productivity under typic ustochrept soils of Karnal. *Annals of Plant and Soil Research*, **4**(1): 124-126.

**Kloepper, J.W. 1994.** Plant growth-promoting rhizobacteria (other systems). In: *Azospirillum*/Plant Associations. (Ed.): Y. Okon, *CRC Press*, Boca Raton, FL. 137-166.

**Kloepper, J.W., Lifshitz, R. and Zablotowicz, R.M. 1989.** Free-living bacterial inocula for enhancing crop productivity. *Trends in Biotechnology*, **7**(2):39-44.

**Kumar , V. and Ahlawat , I. P. S. 2004.** Carry over effect of biofertilizers and nitrogen applied to wheat (*Triticum aestivum*) and direct applied N in maize (*Zea mays*) in wheat maize cropping system. *Indian Journal of*

*Agronomy*, **49**(4): 233-236.

**Kumar A and Dhar S 2010.** Evaluation of organic and inorganic sources of nutrients in maize (*Zea mays*) and their residual effect on wheat (*Triticum aestivum*) under different fertility levels. *The Indian Journal of Agricultural Sciences*, **80**(5): 364-71.

**Kumar, B., & Thenua, O. V. S. 2012.** Studies on integrated nutrient management in wheat Doctoral dissertation, Ph. D. Thesis (Agronomy) submitted by senior author to CCS University, Meerut (UP).

**Kumar, D., & Nikhil, K. 2016.** Effect of FYM, NPK and Algal Fertilizers on the Growth and Biomass of Vetiver Grass (*Vetiveria zizanioides* L. Nass). *International Journal of Engineering and Applied Sciences*, **3**(3), 85-89.

**Kumar, P. & Pannu, R. K. 2012**. Effect of different sources of nutrition and irrigation levels on yield, nutrient uptake and nutrient use efficiency of wheat. *International Journal of Life Science, Botany and Pharma Research*, **1**(4): 187-192.

**Kumar, R., Pandey, D. S., Singh, V. P. and Singh, I. P. 2014.** Nano-technology for better fertilizer use (Research Experiences at Pantnagar). *Research Bulletin* no. 201.

**Kumar, V. & Singh, A. P. 2010.** Long-term effect of green manuring and farmyard manure on yield and soil fertility status in rice-wheat cropping system. *Journal of the Indian Society of soil science*, **58**(4), 409-412.

**Kurtz, W.G.W. and Larue, T.A.G. 1975.** Effect of nitrogen source and carbon metabolism by *Azotobacter vinalandii* sp. grown in chemostat and batch culture. *Canadian Journal of Microbiology*, **21**: 738-741.

**Liang, T., Yin, Q., Zhang, Y., Wang, B., Guo, W., Wang, J. and Xie, L. 2013**.

Effects of carbon nano-particles application on the growth, physiological characteristics and nutrient accumulation in tobacco plants. *Journal of Food, Agriculture & Environment*, **11**(3&4): 954-958.

**Lindsay, W. L., & Norvell, W. A. 1978.** Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil science society of America journal*, **42**(3): 421-428.

**Liscano, J. F., Wilson, C. E., Norman. R. J., Slaton, N. A. 2000.** Zinc availability to rice from seven granular fertilizers. *AAES Research Bulletin*, **96**(3): 1–31.

**Liu J., Zhang Y. and Zhang Z. 2009.** The application research on nano-biotechnology to promote increasing vegetable production. *Hubei Agricultural Sciences*, **1**: 20-25.

**Liu, J., Wang, Y., Shao, X., Geng, Y., Wang, Z., Ma, Y. and Fan, L. 2012.** Effects of combined nitrogen fertilizer and nano-carbon application on yield and nitrogen use of rice grown on saline-alkali soil. J*ournal of Food, Agriculture & Environment*, **10**(1): 558-562.

**Liu, R. and Lal, R. 2015.** Potentials of engineered nano particles as fertilizers for increasing agronomic productions. *Science of the Total Environment*, **514**: 131-139.

**Lu, Q., Lu, C., Zhang, J., & Kuang, T. 200**2. Photosynthesis and chlorophyll afluorescence during flag leaf senescence of field-grown wheat plants. *Journal of Plant Physiology*, **159**(11): 1173-1178.

**Mahmoodzadeh, H., Aghili, R., & Nabavi, M. 2013**. Physiological effects of $TiO_2$ nanoparticles on wheat (*Triticum aestivum*). *Technical Journal of Engineering and Applied Sciences*, ***3***(14), 1365-1370.

**Mahmoud, M.R. 2006.** Residual effect of compost and biofertilizer on maize yield, and some soil chemical properties. *Asian Journal of Agricultural Sciences,* **37**: 185-200.

**Malghani, A.L. Malik, A.U., Sattar, A., Hussain, F., Abbas, G. and Hussain, J. 2012.** Response of growth and yield of wheat to NPK fertilizer. *Science International* (Lahore), **24**(2):185-189.

**Malik, B., Mandal, B., Bandopandhyay, P.K., Gangopadhyay, A., Mani, P.K., Kundu,and Majumdar, D. 2009**. Organic amendment influence on soil organic pools and crop productivity in a nineteen years old rice-wheat agro-ecosystem. *Soil Science society of American Journal*, **72**:775-785.

**Mancuso, S., Azzarello, E., Mugnai, S., Briand, X. 2006.** Marine Bioactive substances (IPA extract) improve foliar ion uptake and water tolerance in potted *Vitis venifera* plants. *Advance Horticulture Science,* **20**:156-161.

**Manikandan, A. and Subramanian, K. S. 2016.** Evaluation of zeolite-based nitrogen nano- fertilizers on maize growth, yield and quality on Inceptisol and Alfisols. *International Journal of Plant and Soil Science*, **9**(4): 1-9.

**Manonmani, V. and Srimathi, P. 2009.** Influence of mother crop nutrition on seed and quality of balckgram. *Madras Agriculture Journal,* **96** (16): 125128.

**Marozsan, M., Veres, S., Gajdos, E., Bakonyi, N., Toth, B. and Levai, L. 2009.** Changes of some chlorophyll-fluorescence parameters under biofertilization. *Zbornik Radova*, *44*, 16-20.

**Mauriya, A.K., Maurya, V.K., Tripathi, H.P., Verma R.K. and Shyam R. 2013.** Effect of site specific nutrient management on productivity and economics of rice (*Oryza sativa*)–wheat (*Tritucum aestivum*) system. *Indian Journal of Agronomy*, **58**(3): 282-287.

**Meena, M.C., K.P. Patel, Dhyan Singh and B.S. Dwivedi 2012.** Long term effect of sewage sludge and farmyard manure on grain yields and availability of zinc and iron under pearl millet (*Pennisetum glaucum*) - Indian mustard (*Brassica juncea*) cropping sequence. *Indian Journal Agriculture Science*, 78, 1028-1032.

**Mehrvarz, S., Chichi, M. R. and Alikhani, H. A. 2008.** Effects of phosphate solubilizing microorganisms and phosphorus chemical fertilizer on yield and yield components of barely (*Hordeum vulgare* L.). *America European Journal of Agriculture and Environmental Science*, **3**(6): 822-828.

**Mehta, S. 2017.** Effect of integrated use of nano and non-nano-fertilizers on quality and productivity of wheat (*Triticum aestivum* L.) Doctoral dissertation, Sher-E-Kashmir University of Agricultural Sciences and Technology of Jammu.

**Minaxi, S., Saxena, J., Chandra, S. and Nain, L. 2013.** Synergistic effect of phosphate solubilizing rhizobacteria and *arbuscular mycorhiza* on growth and yield of wheat plants. *Journal of Soil Science and Plant Nutrition*, **13**(2): 511-525.

**Mir, S., Sirousmehr, A. and Shirmohammadi, E. 2015.** Effect of nano and biological fertilizers on carbohydrate and chlorophyll content of forage sorghum (Speed feed hybrid). *International journal of Biosciences*, **6**(4): 157-164.

**Mirik, M., Aysan, Y. and Cinar, O. 2008.** Biological control of bacterial spot disease of pepper with *Bacillus* strains. *Turky Journal of Agriculture*, **32** (5): 381-390.

**Mohanty, D., Adhikary, S. P., & Chattopadhyay, G. N. 2013.** Seaweed liquid fertilizer (SLF) and its role in agriculture productivity. *Ecoscan*, ***3***, 147-155.

**Munir, T., Rizwan, M., Kashif, M., Shahzad, A., Ali, S., Amin, N., ... & Imran, M. 2018.** effect of zinc oxide nanoparticles on the growth and zn uptake in wheat (*Triticum aestivum* L.) by seed priming method. *Digest Journal of Nanomaterials & Biostructures (DJNB)*, **13**(1).

**Narang R.S., Mahal, S.S., Bedi, S., Gosal, K.S. and Bedi, S. 1997.** Response of wheat to potassium fertilization under maximum yield research strategies. *Environmental Ecology*, **15**(2): 474477.

**Narolia, R. S., Meena, H., Singh, P., Meena, B. S., & Ram, B. 2016.** Effect of irrigation scheduling and nutrient management on productivity, profitability and nutrient uptake of wheat (*Triticum aestivum*) grown under zero-tilled condition in south-eastern Rajasthan. *Indian Journal of Agronomy*, **61**(1), 53-58.

**Nath, D.J., Ozah, B., Baruah, R. and Borah, D.K. 2011.** Effect of Integrated nutrient management on soil enzymes, microbial biomass carbon and bacterial populations under rice (*Oriza sativa*) and wheat (*Triticum aestivum*) sequence. *Indian Journal of Agricultural Sciences*, **81** (12): 1143-1148.

**Nguyen Chu,Bao thi Hoai Tran, and Minh Thi Thanh Hoang 2018.** Plant growth –promoting *rhizobacterium Pseudomonas* PS01 induce salt tolerance in Arabidopsis thaliana.

**Nguyen, M. L., Spaepen, S., du Jardin, P., & Delaplace, P. 2019.** Biostimulant effects of rhizobacteria on wheat growth and nutrient uptake depend on nitrogen application and plant development. *Archives of Agronomy and Soil Science*, **65**(1), 58-73.

**Noreen, F. and Noreen, S. 2014.** Effect of different fertilizers on yield of wheat. *International Journal of Science and Research*, **3**(11):1596-1599.

**Novoa, R., & Loomis, R. S. 1981.** Nitrogen and plant production. *Plant and soil*, **58**(1), 177-204.

**Olsen, S. R. 1954.** *Estimation of available phosphorus in soils by extraction with sodium bicarbonate* (No. 939). US Department of Agriculture.

**Pagnani, G., Galieni, A., Stagnari, F., Pellegrini, M., Del Gallo, M., and Pisante, M. 2020.** Open field inoculation with PGPR as a strategy to manage fertilization of ancient Triticum genotypes. *Biology and Fertility of Soils*, 56, 111-124.

**Pal, A., Dwivedi, S.K. and Kanwar, P.C. 2015.** Effect of seaweed sapson increase yield. Nutrient uptake and soil nutrient balance sheet of rice (*Oryza sativa* L.) *The Ecoscan*, **9**(1&2):531-535.

**Pampolino, M. F., Witt, C., Pasuquin, J. M., Johnston, A. & Fisher, M. J. 2012.** Development approach and evaluation of the Nutrient Expert software for nutrient management in cereal crops. *Computers and electronics in agriculture*, **88**: 103-110.

**Pandey, A. and Kumar, S. 1989.** Potential of *Azotobacter* and *Azospirilla* as biofertilizers for upland agriculture: a review. *Journal of Scientific and Industrial Research*, **48**: 134–144.

**Pandey, A. K. Singh, S. K. & Prasad, R. 2009.** Long term effect of organic and inorganic fertilizer on yield of rice and wheat. *Environment and Ecology*, **27**: 3A, 1292-1295. 6.

**Parewa, H. P., Yadav, J., Rakshit, A., Meena, V. S., & Karthikeyan, N. 2014.** Plant growth promoting rhizobacteria enhance growth and nutrient uptake of crops. *Agriculture and Sustainable Development*, ***2***(2): 101-116.

**Parmar, P. and Sindhu, S. 2013.** Potassium Solubilization by Rhizosphere Bacteria: Influence of Nutritional and Environmental Conditions.

*International Journal of Microbiology Research,* **3**(1): 25-31.

**Parmer, D.K., Sharma, P.K. and Sharma, T.R. 1998.** Integrated nutrient supply system for 'DPP68' vegetable pea (*Pisum sativum* var. arvense) in dry temperature zone of H.P. *Indian Journal of Agricultural Sciences,* **68**: 84-86.

**Patidar, M. and Mali, A.L. 2004.** Effect of farmyard manure, fertility levels and bio-fertilizers on growth, yield and quality of sorghum (*Sorghum bicolor*). *Indian Journal of Agronomy,* **49**: 117-120.

**Patra B. and R. K. Pratik 2018.** Response of wheat to various nitrogen levels under late sown condition. *Journal of Experimental agriculture International,* **21**(1):1-5.

**Popko, M.I, Wilk R, Gramza M,Chojnacka K, Gorecki H. 2018.** Effect of the new plant growth biostimulants based on amino acids on yield and grain quality of winter wheat. *Molecules,* **23**(2):470.

**Pramanick, B., K.Brahmachari.A.Ghoshand S. Zodape, 2014.** Effect of seaweed saps on growth and yield improvement of transplanted rice in old alluvial soil of west Bengal. *Bangladesh Journal of Botany*, **43**(1): 53-58.

**Prasad, B. 1994.** Integrated nutrient management for sustainable agriculture. *Fertilizers News,* 39: 19-29. *Society of Agronomy,* **45**: 453-457.

**Prasad, K., Das, A.K., Oza ,M.D., Brahmbhatt ,H., Siddhanta, A., Meena, R., Eswaran, K., Rajyaguru , M.R. and Ghosh , P.K. 2010**. Detection and quantification of (*Zea mays* L.) Some plant regulators in a seaweed based foliar spray employing amass spectrometric technique sans chromatographic separation. *Journal of Agriculture and Food chemistry,* **58**: 4594-4601.

**Prasad, V., Sudhakar, P., Sreenivasulu, Y., Latha, P., Munaswamy, V., Raja Reddy, K., Sreeprasad, S., Sajanlal, R. and Pradeep, T. 2012.** Effect of nano scale zinc oxide particles on the germination, growth and yield of peanut. *Journal of Plant Nutrition*, **35**: 905-927.

**Qiang, X., Fu-dao, Z., Yu-jun, W., Jian-feng, Z. and Shu-qing, Z. 2008**. Effects of slow/controlled release fertilizers felted and coated by nano-materials on crop yield and quality. *Journal of Plant Nutrition and Fertilizer Science*, **14**: 951–955.

**Radford, P. J. 1967.** Growth analysis formulae-their use and abuse 1. *Crop science*, ***7***(3), 171-175.

**Rai, M. & Ingle, A. 2012.** Role of nanotechnology in agriculture with special reference to management of insect pests. *Applied microbiology and biotechnology*, **94**(2), 287-293.

**Ram, T. and Mir, M.S. 2006.** Effect of integrated nutrient management on yield and yield –attributing characters of wheat (*Triticum aestivum*). *Indian Journal of Agronomy*, **51**(3): 189-192.

**Ramesh, M., Palanisamy, K., Babu, K. and Sharma, N. K. 2014.** Effects of bulk and nano-titanium dioxide and zinc oxide on physio-morphological changes in wheat (*Triticum aestivum). Journal of Global Biosciences*, **3**: 415–422.

**Rameshaiah, G. N., Pallavi, J. & Shabnam, S. 2015.** Nano fertilizers and nano sensors–an attempt for developing smart agriculture. *International Journal of Engineering Research and General Science*, **3**(1): 314-320.

**Rangaswamy G. 1966**. *Agricultural Microbiology*, Bombay Asia Publishing, Delhi, **pp** 321.

**Reazaei, M. and Abbasi, H. 2014.** Foliar application of nano chelates and non-chelate of zinc on plant resistance physiological processes in cotton (*Gossipium hirsutum* L.). *Iranian Journal of Plant Physiology*, **4**(4): 1137-1144.

**Reddy, K. R., Gangathulasi, J., Parakalla, N. S., Hettiarachchi, H., Bogner, J.**

**E., & Lagier, T. 2009.** Compressibility and shear strength of municipal solid waste under short-term leachate recirculation operations. *Waste Management & Research*, **27**(6): 578-587.

**Rezaei, M., & Abbasi, H. 2014.** Foliar application of nanochelate and non-nanochelate of zinc on plant resistance physiological processes in cotton (*Gossipium hirsutum* L.). *Iranian Journal of Plant Physiology*, **4**(4): 1137-1144.

**Richards, L. A. 1954.** Diagnosis and improvement of saline and alkaline soil. United States Salinity Laboratory Staff. Agricultural Handbook no. **60**. United States Department of Agricultural, 160p.

**Richards, L.A. 1968**. Diagnosis and improvement of saline and alkali soil. United States Department of Agronomy, Hand Book No. 60 Oxford and IBH Publishing Company, New York.

**Rizwan, M., Ali, S., Ali, B., Adrees, M., Arshad, M., Hussain, A. & Waris, A. A. 2019.** Zinc and iron oxide nanoparticles improved the plant growth and reduced the oxidative stress and cadmium concentration in wheat. *Chemosphere*, **214**, 269-277.

**Rozalin Nayak, Paikaray, R. K. Sahoo, T. R.; Lal, M. K. Awadhesh Kumar 2017.** Yield, quality and economics of basmati rice as influenced by different organic nutrient management practice. *Central Rice Research Institute, Cuttack*, India. **54**(1): 44-49.

**Saini, Kaur, Mandeep and Walia, US, 2010.** Effect of planting patterns and weed control treatments on Phalaris minor growth and productivity of wheat (*Triticum aestivum*). *Indian Journal of Agronomy*, **55**(2): 110-113.

**Salat, A.2004.** Les biostimulants .PHM [Biostimulants -PHM] revue. *Horticole.* 454:22- 24.

**Sevov, A., & Delibaltova, V. 2013.** Effect of biostimulant fertigation on bread wheat (*Triticum aestivum*) productivity elements and grain yield. *Scientific Papers Series Agronomy*, **56,** 353-356.

**Shaaban, M.M., El-Fouly, M.M. and Abdel-Maguid, A.A. 2004.** Zinc-Boron relationship in wheat plants grown under low or high levels of calcium carbonate in the soil. *Pakistan Journal of Biological Science*s, **7(4):** 633-639.

**Shaaban, M.M., Hussein, M.M. and El-Saady, A.M.2008.** Nutritional status in shoots of barley genotypes as affected by salinity of irrigation water. *American Journal Plant Physiology,* **3**(2): 89-95.

**Shaaban, M.M., Loehnertz, O. and El-Fouly, M.M.2007**. Grapevine genotypic tolerance to lime and possibility of chlorosis recovery through micronutrients foliar application. *International Jouranl of Botany*, **3**(2): 179-187.

**Shabaev, V.P., Smolin, V.Yu. and Maudrick, V.A. 2006.** Nitrogen fixation and $Co_2$exchange in soyabean inoculated with mixed cultures of different microorganisms. *Biology and Fertility of Soils*, **23**(4): 435-430.

**Shah, T.M., Zodape, S. T., Chaudhary, D.R., Eswaran, K. and Chikara, J. 2013.** Seaweed saps on an alternative liquid fertilizer for yield and quality improvement of wheat. *Journal of Plant Nutrition*, **36**:192-200.

**Sharma, Shahwany 2014.** Studies on long term impact of STCR based integrated fertilizer use on pearl millet (*Pennisetum glaucum*) wheat (*Triticum aestivum*) cropping system in semi-arid condition of India. *Journal of Environmental Biology*, **1**(36): 241-247.

**Sharma, V.K., Pandey R.N. and Sharma B.M. 2015.** Studies on long term impact of STCR based integrated fertilizer use on pearl millet (*Pennisetum glaucum*) wheat (*Triticum aestivum*) cropping system in semi-arid condition of India. *Journal of Environmental Biology*, **1**(36): 241-247.

**Sheikhbaglou, R., Sedghi, M., Tajbakhsh, S. M. and Seyed-Sharifi, R. 2010**. Effect of nano iron particles on agronomic traits of soybean. *Science Biological*, **2**(2): 112– 113.

**Sheoran, S., Thakur, V., Narwal, S., Turan, R., Mamrutha, H. M., Singh, V. & Sharma, I. 2015.** Differential activity and expression profile of antioxidant enzymes and physiological changes in wheat (*Triticum aestivum* L.) under drought. *Applied biochemistry and biotechnology*, **177**(6): 1282-1298.

**Shinde, D.B. and Bangar, N.D. 2003**. Studies on dual inoculation of nitrogenous and phosphatic bacterial cultures in sugarcane. *Journal of Maharashtra Agricultural University*, **28**: 190-192.

**Shirinzadeh, A., Soleimanzadeh, H., & Shirinzadeh, Z. 2013.** Effect of seed priming with plant growth promoting rhizobacteria (PGPR) on agronomic traits & yield of barley cultivars. *World Applied Sciences Journal*, **21**(5), 727-731.

**Singh, M.P., Kumar, P., Kumar, A., Kumar, R., Diwedi, A., Gangwar, S., Kumar, V. and Sepat, N.K. 2016.** Effect of NPK with biofertilizers on growth, yield and nutrient uptake of wheat (*Triticum aestivum* L.) in western Uttar Pradesh condition. *Prograssive Agriculture,* **16**(1): 83-87.

**Singh, N.K., Choudhary, F.K. and Patel, D.B. 2013**. Effectiveness of *Azotobacter* bio-innoculant for wheat grown under dry land condition. *Jouneral Environment Biology*, **34**: 927-932.

**Singh, A., Yadav, A. S., & Verma, S. K. 2010.** Productivity, nutrient uptake and water use efficiency of wheat (*Triticum aestivum L.*) under different irrigation levels and fertility sources. *Indian Journal Ecology*, **37**(1): 13-17.

**Singh, B. V. 2019.** Effect of Doses and Sources of Nutrients on Growth, Yield and Nutrient Uptake in Timely Sown Wheat (*Triticum aestivum* L.*)*, Thesis, M. Sc., Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut. 144 P.

**Singh, G.,Sharma, G.L., Golada, S.L. and Choudhary, R. 2012a.** Effect of integrated nutrient management on quality protein maize (*Zea mays* L.). *Crop Research* **44**: 26-29.

**Singh, I.D. and Stoskopf, N.C. 1971**. Harvest Index in Cereals. *Agronomy Journal*, **63**(2) : 224-226.

**Singh, N., & Kushwaha, H. S. 2013.** Residual impact in soybean-wheat system under irrigated condition of Bundelkhand. *Annals of Agricultural Research*, **34**(2).

**Singh, S.K., Thakur, R., Singh, C.S., Singh, M.K., Pal, S.K. and Singh A.K. 2015.** Effect of seaweed sap *Kappaphycus alvarezii* and *Gracilaria edulison* yield and quality of rice. *International Rice symposium*, Nov. 18-20 pp. 631.

**Singh, S.K., Thakur, R., Singh, M.K., Singh, C.S. and Pal, S.K. 2015b.** Effect of fertilizer level and seaweed sap on productivity and profitability of rice (*Oryza sativa*). *Indian journal of Agronomy*, **60**(3): 420-425.

**Singh, Shikha., Singh, M.K., Pal, S.K., Trivedi, K., Yesuraj, D., Singh, C.S., Vijayanand, K.G., Chandramohan, M., Patidar, R., Kubavat, D., Zodape, S.T. and Ghosh, A.2016a.** Sustainable enhancement in yield and quality of rain-fed maize through *Gracilaria edulis* and *Kappaphycus alvarezii* seaweed sap. *Journal of Applied Phycology.*

**Singh, Shikha., Singh, M.K., Pal, S.K., Perween, S., Kumari, J., Zodape, S.T. and Ghosh, A.2015c.** Seaweed sap as productivity booster of maize. *The Bioscan* **10**(3): 1303-1305.

**Singh, Varinderpal., Singh, Bijay., Singh, Yadvinder. Thind, H.S., Singh, Gobinder and Kaur, Satwinderjit. 2012.** Establishment of threshold leaf colour greenness for need based fertilizer nitrogen management in irrigated wheat (*Triticum aestivum* L.) using leaf colour chart. *Field Crops Research*, **130**: 109–119.

**Singh, Y., Singh, B., Ladha, J. K., Bains, J. S., Gupta, R. K., Singh, Jagmohan and Balasubramanian, V. 2007.** On-farm evaluation of leaf color chart for need-based Nitrogen management in irrigated transplanted rice in North Western India. *Nutrient Cycling in Agroecosystems*, **78**: 167–176.

**Sirisena, D. N, Dissanayake D. M. N., Somaweera K. A. T. N., Karunaratne V. and Kottegoda, N. 2013.** Use of Nano-K fertilizer as a source of potassium in rice cultivation. *Annals of Sri Lanka Department of Agriculture*, **15**: 257-262.

**Stępien, A., and Wojtkowiak, K. 2013.** Composition of gluten proteins in spring and winter wheat grain cultivated under conditions of varied fertilization. *Acta Agriculturae Scandinavica*, **63**(7), 588–594.

**Strik, W. A. and Van Staden, J. 2006.** Seaweed products as biostimulants in agriculture. *World seaweed resources: an authoritative reference system* (A multimedia, interactive DVD ROM.).

**Subbiah, B. V. and Asija, G.C. 1956**. A rapid method for the estimation of nitrogen in soil. *Current Science*, **25**: 259 - 260.

**Subramanian K. S., Manikandan A., Thirunavukkarasu M., Sharmila Rahale C. 2015.** Nano-fertilizers for balanced crop nutrition, in Nanotechnologies in food and Agriculture, (Switzerland: *Springer*). **pp** 69-80.

**Suke, S.N., Deotale, R.D., Hiradeve, P., Deogirkar, M. and Sorte, N.V. 2011.** Effect of nutrient and biofertilizers of chemical and biochemical parameters of maize. *Journal of Soil and Crops*, **21**: 107-112.

**Surendar, K. K., Vincent, S., Vanagamudi, M., & Vijayaraghavan, H. 2013.** Plant growth regulators and nitrogen responses on improving nutrient content of black gram (*Vigna mungo* L.). *Plant Gene and Trait*, **4**(1).

**Suriyaprabha, R., Karunakaran, G., Yuvakkumar, R., Prabu, P., Rajendran, V. and Kannan, N. 2012.** Growth and physiological responses of maize (*Zea mays* L.) to porous silica nano-particles in soil. *Journal of Nano-particle Research*, **14**(12): 1-14.

**Sushila, R and Giri, G. 2000.** Influence of FYM, nitrogen and biofertilizers on microbial population, dry matter accumulation and nutrient uptake of wheat under limited water supply. *Biofertilizer News*, **7**: 22-26.

**Swarup, A. and Wanjari, R. H. 2000.** Three decades of All India Coordinated Research Project on Long Term Fertilizer Experiments to study changes in soil quality, crop productivity and sustainability. *Indian Institute of Soil Science*, Bhopal, India: 59.

**Taiz, L. and Zeiger, E. 2006.** *Plant physiology*, 4$^{th}$ Edition. Sinauer Associates, Inc. Sunderland, Massachusetts, USA.

**Tarafdar, J. C., Sharma, S. and Raliya, R. 2013.** Nano-technology: Interdisciplinary science of applications. *African Journal of Biotechnology*, **12**(3): 219- 226.

**Tarafdar, J. C., Sharma, S. 2014.** Nano-technology: Interdisciplinary science of applications. *Asian journal of agricultural sciences*, **9**(2): 114- 125.

**Thalooth, T., Bahr, A., & Tawfik, M.M. 2012.** Productivity of some barley cultivars as affected by inoculation under water stress conditions. *Applied Botany*, 51,10743-10749.

**Totawat, K.L., Somani, L.L., Singh, R. and Singh, G. 2000.** Integrated nitrogen management in maize-wheat cropping sequence on haplustalfs of sub-humid southern plains of Rajasthan. In : Proceeding of International Conference on Managing Natural Resources for Sustainable Agricultural Production in the 21st Century, New Delhi, **3**: 923-924.

**Trivedi, K.; Vijay Anand, K.G.; Vaghela. P.; Ghosh, A. 2018**. Different growth, yield and biochemical responses of maize to the exogenous application of *kappaphycus alvarezii* seeweed extract, at grain- filling stage under normal and drought conditions. *Algal Research* **35**, 236-244.

**United Nations Data Booklet World Population Prospects 2019.**

**USDA Report. 2020.** pp:11-12.

**Vafa, Z. N., Sirousmehr, A. R., Ghanbari, A., Khammari, I. & Falahi, N. 2015.** Effects of nano zinc and Humic Acid on quantitative and qualitative characteristics of savory (*Satureja hortensis* L.). *International Journal of Biosciences*, **6**(3): 124-136.

**Visioli, G., Bonas, U., Dal Cortivo, C., Pasini, G., Marmiroli, N., Mosca, G., 2018a.** Variations in yield and gluten proteins in durum wheat varieties under late-season foliar versus soil application of nitrose fertilizer in a northern Mediterranean environment. *The Journal of the Science of Food and Agriculture*, **98**(6): 2360–2369.

**Walkley, A., & Black, I. A. 1934.** An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, **37**(1), 29-38.

**Walkley, A. & Black, I. A. 1965.** An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid in soil analysis. 1. Experimental. *Soil Science*, **79**: 459-465.

**Wu, M. 2013.** Effects of incorporation of nano-carbon into slow-released fertilizer on rice yield and nitrogen loss in surface water of paddy soil. *Advance Journal of Food Science and Technology*, **5**: 398-403.

**Xiao, G., Zhao, Z., Liang, L., Meng, F., Wu, W. and Guo, Y. 2019.** Improving nitrogen and water use efficiency in a wheat-maize rotation system in the North China Plain using optimized farming practices. *Agricultural Water Management,* **212**:172–180.

**Xiao, T., Boada, R., Llugany, M., & Valiente, M. 2021.** Co-application of Se and a biostimulant at different wheat growth stages: Influence on grain development. *Plant Physiology and Biochemistry*, **160**, 184-192.

**Yadav, D.D., Verma, C.K., Singh, B.P., & Shanker, S. 2011.** Role of biofertilizers in relation to nitrogen levels on growth & yield of wheat (*Triticum aestivum* L.).*Crop Research*, **42**(1, 2 &3): 23-26.

**Youssef, S. M., S. E.-D.Faizy, S. A. Mashali, H. R. El-Ramady 2013.** Effect of different levels of NPK on wheat crop in North Delta and Sh. Ragab Soil and Water Science Department., *Faculty of Agriculture, Kafrelsheikh University*., **3** (3):516.

**Zaidi, A, and Khan, M.S. 2005.** Interactive effect of rhizotrophic microorganism on growth, yield and nutrient uptake of wheat. *Journal of Plant Nutrition*, **28**: 2079-2092.

**Zodape, S. T., Abha Gupta, S. C. Bhandari, U. S. Rawat, D. R. Chaudhary, K. Eswaran and J. Chikara 2013.** Foliar application of seaweed sap as biostimulant for enhancement of yield and quality of tomato (*Lycopersicon esculentum* Mill.). *Journal of Science & Industrial Research*, **70**: 215-219.

## Appendix- I

### Weekly meteorological data during the experimental season *Rabi* (2020-21)

| Month And Date | Standard Weeks | Rainfall (mm) | Temperature (°C) | | Relative Humidity (%) | | Sunshine hours (h/day) |
|---|---|---|---|---|---|---|---|
| | | | Max | Min | Morning | Evening | |
| 05 Nov – 11 Nov | 45 | 0.0 | 28.4 | 11.3 | 83.4 | 45.3 | 7.9 |
| 12 Nov – 18 Nov | 46 | 1.3 | 27.6 | 9.9 | 84.3 | 44.4 | 6.9 |
| 19 Nov – 25 Nov | 47 | 1.4 | 25.0 | 9.5 | 82.4 | 54.7 | 6.2 |
| 26 Nov – 02 Dec | 48 | 0.0 | 25.8 | 8.4 | 83.9 | 45.7 | 7.5 |
| 03 Dec – 09 Dec | 49 | 0.0 | 26.3 | 7.9 | 85.0 | 45.0 | 6.1 |
| 10 Dec – 16 Dec | 50 | 5.9 | 22.9 | 6.4 | 85.6 | 49.9 | 4.8 |
| 17 Dec – 23 Dec | 51 | 0.0 | 20.3 | 6.0 | 87.4 | 51.3 | 5.8 |
| 24 Dec – 31 Dec | 52 | 0.2 | 18.7 | 4.9 | 92.1 | 54.4 | 5.2 |
| 01 Jan – 07 Jan | 1 | 24.0 | 19.0 | 6.2 | 94.1 | 66.1 | 2.8 |
| 08 Jan – 14 Jan | 2 | 0.0 | 18.8 | 5.7 | 94.9 | 63.6 | 3.9 |
| 15 Jan – 21 Jan | 3 | 0.0 | 18.1 | 7.2 | 93.3 | 62.3 | 3.2 |
| 22 Jan – 28 Jan | 4 | 0.0 | 18.8 | 6.5 | 90.0 | 57.3 | 4.8 |
| 29 Jan – 04 Feb | 5 | 1.1 | 21.6 | 7.1 | 85.7 | 56.0 | 6.2 |
| 05 Feb – 11 Feb | 6 | 5.6 | 23.9 | 7.7 | 86.0 | 55.3 | 7.4 |
| 12 Feb – 18 Feb | 7 | 0.0 | 26.6 | 9.8 | 84.3 | 43.0 | 5.9 |
| 19 Feb – 25 Feb | 8 | 0.0 | 29.4 | 12.0 | 83.3 | 40.4 | 7.8 |
| 26 Feb – 04 Mar | 9 | 0.2 | 30.5 | 14.1 | 76.6 | 41.3 | 9.2 |
| 05 Mar – 11 Mar | 10 | 0.0 | 32.2 | 14.5 | 72.6 | 35.4 | 8.7 |
| 12 Mar – 18 Mar | 11 | 0.1 | 31.6 | 15.7 | 71.0 | 32.9 | 6.6 |
| 19 Mar – 25 Mar | 12 | 0.0 | 32.9 | 16.6 | 75.6 | 38.0 | 6.6 |
| 26 Mar – 01 Apr | 13 | 0.0 | 34.0 | 16.9 | 71.9 | 35.1 | 8.8 |
| 02 Apr – 08 Apr | 14 | 0.0 | 35.0 | 17.8 | 48.6 | 26.6 | 8.4 |
| 09 Apr – 15 Apr | 15 | 0.0 | 38.2 | 19.3 | 37.6 | 22.0 | 9.5 |
| 16 Apr – 22 Apr | 16 | 0.1 | 37.0 | 20.8 | 42.6 | 26.1 | 8.0 |

**Appendix- II**

**Analysis of variance for plant population (No $m^{-2}$)**

| Source of variation | d.f. | Mean Sum of Squares | |
|---|---|---|---|
| | | Initial | At harvest |
| Replication | 2 | 125.2 | 75.3 |
| Treatment | 11 | 183.6* | 1392.3* |
| Error | 22 | 167.8 | 220.6 |

Significant at 5 % level of probability.

## Appendix-III

**Analysis of variance for plant height (cm) at various stages**

| Sources of variation | d.f. | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | 30 DAS | 60 DAS | 90 DAS | 120 DAS | At harvest |
| **Replication** | 2 | 0.06 | 0.5 | 4.5 | 2.4 | 1.7 |
| **Treatment** | 11 | 7.1* | 42.8* | 282.5* | 167.9* | 208.7* |
| **Error** | 22 | 0.4 | 4.5 | 13.6 | 20.1 | 21.3 |

Significant at 5 % level of probability.

## Appendix-IV

**Analysis of variance for number of tillers $m^{-1}$ row length at various stages**

| Sources of variation | d.f. | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | 30 DAS | 60 DAS | 90 DAS | 120 DAS | At harvest |
| **Replication** | 2 | 0.9 | 4.4 | 3.6 | 2.8 | 2.1 |
| **Treatment** | 11 | 17.5* | 202.2* | 85.3* | 66.9* | 70.8* |
| **Error** | 22 | 1.8 | 38.3 | 29.8 | 22.3 | 16.4 |

Significant at 5 % level of probability.

## Appendix-V

**Analysis of variance for dry matter accumulation (g m$^{-1}$) at various stages**

| Sources of variation | d.f. | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | 30 DAS | 60 DAS | 90 DAS | 120 DAS | At harvest |
| **Replication** | 2 | 0.02 | 0.4 | 8.1 | 32.2 | 29.6 |
| **Treatment** | 11 | 1.8* | 185.2* | 2057.7* | 3152.3* | 3315.5* |
| **Error** | 22 | 0.2 | 6.4 | 96.0 | 176.9 | 179.1 |

Significant at 5 % level of probability.

## Appendix-VI

**Analysis of variance for crop growth rate at various stages**

| Sources of variation | d.f. | Mean sum of squares | | | |
|---|---|---|---|---|---|
| | | 30-60 DAS | 60-90 DAS | 90-120 DAS | 120 – At harvest |
| **Replication** | 2 | 0.0065 | 0.102 | 0.037 | 0.022 |
| **Treatment** | 11 | 3.491* | 22.679* | 2.791* | 0.213* |
| **Error** | 22 | 0.094 | 1.159 | 0.330 | 0.142 |

Significant at 5 % level of probability.

## Appendix-VII

**Analysis of variance for relative growth rate at various stages**

| Sources of variation | d.f. | Mean sum of squares | | | |
|---|---|---|---|---|---|
| | | 30-60 DAS | 60-90 DAS | 90-120 DAS | 120 – At harvest |
| **Replication** | 2 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Treatment** | 11 | 0.000* | 0.000* | 0.000* | 0.000* |
| **Error** | 22 | 0.000 | 0.000 | 0.000 | 0.000 |

Significant at 5 % level of probability.

## Appendix-VIII

**Analysis of variance for yield attributes**

| Sources of variation | d.f. | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | Effective tillers $m^{-2}$ | Ear length (cm) | Spikelet's per spike | Grains per spike | Test weight (g) |
| **Replication** | 2 | 115.8 | 0.06 | 0.05 | 0.2 | 0.7 |
| **Treatment** | 11 | 1395.3* | 2.9* | 5.5* | 28.8* | 9.7* |
| **Error** | 22 | 197.8 | 0.4 | 0.7 | 4.0 | 5.5 |

Significant at 5 % level of probability.

## Appendix-IX

**Analysis of variance for yield.**

| Sources of variation | d.f. | Mean sum of squares | | | |
|---|---|---|---|---|---|
| | | Grain | Straw | Biological | Harvest index |
| **Replication** | 2 | 1.0 | 1.8 | 5.7 | 1.0 |
| **Treatment** | 11 | 188.1* | 153.6* | 646.6* | 11.9* |
| **Error** | 22 | 10.4 | 19.4 | 58.3 | 6.5 |

Significant at 5 % level of probability.

## Appendix-X

**Analysis of variance for nitrogen content and uptake in grain and straw as well as total nitrogen uptake**

| Sources of variation | D.f. | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | Nitrogen content | | Nitrogen uptake | | Total uptake |
| | | Grain | Straw | Grain | Straw | |
| **Replication** | 2 | 0.002 | 0.000 | 4.6 | 0.7 | 9.2 |
| **Treatments** | 11 | 0.2* | 0.08* | 1967.8* | 495.9* | 4322.7* |
| **Error** | 22 | 0.01 | 0.001 | 38.7 | 6.1 | 75.6 |

Significant at 5 % level of probability.

# Appendix-XI

**Analysis of variance for phosphorus content and uptake in grain and straw as well as total nitrogen uptake**

| Sources of variation | D.f. | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | phosphorus content | | phosphorus uptake | | Total uptake |
| | | Grain | Straw | Grain | Straw | |
| **Replication** | 2 | 0.000 | 0.000 | 0.02 | 0.01 | 0.08 |
| **Treatments** | 11 | 0.006* | 0.001* | 31.1* | 10.4* | 75.8* |
| **Error** | 22 | 0.000 | 0.000 | 0.4 | 0.2 | 1.2 |

Significant at 5 % level of probability.

# Appendix-XII

**Analysis of variance for potassium content and uptake in grain and straw as well as total nitrogen uptake**

| Sources of variation | D.f. | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | Potassium content | | Potassium uptake | | Total uptake |
| | | Grain | Straw | Grain | Straw | |
| **Replication** | 2 | 0.000 | 0.0005 | 0.2 | 1.7 | 3.3 |
| **Treatments** | 11 | 0.02* | 0.03* | 146.5* | 510.1* | 1163.9* |
| **Error** | 22 | 0.001 | 0.004 | 2.8 | 23.0 | 42.1 |

Significant at 5 % level of probability.

# Appendix-XIII

**Analysis of variance for zinc content and uptake in grain and straw as well as total nitrogen uptake**

| Sources of variation | D.f. | Mean sum of squares | | | | |
|---|---|---|---|---|---|---|
| | | Zinc content | | Zinc uptake | | Total uptake |
| | | Grain | Straw | Grain | Straw | |
| **Replication** | 2 | 1.01 | 0.50 | 25.2 | 19.5 | 88.2 |
| **Treatments** | 11 | 132.0* | 24.1* | 11165.4* | 3580.1* | 27113.9* |
| **Error** | 22 | 8.7 | 3.4 | 250.2 | 178.1 | 849.6 |

Significant at 5 % level of probability.

## Appendix-XIV

**Analysis of variance for Agronomic Efficiency (AE)**

| Sources of variation | d.f. | Agronomic use-efficiency (AE) | | |
|---|---|---|---|---|
| | | Nitrogen (N) | Phosphorus (P) | Potassium (K) |
| **Replication** | 2 | 0.08 | 0.5 | 1.1 |
| **Treatment** | 11 | 129.7* | 811.0* | 1824.9* |
| **Error** | 22 | 1.5 | 9.7 | 21.9 |

Significant at 5 % level of probability.

## Appendix-XV

**Analysis of variance for Physiological use-efficiency (AE)**

| Sources of variation | d.f. | Physiological use-efficiency (PE) | | |
|---|---|---|---|---|
| | | Nitrogen (N) | Phosphorus (P) | Potassium (K) |
| **Replication** | 2 | 0.01 | 7.2 | 0.3 |
| **Treatment** | 11 | 361.0* | 12379.2* | 417.5* |
| **Error** | 22 | 2.5 | 138.7 | 5.9 |

Significant at 5 % level of probability.

## Appendix-XVI

**Analysis of variance for Partial factor productivity**

| Sources of variation | d.f. | Partial factor productivity | | |
|---|---|---|---|---|
| | | Nitrogen (N) | Phosphorus (P) | Potassium (K) |
| **Replication** | 2 | 0.2 | 1.8 | 1.8 |
| **Treatment** | 11 | 535.2* | 3345.3* | 3345.3* |
| **Error** | 22 | 7.0 | 43.8 | 43.8 |

Significant at 5 % level of probability.

# Appendix-XVII

**Analysis of variance for protein content (%) and protein yield (kg ha$^{-1}$)**

| Source of variation | d.f. | Mean Sum of Squares | |
|---|---|---|---|
| | | Protein content (%) | Protein yield (kg ha$^{-1}$) |
| Replication | 2 | 0.05 | 142.0 |
| Treatment | 11 | 7.8* | 61754.2* |
| Error | 22 | 0.4 | 1258.8 |

Significant at 5 % level of probability.

# Appendix-XVIII

**Analysis of variance for physical properties of soil**

| Sources of variation | d.f. | Mean sum of squares | | |
|---|---|---|---|---|
| | | Bulk density (g cc$^{-1}$) | Particle density (g cc$^{-1}$) | Aggregate stability (%) |
| **Replication** | 2 | 0.001 | 0.003 | 1.8 |
| **Treatment** | 11 | 0.001* | 0.000* | 2.04* |
| **Error** | 22 | 0.008 | 0.02 | 12.2 |

Significant at 5 % level of probability.

# Appendix-XIX

**Analysis of variance for organic carbon (%), soil pH and EC**

| Sources of variation | d.f. | Mean sum of squares | | |
|---|---|---|---|---|
| | | Organic carbon (%) | Soil pH | EC (dsm$^{-1}$) |
| **Replication** | 2 | 0.000 | 0.03 | 0.000 |
| **Treatment** | 11 | 0.005* | 0.02* | 0.001* |
| **Error** | 22 | 0.001 | 0.2 | 0.001 |

Significant at 5 % level of probability.

# Appendix- XX

**Effect of doses and sources of nutrient on chemical properties of soil**

| Sources of variation | D.f. | Mean sum of squares Available nutrients | | | |
|---|---|---|---|---|---|
| | | N | P | K | Zn |
| **Replication** | 2 | 15.4 | 0.09 | 8.8 | 0.0005 |
| **Treatments** | 11 | 385.1* | 4.6* | 148.9* | 0.002* |
| **Error** | 22 | 145.1 | 0.6 | 79.7 | 0.003 |

Significant at 5 % level of probability.

# Appendix-XXI

**Analysis of variance for biological properties of soil**

| Sources of variation | D.f. | Mean sum of squares | | |
|---|---|---|---|---|
| | | Bacteria (CFU) | Fungi (CFU) | Actinomycetes (CFU) |
| **Replication** | 2 | 0.0005 | 0.000 | 0.000 |
| **Treatment** | 11 | 0.004* | 0.010* | 0.010* |
| **Error** | 12 | 0.002 | 0.001 | 0.001 |

Significant at 5 % level of probability.

## APPENDIX-XXII

**Details of cost of cultivation during crop period wheat**

| S.No. | Particular | Quantity $ha^{-1}$ | Rate (Rs.) | Total (Rs.) |
|---|---|---|---|---|
| **A** | **Common cost** | | | |
| 1. | **Field preparation** | | | |
| A | Pre sowing irrigation by electrical tube-well+ one Labour | 1 | 600/Irrigation + 290/Labour | 890 |
| c. | One deep ploughing by tractor draw M.B. Plough | 1 | 1700/ha | 1700 |
| d. | cross ploughing by tractor drawn cultivator with planking | 2 | 1250/ha | 2500 |
| e. | Making of bund and channels | 5 | 5x290 | 1450 |
| f. | Layout and seed bed preparation | 6 | 6x290 | 1740 |
| 2. | **Seed and sowing** | | | |
| a. | Cost of seed | 100kg | 3600 | 3600 |
| b. | Cost of sowing | 6 Labour | 6x290 | 1740 |
| **3** | **Irrigation management** | | | |
| a. | Irrigation | 5 | 600/irrigation | 3000 |
| b. | Labour | 10 | 10x290 | 2900 |
| **4** | Weeding | 10 | 10x290 | 2900 |
| 5 | Harvesting | 10 Labour | 10x290 | 2900 |
| 6 | Threshing/cleaning bagging | 13 Labour | 13x290 | 3770 |
| 7 | Threshing | - | - | 3100 |
| 8 | Interest on working capital | - | 6% | 2080 |
| 9 | Land rent for crop | - | 1200/6 month | 1200 |
| 10 | Miscellaneous | - | | 1280 |
| | **Total** | | | **36750** |

## APPENDIX-XXIII

**Details of input and output price during crop period *Rabi season* 2020-21**

| Input price | | Output price | |
|---|---|---|---|
| Urea | 5.9 Rs. /kg | Grain*2020-21 | 1975 Rs. /q |
| MOP | 840 Rs. /50 kg | Straw[@] | 500 Rs. /q |
| DAP | 1200 Rs. /50 kg | | |
| NPK (18:18:18) | 80 Rs. / 1 kg | | |
| Nano-N | 240 Rs. /500 ml | | |
| Bio-nano-Zn | 240 Rs. /250 ml | | |
| NPK Consortia liquid | 60 Rs. / 250 ml | | |
| Bio-stimulant liquid | 135 Rs. / 250 ml | | |
| Labour for nano spray 2 Labour | 2x290=580 | | |

*Note: *Prevailing minimum support price have been considered for economic calculation. Selling price of wheat Rs. 1975/q in 2020-21.@Local price of straw Rs. 500/q*

# ABSTRACT

**Name:** Shikhar Verma
**Id. No.:** 4813
**Degree Programme:** M. Sc.
**Year of Admission:** 2019-20
**Major:** Agronomy
**Minor:** Soil Science and Agricultural Chemistry

**Advisor**. N. S. Rana

**Thesis Title:** "Effect of doses and sources of nutrients on growth, yield and quality of timely sown irrigated wheat (*Triticum aestivum* L .)"

Considering the food and nutritional security concerns and post green revolution's second generation problems i.e. increasing input use with declining efficiency trends, deteriorating soil health, depleting water resources, pollution and narrowing profits at the end of farmers, an investigation "Effect of doses and sources of nutrients on growth, yield and quality of timely sown irrigated wheat (*Triticum aestivum* L .)" was carried out on well drained sandy clay loam soil, low in organic carbon and available nitrogen, medium in available phosphorus, potassium and zinc and moderately alkaline in pH during 2020-21 at crop research centre of SVPUA&T, Meerut (U.P.) Novel nutrient sources and their modes of applications with 12 treatments consisting of control, basal application of recommended 100% NPK (150:60:40), 75% NPK (112.5:45:30) + NPK Consortia seed treatment (250 ml in 3 litre water 60 kg$^{-1}$ seed) + NPK (18:18:18 @15 g l$^{-1}$) + Bio-stimulant (625 ml ha$^{-1}$) + Nano N (4 ml l$^{-1}$) + Nano Zn (10 ml l$^{-1}$) in various combinations were attempted on wheat variety HD 2967 in RBD design with three replications.

The results of the study revealed that wheat grown with 75 % NPK + NPK Consortia + NPK + Bio-stimulant + Nano Zn spray attainted significantly better growth as reflected by taller plants (110.6 cm), more no. of tillers m$^{-1}$ row length (68.9), higher dry matter accumulation g m$^{-1}$ row length (294.0), CGR (5.8 g m$^{-2}$ day$^{-1}$) and RGR (0.0022 g g$^{-1}$ day$^{-1}$) recorded at harvest over RDF as also noticed by Mehta (2017). Yield attributes and yields *viz.* effective tillers m$^{-2}$ (301.0), number of grains spike$^{-1}$ (48.2), test weight (39.1 g), grain yield (55.9 q ha$^{-1}$) and straw yield (71.5 q ha$^{-1}$) were also higher in the crop as against respective value of 272.7, 44.2, 37.6, 49.1 & 71.9 with 100% NPK and 224.0, 37.1, 33.5, 28.3 & 47.9 with control. The crop contained 2.1% N, 0.25% P, 0.54% K and 53.4 ppm Zn in grain and 0.61% N, 0.12% P, 1.20% K and 32.1 ppm Zn in straw. Such crop accumulated 162.3 kg N, 22.8 kg P, 118.6 kg K and 535.1 g Zn ha$^{-1}$. Application of 75% NPK with NPK Consortia + NPK spray, NPK Consortia + NPK + Bio-stimulant spray, NPK Consortia + NPK + Bio-stimulant + Nano Zn spray, NPK Consortia + Nano Zn spray and NPK Consortia + Nano N + Nano Zn spray worked synergistically and increased grain yields by 6.3, 8.9, 13.8, 3.0 and 11.6% respectively over 100% NPK. Respective increase in protein yield was 116.3, 160.4, 250.6, 12.9 and 237.4 kg ha$^{-1}$over 100% NPK. Similar result was also put forward by Sharma *et al.* (2015). Nutrient use efficiency i.e. agronomic efficiency for N, P & K (24.5, 61.3 & 92.0 kg of grain in yield increase kg$^{-1}$of nutrient applied), physiological efficiency for N, P & K (23.4, 156.9 & 37.7 kg of yield increase kg$^{-1}$ of nutrient absorbed) and partial factor productivity for N, P & K (49.7, 124.2 & 186.3 kg of grain kg$^{-1}$ of nutrient applied) was also better under treatment. Soil organic carbon (0.49 %), available N (196.2 kg ha$^{-1}$), available P (11.1 kg ha$^{-1}$), available K (149.1 kg ha$^{-1}$), available Zn (0.86 mg kg$^{-1}$), population of bacteria (0.78 No.×10$^{6}$ cfu g$^{-1}$), fungi (0.67 No.×10$^{4}$ cfu g$^{-1}$) & actinomycetes (0.63 No.×10$^{3}$ cfu g$^{-1}$)) was also higher with the treatment. The crop required an investment of ₹ 44241 ha$^{-1}$ and fetched net return of ₹102763 with B:C ratio of 3.3 with 100 % NPK + Bio-stimulant spray. Similar trend was observed by Kumar *et al.* (2014).

Thus, the wheat crop grown with application of 100 % NPK + Bio-stimulant spray had attained better growth (plant height, no. of tiller, dry matter accumulation, CGR, RGR, yield attributes (effective tillers, ear length, spikelets per spike, grains per spike, test weight) yield (grain, straw and biological), nutrient use efficiency, nutrient content, nutrient uptake, protein content, protein yield and fetched higher net returns with higher B:C ratio. Soil physico-chemical (bulk density, particle density, aggregate stability, EC, pH, organic carbon), available nutrient N, P, K and Zn) and biological properties (bacteria, fungi & actinomycetes).

**(N. S. Rana)**
**Advisor**

**(Shikhar Verma)**
**Author**

# VITAE

*Shikhar Verma, The author of this manuscript was born on the $7^{th}$ September 1998 in village-Rampur Kurmiyan, Post- Narendrapur, District- Sultanpur, Uttar Pradesh. He passed his high school Examination in 2012 with $I^{st}$ division from Swami Vivekanand Vidyashram George Town, Allahabad, Intermediate Examination in 2014 with $I^{st}$ division from National institute of open schooling, Aligarh and Graduated in 2019 with $I^{st}$ division from Chandra Bhanu Gupt Krishi Mahavidyalaya Lucknow. The practical crop production course helped him in a big way in understanding the problems encounter by a farmers and skills to deal with under able guidance of the learned faculty. He had opportunity to interact and work with the farmers during his Rural Work Experience Programme. Thereafter, he joined the SVPUA&T Meerut in the year 2019 through state level competitive examination (UPCATET) for Master' degree with major in Agronomy and minor in Soil Science and Agricultural Chemistry and completed the entire course required for the degree.*

***Permanent Address-***

*Shikhar Verma*
*S/O Rakesh Verma*
*vill.- Rampur Kurmiyan*
*Po.- Narendrapur*
*Distt.- Sultanpur*
*State - Uttar Pradesh*
*PIN CODE- 222302*
*MOBILE NO. - 9695616423*
*E-MAIL –shikharsaurabh@gmail.com*