

**“PERFORMANCE OF WHEAT (*Triticum aestivum* L.) UNDER
FOLIAR APPLICATION OF DIFFERENT NUTRIENTS”**

by

Miss. Shaikh Heena Mukimuddin

(Reg. No. 2021/004)

A Thesis submitted to the
**MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA**

in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRONOMY



DEPARTMENT OF AGRONOMY

**POST GRADUATE INSTITUTE
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MAHARASHTRA, INDIA.**

2024

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or another person to any
other University or Institution
for a Degree or
Diploma

Place : MPKV, Rahuri

Date : / /2024

(Heena M. Shaikh)

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CERTIFICATE

This is to certify that the thesis entitled, **“PERFORMANCE OF WHEAT (*Triticum aestivum* L.) UNDER FOLIAR APPLICATION OF DIFFERENT NUTRIENTS”** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (M.S.) in partial fulfillment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) in AGRONOMY**, embodies the results of a piece of *bona fide* research work carried out by **Miss. SHAIKH HEENA MUKIMUDDIN**, under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

Place : MPKV, Rahuri

Date : / /2024

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CERTIFICATE

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Place : MPKV, Rahuri

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(Heena M. Shaikh)

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LIST OF ABBREVIATIONS

%	:	Per cent
&	:	And
@	:	At the rate of
₹	:	Rupees
°C	:	Degree Centigrade
C.D.	:	Critical difference
cm	:	Centi metre
DAS	:	Days after sowing
dm	:	Decimetre
dSm ⁻¹	:	Deci siemen per meter
EC	:	Electrical conductivity
<i>et al.</i>	:	Et alli (and others)
etc.	:	Et cetera (and so on)
Fig.	:	Figure
FYM	:	Farmyard manure
g	:	Gram (s)
GRDF	:	General recommended dose of fertilizer
g ha ⁻¹	:	Gram per hectare
ha	:	Hectare (s)
ha ⁻¹	:	Per hectare
Hrs	:	Hours
i.e.	:	id est (that is)
K	:	Potassium
K ₂ O	:	Potassium oxide
Kg	:	Kilogram
kg ha ⁻¹	:	Kilogram per hectare
L ⁻¹	:	Per litre
m	:	Metre
m ²	:	Square metre

Max.	:	Maximum
Min.	:	Minimum
Met.	:	Meteorological
mg kg ⁻¹	:	Miligram per kilogram
μ mol m ⁻² s ⁻¹	:	Micromole per square metre per second
N	:	Nitrogen
N.S.	:	Non-significant
No.	:	Number
O.C.	:	Organic carbon
P	:	Phosphorus
pH	:	Puissance de hydrogen
P ₂ O ₅	:	Phosphorus pentaoxide
q ha ⁻¹	:	Quintal per hectare
RBD	:	Randomized block design
RDF	:	Recommended dose of fertilizer
RH	:	Relative humidity
S. Em.±	:	Standard error
SPAD	:	Soil plant analysis development
Temp.	:	Temperature
<i>viz.</i>	:	Videlicet (namely)
Wt.	:	Weight

ABSTRACT

“PERFORMANCE OF WHEAT (*Triticum aestivum* L.) UNDER FOLIAR APPLICATION OF DIFFERENT NUTRIENTS”

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AGRONOMY
2024

Research Guide	:	Dr. B. T. Sinare
Department	:	Agronomy

A field investigation entitled “Performance of wheat (*Triticum aestivum* L.) under foliar application of different nutrients” was conducted in *Rabi* season of 2022-2023 at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.)

The experiment consists of nine treatments of foliar spray of water soluble fertilizers *viz.*, T₁ : GRDF (Control); T₂ : GRDF + Water spray; T₃ : GRDF + Foliar spray of 19:19:19 @ 1 %; T₄ : GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %; T₅ : GRDF + Foliar spray of Urea @ 2 %; T₆ : GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %; T₇ : GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively; T₈ : 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L; T₉ : 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L. The general recommended dose of fertilizer (120:60:40 kg ha⁻¹ N:P₂O₅: K₂O) was applied 50 % RDN + 100 % P₂O₅ and K₂O + 10 t ha⁻¹ FYM as a basal and 50 % N as top dressing through urea, SSP and MOP in treatment T₁ to T₇. Thereafter, foliar application of different fertilizers was done at 25 and 40 DAS, respectively. While, in treatment T₈ and T₉, basal dose application was followed by foliar application of nano urea.

The experiment was laid out in randomized block design (RBD) with three replications. The soil was clay loam in texture, medium in available nitrogen ($190.70 \text{ kg ha}^{-1}$), medium in available phosphorus (17.32 kg ha^{-1}) and high in potassium ($435.58 \text{ kg ha}^{-1}$). The soil was slightly alkaline in reaction (pH 8.17) with electrical conductivity of 0.39 dSm^{-1} . Line sowing of wheat seeds was done on flat beds at spacing of 20 cm between rows.

The results revealed that growth attributing characters *viz.*, plant height (98.1 cm), total number of tillers (102.33) and dry matter plant⁻¹ (15.51 g) at harvest, while, number of functional leaves plant⁻¹ (11.07), leaf area plant⁻¹ (1.66 dm^2), total chlorophyll content (33.47 SPAD) and absorbed PAR readings ($984.67 \mu \text{ mol m}^{-2} \text{ s}^{-1}$) at 90 DAS were recorded significantly maximum with application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % at 25 and 40 DAS, respectively. It was at par with the application of GRDF + Foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % as well as application of GRDF + Foliar spray of 19:19:19 @ 1 %.

With respect of yield attributing characters *viz.* length of panicle (9.87 cm), number of spikelets panicle⁻¹ (16.07), number of grains panicle⁻¹ (45.40), weight of grains panicle⁻¹ (1.89 g) and 1000 seed weight (41.67 g) were recorded significantly the highest with application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % at 25 and 40 DAS, respectively.

Significantly higher grain yield and straw yield (4980 and 6064 kg ha^{-1} , respectively) were obtained with application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % which was at par with application of GRDF + Foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % as well as application of GRDF + Foliar spray of 19:19:19 @ 1 %. The lowest grain yield and straw yield (3742 and 4712 kg ha^{-1} , respectively) were found with application of 50 % RDN + 100 % P and K + 10 t ha^{-1} FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L .

As regards grain quality parameters, protein content of wheat was not influenced significantly due to foliar treatments. While, significantly higher protein content (11.44%) and protein yield (569.71 kg ha⁻¹) was recorded with application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %.

Total uptake of N, P and K (104.93, 28.60 and 79.78 kg ha⁻¹, respectively) and micronutrients viz. Zn, Fe, Cu and Mn (469, 2243, 78 and 1045 g ha⁻¹, respectively) by the grain and straw of wheat crop was recorded significantly the highest with application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % compared to all other treatments. The lowest total NPK uptake was recorded with the treatment of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L.

The gross monetary returns (₹ 133596 ha⁻¹), net monetary returns (₹ 73566 ha⁻¹) and B:C ratio (2.23) was obtained significantly higher with application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % as compared to other treatments. The application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L recorded minimum gross monetary returns, net monetary returns and B:C ratio.

It can be concluded that application of GRDF + two foliar sprays of 19:19:19 @ 1 % or urea @ 1 % along with Phule Liquid Micro Grade II @ 0.5 % or application of GRDF + two foliar spray of 19:19:19 @ 1 % only at 25 and 40 DAS, respectively found beneficial for increase in yield contributing characters, uptake of nutrients, yield and monetary returns of wheat grown in medium deep soil.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second most important cereal crop of India and plays a vital role in food and nutritional security of the country. Wheat is the largest grain crop on this planet. Because of its vast acreage, excellent production and significant position in the world's food grain trade, wheat has been considered as 'King of cereals'. Nearly 55 per cent of the world population depends on wheat for about 20 per cent of calories intake. It is one of the major food grains of the country and a staple food of the people of North India, where people have preference for *chapatti* (Anonymous, 2016). In 100 grams, wheat provides 327 kilocalories of food energy and is a rich source of multiple essential nutrients, proteins, fibres, manganese, phosphorous and niacin. Wheat has 71 per cent carbohydrates and 1.5 per cent fat.

Wheat meets 20 per cent total food calories for human being (Khichar and Nivas, 2007). Wheat has relatively high content of 'niacin' and 'thiamine'. It contains the characteristic substance 'gluten' which helps in providing structural framework for the spongy cellular structure of bread, chapatti and other baked products of bakery. It's 13 per cent protein content is mostly gluten (75-80 % of the protein in wheat) (Shewry *et al.*, 2002). It contains more protein than other cereals.

Mainly three varieties of wheat are grown in India, of which *Triticum aestivum* or bread wheat being the most commonly grown. Major wheat cultivating states of India are Uttar Pradesh, Punjab, Haryana, Rajasthan, Bihar, West Bengal, Assam, etc. The second most common variety is *Triticum durum* or macaroni/pasta wheat which is grown in Madhya Pradesh, Maharashtra, Gujarat, Southern Rajasthan and few locations in Punjab. The third kind, *Triticum dicoccum* or Emmer is rarely grown in the country and is only found to be cultivated in Karnataka, Maharashtra and Tamilnadu that too on very small scale as compared to other varieties. Bread wheat, macaroni wheat and emmer wheat contribute about 85, 10 and 5 per cent, respectively (Anonymous, 2017).

India is the third-largest producer of wheat worldwide. India's production volume of wheat during the *rabi* season 2019-20 was reported over 109 million metric tons (Anonymous, 2021a). The overall area under wheat cultivation in India is 31.45 million hectares with an annual yield of 107.6 million tonne in 2020-21 and an average

productivity of 3507 kg ha⁻¹. In India, Uttar Pradesh is leading wheat growing state with an area of 9.65 million ha (36.6 %) with production of 26.87 million tonne (39.3 %) and productivity of 2785 kg ha⁻¹. It occupied an area of 8.00 lakh ha in Maharashtra, with a yield of 13.05 lakh tonne and a productivity of 1574 kg ha⁻¹ in 2019-20 (Anonymous, 2021b).

Generally, availability of nitrogen, phosphorus and potassium in Indian as well as in Maharashtra soil is abundant but its availability to crops is very low. Low quality seed, soil salinity, water logging, inadequate use of fertilizers, lack of irrigation water, high input prices, low farmer's education and meagre use of micronutrients and organic fertilizers are the major reasons for low wheat production (Khan *et al.*, 1999). The major problem in wheat is low fertilizer efficiency. The supply of nutrients via roots is restricted in some soil condition such as high pH and high lime content. The major fraction of potash fertilizer directly applied to soil gets fixed by the clay fraction and becomes unavailable to crop plants (Ali *et al.*, 2007).

Under such situation foliar fertilizer application is very useful. Foliar fertilizer application has become an established technology to enhance yield and improve quality of crop production. It also improves nutrient utilization and lower environmental pollution through reducing the amount of fertilizers added to soil especially wheat (Yaseen *et al.*, 2010). The efficacy of foliar fertilizer application is higher than that of soil fertilizer application under drought and salinity situations. The reasons for this are because of the supply of the required nutrient directly to the location of demand in the leaves and its relatively quick absorption (e.g., 0.5-2.0 h for N and 10-24 h for K), the independence of root activity and soil water availability (Ghasal *et al.*, 2016).

The role of macro and micronutrients is crucial in crop nutrition and thus important for achieving higher yields. Nitrogen (N), phosphorus (P) and potassium (K), being primary essential nutrients, have prime importance in crop nutrition. Nitrogen is a primary constituent of proteins and all enzymes (Raun and Johnson, 1999). Nitrogen is one of the important components of many organic compounds ranging from proteins to nucleic acid. It is a major part of chlorophyll which is an absorber of light energy required for photosynthesis process. The major function of nitrogen is vegetative growth of plants. Phosphorous plays a vital role in energy transfer and protein metabolism. It is

important structural component of many biochemical compounds including nucleic acids. It is associated with root growth of the plants. Potassium is an important nutrient for synthesis of starch, enzyme activation, opening and closing of stomata. It also takes part in chlorophyll formation, grain development and provides resistance for disease and pest attack in various crops.

Micronutrients have prominent effects on dry matter, grain yield and straw yield in wheat (Asad and Rafique, 2000). Copper plays an important role in the metabolism of N compounds. Manganese, along with Zinc, has an effect on protein biosynthesis by adjusting the activity of peptidases and controlling protein metabolism (Hansch and Mendel, 2009).

Phule Liquid Micro Grade II, is a liquid micronutrient solution developed by Micronutrient Research Scheme, Department of Soil Science and Agricultural Chemistry, MPKV, Rahuri. It contains Fe (2.5 %), Zn (2.0 %), Mn (1 %), Cu (1 %), Mo (0.1 %) and B (0.5 %). These micronutrients are used for all field and fruit crops.

Different methods are used for micronutrient application such as seed priming, soil application and fortification, but foliar application is more beneficial. Water soluble fertilizers that can be dissolved in water and added are easy to control the precise amount of nutrients available to plants. The ultimate goal of fertilizing is to supply plant with the rights amount of nutrients yet at the same time not toxifying the soil via over fertilization. The foliar application of macronutrients caused a significant and/or highly significant effect on some of growth parameters and yield components during the two growing seasons (Abd El-Ghany *et al.*, 2013).

Foliar spray of NPK (19:19:19) at 0.5 per cent improved grain yield of wheat. A favorable balance of macro and micronutrients is also required for optimum crop production (Surve and Bhosale, 2015). Water soluble fertilizer improve Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems. It can be greatly impacted by fertilizer management as well as by soil and plant water management. The objective of nutrient use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop while minimizing nutrient losses from the field. Nitrogen loss is mainly due to leaching,

volatilization and denitrification. Nutrient use efficiency of fertilizers is about 90% when used as foliar application.

Both macro-nutrients and micronutrients are foliar applied in combination with each other, which results in significant increase in crop production. The advantage of foliar application is direct involvement of nutrient into metabolism of the plant tissue, with a very low consumption of energy for transportation within the plant. Another advantage is the opportunity to combine fertilizer application with that of pesticides and in many cases with beneficial synergistic effects. So, when nutrients are not available to plants at specific stage of crop under such situation, the use of water soluble fertilizers through foliar application for enhancing the crop productivity is the best solution.

Foliar fertilization is generally used for better management of nutritional status, growth, to correct deficiencies quickly and improve disease resistance for better crop quality. Foliar application could be considered one of the most common methods, which used to deliver the needed nutrients to plants in adequate concentrations and improve plant nutritional status as well as increase the crop yield and its quality (Smolen, 2012). Foliar fertilization can improve the efficiency and rapidity of utilization of a nutrient urgently required by the plant for maximum growth and yield (Oosterhuis, 1999). Foliar fertilizers are increasingly used in agriculture and new commercial products are continuously released by fertilizer companies because of the increasing demand. There is indeed abundant evidence showing the beneficial effects of applying foliar fertilizers as a complementary strategy to soil treatments in terms of improved plant metabolism, yields and quality of crops. The efficiency of nutrient uptake is 8-9 folds higher when nutrients are foliar applied (Kaushal *et al.*, 2014).

Hence, the experiment entitled “Performance of wheat crop under foliar application of different nutrients” was conducted at Post Graduate Institute Farm, MPKV, Rahuri during *rabi*, 2022-23 with following objectives:

1. To study the effect of foliar nutrition on growth, yield and quality of wheat.
2. To study the effect of foliar nutrition on nutrient uptake in wheat.
3. To workout the economics of various treatments.

2. REVIEW OF LITERATURE

An attempt has been made to review the work done on foliar nutrition on wheat crop.

2.1 Effect of foliar application of different nutrients on growth and yield contributing characters of wheat

Hussain *et al.* (2005) studied the effect of foliar application of plant micronutrient mixture on growth and yield of wheat. A field experiment was conducted to study effect of nutrient mixture plant care sprayed on foliage at different physiological growth stages of wheat. The composition of nutrient mixture was N 200 g, P₂O₅ 200 g, K₂O 200 g, zinc 750 mg, iron 1500 mg, copper 750 mg, boron 300 mg, manganese 750 mg, magnesium 375 mg and molybdenum 8 mg. The results indicated that there was significant improvement in number of grains spike⁻¹ and 1000 grain weight when the nutrient mixture was sprayed on wheat foliage at three growth stages i.e. at tillering, booting and milking.

Talpur (2005) studied the comparative effects of foliar and soil application of zinc on growth and yield of wheat. Zinc applied both foliar and soil treatment significantly increased plant height at flag leaf and harvesting stages. Foliar application @ 0.30 % Zn and soil added Zn @ 5.00 kg ha⁻¹ had non significant difference. Followed by foliar application of Zn @ 0.25 and 0.20 % treatments at flag leaf and harvesting stage. The data regarding 1000 grains weight revealed that foliar application of zinc @ 0.30 % gave significant values of 36.31 g, followed by 35.62 g of soil added zinc, whereas control recorded minimum 33.72 g. Grain, straw and biological yield performed significant increase of 12.86, 11.40 and 12.01 per cent, respectively with foliar application of zinc @ 0.30 % increase over control. Foliar zinc application proved to be the best fertilization practice for getting economically profitable yield, as compared to soil application. It is suggested that foliar application of zinc @ 0.30 % should be used in three equal splits at 30, 40 and 50 days after sowing for getting economically profitable yield.

Arif *et al.* (2006) conducted an experiment on Agricultural Research Farm of Agricultural University, Peshawar during winter 2005-2006. The treatments consist of

control (water spray), spray at tillering (single spray) and spray at jointing (two sprays) and spray at boot stage (three sprays). Significant increase was recorded in number of spikes m^{-2} , grains spike $^{-1}$, thousand grain weight, biological grain yield with three foliar applications of nutrients. It was followed by two foliar sprays which was statistically similar to that of three foliar sprays. It was concluded that three foliar sprays of nutrients at tillering jointing and boot stages along with half of the recommended doses of N and P helped in enhancing yield and yield components of wheat.

Jamal *et al.* (2006) studied the effect of different concentrations of nitrogen, phosphorus and potassium (NPK) i.e., NH_4NO_3 , K_2HPO_4 and KH_2PO_4 on the yield parameters of wheat when applied as both through soil and foliage. The effect of $(\text{NH}_4)_2\text{SO}_4$ through foliar application on same plant was also studied. The number of fertile tillers plant $^{-1}$, spike length, spike diameters, awn length, number of grains spike $^{-1}$ and 1000-grain weight was obtained higher value from foliar + soil applied treatment on average.

Memon *et al.* (2007) conducted an experiment during *rabi* 2003-04 to determine the effect of nitrogen application method on growth and yield of wheat variety TJ-83. Different nitrogen application methods such as broadcasting, drilling and foliar spray were tested. The results revealed that foliar spray of N has greater effect on crop productivity and proved to be most efficient as compared to drilling or broadcast method.

Khan *et al.* (2009) observed the response of wheat to foliar application of urea at different growth stages on yield and yield component of wheat with six concentrations of urea i.e. 0, 2, 4, 6, 8 and 10 per cent as foliar application and it was found that foliar application of urea significantly increased plant height, spike length, number of grains spike, hundred grain weight, biological yield, grain yield and N uptake by the crop. The foliar spray of 4 per cent urea solution was found to be most effective for enhancing the quantitative and qualitative traits when sprayed at tillering, stem elongation and boot stage.

Amal *et al.* (2011) carried out two field experiments to study the response of two wheat cultivars to foliar spray of urea and potassium on growth and productivity at Egypt. Foliar spray of urea and potassium caused significant stimulatory effect on growth parameters. however, foliar feeding with urea 2 % + K_2O 2 % gave the highest significant

values for all growth characters at 65, 90 and 115 days after sowing and for yield contributing characters *viz.* plant height (cm), number of spike m^{-2} , weight of spikes m^{-2} as well as grain, straw and biological yields.

Rahman *et al.* (2014) conducted a field trial to study the response of wheat to foliar application of urea fertilizer at Field Research Site of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur-1706 during November 2011 to March 2012. A non-fertilized control was compared with two foliar fertilized treatments receiving 20 kg ha^{-1} of N in soil at crop emergence and also received foliar spray of 1 and 2 per cent urea in each time at 36, 53 and 68 DAS. SPAD value was taken from middle portion of the latest fully developed leaf of tagged plants at 3 days interval from 36 DAS using Minolta Chlorophyll meter upto 89 DAS. Perusal of the data revealed that significant effect was found in total dry matter production, leaf area index and SPAD values for chlorophyll content. Significant increase was recorded in number of effective tillers m^{-2} , spikelets spike $^{-1}$ and grains spike $^{-1}$ with foliar application of urea @ 2 %. Maximum thousand-grain weight was recorded from 1 % urea spray which was statistically similar to that of 2 per cent urea foliar spray.

Singh and Goswami (2014) reported that the application of zinc @ 7 kg ha^{-1} + application of boron @ 0.25 kg ha^{-1} in soil + foliar spray @ 0.25 kg ha^{-1} recorded the maximum plant height (88.09 cm in 1st year and 90.47 cm in 2nd year) which was followed by the treatment combination zinc @ 7 kg ha^{-1} and foliar spray of boron @ 0.5 kg ha^{-1}) with values of 86.88 and 87.89 cm in 1st year and in 2nd year, respectively and the minimum (82.13 cm in 1st year and 82.88 cm in 2nd year) was recorded with control plot.

Surve and Bhosale (2015) reported that the growth contributing characters of wheat *viz.*, plant count, plant height, number of functional leaves, number of tillers, leaf area and dry matter were found significantly higher in treatment of foliar spray of NPK through 19:19:19 at 0.5 % given at tillering and flowering stage.

Sharma and Singh (2016) conducted an on-farm testing on farmer's fields of Kota district to assess the impact of foliar sprays of water soluble fertilizer on yield and profitability of wheat (*Triticum aestivum* L.) during *rabi* seasons of 2018-19 and 2019-20. This testing consists of RDF ($120:60:40:25 \text{ kg ha}^{-1}$ N: P_2O_5 : K_2O : ZnSO_4) followed by foliar application of NPK 19:19:19 @ 0.5 % at tillering and spike initiation

stages of wheat and a local check with only recommended doses of fertilizers (RDF and no sprays of 19:19:19). Results of two years data revealed the improvement in yield attributes *viz.* number of effective tillers (364 m^{-2}), number of grains ear⁻¹ (42.6) and 1000 seed weight (45.14 g) over local check.

Wagan *et al.* (2017) conducted a field experiment during the year 2013-2014 at Agriculture Chemistry (soil) Section, ARI Tando jam to observe the effect of foliar applied urea on growth and yield of wheat. The experiment was laid out in a three replicated randomized complete block design (RCBD) having net plot size 5m×4m. The wheat variety TJ-83 (Tando Jam-83) was tested against six treatments of foliar applied urea such as (T_1 = control (sole water), T_2 = 1 %, T_3 = 2 %, T_4 =3 %, T_5 = 4 % and T_6 = 5 %). Basal dose of phosphorus @ 84 kg ha^{-1} and nitrogen @ 120 kg ha^{-1} was applied at the time of sowing. The results indicated that the maximum plant height (97.1 cm), number of tillers plant⁻¹ (10.0), spike length (12.4 cm), spikelets spike⁻¹ (22.5), number of grains spike⁻¹ (65.4), grain weight spike⁻¹ (26.4) and 1000 grain weight (73.2 g) was observed in foliar applied urea @ 5 %. The results were statistically significant.

Mehta and Bharat (2019) conducted an experiment on “Effect of integrated use of nano and non-nano fertilizers on yield and yield attributes of wheat (*Triticum aestivum* L.)” at the research farm of Farming System Research Centre of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha during the *rabi* season of 2015-2016. The experimental results revealed that treatment T_7 (100 % NPK + Nano NPK (L) sprays at 20, 30 & 45 DAS @ 3 ml litre^{-1} of water + 2 Nano-K (L) sprays at grain development stage at 110 and 125 DAS @ 4 ml litre^{-1} of water) recorded significant improvement in yield attributes *viz.* number of effective tillers metre⁻¹ row length, length of ear (cm), number of grains per ear and 1000-grain weight (g). Though it was statistically at par with the treatment T_3 (100 % N + 100 % P_2O_5 + 50 % K_2O + 50 % Nano-K (G) @ 31.25 kg ha^{-1} + 2 Nano-K (L) sprays at grain development stage at 110 and 125 DAS @ 4 ml litre^{-1} of water) and T_2 (100 % N + 100 % P_2O_5 + 100 % Nano-K (G) @ 62.5 kg ha^{-1})

Abrol *et al.* (2019) conducted a research trial during *rabi* season of 2015–16 to 2017–18 at Research Farm of Advanced Centre for Rainfed Agriculture, Jammu to study the effect of foliar application of nutrients on crop performance, economics,

resource use efficiency and soil properties in wheat (*Triticum aestivum*. L). The experiment composed of seven treatments (*viz.* control, 0.5 % K foliar spray (KNO_3), 0.5 % K foliar spray (KNO_3) + 0.5 % N foliar spray (Urea), 0.5 % K foliar spray (KCl), 0.5 % K foliar spray (KCl) + 0.5 % N foliar spray (Urea), 0.5 % N foliar spray (Urea), foliar spray of water) was laid out in randomized block design with three replications. Results revealed that all growth and yield attributes, *viz.* plant height (102.8 cm), number of tillers metre^{-1} row (112.4), spike length (9.8 cm), 1000 seed weight (37.25 g) were significantly higher with foliar spray of 0.5 % K (KCl) + foliar spray of 0.5 % N (Urea).

Borse *et al.* (2019) conducted an experiment at Coastal Soil Salinity Research Station, Navsari Agricultural University, Danti during *rabi* seasons of 2016-17 and 2017-18 to study the effect of different levels of fertilizer on yield and nutrient uptake of wheat. Application of FYM @10 t ha^{-1} and higher dose of fertilizer i.e., 120 % RDF (216:108:00 kg NPK ha^{-1}) recorded significantly higher values of the growth parameters like plant height (87.3 and 87.4 cm), total tillers m^{-1} (110.3 and 110.9), yield attributes like effective tillers (105.2 and 106.2), spike length (8.5 and 8.8 cm), number of spikelets spike^{-1} (12.8 and 13.4) and grains spike^{-1} (29.2 and 29.1).

Louhar (2019) studied “Growth and yield attributes of wheat crop in response to application of micronutrients” and stated that micronutrient application substantially improved leaf area index (LAI), leaf area duration, CGR (Crop growth rate), RGR (Relative growth rate), NAR (Net assimilation rate), plant height, spike length, spikelets spike^{-1} , grains spike^{-1} , 1000 seed weight, tillers m^{-2} , and chlorophyll content of wheat.

Muhammad *et al.* (2019) conducted an experiment to test the results of foliar application of micronutrients on growth, quality and yield of three wheat varieties. The trial was performed at Agronomic Research Farm, University of Agriculture Faisalabad. Wheat varieties Jouhar 2016, Ujala 2015 and Gold 2016 were sown. Combination of micronutrient (Zn 2 %, B 0.5 %, Fe 1 %, Mn 1 % and Cu 0.5 %) with different amounts (no spray, water spray, 1000 ml ha^{-1} , 1250 ml ha^{-1} and 1500 ml ha^{-1}) was sprayed at booting stage. Statistically highly significant effect of 1250 ml ha^{-1} spray of micronutrients mixture was observed on plant height (95.33 cm), number of

tillers m^{-1} (107), number of grains spike $^{-1}$ (44.33) and 1000 grain weight (48 g) under Ujala 2015 + 1250 ml ha^{-1} micronutrients.

Yadav *et al.* (2019) conducted experiments and they noted that the foliar application of fertilizers helps in increasing leaf area and vegetative growth of plant because it improved many physiological growth processes.

Yadav *et al.* (2021) conducted an experiment entitled “Effect of foliar application of different nutrients on growth and yield of wheat (*Triticum aestivum* L.) under sodic soil” at main experiment station, Acharya Narendra Dev University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) during *rabi* season - 2017-18. All the foliar application of nutrients increased the growth characters *viz.*, plant height (cm), number of tillers m^{-2} , dry weight plant $^{-1}$ and found significantly superior with foliar application of 0.7% zinc sulphate at all the stages of crop over control. Yield characters *viz.*, length of spike (10.5 cm), number of grains spike $^{-1}$ (45.10), number of grains plant $^{-1}$ (40.20) were recorded significantly higher with foliar application of 0.7 % zinc sulphate followed by foliar application of 0.3% of potassium nitrate over control.

Dhaker *et al.* (2022) conducted a field experiment at Agricultural Research Station, Kota, Rajasthan, during *rabi* season of 2021-2022 to assess the effect of nutrient management on growth and productivity of wheat (*Triticum aestivum* L.) under rice-based cropping system. The treatment consisted of eight nutrient levels and combinations *viz.*, 100 % RDF, RDF + FYM, 125 % RDF, 150 % RDF, RDF + Zn, RDF + S, RDF + Zn + S and RDF + Foliar sprays of NPK. Results indicated that maximum plant height, Number of effective tillers m^{-1} length, dry matter accumulation, CGR, earhead length, number of grains earhead $^{-1}$ and 1000 seed weight with application of 150 % RDF. It was significant among all other treatments. However, 125 % RDF, RDF + FYM and RDF + Zn + S treatments found at par with it. Further, applications of RDF + Zn + S, RDF + Zn and RDF + S as well as RDF + foliar sprays of NPK 19:19:19 also enhanced the growth and productivity of wheat as compared to 100 % RDF.

Nitharwal *et al.* (2022) investigated field experiment at Instructional Farm, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *rabi* season of 2019-20 to find out the influence of different levels and methods of N P K fertilizer application on the growth and production of wheat (*Triticum aestivum* L.) in Arid Region

of Rajasthan. The treatment consisted of four fertility levels in main plot, viz. F_0 - control, F_1 - 50 % recommended dose of fertilizer (RDF), F_2 - 75 % recommended dose of fertilizer (RDF), F_3 - 100 % recommended dose of fertilizer (RDF) and five foliar fertilization with soluble N P K in the sub plot viz. S_0 - control (no spray), S_1 - one spray (60 DAS), S_2 - two spray (45 and 60 DAS), S_3 - three spray (45, 60 and 75 DAS), S_4 - four spray (45, 60, 75 and 90 DAS). Results indicated that application of 100 % RDF and three foliar spray of NPK produced significantly higher growth and yield attributes like plant height, dry matter accumulation, effective tillers, spike length, number of grains spike⁻¹ and 1000 seed weight of wheat.

2.2 Effect of foliar application of different nutrients on yield of wheat

Emam and Borjian (2000) conducted research trial on two winter wheat cultivars (Phalat and Marvdasht) and five levels of foliar urea application (0, 8, 16, 24 and 32 kg N ha⁻¹) at three times of application (pre-anthesis, anthesis and post-anthesis). The results revealed that cultivars responded differently to the rate of foliar N feeding so that, over the growth stages, Marvdasht cultivar produced significantly greater grain yield (+19 %) by application of 8 kg N ha⁻¹, whereas, the Phalat cultivar had greater grain yield (+27 %) when it was supplied by 16 kg N ha⁻¹. Increase in grain yield was mainly due to an increase in number of grains ear⁻¹. The fertile ears m⁻² and mean grain weight were not significantly affected by foliar urea feeding; however, the harvest index and biological yield were increased. The pre-anthesis foliar feeding with urea resulted in higher yields as compared with later applications. Also, the early foliar urea feeding increased the harvest index from 42.4 to 46.9 per cent at 32 kg N ha⁻¹ in Marvdasht cultivar.

Muhammad *et al.* (2006) conducted experiment to evaluate the effect of foliar application of macro and micronutrients on yield and yield components of wheat. The results revealed that significant increase in grain yield with foliar application of nutrients. Maximum grain yield of 2752.7 kg ha⁻¹ was produced by two sprays at jointing stage (The nutrient solution consisted of N, P and K at the rate of 100 g L⁻¹ and all micro nutrients at the rate of 0.8 g L⁻¹ where combination of nutrients solution was applied at the rate of 25 L ha⁻¹ at jointing stage) and was at par with foliar spray of same nutrient combination thrice at booting stage (2642 kg ha⁻¹). While, the minimum grain yield (1695 kg ha⁻¹) and straw yield (3997 kg ha⁻¹) was produced by water spray. Similarly maximum

thousand grain weight (46 g) and grain yield (2950 kg ha⁻¹) were recorded in plots sprayed with 0.5 % N + 0.5 % K + 0.5 % Zn solution (twice), followed by the lowest values (36 g) and (1450 kg ha⁻¹) in plots having no spray (control).

Khan *et al.* (2009) conducted field experiment during two growing seasons to study the effect of foliar feeding of iron, zinc and potassium on grain yield and protein percentage of bread wheat. Results indicated that the combination of the foliar applications of Fe and Zn increased grain yield and straw yield.

Habib (2009) reported that foliar application of Zn and Fe increased seed yield and quality compared with control in wheat. The treatments were control (no Zn and Fe Application), 150 g Zn ha⁻¹ as ZnSO₄, 150 g Fe ha⁻¹ as Fe₂O₃, and a combination of both Zn and Fe. Among treatments, application of (Fe + Zn) obtained the highest seed yield. Results showed that foliar application of Zn and Fe increased seed yield compared with control.

Khan *et al.* (2010) reported that application of commercial micronutrients mixture Shelter (Zn - 2 %, Fe - 1 %, Mn - 2 % Cu - 1 % and B - 1 %) at tillering + booting + jointing stages of wheat significantly increased the straw yield (7016 kg ha⁻¹), and biological yield (10885 kg ha⁻¹) and maximum grain yield (4237 kg ha⁻¹) as compared to control.

Hasina *et al.* (2011) investigated to quantify the response of yield and yield component of wheat toward foliar spray of nitrogen, potassium and zinc at Agricultural Research Farm, Khyber Pakhtunkhwa Agricultural University, Peshawar during 2002-2003. Yield and yield component of wheat showed significant response towards foliar spray of nitrogen, potassium and zinc. Maximum grain yield (2925 kg ha⁻¹), straw yield (6074 kg ha⁻¹) and biological yield (8999 kg ha⁻¹) were produced in plots under the effect of foliar spray of 0.5 % N + 0.5 % K + 0.5 % Zn solution (once), while control (no spray) plots produced minimum grain yield (1450 kg ha⁻¹), straw yield (3997 kg ha⁻¹) and biological yield (5447 kg ha⁻¹).

Muaid *et al.* (2014) observed that a phosphite based product, Nutri-phite (3 % N, 8.7 % P, and 5.8 % K) was used as model phosphite formulation for foliar application in winter wheat increased grain yield by Nutri-phite treatments.

Rahman *et al.* (2014) studied the response of wheat to foliar application of urea fertilizer by performing an experiment at Field Research Site, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur-1706 during November, 2011 to March, 2012. Three fertilizer treatments were maintained in the 3m × 2m experimental plots in a Randomized Complete Block Design (RCBD) with four replications. A non-fertilized control was compared with two fertilized treatments receiving 20 kg ha⁻¹ of N in soil at crop emergence plus supplementary nitrogen which was applied as follows, two treatments plots were applied via foliar spray 1 % (FN₃₈ = 38 kg N ha⁻¹) and 2 % (FN₇₇ = 77 kg N ha⁻¹) urea in each time at 36, 53 and 68 DAS. From the results, it was concluded that foliar spray of 1 % urea solution at tillering, jointing and booting stages along with 20 kg ha⁻¹ of N at crop emergence helped in enhancing yield and yield components of wheat.

Singh and Goswami (2014) concluded that the application of zinc and boron in combination of zinc @ 7 kg ha⁻¹ and boron @ 0.25 kg ha⁻¹ foliar spray obtained maximum grain yield (51 q ha⁻¹) and straw yield (75 q ha⁻¹). This increase in yield with increasing dose of zinc and boron might be due to increased photosynthetic efficiency and carbohydrate metabolism resulting in superior vegetative growth and yield attributes.

Amanullah *et al.* (2015) reported that out of 80 kg N ha⁻¹ applied in the form of urea, 70 kg N ha⁻¹ was applied to the soil at sowing time, and the remaining 10 kg N ha⁻¹ was applied in the form of foliar spray (2 % N). The required foliar N was applied in various combinations (splits) at different growth stages *viz.* 30, 60, 90 and 120 days after emergence (DAE). Phenological development (days to anthesis and physiological maturity) was delayed, yield components and yield increased significantly with foliar N over control (water spray without N). Wheat grain yield increased to the highest level (4427 kg ha⁻¹) when 100 % foliar N was applied (no split) at 90 DAE, followed by 4050 kg ha⁻¹ at 120 DAE, while the control (no foliar N) resulted in the lowest grain yield (2573 kg ha⁻¹). The results concluded from this study that 2 % foliar N application in a single split either at 90 or 120 DAE could improve wheat productivity under dry land condition.

Sabir *et al.* (2015) reported that the both soil application and foliar spray of ZnSO₄ significantly increased grain yield, straw yield and biological yield while its

effect on harvest index was not significant. Foliar spray of 0.5 and 1.0 % ZnSO_4 increased grain yield by 10 and 18.8 per cent, respectively.

Latief *et al.* (2015) conducted a field experiment to study the “Yield and nutrient uptake of wheat (*Triticum aestivum* L) as influenced by different levels of nitrogen and foliar spray of nutrient mixture” during *rabi* season of 2007-2008 and 2008-2009 at Crop Research Farm, Department of Agronomy, Allahabad Agricultural Institute, Allahabad. The results showed that the highest grain and straw yield was recorded with application of 120 kg N ha^{-1} and foliar spray of 2 % Diammonium phosphate (DAP) + 1 % KCl + nutrient mixture whereas the lowest value was recorded with application of 30 kg N ha^{-1} and foliar spray of 2 % DAP + 1 % KCl + 100 ppm maleic hydrazide. Different nitrogen levels and foliar spray of nutrient mixture did not influence harvest index significantly. The interaction effect between nitrogen levels and foliar spray of nutrient mixture was found significant for grain, straw and biological yield with combination of 120 kg N ha^{-1} and foliar spray of 2 % DAP + 1 % KCl + nutrient mixture resulted in the highest grain (49.20 q ha^{-1}), straw (78.10 q ha^{-1}) and biological yield (123.20 q ha^{-1}).

Surve and Bhosale (2015) observed that higher grain yield (37.55 q ha^{-1}) and protein content (12.81 %) was obtained due to the foliar spray of 0.5 % NPK (19:19:19) at tillering and flowering.

Ali *et al.* (2016) reported that the application of NPK by foliar treatment, significant increase was seen in grain yield, biological yield and straw yield. Harvest index of wheat was not influenced significantly by given treatments. The grain yield increase was mainly due to increase in grain number with no significant change in mean grain weight.

Bhujade *et al.* (2016) observed that the yield of wheat was significantly influenced due to the application of Zn. Significantly, higher grain yield (33.44 q ha^{-1}) and straw yield (69.36 q ha^{-1}) were recorded due to soil application of $\text{ZnSO}_4 @ 50 \text{ kg ha}^{-1}$ with two foliar sprays of $\text{ZnSO}_4 @ 0.5 \%$ over control.

Ghasal *et al.* (2016) conducted field experiment during winter season of 2013-14 at Indian Agriculture Institute, New Delhi to find out the effect of zinc (Zn) fertilization on concentration and uptake of macro and micro-nutrients in high-yielding wheat varieties. Their findings revealed that among the Zn-fertilization treatments, an

application of $1.25 \text{ kg Zn ha}^{-1}$ through EDTA + 0.5 % foliar spray was found superior and resulted in the maximum grain yield, which was at par to that rest of treatments except the control.

Sharma (2016) demonstrated the effect of foliar spray of nitrogen, phosphorus and potassium on grain yield of wheat during *rabi* 2010-11 at farmer's fields in Transitional Plain of Luni Basin of Rajasthan and revealed that yield enhancement due to foliar fertilization ranged between 9.88 per cent with urea to 16.83 per cent with soluble NPK. The foliar spray of DAP, KCl, K_2SO_4 and KNO_3 enhanced wheat grain yield by 12.62, 12.08, 13.67 and 14.13 per cent, respectively.

Sharma and Singh (2016) conducted a research trial on foliar spray of water soluble fertilizers at Kota district to assess the impact of foliar sprays of water soluble fertilizer on yield and profitability of wheat during *rabi* seasons of 2018-19 and 2019-20 and revealed RDF + two foliar application of NPK 19:19:19@ 0.5 % that at tillering and spike initiation stages recorded 8.30 per cent enhancement in grain yield over local check (48.99 q ha^{-1}).

Khattak *et al.* (2017) conducted a research trial at Agricultural Research Institute, D.I. Khan, Khyber Pakhtunkhwa (KP), Pakistan during *rabi* 2013-14. The major aims of the study were to test the effect and economics of soil vs. foliar applied nitrogen fertilizer and nitrogen use efficiency on wheat variety Hashim-08. Fertilizer applications (foliar and soil) were assigned to main plots, while nitrogen levels 0, 24, 36, 48, 60 and 120 kg ha^{-1} were kept in sub plots. Results revealed that foliar application of N @ 120 kg ha^{-1} recorded maximum plant height (89 cm), number of tillers m^{-2} (313), grains spike⁻¹ (48), 1000-grain weight (43.0 g) and economic yield (3760 kg ha^{-1}).

Wagan *et al.* (2017) conducted a field experiment during the year 2013-2014 at Agriculture Chemistry (soil) Section ARI Tando jam to observe the effect of foliar applied urea on growth and yield of wheat. The experiment was laid out in three replicated randomized complete block design (RCBD) having net plot size $5\text{m} \times 4\text{m}$. The wheat variety TJ-83 (Tando Jam-83) was tested against six treatments of foliar applied urea such as (T_1 = Control (sole water), T_2 =1 %, T_3 = 2 %, T_4 =3%, T_5 =4%, and T_6 =5 %). Results concluded that the maximum grain yield (5774 kg ha^{-1}) and straw yield (6275 kg ha^{-1}) was observed in foliar sprays applied urea 5%. The minimum grain yield (4920 kg ha^{-1}) was observed in foliar sprays applied urea 5%.

ha⁻¹) and straw yield (5420 kg ha⁻¹) was observed under the control treatment (Sole water).

Borse *et al.* (2019) conducted a field trial at Coastal Soil Salinity Research Station, Navsari Agricultural University, Danti during *rabi* seasons of 2016-17 and 2017-18 to study the effect of different levels of fertilizer on yield and nutrient uptake of wheat. Based on pooled results of two years it was revealed that the application of 120% RDF (216:108:00 kg NPK ha⁻¹) treatment registered significantly the highest grain yield (3896 kg ha⁻¹) and straw yield (5323 kg ha⁻¹) than rest of fertilizer levels.

Mehta and Bharat (2019) studied “Effect of integrated use of nano and non-nano fertilizers on yield and yield attributes of wheat (*Triticum aestivum* L.)” at the research farm of Farming System Research Centre of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha during the *rabi* season of 2015-2016. The experimental results revealed that treatment T₇ (100 % NPK + Nano NPK (L) sprays at 20, 30 and 45 DAS @ 3 ml litre⁻¹ of water + 2 Nano-K (L) sprays at grain development stage at 110 and 125 DAS @ 4 ml litre⁻¹ of water) recorded significantly higher grain yield (44.45 q ha⁻¹), straw yield (55.99 q ha⁻¹) and harvest index (44.25 %). It was concluded that treatment T₇ (100 % NPK + Nano NPK (L) sprays at 20, 30 and 45 DAS @ 3 ml/litre of water + 2 Nano-K (L) sprays at grain development stage @ 4 ml/litre of water 115 and 125 DAS) was the best treatment in increasing the grain yield of wheat.

Muhammad *et al.* (2019) tested the result of foliar application of micronutrients on growth, quality and yield of three wheat varieties at Agronomic research area, University of Agriculture Faisalabad. Wheat varieties Jouhar 2016, Ujala 2015 and Gold 2016 were sown. Combination of micronutrient (Zn 2 %, B 0.5 %, Fe 1 %, Mn 1 % and Cu 0.5 %) with different amounts (no spray, water spray, 1000 ml ha⁻¹, 1250 ml ha⁻¹ and 1500 ml ha⁻¹) was sprayed at booting stage. Results documented the significant higher yield i. e. grain yield (5336.3 kg ha⁻¹) and biological yield (12829 kg ha⁻¹) under Ujala 2015 + 1250 ml ha⁻¹ micro nutrients spray.

Abrol *et al.* (2019) studied the effect of foliar application of nutrients on crop performance, economics, resource use efficiency and soil properties in wheat (*Triticum aestivum* L.) during *rabi* season of 2015-16 to 2017-18 at research farm of

Advanced Centre for Rainfed Agriculture, Jammu. Among all other treatments, they found that the highest grain (2198 kg ha^{-1}) and straw yield (3430 kg ha^{-1}) were obtained with foliar application of 0.5 % K (KCl) + 0.5 % N (urea) in addition to 100 % RDF soil application.

Yadav *et al.* (2021) investigated the effect of foliar application of different nutrients on growth and yield of wheat (*Triticum aestivum* L.) under sodic soil at main experiment station, Acharya Narendra Dev University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) during *rabi* season - 2017-18. Results indicated that the significant grain yield (48.50 q ha^{-1}), 1000 seed weight (38.26g) and harvest index (29.80 %) with foliar application of 0.7 % zinc sulphate followed by foliar application of 0.3 % of potassium nitrate over control.

Dhaker *et al.* (2022) assessed the effect of nutrient management on growth and productivity of wheat (*Triticum aestivum* L.) under rice-based cropping system at Agricultural Research Station, Kota, Rajasthan, during *rabi* season of 2021-2022. The treatment consisted of eight nutrient levels and combinations *viz.*, 100 % RDF, RDF + FYM, 125 % RDF, 150 % RDF, RDF + Zn, RDF + S, RDF + Zn + S and RDF + Foliar sprays of NPK. Among all these treatments, application of 150 % RDF produced significantly higher grain yield, straw yield and biological yield. However, it was at par with RDF + FYM, 125 % RDF, RDF + Zn + S. RDF + Zn and RDF + foliar spray of NPK 19:19:19 treatments. All these treatments as well as RDF + S recorded significantly higher grain yield, straw yield and biological yield over 100 % RDF.

Nitharwal *et al.* (2022) carried out a field experiment to find out the influence of different levels and methods of N P K fertilizer application on the growth and production of wheat (*Triticum aestivum* L.) at Instructional Farm, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *rabi* season of 2019-20. Significantly, the maximum grain yield, straw yield, biological yield and harvest index recorded under the application of 100 % RDF and three foliar spray of NPK as compared to other treatments.

2.3 Effect of foliar application of different nutrients on quality of wheat

Kharub *et al.* (2002) conducted experiments to study the effect of liquid fertilizers on productivity and quality of the wheat. The liquid fertilizers polyfeed, polywheat and multi K were applied with different doses, time and fertilizer combinations (12 treatments). The grain and straw yield were at par with the application of these fertilizers and also with different doses (2 %). Nutrient response (grain/kg NPK) was comparable in 75 % of recommended fertilizer + liquid fertilizer (polyfeed + polywheat and polyfeed + multi K) with recommended dose. Maximum protein content (13.52 %) was recorded in polyfeed + multi K (2 %) two sprays after heading, which was significantly higher than recommended fertilizer dose (12.76 %). Among liquid fertilizers polyfeed + multi K was superior to polyfeed + polywheat.

Sadaphal and Das (2002) reported that spraying urea resulted in considerable increase in both crude and true protein content. Spraying urea resulted in considerable increase in both crude and true protein contents, the response in protein to different concentrations being linear at all the three frequencies. Increase in total protein content was largely due to that in the true protein fraction. The range of increase in protein varied from 18 to 34 per cent. Spraying after blooming was more efficient than at heading or at blooming for enhancing the rate of accumulation of protein in grain. Increase in protein yield per acre due to N sprays ranged from 24 to 60 per cent. Increase in gluten followed the pattern of protein and were of the order of 53 to 70 per cent. Gluten constituted 70 per cent of crude protein and 80 per cent of true protein in non-sprayed wheat and 82 per cent of crude protein and 90 per cent of true protein in N sprayed wheat.

Boris and Zlatko (2006) reported that late foliar application of urea (30 kg N ha⁻¹) treatment around flowering at low (67 kg N ha⁻¹) and high (194 kg N ha⁻¹) basal N fertilization rates. Late foliar application of urea improved grain quality at both low and high N rates by an average of 5 g kg⁻¹ (4.5 %) for protein content.

Burhan (2008) revealed that the late season nitrogen application influences the protein content of wheat under different ecological condition.

Yaseen *et al.* (2010) investigated the influence of foliar spraying with urea (1 %) and different treatment of micronutrients (Fe, Zn, Mn) on growth and chemical

constituents of wheat yield at Qualubia Governorate, Egypt. Concerning the interaction effect between spraying additional nitrogen and micronutrients, results revealed marked positive effect. Spraying manganese in combination with spraying 1 % urea gave the highest grain yield (2.98 t/fed.) as compared with the other treatments. Biological yield increases ranged between 12 to 35 per cent over control treatment. The lowest increment (12 %) resulted from spraying plants with iron, whereas, the highest (35 %) was obtained from spraying the plants with the mixture of the three nutrients (Fe + Zn + Mn).

Blandino *et al.* (2015) studied the effect of N fertilization was evaluated on two common wheat (*Triticum aestivum* L.) and two durum wheat (*Triticum durum*) cultivars. Late-season N was soil-applied (40 kg N ha⁻¹) as ammonium nitrate at heading and foliar sprayed (5 kg N ha⁻¹) at flowering and compared with a control (without N fertilization) after the vegetative growth stage. Nitrogen soil application increased grain protein content (GPC) (+15 %) for both crops.

Sabir *et al.* (2015) reported that the treatments receiving ZnSO₄ as 5 kg ha⁻¹ soil application + 1.0 % foliar spray, 15 kg ha⁻¹ soil application + 1.0 % foliar spray and 5 kg ha⁻¹ soil application + 0.5 % foliar application recorded 29.5, 29.0 and 27.5 per cent higher protein contents, respectively over the control.

Borse *et al.* (2019) studied the effect of different levels of fertilizer on yield and nutrient uptake of wheat at Coastal Soil Salinity Research Station, Navsari Agricultural University, Danti during *rabi* seasons of 2016-17 and 2017-18 to study and reported that fertilizer levels remarkably affect the protein content in grain, 120 % RDF treatment noted significantly higher protein content (11.40 %). The improvement in protein content in grain was owing to increase in N content in grain due to enhanced availability of this nutrient and improved soil environment with fertilizer application.

Muhammad *et al.* (2019) studied the foliar application of micro nutrients on growth, quality and yield of three wheat varieties and revealed that the treatment V₂F₄ (Ujala 2015 + 1250 ml ha⁻¹ micro nutrients) recorded statistically the highest protein contents (11.4 %). Minimum protein percentage (9.0 %) was recorded under treatment of V₃F₁ (Gold 2016 + control) that is statistically similar with treatment V₁F₁ (Jouhar 2016 + control). In case of carbohydrate, maximum concentration (63.7 %) was found in treatment V₂F₄ (Ujala 2015 + 1250 ml ha⁻¹ micro nutrients) followed by V₃F₄ (Gold 2016

+ 1250 ml/ha micro nutrients) that is obtained (63.1 %) carbohydrates. On the other hand, the statistically the lowest carbohydrates concentration was gathered under treatment V_3F_1 (Gold 2016 + control) that is statistically at par with treatments V_1F_1 (Jouhar 2106 + control) and V_2F_1 (Ujala 2015).

2.4 Effect of foliar application of different nutrients on nutrient uptake

Khan *et al.* (2009) observed that N concentration within the plant leaves increased by increasing N concentration by foliar applications. The maximum N concentration in leaves after 72 hours was recorded when 10 per cent urea spray was applied which was 5.67 per cent. The N concentration in plant leaves was 5.61 per cent after 48 hours and 5.57 per cent after 24 hours at said level of foliar application. Minimum absorption of N was noted in plants when sprayed only with water having no urea.

Yaseen *et al.* (2010) conducted a field trial at Qualubia Governorate, Egypt to investigate the influence of foliar spraying with urea (1 %) and different treatment of micronutrients (Fe, Zn, Mn) on growth and chemical constituents of wheat yield. Results showed that additional nitrogen foliar spray (1 % urea) gave significant increase in nitrogen concentration and uptake in both grain and straw as compared with the control. Results also revealed that spraying wheat plant with (1 % urea) showed marked increment in micronutrients concentration and uptake. Concerning the effect of spraying micronutrients foliar spray and the interaction, results showed positive marked effects on all the parameters in addition to the significant increment of in nutrient uptake.

Saleem *et al.* (2013) observed that soil application of urea was compared with 1 % spray of urea (6 sprays, from 2 leaves to booting stage), 2 % spray of urea (at two leaves, tillering and booting stage), 3% spray of urea (at tillering and booting stage) and urea as soil application + 2 % spray of urea (at tillering and booting stage). Concentration and uptake of nitrogen increased in grain by foliar application of urea as compared to soil application at sowing due to efficient mobilization of nitrogen to grain after foliar fertilization.

Muaid *et al.* (2014) reported that grain P concentration of plots treated with two applications of Nutri-phite ranged from 13 to 55 per cent more than the non-treated. Grain P uptake was increased due to application of Nutri-phite. It increased grain

P concentration by 11.6 per cent. The higher grain P concentration of plots treated with Nutri-phite compared to the other treatments clearly demonstrates its potential in improving P status of wheat grain.

Surve and Bhosale (2015) reported that total nitrogen uptake of wheat was significantly highest ($119.12 \text{ kg ha}^{-1}$) in the treatment receiving 2 % foliar spray of urea. The total phosphorous uptake was higher (23.80 kg ha^{-1}) in treatment of foliar spray of NP through 12:61:00 at 0.5 %. The total potassium uptake was recorded significantly the highest ($123.18 \text{ kg ha}^{-1}$) in the treatment foliar spray of K through 0:0:50 at 0.5 %.

Ghasal *et al.* (2016) conducted field experiment during winter season of 2013-14 at Indian Agriculture Institute, New Delhi to find out the effect of zinc (Zn) fertilization on concentration and uptake of macro and micro-nutrients in high-yielding wheat varieties. Results indicated that the highest N (2.28 %), P (0.359 %), K (0.48 %), Zn (40.6 mg kg^{-1}), Fe (124.8 mg kg^{-1}) and Mn (33.7 mg kg^{-1}) contents were registered in grain of 'HD 2967', 'HD 2967', 'HD 2687', 'HD 2851', 'HD 2687' and 'HD 2894', respectively. The concentration of macro and micro-nutrients was recorded statistically identical in different treatments of Zn fertilization. However, significant increase in macro and micro-nutrients uptake was registered due to Zn fertilization and the highest uptake of nutrients was recorded with application of $1.25 \text{ kg Zn ha}^{-1}$ through Zn-EDTA + 0.5 % foliar spray of Zn-EDTA at maximum tillering and booting stages. Thus, soil ($1.25 \text{ kg Zn ha}^{-1}$) + foliar (0.5 %) application of Zn-EDTA was found superior with respect to macro and micro-nutrients uptake.

2.5 Economics

Khan *et al.* (2009) observed that the maximum net income and B:C ratio recorded where foliar nutrition of fertilizers was exogenously applied at different growth stages of wheat and observed increase in B:C ratio due to foliar nutrition of fertilizers.

Muhammad *et al.* (2010) recorded maximum net income ($\text{₹ } 58384 \text{ ha}^{-1}$) and B:C ratio (2.97) where shelter was exogenously applied at four growth stages of wheat compared with that of control. The increase in B:C ratio due to foliar application of shelter at four growth stages is supposed to be due to enhanced grain yield markedly.

Sharma (2016) conducted economic analysis for the experiment of foliar spray of nitrogen, phosphorus and potassium on grain yield of wheat during *rabi* 2010-

11. From this, he concluded that the application of K_2SO_4 and KNO_3 enhanced grain yield by 13.67 and 14.13 per cent, respectively but these two fertilizers were not found economical because of the higher cost of chemicals. Therefore, foliar spray of soluble NPK, DAP, urea and KCl at tillering and flowering stages may be promoted along with farmer's practice for enhancing the wheat productivity in Rajasthan.

Sharma and Singh (2016) analyzed the economics of different foliar treatments of 19:19:19 @ 0.5 % at tillering and spike initiation stage of wheat and revealed that foliar application of water soluble 19:19:19 @ 0.5 % in wheat provided higher net returns over local check during both the years. Additional cost of two foliar sprays of NPK 19:19:19 work out to be ₹ 2960 ha⁻¹ which in turn fetched additional returns of ₹ 9403 ha⁻¹ with B:C Ratio (3.18). This treatment fetched average net returns of ₹ 67554 ha⁻¹ which represents 10.24 per cent increase over local check (₹ 61112 ha⁻¹).

Khattak *et al.* (2017) studied effect of soil application and foliar application of nutrients on wheat and discovered that comparing the value cost ratios (VCR) for the treatments showing higher grain yield and protein content, the VCR for 5 kg ha⁻¹ $ZnSO_4$ as soil + 1.0 % $ZnSO_4$ as foliar (10.23) was three times higher than the VCR for 15 kg ha⁻¹ $ZnSO_4$ as soil + 1.0 % $ZnSO_4$ as foliar (3.46), thus confirming the superiority of the former over the latter in terms of effectiveness.

Borse *et al.* (2019) conducted at Coastal Soil Salinity Research Station, Navsari Agricultural University, Danti during *rabi* seasons of 2016-17 and 2017-18 to study the effect of different levels of fertilizer on yield and nutrient uptake of wheat. On the basis of pooled results, it was confirmed that the net returns ha⁻¹ (₹ 51569 and ₹ 51468) and BCR (2.28 and 2.29) were maximum under FYM @ 10 t ha⁻¹ and 120 % RDF treatments, respectively as compared to other treatments.

Abrol *et al.* (2019) conducted an investigation during *rabi* season of 2015–16 to 2017–18 at research farm of Advanced Centre for Rainfed Agriculture, Jammu to study the effect of foliar application of nutrients on crop performance, economics, resource use efficiency and soil properties in wheat (*Triticum aestivum*. L). From the economics of all treatments, it revealed that 0.5 % K foliar spray (KCl) + 0.5 % N foliar spray (Urea) recorded the highest net returns (₹ 29008 ha⁻¹) and B:C ratio (2.45) than other treatments.

Dhaker *et al.* (2022) assessed the effect of nutrient management on growth and productivity of wheat (*Triticum aestivum* L.) under rice-based cropping system at Agricultural Research Station, Kota, Rajasthan, during *rabi* season of 2021-2022. Economic evaluation revealed that maximum net return was obtained with the application of 150 % RDF treatment (₹ 106464 ha⁻¹) due to greater yield advantage, however, it was not significantly superior over 125 % RDF, RDF + FYM and RDF + Zn + S (₹103460, 99907 and 99155 ha⁻¹) treatments during experimentation. Conversely, maximum B: C ratio was fetched with application of 125 % RDF (3.27) which was significantly higher over RDF + FYM, 100 % RDF, RDF + Zn + S, RDF + S and foliar sprays of NPK 19:19:19 treatment. Further, application of RDF + FYM @ 10 t ha⁻¹ RDF + S, RDF + Zn + S and foliar sprays of NPK 19:19:19 also fetched significantly higher net returns as compared to RDF.

Nitharwal *et al.* (2022) analyzed the economics of treatments performed to find out the influence of different levels and methods of N P K fertilizer application on the growth and production of wheat (*Triticum aestivum* L.). Application of 100 % RDF recorded the significantly maximum gross and net profit (₹ 108568 and 76682 ha⁻¹) as well as with 2.40 benefit: cost ratio, followed by 75 % RDF (₹ 100668 and 69909 ha⁻¹) and 2.27, respectively. Three foliar spray of soluble N: P: K observed the significantly higher gross and net return (₹ 98116 and 67326 ha⁻¹) over rest of the treatments, but statistically at par with four foliar spray of soluble N:P:K (₹ 99923 and 68257 ha⁻¹). Three foliar sprays of soluble N: P: K observed the significantly higher benefit: cost ratio 2.16 over rest of the treatments, but it was statistically at par with four foliar sprays of soluble N: P: K.

3. MATERIALS AND METHODS

The field experiment entitled “Performance of wheat (*Triticum aestivum* L.) under foliar application of different nutrients” was conducted at Post Graduate Institute Farm, MPKV, Rahuri during *rabi* 2022-23. The details of the material used and methods during the experiment are summarized in this chapter.

3.1 Details of Experimental Material

3.1.1 Location of the experimental site

The field experiment was conducted at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during *rabi* season of 2022-23.

3.1.2 Soil

The topography of experimental plot was uniform and leveled. The soil samples were collected from three randomly selected spots from experimental area and prepared composite samples to know the initial physical and chemical properties of soil. The data regarding the physical and chemical properties of the experimental field and analytical methods used are presented in table 1.

Table 1. Physico-chemical properties of soil and methods used for soil analysis

Sr. No.	Particulars	Composition	Methods	Reference
A	Mechanical composition			
1.	Coarse sand (%)	6.73	International pipette method	Piper (1966)
2.	Fine sand (%)	10.19		
3.	Silt (%)	29.13		
4.	Clay (%)	53.38		
5.	Textural class	Clay		
B	Chemical composition			
1	pH(1:2.5)	8.17	Potentiometry	Jackson(1973)
2	Electrical conductivity (dS m ⁻¹)	0.39	Conductometry	Jackson (1973)
3	Organic carbon (%)	0.57	Wet oxidation method Walkey and Black	Nelson and Sommer (1982)
4	Available nitrogen (kg ha ⁻¹)	190.70	Alkaline permanganate method	Subbiah and Asija (1956)

Table 1 contd....

Sr. No.	Particulars	Composition	Methods	Reference
5	Available phosphorous (kg ha ⁻¹)	17.32	Olsen method 0.5 M NaHCO ₃ (pH 8.5)	Watanabe and Olsen(1965)
6	Available potassium (kg ha ⁻¹)	435.58	Flame photometry 1 N NH ₄ OAC (pH 7)	Jackson (1973)
7	Available zinc (mg kg ⁻¹)	0.73	DTPA extraction method	Lindsay and Norvell (1978)
8	Available iron (mg kg ⁻¹)	4.39		
9	Available copper (mg kg ⁻¹)	1.49		
10	Available manganese (mg kg ⁻¹)	8.81		

The soil of experimental plot was slightly alkaline in reaction (pH 8.17), medium in organic carbon (0.57 %), non-calcareous in nature, silty clay in texture, low in available nitrogen (190.70 kg ha⁻¹), medium in available phosphorous (17.32 kg ha⁻¹), and very high in available potassium (435.58 kg ha⁻¹).

3.2 Geographical and Climatic Conditions

3.2.1 General conditions

Geographically, the Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri lies between 19°51' and 19°64' North latitude and between 76°32' and 76°10' East longitude. The altitude varies from 491 and 537 metre above mean sea level. This area is lying on eastern site of western ghat and falls under rain shadow area.

Climatologically this area falls in the scarcity zone (semi-arid tropics) with an annual rainfall from 317 to 691 mm. The average annual rainfall ranging is 520 mm. The rainfall is erratic and uneven distributed in 15 to 45 rainy days in different years. Out of the total annual rainfall about more than 80 per cent of the rainfall receiving from South-West monsoon (June-September) while the rest is received from East monsoon (October and November) and practically negligible rains received during summer. Agro-climatically the location is in the drought prone area of Maharashtra.

The annual mean maximum temperature is 38 to 42°C. The annual mean minimum temperature is 38 to 42°C. The mean relative humidity at morning hours and evening hours is about 57 and 33 per cent, respectively.

During the crop growth season of the year 2022-23, the weekly maximum and minimum temperatures were ranged between 33.9 and 27.9°C and 18.3 and 11.6°C, respectively. The mean weekly morning relative humidity was ranged between 87.85 and 69.71 per cent and evening humidity ranged between 48.00 and 19.00 per cent. The total rainfall during the crop growth period was 2.5 mm. Wind speed was ranged between 0.6 and 1.7 km hr⁻¹ while bright sunshine hours were ranged between 5.6 and 10.7 during the growing period of crop.

3.3 Cropping History of Experimental Field

The cropping history of experimental field for previous two years are presented in table 3.

Table 3. Cropping history of experimental field

Sr. No.	Year	Season		
		<i>Kharif</i>	<i>Rabi</i>	<i>Summer</i>
2.	2020-21	Soybean	Wheat	Fallow
3.	2021-22	Soybean	Chickpea	Fallow
4.	2022-23	Maize	Present Investigation (Wheat)	-

3.4 Experimental Details

1.	Name of Crop	:	Wheat
2.	Variety	:	Phule Samadhan
3.	Season	:	<i>Rabi</i> 2022 - 23
4.	Plot Size	:	Gross : 2.80 m x 3.60 m Net : 2.40 m x 3.20 m
5.	Sowing Date	:	25/11/2022
6.	RDF	:	120:60:40 kg ha ⁻¹ N : P ₂ O ₅ : K ₂ O
7.	Seed Rate	:	100 kg ha ⁻¹
8.	Design	:	Randomized Block Design
9.	Replication	:	Three
10.	Place of Research	:	PGI Farm, MPKV, Rahuri
11.	Spacing	:	20 cm between two rows

3.4.1 Treatment details

In this experiment, there were nine treatments of foliar spray of water soluble fertilizers having different nutrient composition and the treatments were replicated thrice in randomized block design. The details regarding treatments along with symbols used are given in table 4.

Table 4. Details of the treatments and symbols used

Treat. No.	Treatments
T ₁	GRDF (Control)
T ₂	GRDF + Water spray
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %
T ₅	GRDF + Foliar spray of Urea @ 2 %
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L

Note:

- Two foliar sprays taken at 25 DAS (tillering) and 40 DAS (jointing), respectively from T₂ to T₉.
- GRDF -120:60:40 kg ha⁻¹ N :P₂O₅ :K₂O + FYM @ 10 t ha⁻¹ applied in treatment T₁ to T₇. 50 % N and full P & K applied as basal dose and 50 % N applied as top dressing for treatment T₁ to T₇.
- Phule Liquid Micro Grade II contains Zn (3 %), Fe (2.5 %), Mn (1.0 %), Cu (1.0 %), B (0.5 %) and Mo (0.1 %).

3.4.2 Design and Layout

The present experiment was laid out as per plan of layout in randomized block design (RBD). The field was prepared in flat beds according to size. The layout consisted of total 27 experimental units in three replications. Each experimental plot was with gross plot size of 2.80 m x 3.60 m and net plot size of 2.40 m x 3.20 m. The treatments were assigned to various plots at random as shown in plan of layout (Fig. 2).

3.5 Details of Field Operations

The details of various field operations carried out in the experimental plot during *rabi*, 2022-23 that are presented in table 5.

Table 5. Schedule of cultural operations carried out in the experimental plot

Sr. No.	Name of operations	Frequency	Date
A.	Preparatory operations		
1.	Ploughing	1	12/11/2022
2.	Harrowing	1	18/11/2022
3.	Application of FYM	1	19/11/2022
4.	Preparation of layout	1	23/11/2022
B.	Sowing		
1.	Seed treatment	1	25/11/2022
2.	Application of basal dose of fertilizers	1	25/11/2022
3.	Sowing of seeds	1	25/11/2022
C.	Intercultural operations		
1.	Gap filling	1	02/12/2022
2.	Weeding	2	14/12/2022, 02/01/2023
4.	Foliar spray of fertilizers		
	a. At 25 DAS	1	19/12/2022
	b. At 40 DAS	1	04/01/2023
5.	Top dressing of fertilizers	1	23/12/2022
D.	Irrigation	5	25/11/2022, 10/12/2022, 23/12/2023, 12/01/2023, 05/02/2023
E.	Harvesting	1	08/03/2023
F.	Threshing and Winnowing	1	15/03/2023

3.5.1 Land preparation

The experimental field was cultivated with tractor drawn plough and land was prepared by harrowing. The field was demarcated as per plan of layout with provision of irrigation channels. After proper field conditions, layout prepared just to keep field ready for sowing.

3.5.2 Seeds and sowing

Good quality seeds of variety Phule Samadhan were used for present investigation and were obtained from Chief Scientist (Seed), Seed Cell unit, MPKV, Rahuri. Sowing was done on 25th November, 2022 with seed rate of 100 kg ha⁻¹. Seed treatment was done with thirum @ 3 g/kg seeds to protect the crop from fungal diseases and *Azotobacter* @ 250 g/10 kg seeds to increase nitrogen fixation in soil. Then treated seeds sown manually at 4-5 cm sowing depth by keeping row to row distance of about 20 cm.

3.5.3 Fertilizer application

General recommended dose of fertilizer viz. FYM @ 10 t ha⁻¹ and 120:60:40 N :P₂O₅ : K₂O kg ha⁻¹ was applied through straight fertilizers viz., urea, single super phosphate and muriate of potash. 50 % N and full P & K applied as basal dose to all treatment plots, while remaining 50 % nitrogen applied as top dressing for treatment T₁ to T₇. Two foliar applications of different nutrients were done as per the treatment at 25 and 40 DAS.

3.5.4 Weeding

Two hand weedings were done in all treatment plots with the help of weeding hook.

3.5.5 Irrigation

First irrigation was given immediately after sowing of crop to ensure proper germination and then four irrigations were given at 10-15 days interval during the growth period of crop.

3.5.6 Plant protection measures

No incidence of pests and diseases was noticed on the crop, so plant protection measures were not undertaken.

3.5.7 Harvesting

Harvesting was done as soon as the crop come to maturity stage. The harvesting is done by cutting the plant by sickle. The border line was harvested first and removed out from experimental area. Previously selected five plants were harvested separately for recording post-harvest observations and their seed yield added to final net plot yield. The wheat crop from net plot harvested separately and left for sun drying for eight days in respective plots. After complete drying, the harvested produce from each net plot were weighed just before threshing to record biological yield and then the grains were separated plot wise by threshing. These grains and straw were weighed separately for each net plot. The weight of clean grain and straw was recorded as per treatment in kg plot⁻¹ and converted into kg ha⁻¹ for analysis purpose.

3.6 Details of Biometric Observations

The details regarding various biometric observations recorded during investigation are given in table 6.

Table 6. Details of biometric and other observations recorded

Sr. No.	Particulars	Frequency	Observations recorded DAS	Sample size
A.	Plant Count:			
1.	Initial plant count	1	15 DAS	1 m length
2.	Final plant count	1	At harvest	1 m length
B.	Growth Studies:			
1.	Plant height (cm)	4	30, 60, 90 DAS and at harvest	5 plants
2.	Total number of tillers	4	30, 60, 90 DAS and at harvest	1 m length
3.	No of functional leaves plant ⁻¹	3	30, 60, and 90 DAS	5 plants
4.	Leaf area plant ⁻¹ (dm ²)	3	30, 60, and 90 DAS	2 plants
5.	Dry matter plant ⁻¹ (g)	4	30, 60, 90 DAS and at harvest	2 plants
6.	Total chlorophyll content (SPAD)	3	30, 60, and 90 DAS	2 plants
7.	Absorbed PAR (μ mol m ⁻² s ⁻¹)	3	30, 60 and 90 DAS	Net plot

Table 6 contd.....

Sr. No.	Particulars	Frequency	Observations recorded DAS	Sample size
C.	Yield contributing characters:			
1.	Length of panicle (cm)	1	At harvest	5 panicles
2.	Number of spikelet panicle ⁻¹	1	At harvest	5 panicles
3.	Number of grains panicle ⁻¹	1	At harvest	5 panicles
4.	Weight of grains panicle ⁻¹ (g)	1	At harvest	5 panicles
5.	1000 seed weight (g)	1	At harvest	Samples from each net plot
D.	Yield			
1.	Grain yield (kg plot ⁻¹)	1	At harvest	Net plot
2.	Straw yield (kg plot ⁻¹)	1	At harvest	Net plot
E.	Chemical analysis			
I.	Initial Analysis			
1.	Soil Analysis (pH, EC, OC, N, P, K and micronutrients)	1	At initial	Composite sample
II.	At Harvest			
1.	Residual soil available N, P, K (kg ha ⁻¹) and micronutrients (mg kg ⁻¹)	1	At harvest	Net plot
2.	Total uptake of NPK (kg ha ⁻¹) and micronutrients (g ha ⁻¹)	1	At harvest	Net plot
F.	Quality Studies			
1.	Protein content in grain (%)	1	At harvest	Sample from each net plot
G.	Economics			
1.	Cost of cultivation (₹ ha ⁻¹)			
2.	Gross monetary returns (₹ ha ⁻¹)			
3.	Net monetary returns (₹ ha ⁻¹)			
4.	B:C ratio			

3.6.1 Sampling technique

For recording biometric observations five plants were selected randomly from each net plot of individual treatment treated as observation plant, for demarcation of these plants the bamboo pets/sticks were fixed adjoining to each observation plant. Various biometric observations *viz*; plant count, plant height, number of functional leaves, total number of tillers, leaf area, dry matter, chlorophyll content, absorbed PAR, length of panicle, number of spikelets panicle⁻¹, number of grains panicle⁻¹, weight of grains panicle⁻¹ and 100 grain weight as influenced by the different treatments etc. were recorded separately at 30, 60, 90 DAS and at harvest.

3.6.2 Plant count (No. m⁻¹ row length)

The initial plant count was recorded by counting all the plants in per meter length at 15 DAS and at harvest of crop. Five rows from each net plot were selected by random sampling and within each row, one metre length was marked by random selection. Then all the plants from one metre length were counted and averaged to express plant stand per meter length.

3.6.3 Growth studies

3.6.3.1 Plant height (cm)

Plant height was recorded at periodical intervals at 30, 60, 90 DAS and at harvest from 5 randomly selected plants. The measurement was made from the base of the plant to the fully opened leaf at 30 DAS and up to the base of ear head at 60, 90 DAS and at harvest and expressed in cm.

3.6.3.2 Total number of tillers m⁻¹ length

The total number of tillers from one meter length of five randomly selected places from each net plot was counted. The average number of tillers per meter length was computed and recorded separately.

3.6.3.3 Number of functional leaves plant⁻¹

The number of functional leaves plant⁻¹ was counted by actual count of functional leaves at 30, 60, 90 DAS.

3.6.3.4 Leaf area plant⁻¹ (dm²)

The plants taken for dry matter study were used for measuring leaf area. It was measured by placing leaves on the screen of leaf area meter at an interval of 30, 60 and 90 DAS.

3.6.3.5 Dry matter plant⁻¹ (g)

For dry matter studies two representative plants were selected randomly and uprooted from ring line of each plot at 30, 60, 90 DAS and at harvest. The roots of each plant were discarded and then they were air dried and kept in hot air oven at 60±5°C until the constant weight of dried plants was obtained. After subjecting these dried plants to air cooling the weight was recorded.

3.6.3.6 Chlorophyll content (%)

Chlorophyll present in leaves of major leaf of five randomly selected plants from each treatment was measured by using SPAD meter at 30, 60 and 90 DAS. Then by taking average of all five observations from each plot was calculated and expressed in percentage.

3.6.3.7 Absorbed PAR ($\mu \text{ mol m}^{-2} \text{ s}^{-1}$)

During photosynthesis plants use energy in the region of the electromagnetic spectrum from 400 to 700 nm. The radiation in this range referred to as photosynthetically active radiation can be measured in energy units of quanta (photons) per unit time per unit surface area. The photosynthetically active radiation was measured on a clear sky between 11 a.m. to 1:00 p.m. with the LI191SA Line Quantum Sensor (LI-COR make) at an interval of 30 days starting from 30 DAS upto 90 DAS. The observations were recorded across the rows.

The incident PAR (PAR₀) was measured half to one foot above the canopy by line quantum sensor facing towards sky. The transmitted PAR (PAR_t) was measured by placing the line quantum sensor at ground level facing upwards. The reflected PAR by soil (PAR_s) was measured at half to one foot above the ground by facing line quantum sensor towards soil. The reflected PAR by canopy + soil (PAR_c) was measured by holding the line quantum sensor one foot above the canopy facing towards canopy. The absorbed photosynthetically active radiation was calculated using the following formula given by Gallo and Daughtry (1986).

$$APAR = (PAR_0 + PAR_s) - (PAR_t + PAR_c)$$

Where,

APAR :- Absorbed photosynthetically active radiation ($\mu \text{ mol m}^{-2} \text{ s}^{-1}$)

PAR_0 :- Incident radiation ($\mu \text{ mol m}^{-2} \text{ s}^{-1}$)

PAR_c :- Plant canopy reflected radiation ($\mu \text{ mol m}^{-2} \text{ s}^{-1}$)

PAR_t :- Transmitted radiation ($\mu \text{ mol m}^{-2} \text{ s}^{-1}$)

PAR_s :- Soil surface reflected radiation ($\mu \text{ mol m}^{-2} \text{ s}^{-1}$)

3.6.4 Yield contributing characters

3.6.4.1 Panicle length (cm)

The panicle length was measured from the basal spikelet to the tip of ear head excluding awns from five randomly selected plants. Then mean length of panicle in cm was worked out.

3.6.4.2 Number of spikelet panicle⁻¹

Five randomly selected panicle from plots were used for counting number of spikelets and average of these spikelets was used to indicate number of spikelets panicle⁻¹.

3.6.4.3 Number of grains panicle⁻¹

The panicles from each treatment which were used for measuring panicle length were used for this study. The grain number panicle⁻¹ was counted from the five randomly selected panicles and the mean was computed.

3.6.4.4 Weight of grains panicle⁻¹ (g)

Five randomly selected panicles were threshed separately and grain weight was recorded. The grain weight panicle⁻¹ was obtained by computing the mean of five selected panicles and expressed in gram.

3.6.4.5 1000 seed weight (g)

1000 seeds were counted and weighted on an analytical weighing balance from the composite seeds of each net plot and values were recorded.

3.6.4.6 Grain yield plot⁻¹ (kg)

The produce of each net plot was threshed separately, cleaned and the grain yield was recorded in kilogram per net plot. The grain yield received from each net plot was converted on hectare basis in kilogram.

3.6.4.7 Straw yield plot⁻¹ (kg)

After threshing, straw yield was calculated plot wise by subtracting grain yield from biological weight and expressed in kg ha⁻¹.

3.6.4.8 Harvest index (%)

Harvest index is the ratio of economic yield to biological yield plot⁻¹ (Salisbury and Ross, 1986). It was calculated by using following formula:

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

3.7 Chemical Analysis

Studies pertaining to nitrogen, phosphorus and potassium content and uptake by grain and straw of wheat and nitrogen, phosphorus and potassium status in soil before sowing and after harvest of wheat were carried out as described here after.

3.7.1 Soil analysis

Soil samples from 0-30 cm soil depth from each net plot were collected after harvest of the crop and grind in wooden pestle and mortar after air drying and passed through 2 mm sieve and these were used for chemical analysis for determination of residual available NPK in the soil after harvest. The methods used for this determination are given in Table-7.

Table 7. Methods used for soil analysis

Sr. No.	Determination	Method used	References
1.	Nitrogen (kg ha ⁻¹)	Alkaline permanganate method	Jackson (1973)
2.	Phosphorus (kg ha ⁻¹)	Olsen method 0.5 M NaHCO ₃ (pH 8.5)	Watanabe and Olsen(1965)
3.	Potassium (kg ha ⁻¹)	Flame photometry 1 N NH ₄ OAC (pH 7)	Jackson (1973)
4.	Micronutrients (mg kg ⁻¹)	DTPA extraction method	Jackson (1973)

3.7.2 Plant analysis

Representative samples of grain and straw of wheat were drawn from each net plot produce after harvesting for chemical studies. The samples were oven dried at 65 ± 5 °C to constant weight and powdered by mechanical willy grinder. Then samples were

analyzed for estimation of nitrogen, phosphorus and potassium contents. The methods used for determination of various elements from plant materials are given in table -8.

Table 8. Methods used for plant analysis

Sr. No.	Determination	Method used	References
1.	Nitrogen (%)	Micro-kjeldahl	Jackson (1973)
2.	Phosphorus (%)	Vanado-molybdate phosphoric acid yellow colour in nitric acid system	Jackson (1973)
3.	Potassium (%)	Flame photometry	Jackson (1973)
4.	Micronutrient (mg kg ⁻¹)	Atomic Absorption Spectrophotometer	Jackson (1973)
5.	Protein content (%)	Micro-kjeldhal	Jackson (1973)

3.7.2.1 Nitrogen content (%) and uptake (kg ha⁻¹)

Estimation of N content in grain and straw was determined on dry weight basis by Micro Kjeldahl's method as described by Jackson (1973). The uptake of nitrogen by grain and straw of wheat was calculated by using the formula as under.

$$\text{N uptake by grain/straw (kg ha}^{-1}\text{)} = \frac{\text{Nitrogen content in grain/straw (\%)} \times \text{Dry matter of grain/straw yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Total uptake of N (kg ha}^{-1}\text{)} = \text{N uptake by grain (kg ha}^{-1}\text{)} + \text{N uptake by straw (kg ha}^{-1}\text{)}$$

3.7.2.2 Phosphorus content (%) and uptake (kg ha⁻¹)

Estimation of phosphorus content in grain and straw was determined on dry weight basis by Vanado-molybdate phosphoric yellow colour method as described by Jackson (1973). The uptake of phosphorus by grain and straw of wheat was calculated by using following formula:

$$\text{P uptake by grain/straw (kg ha}^{-1}\text{)} = \frac{\text{Phosphorous content in grain/straw (\%)} \times \text{Dry matter of grain/straw yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Total uptake of P (kg ha}^{-1}\text{)} = \text{P uptake by grain (kg ha}^{-1}\text{)} + \text{P uptake by straw (kg ha}^{-1}\text{)}$$

3.7.2.3 Potassium content (%) and uptake (kg ha⁻¹)

Estimation of potassium content in grain and straw was carried out by using Flame photometric method as described by Jackson (1973). The uptake of potassium by grain and straw of wheat was calculated by using the formula as under.

$$\text{K uptake by grain/straw (kg ha}^{-1}\text{)} = \frac{\text{Potassium content in grain/straw (\%)} \times \text{Dry matter of grain/straw yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Total uptake of K (kg ha}^{-1}\text{)} = \text{K uptake by grain (kg ha}^{-1}\text{)} + \text{K uptake by straw (kg ha}^{-1}\text{)}$$

3.7.2.4 Micronutrient content (mg kg⁻¹) and uptake (g ha⁻¹)

Estimation of micronutrient *viz.* Zn, Fe, Cu and Mn content in grain and straw was carried out by using Atomic Absorption Spectrophotometer as described by Jackson (1973). The uptake of micronutrient by grain and straw of wheat was calculated by using the formula as under.

$$\text{Micronutrient uptake by grain/straw (g ha}^{-1}\text{)} = \frac{\text{Micronutrient content in grain/straw (mg kg}^{-1}\text{)} \times \text{Dry matter of grain/straw yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Total uptake of micronutrient (g ha}^{-1}\text{)} = \text{Micronutrient uptake by grain (g ha}^{-1}\text{)} + \text{Micronutrient uptake by straw (g ha}^{-1}\text{)}$$

3.8 Quality of Grain (Protein Content)

Grain samples were digested by using diacid method, 30 % H₂O₂ and Conc. H₂SO₄. Nitrogen content in grain was estimated by 'N' analyzer (distillation) method and from which protein content was calculated by multiplying nitrogen percentage with factor 6.25.

3.9 Economics

The economic evaluation in terms of gross and net monetary returns, cost of cultivation and B:C ratio were computed treatment wise. For calculation of gross monetary returns and cost of cultivation, the prices mentioned in Appendix-I and II were considered respectively.

3.9.1 Cost of cultivation (₹ ha⁻¹)

The expenses incurred for all the cultivation operations from preparatory tillage to harvesting including the cost of inputs *viz.* seeds, fertilizers, etc. applied to each treatment was calculated on the basis of prevailing local charges.

3.9.2 Gross monetary returns (₹ ha⁻¹)

The gross monetary returns were worked out by considering the prevailing market price of the produce during the year of experimentation.

3.9.3 Net monetary returns (₹ ha⁻¹)

Net monetary returns were worked out by subtracting cost of cultivation from gross monetary returns.

Net monetary returns (₹ ha⁻¹) = Gross monetary returns (₹ ha⁻¹) - Cost of cultivation (₹ ha⁻¹)

3.9.4 Benefit cost ratio

The benefit cost ratio was worked out by using formula.

$$\text{Benefit: Cost ratio} = \frac{\text{Gross monetary returns (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

3.10 Statistical Analysis

The experimental data collected during the course of investigation were statistically analyzed with split plot design programme by adopting standard statistical techniques of analysis of variance (Panse and Sukhatme, 1985). Whenever the results were significant, critical difference (C.D.) at P=0.05 levels were calculated for comparison of treatment means. The data are appropriately presented in tables and suitably depicted by graphical illustrations.

4. RESULTS AND DISCUSSION

The chapter embodies results of the present investigation entitled “Performance of wheat (*Triticum aestivum* L.) under foliar application of different nutrients” conducted in *rabi* season of 2022-2023 at the Instructional Farm, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri. The data pertaining to various parameters *viz.*, growth attributes, yield attributes and yield, nutrient content, uptake and status after harvest of wheat were statistically analyzed to test significance of results. The results of individual effects for different characters are presented in relevant tables along with statistical inferences.

4.1 Plant Count

4.1.1 Initial and final plant count (No. m⁻¹ row length)

The data regarding mean initial and final plant count of wheat as influenced by different treatments are presented in table 9. The mean initial plant count and final plant count was 42.77 and 39.86 plants m⁻¹ length, respectively.

Table 9. Initial and final plant count of wheat as influenced by different treatments

Tr. No.	Treatment	Initial plant count (At 15 DAS)	Final plant count (At harvest)
T ₁	GRDF (Control)	42.56	39.45
T ₂	GRDF + Water spray	43.78	40.67
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	44.23	41.32
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	43.69	40.78
T ₅	GRDF + Foliar spray of Urea @ 2 %	43.28	40.38
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	42.45	39.44
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	41.23	38.72
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	41.88	38.39
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	42.47	39.58
	S.Em. ±	2.20	2.16
	C.D. at 5%	NS	NS
	General Mean	42.77	39.86
	C.V.	8.92	9.38

The mean initial and final plant count of wheat was not influenced significantly due to the treatments of foliar application of different nutrients. The uniform initial and final plant population of wheat indicated that the differences in various parameters under study are due to treatments and not due to the plant population.

4.2. Growth Studies

4.2.1 Plant height (cm)

The data pertaining to average plant height recorded periodically at 30, 60, 90 DAS and at harvest are presented in table 10 and graphed in fig. 3. The mean plant height at 30, 60, 90 DAS and at harvest were 35.35, 64.37, 82.99 and 84.39 cm, respectively.

Table 10. Plant height of wheat as influenced periodically by different treatments

Tr. No.	Treatment	Plant height (cm)			
		30 DAS	60 DAS	90 DAS	At harvest
T ₁	GRDF (Control)	33.72	60.55	79.07	80.79
T ₂	GRDF + Water spray	34.63	61.52	79.39	81.02
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	37.36	68.27	86.74	87.35
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	38.71	74.19	96.36	98.17
T ₅	GRDF + Foliar spray of Urea @ 2 %	35.35	64.33	82.32	83.70
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	38.08	71.72	91.07	92.36
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	34.91	63.83	81.23	82.75
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	32.09	56.27	74.70	76.33
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	33.30	58.14	76.06	77.18
	S.Em. ±	1.73	3.11	4.08	4.39
	C.D. at 5%	NS	9.32	12.24	13.17
	General Mean	35.35	64.37	82.99	84.39
	C.V.	8.48	8.37	8.52	9.01

Initially, the plant height was at lower magnitude up to 30 DAS. The plant growth in terms of plant height was more vigorous during the period of 30 to 90 DAS and thereafter, the rate of growth was decreased. The plant height was significantly influenced due to foliar application of different nutrients to wheat.

At 60, 90 DAS and at harvest, application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded significantly higher plant height i. e. 74.19, 96.36 and 98.17 cm, respectively which was at par with the application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (71.72, 91.07 and 92.36 cm, respectively) and application of GRDF + Foliar spray of 19:19:19 @ 1 %, (68.27, 86.74 and 87.35 cm, respectively). There was a non-significant difference between different treatments at 30 DAS. The minimum plant height of wheat was recorded in the treatment having application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L (56.27, 74.70 and 76.33 cm, respectively).

The significant increase in plant height of wheat upto harvest was most favourably due to availability of macro and micro nutrients through foliar application of different nutrients. Nitrogen plays important role in photosynthesis, formation of amino acids, building blocks of protein, cell division and boosts the production of carbohydrates. Phosphorus is also involved in photosynthesis, respiration, cell division, cell enlargement and promotes early root formation and growth. Potassium is essential for carbohydrate metabolism, translocation of starch and protein synthesis. It increases photosynthesis, quality of seeds and disease resistance. Micronutrients also play a vital role in cell division, carbohydrate metabolism and photosynthesis. So, the foliar application of balanced nutrients resulted in increase in height of wheat.

These results are in conformity with Talpur (2005), Khan *et al.* (2009), Surve and Bhosale (2015), Wagan *et al.* (2017), Muhammad *et al.* (2019), Abrol *et al.* (2019) and Yadav *et al.* (2021)

4.2.2 Total number of tillers metre⁻¹ length

The findings obtained about total number of tillers meter⁻¹ length in wheat crop displayed in table 11 and graphically presented in fig. 4. From this, it revealed that by the application of different treatments, total number of tillers in wheat was not

influenced significantly upto 30 DAS; but there was significant difference observed in total number of tillers from 60 DAS upto harvest of wheat.

The mean total number of tillers found 59.27, 79.28, 76.34 and 74.46 at 30, 60, 90 DAS and at harvest, respectively. Among all the treatments, at 60, 90 DAS and at harvest, wheat crop applied with GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % showed significantly maximum total number of tillers (91.05, 88.21 and 86.63, respectively). It was at par with application of GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (85.37, 82.66 and 80.67, respectively) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (82.52, 79.48 and 77.24, respectively).

Table 11. Total number of tillers metre⁻¹ length in wheat as influenced periodically by different treatments

Tr. No.	Treatment	Total number of tillers (m ⁻¹ length)			
		30 DAS	60 DAS	90 DAS	At harvest
T ₁	GRDF (Control)	58.33	75.83	72.33	70.57
T ₂	GRDF + Water spray	58.50	76.45	73.60	71.30
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	60.67	82.52	79.48	77.24
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	62.00	91.05	88.21	86.63
T ₅	GRDF + Foliar spray of Urea @ 2 %	59.50	78.12	75.39	73.60
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	61.67	85.37	82.66	80.67
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	59.33	77.23	74.72	72.30
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	56.00	72.67	69.51	68.37
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	57.40	74.28	71.15	69.43
	S.Em. ±	2.89	3.66	3.58	3.47
	C.D. at 5%	NS	10.99	10.72	10.40
	General Mean	59.27	79.28	76.34	74.46
	C.V.	8.44	8.00	8.12	8.07

However, the application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L produced significantly minimum total number of tillers (72.67, 69.51 and 68.37, respectively).

The highest total number of tillers found in wheat crop might be due to addition of GRDF in conjunction with foliar spray of all necessary macro and micro nutrients and their uptake by wheat crop. It results in increased availability of all nutrients to plants and enhanced meristematic activity, cell division, enlargement and elongation of cells resulting in higher plant height and total number of tillers. Similar findings were documented by Jamal *et al.* (2006), Surve and Bhosale (2015), Sharma and Singh (2016), Wagan *et al.* (2017), Abrol *et al.* (2019), Yadav *et al.* (2021) and Nitharwal *et al.* (2022).

4.2.3 Number of functional leaves plant⁻¹

Data pertaining to periodical number of functional leaves plant⁻¹ of wheat as influenced by different treatments during *rabi* season, 2022 are presented in table 12 and graphically depicted in fig. 5 The mean number of functional leaves plant⁻¹ were 6.56, 10.72 and 9.46 at 30, 60, and 90 DAS, respectively. The number of functional leaves plant⁻¹ of wheat was influenced significantly at 60 and 90 DAS due to foliar application of different nutrients at 25 and 40 DAS, respectively. While, it was not influenced significantly when recorded at 30 DAS.

An application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded significantly the highest number of functional leaves plant⁻¹ of wheat at 60 DAS (12.40) and 90 DAS (11.07) which was at par with application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (12.16 and 10.87 at 60 and 90 DAS, respectively) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (11.97 and 10.23 at 60 and 90 DAS, respectively).

Significantly, minimum number of functional leaves plant⁻¹ of wheat was recorded periodically in the treatment consisting application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L (9.27 and 8.27 at 60 and 90 DAS, respectively).

Table 12. Number of functional leaves plant⁻¹ of wheat as influenced periodically by different treatments

Tr. No.	Treatment	Number of functional leaves plant ⁻¹		
		30 DAS	60 DAS	90 DAS
T ₁	GRDF (Control)	6.20	10.03	8.80
T ₂	GRDF + Water spray	6.27	10.07	8.93
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	6.83	11.97	10.23
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	7.20	12.40	11.07
T ₅	GRDF + Foliar spray of Urea @ 2 %	6.53	10.65	9.39
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	7.07	12.16	10.87
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	6.41	10.43	9.13
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	6.07	9.27	8.27
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	6.13	9.47	8.47
	S.Em. ±	0.33	0.51	0.50
	C.D. at 5%	NS	1.53	1.50
	General Mean	6.56	10.72	9.46
	C.V.	8.64	8.22	9.15

Wheat crop showed luxurious availability of macro and micro nutrients with application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % at 25 and 40 DAS, respectively as nitrogen is essential for chlorophyll metabolism and directly involved in photosynthesis. While, phosphorus offered its role in cell division and enlargement and also potassium is essential for carbohydrate metabolism and translocation of starch which might be reflected in luxurious growth of wheat and produced higher number of functional leaves in this treatment. These results are fairly similar with Rahman *et al.* (2014), Surve and Bhosale (2015) and Dhaker *et al.* (2022).

4.2.4 Leaf area plant⁻¹ (dm²)

The data on leaf area plant⁻¹ as influenced by different treatments are presented in table 13 and depicted in fig. 6 graphically. The data outlined in table 13 indicated that leaf area plant⁻¹ differed significantly due to the treatments of foliar application of nutrients. The mean leaf area plant⁻¹ was 0.62, 1.69 and 1.42 dm² at 30, 60 and 90 DAS, respectively.

At 30 DAS, there was no any significant difference in leaf area plant⁻¹ between all the treatments of foliar application of different nutrients.

Table 13. Leaf area plant⁻¹ of wheat as influenced periodically by different treatments

Tr. No.	Treatment	Leaf area plant ⁻¹ (dm ²)		
		30 DAS	60 DAS	90 DAS
T ₁	GRDF (Control)	0.60	1.59	1.32
T ₂	GRDF + Water spray	0.61	1.61	1.33
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	0.64	1.78	1.53
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	0.67	1.93	1.66
T ₅	GRDF + Foliar spray of Urea @ 2 %	0.62	1.69	1.41
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	0.66	1.84	1.63
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	0.62	1.66	1.36
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	0.56	1.56	1.24
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	0.58	1.57	1.27
	S.Em. ±	0.03	0.08	0.07
	C.D. at 5%	NS	0.24	0.21
	General Mean	0.62	1.69	1.42
	C.V.	8.33	7.99	8.76

At 60 and 90 DAS, various treatments showed significant influence on leaf area plant⁻¹ of wheat. At 60 and 90 DAS, the maximum leaf area was found with the

application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % at (1.93 and 1.66 dm² plant⁻¹). It was at par with application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (1.84 and 1.63 dm²) and also application of GRDF + Foliar spray of 19:19:19 @ 1 % (1.78 and 1.53 dm² plant⁻¹). The minimum leaf area of wheat was recorded with the application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L (1.56 and 1.24 dm² plant⁻¹) at 60 and 90 DAS, respectively.

This might be due to vigorous growth of plants with optimum levels of macro and micro nutrients in terms of plant height, number of tillers, number of leaves and leaf area, which resulted in adequate food supply to sink and ultimately reflected on higher dry matter production. The results are in conformity with Rahman *et al.* (2014), Surve and Bhosale (2015) and Yadav *et al.* (2019).

4.2.5 Dry matter plant⁻¹ (g)

Data pertaining to dry matter plant⁻¹ of wheat as influenced by different treatments is presented in table 14 and graphically depicted in fig. 7. The mean dry matter plant⁻¹ of wheat at 30, 60, 90 DAS and at harvest was (2.45, 5.69, 10.04 and 13.10 g, respectively) during investigation. The dry matter plant⁻¹ in wheat was influenced significantly due to foliar application of different nutrients.

There was a non-significant difference among different treatments at 30 DAS. While, at 60, 90 DAS and at harvest, the application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded significantly maximum dry matter plant⁻¹ (6.62, 11.51 and 15.51 g, respectively) while, it was at par with the application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (6.36, 11.16 and 14.87 g, respectively) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (6.02, 10.89 and 14.53 g, respectively). Significantly, minimum dry matter plant⁻¹ of wheat was recorded in the treatment having application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L (5.01, 9.08 and 10.86 g, respectively).

Dry matter production is the relative process of effective utilization of the resources in better crop production environment. When wheat crop is subjected with foliar application of different nutrients, it results into higher dry matter plant⁻¹ because

there is sufficient availability of nutrients to the wheat crop that results in increase in photosynthetic activities. Increased plant height, more number of leaves and higher leaf area due to application of foliar nutrients might have resulted in increase in dry matter plant⁻¹.

Table 14. Dry matter plant⁻¹ of wheat as influenced periodically by different treatments

Tr. No.	Treatment	Dry matter plant ⁻¹ (g)			
		30 DAS	60 DAS	90 DAS	At harvest
T ₁	GRDF (Control)	2.43	5.35	9.35	12.36
T ₂	GRDF + Water spray	2.43	5.46	9.55	12.57
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	2.47	6.02	10.89	14.53
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	2.50	6.62	11.51	15.51
T ₅	GRDF + Foliar spray of Urea @ 2 %	2.44	5.69	9.72	13.22
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	2.48	6.36	11.16	14.87
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	2.44	5.58	9.64	12.94
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	2.41	5.01	9.08	10.86
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	2.42	5.13	9.30	11.07
	S.Em. ±	0.13	0.29	0.54	0.73
	C.D. at 5%	NS	0.87	1.62	2.20
	General Mean	2.45	5.69	10.04	13.10
	C.V.	9.53	8.78	9.31	9.68

Similar results were reported by Surve and Bhosale (2015), Yadav *et al.* (2021), Nitharwal *et al.* (2022) and Dhaker *et al.* (2022).

4.2.6 Total chlorophyll content (SPAD)

Data regarding total chlorophyll content of wheat as influenced by different treatments during *rabi* season, 2022 are displayed in table 15 and graphically demonstrated in fig. 8.

The mean total chlorophyll content of wheat was 22.94, 39.63 and 28.74 SPAD at 30, 60 and 90 DAS, respectively during experimentation. The total chlorophyll content of wheat was influenced significantly due to foliar application of different nutrients. There was a non-significant difference in total chlorophyll content of wheat among different treatments at 30 DAS. The total chlorophyll content continued to increase up to 60 DAS and there after it declined towards maturity.

Table 15. Total chlorophyll content of wheat as influenced periodically by different treatments

Tr. No.	Treatment	Total chlorophyll content (SPAD)		
		30 DAS	60 DAS	90 DAS
T ₁	GRDF (Control)	21.27	37.43	27.53
T ₂	GRDF + Water spray	22.20	37.77	27.87
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	24.83	41.30	30.17
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	26.47	46.53	33.47
T ₅	GRDF + Foliar spray of Urea @ 2 %	23.47	40.03	28.53
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	25.30	43.57	31.67
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	22.93	39.56	28.08
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	20.67	34.77	24.93
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	21.00	35.73	26.43
	S.Em. ±	1.19	1.92	1.54
	C.D. at 5%	NS	5.77	4.62
	General Mean	22.94	39.63	28.74
	C.V.	8.99	8.41	9.27

At 60 and 90 DAS, significantly the maximum total chlorophyll content of wheat (46.53 and 33.47 SPAD) was recorded with the application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % while, it was at par with the application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %

(43.57 and 31.67 SPAD) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (41.30 and 30.17 SPAD). Significantly, minimum total chlorophyll content of wheat was recorded in the treatment having application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L (34.77 and 24.93 SPAD).

The foliar application of all the necessary major and minor nutrients enhances their availability to plants which results in better metabolic activity and physiological performance. It improves the photosynthetic efficiency of crop which ultimately increases the chlorophyll content in the crop. Similar results were accounted by Rahman *et al.* (2014).

4.2.7 Absorbed PAR ($\mu \text{ mol m}^{-2} \text{ s}^{-1}$)

Data in respect of absorbed photosynthetic active radiation (APAR) of wheat as influenced by different treatments during *rabi* season, 2022 is represented in table 16 and fig. 9.

The mean APAR of wheat was 448.78, 782.82 and 886.56 $\mu \text{ mol m}^{-2} \text{ s}^{-1}$ at 30, 60 and 90 DAS, respectively during experimentation. The APAR of wheat was influenced significantly due to foliar application of different nutrients. There was a non-significant difference in total chlorophyll content of wheat among different treatments at 30 DAS. The APAR of wheat increased progressively at every growth stage of wheat crop.

At 60 and 90 DAS, significantly the maximum APAR of wheat was recorded with the application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (897.78 and 984.67 $\mu \text{ mol m}^{-2} \text{ s}^{-1}$ respectively) while, it was at par with the application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (842.67 and 943.78 $\mu \text{ mol m}^{-2} \text{ s}^{-1}$ respectively) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (811.22 and 928.00 $\mu \text{ mol m}^{-2} \text{ s}^{-1}$ respectively). Significantly, minimum APAR of wheat was recorded in the treatment having application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L (700.67 and 818.33 $\mu \text{ mol m}^{-2} \text{ s}^{-1}$, respectively).

Table 16. Periodical Absorbed PAR of wheat as influenced by different treatments

Tr. No.	Treatment	Absorbed PAR ($\mu \text{ mol m}^{-2} \text{ s}^{-1}$)		
		30 DAS	60 DAS	90 DAS
T ₁	GRDF (Control)	442.33	753.22	852.67
T ₂	GRDF + Water spray	436.67	761.78	862.33
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	469.67	811.22	928.00
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	481.67	897.78	984.67
T ₅	GRDF + Foliar spray of Urea @ 2 %	457.33	782.78	881.33
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	476.67	842.67	943.78
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	449.00	773.11	873.67
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	402.67	700.67	818.33
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	411.67	722.11	834.33
	S.Em. $\pm$	22.32	34.69	30.61
	C.D. at 5%	NS	104.01	91.77
	General Mean	448.78	782.82	886.56
	C.V.	8.62	7.83	5.97

This might be due to the quick absorption of nitrogen, phosphorous, potassium and micronutrients like zinc, iron, copper and manganese. It helped in expansion of leaf area owing to increased meristematic activity and provided greater photosynthetic surface to intercept more radiant energy and improved the capacity of the plants to utilize more available nutrients. These findings are in conformity with Memon *et al.* (2007).

4.3 Yield Contributing Characters

The data recorded on yield contributing characters *viz.* length of panicle (cm), number of spikelets panicle⁻¹, number of grains panicle⁻¹, weight of grains panicle⁻¹ (g) and 1000 seed weight (g) of wheat as influenced by various treatments presented in table 17 and graphically displayed in fig. 10 and 11.

4.3.1 Length of panicle (cm)

Data presented in table 17 and fig. 10 revealed that foliar application of different nutrients increased length of panicle in wheat crop significantly. The mean length of panicle in wheat was (8.02 cm) at harvest.

Significantly, higher length of panicle in wheat (9.87 cm) was recorded with the application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %. It was at par with the application of GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (9.27 cm) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (8.93 cm). Significantly, minimum length of panicle was recorded with the application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L (6.03 cm). These findings are in accordance with Jamal *et al.* (2006), Khan *et al.* (2009), Wagan *et al.* (2017), Abrol *et al.* (2019), Yadav *et al.* (2021), Nitharwal *et al.* (2022) and Dhaker *et al.* (2022).

4.3.2 Number of spikelets panicle⁻¹

Differences in number of spikelets panicle⁻¹ due to foliar application of different nutrients were observed to be significant. The mean number of spikelets panicle⁻¹ in wheat was (13.58) at harvest.

The application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded higher number of spikelets panicle⁻¹ in wheat (16.07) at harvest which was significantly higher than other treatments. But, it remained at par with the application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (15.40) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (14.93) at the time of harvest. The application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L recorded the minimum number of spikelets panicle⁻¹ in wheat (11.33).

The sufficient availability of both macro and micro nutrients through foliar spray is the main cause for increase in number of spikelets panicle⁻¹ in wheat. NPK and micronutrients are essential for translocation of starch, carbohydrate metabolism and building blocks of protein. Similar findings were found by Hussain *et al.* (2005), Arif *et al.* (2006), Jamal *et al.* (2006) and Amal *et al.* (2011).

4.3.3 Number of grains panicle⁻¹

Number of grains panicle⁻¹ were affected significantly by different treatments of foliar application of nutrients. The mean number of grains panicle⁻¹ in wheat was about (37.84).

Table 17. Yield contributing characters of wheat as influenced by different treatments

Tr. No.	Treatment	Length of panicle (cm)	Number of spikelets panicle ⁻¹	Number of grains panicle ⁻¹	Weight of grains panicle ⁻¹ (g)	1000 seed weight (g)
T ₁	GRDF (Control)	7.37	12.57	35.93	1.43	39.96
T ₂	GRDF + Water spray	7.63	12.93	36.67	1.47	40.08
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	8.93	14.93	39.45	1.63	41.32
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	9.87	16.07	45.40	1.89	41.67
T ₅	GRDF + Foliar spray of Urea @ 2 %	8.47	13.60	38.06	1.55	40.88
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	9.27	15.40	43.53	1.78	41.12
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	8.15	13.32	37.60	1.41	40.93
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	6.03	11.33	31.20	1.22	39.27
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	6.43	12.07	32.73	1.29	39.56
	S.Em. ±	0.42	0.73	2.23	0.07	0.21
	C.D. at 5%	1.26	2.19	6.69	0.21	NS
	General Mean	8.02	13.58	37.84	1.52	40.53
	C.V.	9.10	9.33	10.22	8.56	9.02

Significantly, higher number of grains panicle⁻¹ in wheat (45.40) were observed when it was treated with the application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % among all other treatments but was remained at par with the application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (43.53) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (39.45) at the time of harvest. The minimum number of grains panicle⁻¹ in wheat (31.20) recorded with application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L.

The effective absorption of nitrogen helped in formation of amino acids and boosts the production of carbohydrate. Phosphorus is vital for seed formation. Potassium plays important role in translocation of starch and protein synthesis. This was reflected in production of higher number of grains panicle⁻¹ in wheat. These findings are in accordance with reports of Arif *et al.* (2006), Khan *et al.* (2009), Rahman *et al.* (2014), Sharma and Singh (2016), Wagan *et al.* (2017), Yadav *et al.* (2021), Nitharwal *et al.* (2022) and Dhaker *et al.* (2022).

4.3.4 Weight of grains panicle⁻¹ (g)

The weight of grains panicle⁻¹ in wheat differed significantly by different treatments consisting two foliar applications of nutrients at 25 and 40 DAS, respectively. Mean weight of grains panicle⁻¹ in wheat was about (1.52 g).

Among all the treatments, higher weight of grains panicle⁻¹ in wheat (1.89 g) was observed in the treatment of application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % which was significantly higher but statistically remain at par with application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (1.78 g) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (1.63 g). The minimum weight of grains panicle⁻¹ (1.22 g) in wheat recorded with the application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L. Similar results were reported by Amal *et al.* (2011), Ali *et al.* (2016), and Wagan *et al.* (2017).

4.3.5 1000 seed weight (g)

The results in respect of 1000 seed weight in wheat was not influenced significantly with different foliar treatments. The mean 1000 seed weight of wheat was

40.53 g. However, the treatment of application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded numerically higher 1000 seed weight in wheat (41.67 g). Minimum 1000 seed weight (39.27 g) recorded with the application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L.

These results are in collaboration with Emam and Borjian (2000), Hussain *et al.* (2005), Talpur (2005), Arif *et al.* (2006), Muhammad *et al.* (2006), Hasina *et al.* (2011), Ali *et al.* (2016) and Abrol *et al.* (2019).

4.4 Yield Studies

4.4.1 Grain yield (kg ha⁻¹)

The data pertaining to grain yield (kg ha⁻¹) of wheat as influenced by different treatments of foliar application of nutrients at 25 and 40 DAS, respectively are presented in table 18 and graphically depicted in fig. 12. The mean grain yield of wheat was 4370 kg ha⁻¹.

The application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % produced significantly the highest grain yield (4980 kg ha⁻¹) of wheat among all treatments, but remained at par with the application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (4825 kg ha⁻¹) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (4641 kg ha⁻¹).

The lowest grain yield in wheat (3742 kg ha⁻¹) was obtained with the application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L. This revealed that the recommended 50 % dose of N could not be replaced by foliar spray of nano urea @ 2 ml/L.

Yield is a function of dry matter production and its efficiency to translocate and accumulate in different plant parts and ultimately in yield attributing traits. This significant difference in grain yield of wheat may be due to involvement of sprayed nutrients in chlorophyll synthesis, enzyme activity, stomata regulation, starch translocation and assimilation into grains. It may result in increasing number and weight of wheat grains as well as physiological performance of wheat. Rapid and efficient response is given by the nutrients applied through foliar spray. There was cumulative

effect in the more accumulation of photosynthates and its translocation from sink to reproductive part like grain of wheat.

The results are in comparison with the results found by Muhammad *et al.* (2006), Hasina *et al.* (2011), Rahman *et al.* (2014), Surve and Bhosale (2015), Wagan *et al.* (2017), Abrol *et al.* (2019), Nitharwal *et al.* (2022) and Dhaker *et al.* (2022).

4.4.2 Straw yield (kg ha^{-1})

Data with respect to straw yield (kg ha^{-1}) of wheat as influenced by different treatments of foliar application of nutrients at 25 and 40 DAS are presented in table 18 and graphically depicted in fig. 12. The mean straw yield of wheat was about (5377 kg ha^{-1}).

Significantly, the highest straw yield (6064 kg ha^{-1}) was observed in wheat when it was treated with the application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % among all other treatments but was remained at par with the application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (5876 kg ha^{-1}) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (5655 kg ha^{-1}).

The lowest straw yield in wheat (4712 kg ha^{-1}) was obtained with the application of 50 % RDN + 100 % P and K + 10 t ha^{-1} FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L at 25 and 40 DAS, respectively. This may be due to the requirement of nutrients was not fulfilled through given spray of nano urea at 25 and 40 DAS to the wheat.

The highest straw yield obtained due to the availability of both macro and micro nutrients is uniform throughout the vegetative growth stage of crop. Due to foliar application of nutrients, there was increase in plant height, total number of tillers, number of leaves leaf area and dry matter accumulation which may results into higher straw yield of wheat. These results agreed with findings of Muhammad *et al.* (2006), Khan *et al.* (2010), Wagan *et al.* (2017), Borse *et al.* (2019), Dhaker *et al.* (2022) and Nitharwal *et al.* (2022).

4.4.3 Biological yield (kg ha^{-1})

The data regarding biological yield (kg ha^{-1}) of wheat as influenced by different treatments of foliar application of nutrients at 25 and 40 DAS are presented in

table 18 and graphically depicted in fig. 12. The mean biological yield of wheat was about (9745 kg ha⁻¹).

Table 18. Grain yield, straw yield, biological yield and harvest index of wheat as influenced by different treatments

Tr. No.	Treatment	Yield (kg ha ⁻¹)			Harvest Index (%)	Increase in yield over control (%)
		Grain	Straw	Biological yield		
T ₁	GRDF (Control)	4189	5247	9436	44.39	0
T ₂	GRDF + Water spray	4233	5288	9521	44.45	1.05
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	4641	5655	10296	45.07	10.79
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	4980	6064	11044	45.09	18.88
T ₅	GRDF + Foliar spray of Urea @ 2 %	4379	5338	9717	45.06	4.54
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	4825	5876	10701	45.08	15.18
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	4347	5312	9659	45.00	3.77
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	3742	4712	8454	44.26	-
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	3931	4929	8860	44.37	-
	S.Em. ±	189.09	221.06	405.29		-
	C.D. at 5%	567.28	663.19	1215.88		-
	General Mean	4370	5377	9745	44.75	-
	C.V.	8.03	8.07	8.00		-

The application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded the highest biological yield (11044 kg ha⁻¹) of wheat. It was significant among all other treatments but statistically remained at par with the application GRDF + foliar spray of urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (10701 kg ha⁻¹) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (10296 kg ha⁻¹). Significantly, the lowest biological yield in wheat (8454 kg ha⁻¹) obtained with the

application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L.

Biological yield is related with grain yield and straw yield. The healthy growth performance by wheat crop when it sprayed with all the nutrients gives the results of the highest grain yield and straw yield. So, the biological yield also gets increased. The results are in confirmation with Arif *et al.* (2006), Khan *et al.* (2010), Hasina *et al.* (2011), Muhammad *et al.* (2019), Dhaker *et al.* (2022) and Nitharwal *et al.* (2022).

4.4.4 Harvest Index (%)

The data on harvest index of wheat as influenced by different treatments of foliar application of nutrients at 25 and 40 DAS are presented in table 18. The mean harvest index of wheat was about (44.75 %).

The wheat crop when treated with GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % reported the numerically higher harvest index (45.09 %). The lower harvest index of wheat (44.26 %) was observed when it was treated with 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L.

Harvest index is function of grain yield and biological yield. The maximum grain yield obtained with application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % was responsible for getting higher harvest index with it. Similar results were found by Ali *et al.* (2016), Yadav *et al.* (2021), Dhaker *et al.* (2022), and Nitharwal *et al.* (2022).

4.5 Quality Studies

4.5.1 Protein content (%) and protein yield (kg ha⁻¹)

Table 19 and fig. 13 represented the results with respect to protein content (%) and protein yield (kg ha⁻¹) of wheat influenced by different treatments of foliar application of nutrients. The mean protein content was 11.00 % and mean protein yield was 480.68 kg ha⁻¹. The protein content of wheat was not influenced significantly due to foliar application of different nutrients.

The application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % to the wheat crop recorded numerically higher protein content (11.44 %) while, the lower protein content of wheat (10.50 %) observed when

treated with 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + foliar spray of Nano Urea @ 2 ml/L.

Table 19. Protein content and protein yield of wheat as influenced by different treatments

Tr. No.	Treatment	Protein content (%)	Protein yield (kg ha ⁻¹)
T ₁	GRDF (Control)	10.81	452.83
T ₂	GRDF + Water spray	10.88	460.55
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	11.23	521.18
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	11.44	569.71
T ₅	GRDF + Foliar spray of Urea @ 2 %	11.15	488.25
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	11.31	545.70
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	11.04	479.90
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	10.50	392.91
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	10.56	415.11
	S.Em. ±	0.64	23.82
	C.D. at 5%	NS	71.45
	General Mean	11.00	480.68

As grain yield of wheat was influenced significantly due to different treatments, the protein yield of wheat influenced significantly. The highest protein yield was found with application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (569.71 kg ha⁻¹). It was followed by GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (545.70 kg ha⁻¹) and application of GRDF + foliar spray of 19:19:19 @ 1 % (521.18 kg ha⁻¹). While, the lowest protein yield accounted with application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L (392.91 kg ha⁻¹).

Similar results were stated by Kharub *et al.* (2002), Sadaphal and Das (2002), Borse *et al.* (2019) and Muhammad *et al.* (2019).

4.6 Nutrient Uptake Studies at Harvest (kg ha^{-1})

4.6.1 Nitrogen uptake (kg ha^{-1})

The data regarding total uptake of nitrogen by grain and straw of wheat as influenced by different treatments of foliar nutrition are given in table 20 and depicted in fig. 14. From this, it was revealed that the mean nitrogen uptake of wheat by grain and straw of wheat was 67.69 and 19.78 kg ha^{-1} , respectively. While, mean total uptake of nitrogen by wheat was 89.49 kg ha^{-1} .

Table 20. Nitrogen uptake by grain and straw of wheat as influenced by different treatments after harvest of wheat

Tr. No.	Treatment	Nitrogen uptake (kg ha^{-1})		
		Grain	Straw	Total
T ₁	GRDF (Control)	63.77	18.05	81.82
T ₂	GRDF + Water spray	64.81	18.61	83.42
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	73.51	21.72	95.23
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	80.19	24.74	104.93
T ₅	GRDF + Foliar spray of Urea @ 2 %	68.59	19.64	88.23
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	76.85	23.03	99.88
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	67.70	19.12	86.82
T ₈	50 % RDN + 100 % P and K + 10 t ha^{-1} FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	55.32	15.08	70.40
T ₉	50 % RDN + 100 % P and K + 10 t ha^{-1} FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	58.46	18.05	76.51
	S.Em. $\pm$	3.47	1.41	4.51
	C.D. at 5%	10.41	4.23	13.53
	General Mean	67.69	19.78	89.49

Nitrogen uptake by grain (80.19 kg ha^{-1}), straw (24.74 kg ha^{-1}) and total (104.93 kg ha^{-1}) uptake of wheat was found maximum with application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %. It was significantly superior over all treatments but at par with application of GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (76.85, 23.03 and 99.88 kg ha^{-1}

respectively) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (73.51, 21.72 and 95.23 kg ha⁻¹ respectively). The minimum nitrogen uptake by grain (55.32 kg ha⁻¹), straw (15.08 kg ha⁻¹) and total uptake (70.40 kg ha⁻¹) of wheat found with application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L.

4.6.2 Phosphorous uptake (kg ha⁻¹)

The table 21 represented the values of phosphorous uptake by grain and straw as well as total phosphorous uptake by wheat crop as influenced by different treatments and it is depicted in fig. 15. The mean phosphorous uptake by grain, straw of wheat and total uptake was 14.67, 8.17 and 22.85 kg ha⁻¹, respectively.

Table 21. Phosphorous uptake by grain and straw of wheat as influenced by different treatments after harvest of wheat

Tr. No.	Treatment	Phosphorous uptake (kg ha ⁻¹)		
		Grain	Straw	Total
T ₁	GRDF (Control)	13.64	7.56	21.20
T ₂	GRDF + Water spray	13.78	7.61	21.39
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	16.34	9.05	25.39
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	18.41	10.19	28.60
T ₅	GRDF + Foliar spray of Urea @ 2 %	14.64	8.11	22.75
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	17.41	9.87	27.28
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	14.54	8.07	22.61
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	11.20	6.41	17.61
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	12.11	6.70	18.81
	S.Em. ±	1.04	0.61	1.73
	C.D. at 5%	3.11	1.83	5.19
	General Mean	14.67	8.17	22.85

Application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded significantly the highest phosphorous uptake by grain

(18.41 kg ha⁻¹), straw (10.19 kg ha⁻¹) and total uptake (28.60 kg ha⁻¹) of wheat. It was followed by application of GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (17.41, 9.87 and 27.28 kg ha⁻¹, respectively) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (16.34, 9.05 and 25.39 kg ha⁻¹, respectively). Among all the treatments, lower phosphorous uptake by grain (11.20 kg ha⁻¹), straw (6.41 kg ha⁻¹) and total uptake (17.61 kg ha⁻¹) of wheat was obtained with application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L.

4.6.3 Potassium uptake (kg ha⁻¹)

The data related to potassium uptake by grain and straw as well as total potassium uptake by wheat crop as influenced by different treatments are presented in table 22 and depicted in fig. 16. From the data, it found that the mean potassium uptake by grain, straw of wheat and total uptake was 17.12, 51.40 and 68.53 kg ha⁻¹, respectively.

Significantly maximum potassium uptake by grain (20.60 kg ha⁻¹), straw (59.18 kg ha⁻¹) and total uptake (79.78 kg ha⁻¹) of wheat observed with the application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % and this treatment was at par with application of GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (19.96, 56.88 and 76.84 kg ha⁻¹, respectively) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (18.79, 54.29 and 73.08 kg ha⁻¹, respectively). However, the application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L recorded minimum potassium uptake by grain (13.83 kg ha⁻¹), straw (44.48 kg ha⁻¹) and total uptake (58.31 kg ha⁻¹) of wheat.

The result of getting higher nutrient uptake might be due to foliar application of all major and minor nutrients to wheat crop. The ammonium molybdenum present in Phule Liquid Micro Grade II was responsible for mobilization of nutrients and boosting the uptake of nutrients by vegetative parts of plant. Hence, the uptake of nutrients is maximum in treatment having foliar spray of Phule Liquid Micro Grade II.

Table 22. Potassium uptake by grain and straw of wheat as influenced by different treatments after harvest of wheat

Tr. No.	Treatment	Potassium uptake (kg ha ⁻¹)		
		Grain	Straw	Total
T ₁	GRDF (Control)	15.85	49.53	65.38
T ₂	GRDF + Water spray	16.39	50.34	66.73
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	18.79	54.29	73.08
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	20.60	59.18	79.78
T ₅	GRDF + Foliar spray of Urea @ 2 %	17.34	50.82	68.16
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	19.96	56.88	76.84
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	16.83	50.57	67.40
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	13.83	44.48	58.31
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	14.53	46.53	61.06
	S.Em. ±	0.94	2.48	3.45
	C.D. at 5%	2.83	7.44	10.35
	General Mean	17.12	51.40	68.53

These results are in collaboration with findings of Yaseen *et al.* (2010), Saleem *et al.* (2013), Muaid *et al.* (2014), Surve and Bhosale (2015) and Ghasal *et al.* (2016),

4.6.4 Micronutrient uptake (g ha⁻¹)

The findings related to total uptake of micronutrients like Zinc, Iron, Copper and Manganese by wheat crop as influenced by different treatments are given in table 23 and depicted in fig. 17. From that, it found that the mean total uptake of Zn, Fe, Cu and Mn by wheat was 399, 1919, 65 and 892 g ha⁻¹, respectively.

Significantly, maximum total uptake of micronutrients *viz.* Zn, Fe, Cu and Mn (469, 2243, 78 and 1045 g ha⁻¹) by wheat observed with the application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % and this treatment was at par with application of GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (448, 2146, 74 and 1003 g ha⁻¹) and application of GRDF

+ Foliar spray of 19:19:19 @ 1 % (425, 2034, 70 and 949 g ha⁻¹). However, the application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L recorded minimum total uptake of Zn, Fe, Cu and Mn (333, 1605, 51 and 746 g ha⁻¹) by wheat.

Table 23. Micronutrient uptake as influenced by different treatments after harvest of wheat

Tr. No.	Treatment	Micronutrient uptake (g ha ⁻¹)			
		Zn	Fe	Cu	Mn
T ₁	GRDF (Control)	379	1847	61	850
T ₂	GRDF + Water spray	383	1870	63	859
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	425	2034	70	949
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	469	2243	78	1045
T ₅	GRDF + Foliar spray of Urea @ 2 %	397	1910	65	885
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	448	2146	74	1003
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	402	1920	66	898
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	333	1605	51	746
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	353	1700	56	788
	S.Em. ±	19.25	91.79	3.47	45.46
	C.D. at 5%	57.70	275.19	10.40	136.29
	General Mean	399	1919	65	892

The results of getting maximum micro nutrient uptake might be due to foliar application of all the necessary nutrients to wheat crop. The complexes present in different nutrient solutions are enacted on mobility of nutrients through plant parts. It helps in uptake of micronutrients directly through vegetative part of plant and also helped in their rapid translocation.

Parallel findings were discovered by Khan *et al.* (2010), Yaseen *et al.* (2010), Muaid *et al.* (2014), Ghasal *et al.* (2016) and Muhammad *et al.* (2019).

4.7 Soil Studies

4.7.1 pH, EC, OC Content in soil

The pH, electrical conductivity and organic carbon content within treated plot of wheat after harvest is included in table 24.

Table 24. Soil chemical properties as influenced by different treatments after harvest of wheat

Tr. No.	Treatment	pH (1:2.5)	EC (dSm ⁻¹)	Org. C. (%)
T ₁	GRDF (Control)	8.12	0.34	0.59
T ₂	GRDF + Water spray	8.15	0.35	0.58
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	8.14	0.36	0.58
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	8.15	0.36	0.59
T ₅	GRDF + Foliar spray of Urea @ 2 %	8.14	0.35	0.57
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	8.13	0.36	0.58
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	8.16	0.37	0.57
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	8.18	0.35	0.58
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	8.13	0.37	0.57
	S.Em. ±	0.36	0.03	0.03
	C.D. at 5%	NS	NS	NS
	General Mean	8.14	0.36	0.58
	Initial	8.17	0.39	0.57

Foliar application of different nutrients had not found any significant difference on pH, electrical conductivity and organic carbon content in the soil of treated plot of wheat. After harvest of wheat, the mean pH, electrical conductivity and organic carbon content in soil were 8.14, 0.36 dSm⁻¹ and 0.58 per cent, respectively.

4.7.2 Soil available nutrient after harvest of wheat crop (kg ha⁻¹)

The nutrient status of soil after harvest of wheat crop is presented in table 25 and fig. 18, 19 and 20. The availability of nitrogen, phosphorous and potassium in the soil of treated plot of wheat was affected significantly due to the treatments of foliar

application of different nutrients. The mean available nitrogen, phosphorus and potassium content in soil after harvest of wheat crop were 178.54, 15.39 and 413.25 kg ha⁻¹, respectively.

Application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % exhausted more amount of nutrients. So, the availability of nitrogen, phosphorus and potassium (171.65, 14.11 and 398.19 kg ha⁻¹, respectively) get reduced significantly. The plots treated with GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % and with GRDF + Foliar spray of 19:19:19 @ 1 % also exhausted higher nutrients from the soil and showed lower value of available nitrogen, phosphorous and potassium in soil.

Table 25. Soil available nutrients as influenced by different treatments after harvest of wheat

Tr. No.	Treatment	Soil available nutrient (kg ha ⁻¹)		
		N	P	K
T ₁	GRDF (Control)	187.67	16.69	429.67
T ₂	GRDF + Water spray	187.13	16.23	423.23
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	178.60	15.03	408.53
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	171.65	14.11	398.19
T ₅	GRDF + Foliar spray of Urea @ 2 %	184.89	15.36	417.89
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	175.54	14.46	403.18
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	185.63	15.82	419.66
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	165.99	15.35	407.59
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	169.73	15.50	411.32
	S.Em. ±	4.12	0.29	6.09
	C.D. at 5%	12.36	0.87	18.25
	General Mean	178.54	15.39	413.25
	Initial	190.70	17.32	435.58

This minimum availability of nutrients may be due to higher uptake of nutrients by wheat crop as well as higher biological yield. These results are similar with the results reported by Khattak *et al.* (2017) and Abrol *et al.* (2019).

4.7.3 Soil available micronutrient after harvest of wheat crop (mg kg⁻¹)

The data regarding availability of micronutrients like Zn, Fe, Cu and Mn within the soil of treated plot after harvest of wheat crop was given in table 26 and fig. 21. From the results, it revealed that the availability of Zn, Fe, Cu and Mn was not influenced significantly due to the different treatments. The non significant difference among all the treatments may be due to the application of different nutrients through foliar spray.

Table 26. Soil available micronutrients as influenced by different treatments after harvest of wheat

Tr. No.	Treatment	Soil available micronutrients (mg kg ⁻¹)			
		Zn	Fe	Cu	Mn
T ₁	GRDF (Control)	0.75	4.42	1.57	8.92
T ₂	GRDF + Water spray	0.74	4.39	1.54	8.90
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	0.72	4.31	1.46	8.77
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	0.72	4.26	1.41	8.63
T ₅	GRDF + Foliar spray of Urea @ 2 %	0.73	4.34	1.49	8.81
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	0.72	4.29	1.42	8.70
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	0.73	4.37	1.51	8.85
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	0.70	4.30	1.41	8.64
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	0.70	4.31	1.44	8.69
	S.Em. ±	0.04	0.19	0.07	0.41
	C.D. at 5%	NS	NS	NS	NS
	General Mean	0.72	4.33	1.47	8.77
	Initial	0.73	4.39	1.49	8.81

The value of mean soil available micronutrients was Zn (0.72 mg kg^{-1}), Fe (4.33 mg kg^{-1}), Cu (1.47 mg kg^{-1}) and Mn (8.77 mg kg^{-1}). The numerically higher values of soil available micronutrients *viz.* Zn, Fe, Cu and Mn (0.75 , 4.42 , 1.57 and 8.92 mg kg^{-1} , respectively) found in the plot having application of GRDF only to wheat crop.

These findings are in collaboration with Ghasal *et al.* (2016), Khattak *et al.* (2017) and Abrol *et al.* (2019).

4.8 Economics

The economic evaluation of wheat crop was assessed in terms of cost of cultivation, gross monetary returns, net monetary returns and benefit: cost ratio and documented in table 27 and graphically displayed in fig. 22 and 23. The details of input and output prices are given in Appendix I and II.

4.8.1 Cost of cultivation (₹ ha^{-1})

Wheat crop applied with GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5% and 1% , respectively accounted the highest cost of cultivation ($\text{₹ } 61425 \text{ ha}^{-1}$) among all other treatments. It was followed by application of GRDF + Foliar spray of $19:19:19$ @ 1% + Phule Liquid Micro Grade II @ 0.5% ($\text{₹ } 59987 \text{ ha}^{-1}$) and GRDF + Foliar spray of Urea @ 1% + Phule Liquid Micro Grade II @ 0.5% ($\text{₹ } 59892 \text{ ha}^{-1}$). This may be due to high cost of nutrients used for foliar spray. While, the lowest cost of cultivation found with the application of GRDF only ($\text{₹ } 58311 \text{ ha}^{-1}$).

4.8.2 Gross monetary returns (₹ ha^{-1})

Mean gross monetary returns of wheat crop obtained was ($\text{₹ } 117145 \text{ ha}^{-1}$). Significantly, the highest gross monetary returns ($\text{₹ } 133596 \text{ ha}^{-1}$) obtained in wheat with the application of GRDF + Foliar spray of $19:19:19$ @ 1% + Phule Liquid Micro Grade II @ 0.5% as compared to other treatments. It was at par with application of GRDF + Foliar spray of Urea @ 1% + Phule Liquid Micro Grade II @ 0.5% ($\text{₹ } 129439 \text{ ha}^{-1}$) and application of GRDF + Foliar spray of $19:19:19$ @ 1% ($\text{₹ } 124508 \text{ ha}^{-1}$). The lowest gross monetary returns found with 50% RDN + 100% P and K + 10 t ha^{-1} FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L ($\text{₹ } 100618 \text{ ha}^{-1}$).

The highest gross monetary returns documented because of higher grain yield and straw yield due to foliar application of different nutrients to wheat crop.

Table 27. Cost of cultivation, gross monetary returns, net monetary returns and B:C ratio of wheat as influenced by different treatments

Tr. No.	Treatment	Cost of cultivation (₹ ha ⁻¹)	Gross monetary returns (₹ ha ⁻¹)	Net monetary return (₹ ha ⁻¹)	B:C ratio
T ₁	GRDF (Control)	58311	112596	54285	1.93
T ₂	GRDF + Water spray	59029	113757	54728	1.93
T ₃	GRDF + Foliar spray of 19:19:19 @ 1 %	59348	124508	65160	2.10
T ₄	GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	59987	133596	73609	2.23
T ₅	GRDF + Foliar spray of Urea @ 2 %	59157	117482	58325	1.98
T ₆	GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %	59892	129439	69547	2.16
T ₇	GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively	61425	116643	55218	1.89
T ₈	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L	58709	100618	41909	1.71
T ₉	50 % RDN + 100 % P and K + 10 t ha ⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L	59220	105669	46449	1.78
	S.Em. ±	-	5301.92	5301.92	-
	C.D. at 5%	-	15895.15	15895.15	-
	General Mean	-	117145	57692	-

4.8.3 Net monetary returns (₹ ha⁻¹)

According to data presented in table 27, mean net monetary returns in wheat crop was (₹ 57692 ha⁻¹). Among all the treatments, application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % produced significantly higher net monetary returns (₹ 73609 ha⁻¹) which was at par with application of GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (₹ 69547 ha⁻¹) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (₹ 65160 ha⁻¹). Significantly, the lowest net monetary returns documented with application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L (₹ 41909 ha⁻¹).

The higher grain and straw yield with lower cost of cultivation were responsible for getting the highest net monetary returns in wheat crop. These results are in conformity with Surve and Bhosale (2015), Sharma and Singh (2016) and Nitharwal *et al.* (2022).

4.8.4 B:C ratio

The B:C ratio is related with gross monetary returns and cost of cultivation. The wheat crop applied with application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % documented the highest B:C ratio (2.23) because of getting the highest gross monetary returns as compared to other treatments. It was followed by GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % (2.16) and application of GRDF + Foliar spray of 19:19:19 @ 1 % (2.10). While, the lowest B:C ratio accounted with application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L (1.71).

Muhammad *et al.* (2010), Abrol *et al.* (2019), Nitharwal *et al.* (2022) and Dhaker *et al.* (2022) found similar outcomes about B:C ratio in wheat crop.

5. SUMMARY AND CONCLUSION

Summary

A field investigation entitled “Performance of wheat (*Triticum aestivum* L.) under foliar application of different nutrients” was conducted in *rabi* season of 2022-2023 at the Instructional Farm, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment consists of 9 treatments *viz.*, T₁ : GRDF (Control); T₂ : GRDF + Water spray; T₃ : GRDF + Foliar spray of 19:19:19 @ 1 %; T₄ : GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %; T₅ : GRDF + Foliar spray of Urea @ 2 %; T₆ : GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 %; T₇ : GRDF + Foliar spray of Phule Liquid Micro Grade II @ 0.5 % and 1 %, respectively; T₈ : 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L; T₉ : 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 4 ml/L. GRDF consists of application of FYM @ 10 t ha⁻¹ and fertilizer dose 120:60:40 kg ha⁻¹ N:P₂O₅:K₂O.

The experiment was laid out in randomized block design (RBD) with three replications. The soil was clay loam in texture, medium in available nitrogen (190.70 kg ha⁻¹), medium in available phosphorus (17.32 kg ha⁻¹) and high in potassium (435.58 kg ha⁻¹). The soil was slightly alkaline in reaction (pH 8.17) with medium in organic carbon content (0.57 %).

Line sowing of wheat seeds was done on flat beds at spacing of 20 cm between rows. The recommended dose of fertilizer (120:60:40 kg N, P₂O₅, K₂O ha⁻¹) was applied 60:60:40 kg N, P₂O₅, K₂O ha⁻¹ as a basal and 60 kg N as top dressing through urea, SSP and MOP in treatment T₁ to T₇. Thereafter, foliar application of different fertilizers was done at 25 and 40 days after sowing, respectively. While in treatment T₈ and T₉, basal dose application was followed by foliar application of nano urea at 25 and 40 days after sowing, respectively.

Periodical observations on the growth characters, yield contributing characters, grain yield and straw yield were recorded during investigation. Soil analysis was also done initially and after harvest for calculating amount of available nutrients in soil. Furthermore, the uptake of nitrogen, phosphorous and potassium by grain and straw

was also estimated. Based on input and output data, economic analysis also came out for all the treatments of foliar application of nutrients given to wheat crop. The most important findings emerging from investigation are summarized below:

5.1 Effect on growth characters of wheat

Upto 30 DAS, growth performance of wheat was almost uniform and not influenced significantly due to foliar application of nutrients at 25 DAS and 40 DAS, respectively. Afterwards, the results of plant height, total number of tillers, number of functional leaves plant⁻¹, leaf area plant⁻¹, dry matter plant⁻¹, total chlorophyll content and absorbed PAR readings found significant.

Application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded significantly higher plant height (98.17 cm), total number of tillers (86.63), number of functional leaves plant⁻¹ (11.07), leaf area plant⁻¹ (1.66 dm²), dry matter plant⁻¹ (15.51g), total chlorophyll content (33.47 SPAD) and absorbed PAR readings (984.67 μ mol m⁻² s⁻¹). This treatment was found significant but at par with the application of GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % with plant height (92.36 cm), total number of tillers (80.67), number of functional leaves plant⁻¹ (10.87), leaf area plant⁻¹ (1.63 dm²), dry matter plant⁻¹ (14.87 g), total chlorophyll content (31.67 SPAD) and absorbed PAR (943.78 μ mol m⁻² s⁻¹) readings as well as application of GRDF + Foliar spray of 19:19:19 @ 1 % recorded plant height (87.35 cm), total number of tillers (77.24), number of functional leaves plant⁻¹ (10.23), leaf area plant⁻¹ (1.53 dm²), dry matter plant⁻¹ (14.53 g), total chlorophyll content (30.17 SPAD) and absorbed PAR readings (928.00 μ mol m⁻² s⁻¹).

Significantly minimum plant height (76.33 cm), number of tillers (68.37), number of functional leaves plant⁻¹ (8.27), leaf area plant⁻¹ (1.24 dm²), dry matter plant⁻¹ (10.86 g), total chlorophyll content (24.93 SPAD) and absorbed PAR readings (818.33 μ mol m⁻² s⁻¹) were recorded with the application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L.

5.2 Effect on yield attributes and yield

The practical way of judging the superiority of any technology lies in the evaluation of yields. In the present study, significant differences were observed in grain and straw yield of wheat because of foliar feeding of different nutrients. Among yield

contributing characters, significantly higher length of panicle (9.87 cm), number of spikelets panicle⁻¹ (16.07), number of grains panicle⁻¹ (45.40) and weight of grains panicle⁻¹ (1.89 g) were obtained with application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %. The next best treatment was application of GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded yield attributes viz., length of spike (9.27 cm), number of spikelets panicle⁻¹ (15.40), number of grains panicle⁻¹ (43.53) and weight of grains panicle⁻¹ (1.78 g) followed by application of GRDF + Foliar spray of 19:19:19 @ 1 % produced length of panicle (8.93 cm), number of spikelets panicle⁻¹ (14.93), number of grains panicle⁻¹ (39.45) and weight of grains panicle⁻¹ (1.63 g).

Application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L showed minimum length of panicle (6.03 cm), number of spikelets panicle⁻¹ (11.33), number of grains panicle⁻¹ (31.20), weight of grains panicle⁻¹ (1.22 g).

Among all the treatments given to wheat crop, significantly higher grain yield and straw yield (4980 and 6064 kg ha⁻¹, respectively) were recorded under the treatment of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %. It was found at par with GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % and GRDF + Foliar spray of 19:19:19 @ 1 % produced grain yield (4825 and 4641 kg ha⁻¹, respectively) and straw yield (5876 and 5655 kg ha⁻¹, respectively). The lowest grain yield and straw yield (3742 and 4712 kg ha⁻¹, respectively) were found with application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L.

5.3 Effect on quality parameters

Among the grain quality parameters studied in different treatments, protein content is an important component of wheat. Protein content of wheat was not influenced significantly due to foliar treatments. However, protein yield was influenced significantly due to different treatments. Among all treatments, numerically higher protein content (11.44 %) and significantly higher protein yield (569.71 kg ha⁻¹) was recorded with treatment of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %.

5.4 Effect on nutrient content and uptake

Total NPK uptake (104.93, 28.60 and 79.78 kg ha⁻¹, respectively) by the grain and straw of wheat crop was recorded significantly the highest values in treatment of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % compared to all other treatments. It was followed by application of GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded (99.88, 27.28 and 76.84 kg ha⁻¹, respectively) and application of GRDF + Foliar spray of 19:19:19 @ 1 % obtained (95.23, 25.39 and 73.08 kg ha⁻¹, respectively). The lowest total NPK uptake was recorded under the treatment of 50 % RDN + 100 % P and K +10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L (70.40, 17.61 and 58.31 kg ha⁻¹, respectively).

In case of micronutrients, the application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded significantly the highest total uptake of Zn, Fe, Cu and Mn (469, 2243, 78 and 1045 g ha⁻¹, respectively) by grain and straw of wheat. It was at par with application of GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded (448, 2146, 74 and 1003 g ha⁻¹, respectively) and application of GRDF + Foliar spray of 19:19:19 @ 1 % obtained (425, 2034, 70 and 949 g ha⁻¹, respectively). Significantly, the lowest total uptake of Zn, Fe, Cu and Mn was recorded under the treatment of 50 % RDN + 100 % P and K +10 t ha⁻¹ FYM as basal dose + Foliar spray of Nano Urea @ 2 ml/L (333, 1605, 51 and 746 g ha⁻¹, respectively).

5.5 Economics

In the present investigation, significantly higher gross monetary returns (₹ 133596 ha⁻¹), net monetary returns (₹ 73609 ha⁻¹) and B:C ratio (2.23) was obtained with application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % as compared to other treatments. It was at par with application of GRDF + Foliar spray of Urea @ 1 % + Phule Liquid Micro Grade II @ 0.5 % with gross monetary returns (₹ 129439 ha⁻¹), net monetary returns (₹ 69547 ha⁻¹) and B:C ratio (2.16) as well as application of GRDF + Foliar spray of 19:19:19 @ 1 % with gross monetary returns (₹ 124508 ha⁻¹), net monetary returns (₹ 65160 ha⁻¹) and B:C ratio (2.10). While the application of 50 % RDN + 100 % P and K + 10 t ha⁻¹ FYM as basal dose + Foliar spray

of Nano Urea @ 2 ml/L gives minimum gross returns (₹ 100618 ha⁻¹), net returns (₹ 41909 ha⁻¹) and B:C ratio (1.71).

Conclusion

Based on the results obtained from present investigation, following conclusions can be drawn :

1. The growth parameters *viz.* plant height, number of tillers, number of functional leaves, leaf area, dry matter plant⁻¹, chlorophyll content, absorbed PAR values and yield contributing characters *viz.* length of panicle, number of spikelets panicle⁻¹, number of grains panicle⁻¹, weight of grains panicle⁻¹ and 1000 seed weight were recorded higher with application of GRDF + foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %.
2. Application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % to wheat crop produced higher grain yield, straw yield, biological yield and harvest index in comparison with other treatments.
3. The quality parameter *viz.* protein content was not differed due to various foliar sprays, while application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 % recorded higher protein yield in wheat.
4. Higher uptake of nitrogen, phosphorous, potassium and micronutrients in grain and straw was recorded the highest with the application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %.
5. The gross monetary returns, net monetary returns and B:C ratio were obtained higher with an application of GRDF + Foliar spray of 19:19:19 @ 1 % + Phule Liquid Micro Grade II @ 0.5 %.

On the basis of one year experimentation, it can be concluded that application of GRDF + two foliar sprays of 19:19:19 @ 1 % or urea @ 1 % along with Phule Liquid Micro Grade II @ 0.5 % or GRDF + two foliar sprays of 19:19:19 @ 1 % at 25 and 40 DAS, respectively found beneficial for increase in growth, yield and monetary returns of wheat grown in medium deep soil.

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7. APPENDICES

Appendix-I : Price of inputs and output per unit

Sr. No.	Particulars	Unit	Price ₹
1.	Hired human labour		
	Male	day ⁻¹	337
	Female	day ⁻¹	337
2.	Land preparation		
i.	Ploughing (Tractor)	ha ⁻¹	2500
ii.	Harrowing (Tractor)	ha ⁻¹	1500
iii.	Seed	kg ⁻¹	50
3.	Fertilizers		
i.	FYM	ton ⁻¹	1200
ii.	Urea	kg ⁻¹	6
iii.	SSP	kg ⁻¹	12
vi.	MOP	kg ⁻¹	34
v.	19:19:19	kg ⁻¹	30
vi.	Phule Liquid Micro Grade II	lit ⁻¹	300
vii.	Nano urea	lit ⁻¹	480
4.	Irrigation charges	day ⁻¹	200
5.	Output		
i.	Seed	kg ⁻¹	25
ii.	Straw	kg ⁻¹	1.5
6.	Land revenue	year ⁻¹	750
7.	Interest on working capital	year ⁻¹	13 %

Appendix II. Details of cost of cultivation in different treatment. (₹ ha⁻¹)

Sr. No.	Particulars	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉
1	Land Preparation									
	a. Ploughing	2500	2500	2500	2500	2500	2500	2500	2500	2500
	b. Harrowing	1500	1500	1500	1500	1500	1500	1500	1500	1500
	c. Layout Preparation	3370	3410	3410	3410	3410	3410	3410	3410	3410
2	Seed and sowing	8870	8870	8870	8870	8870	8870	8870	8870	8870
3	FYM	12000	12000	12000	12000	12000	12000	12000	12000	12000
4	Fertilizer and labours	9652	9652	9652	9652	9652	9652	9652	8872	8872
5	Gap filling	674	674	674	674	674	674	674	674	674
7	Weeding	6740	6740	6740	6740	6740	6740	6740	6740	6740
9	Fertilizer									
	a. Urea		-	-	-	60	30	-	-	-
	b. 19:19:19		-	150	150	-	-	-	-	-
	c. Phule Liquid Micronutrient Grade II		-	-	750	-	750	2250	-	-
	d. Nano urea		-	-	-	-	-	-	480	960
10	Spraying charges		674	674	674	674	674	674	674	674
11	Irrigation charges	2696	2696	2696	2696	2696	2696	2696	2696	2696
12	Harvesting	4000	4000	4000	4000	4000	4000	4000	4000	4000
13	Threshing and winnowing	2046	2046	2046	2046	2046	2046	2046	2046	2046
14	Cost A (Working capital)	54048	54762	54912	55662	54822	55542	57012	54462	54942
15	Land revenue	750	750	750	750	750	750	750	750	750
16	Interest on working capital	3513	3559	3569	3618	3563	3612	3705	3540	3571
17	Cost B (14 +15)	4263	4309	4319	4368	4313	4362	4455	4290	4321
18	Cost of cultivation (Cost A+Cost B)	58311	59072	59231	60030	59135	59904	61468	58752	59263

8. VITAE

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