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A Paradigm Shift towards Beneficial Microbes Enhancing the Efficiency of Organic and Inorganic Nitrogen Sources for a Sustainable Environment

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Abstract: The use of beneficial microbes as biofertilizer has become fundamental in the agricultural sector for their potential role in food safety and sustainable crop production. A field trial was conducted to study the influence of beneficial microbes on the efficiency of organic and inorganic sources. The experiment was conducted in two consecutive years (2008–2009 and 2009–2010) in a farmer's field at Dargai Malakand Division. A randomized complete block design was used with four replications. The results revealed a significantly higher straw and grain nitrogen concentrations for the treatments receiving 50% N from urea + 50% N from FYM + BM, followed by the treatments receiving 50% N from urea + 50% N from (FYM + PM) + BM and 120 kg N ha^{-1} from urea fertilizer, respectively. Comparing the relevant treatments with and without BM, an increasing trend in N concentrations in straw and grain was observed with BM. The results revealed the highest grain total nitrogen, straw total nitrogen and total nitrogen uptake by wheat crop for the treatments receiving 120 kg N ha^{-1} from urea, followed by the treatments receiving 50% N from urea + 50% N from PM + BM and 50% N from urea + 50% N from (FYM + PM) + BM. Moreover, after comparing the relevant treatments with and without BM, for the parameters mentioned, an increasing trend in nitrogen uptake was observed. Significantly higher total soil nitrogen was obtained for treatment with 50% N from urea + 50% N from FYM + BM, followed by the treatment with 50% N from urea + 50% N from (FYM + PM) + BM or 50% N from urea + 50% N from PM + BM, respectively, as compared to the control treatment plot. Markedly higher soil mineral nitrogen was obtained for the 50% N from urea + 50% N from (FYM + PM) + BM treatment, followed by the treatment with 50% N from urea + 50% N from FYM + BM and 50% N treatment from urea + 50% N from PM + BM, compared to the control treatment. Comparing the relevant treatments with and without BM, an increasing trend in total soil N (g kg^{-1} soil) and soil mineral N (mg kg^{-1} soil) was noted with BM application. From the results, a significant increase in soil organic matter status (g kg^{-1} soil) due to application of organic and inorganic fertilization was summarized. Significantly higher soil organic matter (g kg^{-1} soil) was recorded for the treatment receiving 50% N from urea + 50% N from FYM + BM compared to untreated control plots. Our study further revealed an increasing trend in soil organic matter status (g kg^{-1} soil) when comparing the relevant treatments with and without BM.

Keywords: beneficial microbes; farmyard manure (FYM); poultry manure (PM); beneficial microorganisms (BM); nitrogen uptake and soil mineral nitrogen

1. Introduction

The growing world population is leading changing land use patterns, as agricultural land is being converted into housing estates and commercial areas. Shallow soil, low fertility, steep slopes, aridity and stoniness are some of the factors which render the agricultural land unsuitable for cultivation. Population pressure is another factor responsible for land degradation. Land scarcity is the major limiting factor for crop production. Therefore, increasing the yield per unit area is the only option available to improve the quantity and quality of crops. Soil fertility mainly depends on the availability of nutrient elements such as N, P and K. Among the major elements, N is an important element for soil fertility, which largely controls crop production. Wheat (*Triticum aestivum* L.), the major staple crop in Pakistan, is grown on both irrigated and rainfed land. The area, production and yield in Pakistan during the period 2009–2010 were 9.042 million hectares, 23.87 (24) million tons and 2716 kg ha^{-1}, respectively (Agricultural Statistics of KP, 2009–2010). Pakistan produces 4.8 million tons of urea, while the country requirement is around 5.6 million tons, leaving a gap of 0.8 million tons in supply and demand. Delays in the announcement of a fertilizer policy and the installation of additional fertilizer plants are the major reasons for not achieving self-sufficiency in fertilizer production.

Due to the easy availability of chemical fertilizers, the farming community has able to obtain maximum production from their crops through the use of chemical fertilizers. Therefore, the use of organic material declined very rapidly. The rapid increase in chemical fertilizers prices and limitations in their timely availability are the major problems preventing farmers from applying chemical fertilizers as recommended. In recent times, the problem of soil degradation has promoted farmers to start using organic fertilizer again in their agriculture. In addition, nutrient supplementation with chemical fertilizers is not affordable by many farmers. The use of on-farm nutrient sources needs to be explored to achieve a satisfactory level of sustainable crop yields and profitable returns, which can be achieved through integrated nutrient management. Ahmad et al. [1] reported that the wheat yield could be significantly increased under rain field conditions through the combined use of organic and mineral fertilizers. Nawaz et al. [2] reported that farmyard manure (FYM) application produced the maximum grain and straw during the whole experiment compared with other organic fertilizers under rainfed conditions. Jadoon et al. [3] found that the use of farmyard manure enhanced the grain yields of maize significantly over control plots. The organic matter content and water content were significantly improved, while the bulk density and soil strength were significantly reduced by the application of FYM.

Effective microorganisms/beneficial microorganisms (BM/EM) technology are mixed cultures of beneficial and naturally occurring microorganisms that can be applied as inoculants to increase the microbial diversity of soil and plant. Numerous researches have revealed that inoculation of BM cultures into the soil/plant ecosystem can improve soil quality, soil health and growth, yield and crop quality. Beneficial microorganisms technology consists of species of microorganisms such as rhizosphere, prebiotics, plant growth-promoting rhizobacteria, microbiome, fermentation, fungi and probiotics. Lactic acid bacteria and yeast are predominant, while actinomycetes, photosynthetic bacteria and other types of organisms are fewer in number. All microorganisms are compatible with each other and can co-exist in liquid culture.

Beneficial microorganisms should not be considered as a substitute for other management practices. However, it is an added dimension for optimizing our best soil and crop management practices, such as use of organic amendments, crop rotations, recycling of crop residues, conservation tillage and bio-control of pests. Beneficial microbes can increase the beneficial effects of these practices when used properly. Beneficial microbe technology has been recognized in many countries in a very short period of time after encouraging results relating to the technology in question were obtained. The main objectives of the study were (1) to enhance efficiency of organic and inorganic N fertilizer sources through beneficial microbes for sustainable wheat production, (2) to assess changes in important soil physical, chemical and biological soil properties by the use of organic and inorganic N fertilizer sources and beneficial microbes, (3) to evaluate the effect of beneficial microbes on nitrogen availability from farmyard manure (FYM) and poultry manure (PM) and a combination of both sources and (4) to quantify the effect of beneficial microbes on the decomposition of farmyard manure (FYM) and poultry manure (PM).

2. Materials and Methods

A wheat field experiment was conducted in two consecutive years (2008–2009 and 2009–2010) at Dargai Malakand Division Farmer Field to evaluate the effects of beneficial microbes (BM) on improving the efficiency of organic and inorganic N fertilizer sources.

2.1. Experimental Site

The experimental site was located at 32°N latitude, 72°E longitude. The site is about 477 m above the sea level. The soil of the experimental field was sandy clay loam and well drained. The soil of experimental field was alkaline in nature (pH 8.3), non-saline (EC 2.31 dS m^{-1}), low in organic matter (0.71%), total N (0.603 g kg^{-1} soil) and mineral N of 8.88 mg kg^{-1} soil. A composite soil sample of about 1 kg was collected for analysis from the eight randomly collected samples taken from 0–30 cm depth of the experimental site characterization field (Table 1). The climate of the experimental site is classified as semiarid tropical with annual average rainfall of 155 mm, with more than 70% of it occurring from July to the end of September. Mean temperature is lowest (3 °C) in January and highest (41 °C) in July.

Table 1. Physical and chemical properties of 0–30 cm layer of the experimental field.

Soil Properties	Unit	Values
Chemical		
pH	-	8.3
EC	dS m^{-1}	2.31
Organic matter	(%)	0.71
Mineral N	mg kg^{-1} soil	8.88
Total N	mg kg^{-1} soil	603
Physical		
Sand	g kg^{-1}	407
Silt	g kg^{-1}	283
Clay	g kg^{-1}	308
Texture		Sandy clay loam
Bulk density	g/cm^3	1.440

2.2. Materials and Treatments

The experiment consisted of two factors, i.e., wheat varieties and fertilizer treatments. Wheat varieties were Uqab (V_1) and Fakhar-e-Sarhad (V_2). Fertilizer treatments were: T_1 (control, i.e., No fertilizer), T_2 (120 kg N ha^{-1} from urea), T_3 (60 kg N ha^{-1} from urea),

T_4 (50% N from urea + 50% FYM), T_5 (50% N from urea + 50% PM), T_6 (50% N from urea + 50% N from (FYM + PM)), T_7 (60 kg N ha^{-1} from urea + BM), T_8 (50% N from urea + 50% N from FYM + BM), T_9 (50% N from urea + 50% N from PM + BM), and T_{10} (50% N from urea + 50% N from (FYM + PM) + BM). The amounts of N, FYM, PM and BM applied to plots for each treatments are given in Table 2. Wheat was sown in a line with hands 30 cm apart. Phosphorus and potassium were applied to the recommended doses (90–60 kg ha^{-1} P_2O_5-K_2O) in all treatments except the control as triple supper phosphate (TSP) and sulfate of potash (SOP). Urea was used as the source of inorganic nitrogen. Farmyard manure (FYM) from dairy farm and poultry manure (PM) from poultry farm were used to obtain 60 kg N ha^{-1} based on chemical composition (Table 3). In case of combined application of FYM and PM, both were mixed in such a way to obtain 30 kg N ha^{-1} from each source. The entire FYM, PM, Phosphorous, Potash and half N from urea were applied to all treatment except control before sowing of wheat and half of the N from urea was applied in 2nd irrigation. Certified seed of Uqab and Fakhr-e-Sarhad wheat varieties recommended for irrigated land of Khyber Pakhtunkhwa were sown on 2 December 2008 and 25 November 2009. In both years, a uniform seed rate of 100 kg ha^{-1} was used in all treatments. Bromoxynil + MCPA was sprayed at the 6-leaf stage of wheat to control of weeds @ 3 mL per liter of water.

Table 2. Rate of N, FYM, PM and BM applied in different treatments.

	Fakhar-e-Sarhad				Uqab			
	Nitrogen (kg ha^{-1})				Nitrogen (kg ha^{-1})			
Treatments:	**N**	**FYM**	**PM**	**BM**	**N**	**FYM**	**PM**	**BM**
T_1	0	0	0	0	0	0	0	0
T_2	120	0	0	0	120	0	0	0
T_3	60	0	0	0	60	0	0	0
T_4	60	60	0	0	60	60	0	0
T_5	60	0	60	0	60	0	60	0
T_6	60	30	30	0	60	30	30	0
T_7	60	0	0	25	60	0	0	25
T_8	60	60	0	25	60	60	0	25
T_9	60	0	60	25	60	0	60	25
T_{10}	60	30	30	25	60	30	30	25

Table 3. Physico-Chemical Characteristics of FYM and PM used in the experiment.

	2008–2009		2009–2010	
Quality Parameters	**FYM**	**PM**	**FYM**	**PM**
	(%)	**(%)**	**(%)**	**(%)**
Total N	0.8	1.4	0.62	2.21
Mineral N	0.12	0.16	0.13	0.17
Ec (dS m^{-1})	4.92	4.43	4.86	4.63
pH	8.0	7.98	8.1	7.99
Moisture content (%)	14.85	13.72	14.96	13.43

Sources of nutrients were urea (46% N), triple super phosphate (46% P_2O_5) and sulfate of potash (50% K_2O).

Quantity of farmyard manure and poultry used to obtain 60 kg N ha^{-1} was 7792 kg and 4286 kg during the period 2008–2009 and 9693 kg and 2715 kg during the period 2009–2010, respectively; in case of combined use, FYM and PM were mixed in such a way to obtain 30 kg from each source based on their chemical analysis.

2.3. Farmyard Manure and Poultry Manure Analysis

About 1 kg composite sample was taken from fully matured heap of farmyard manure (FYM) and poultry manure (PM) and mixed well before analysis. The FYM and PM used in the experiment had a total N of 0.80% and 1.4% in 2008–2009 and 0.62% and 2.21% N in 2009–2010, respectively, on wet basis. The pH value of FYM and PM sample was 8.0 and 7.98 during the year 2008–2009, while the pH was 8.1 and 7.99 for the year 2009–2010, respectively. The electrical conductivities of FYM and PM were 4.92 and 4.43 in 2008–2009 and 4.86 and 4.63 and 2009–2010, respectively.

2.4. Preparation of Extended BM

Basic culture of beneficial microbes (BM) under the commercial name of BM Bioaab was obtained from Chinar Agro Trade Batkhela. Extended Bioaab was prepared by adding 1 kg of molasses (gur) to 20 L of water and mixing thoroughly to make a homogenous solution, then 1 L of basic Bioaab was added, the drum was air tight and placed in the shade for seven days. After every 24 h, the solution was shaken with a stick and sealed air tight again. The extended Bioaab was used in 1st and 3rd irrigation @ 25 L ha^{-1}.

2.5. Experimental Design

Randomized complete block design (RCBD) was used with 4 replications. The size of subplots was 1.5 m × 5 m. One-meter-wide water channel was made in center of experimental field. There were a total of 20 treatments (2 wheat varieties and 10 nitrogen management treatments including control (Zero N)). There were six rows of wheat in each treatment plot.

2.6. Data Recorded

2.6.1. Total Soil Nitrogen

The total soil nitrogen for each treatment after each harvest was determined following the Kjeldahl method of Bremmer and Mulvaney [4].

2.6.2. Determination of Mineral N in Soil

To determine total mineral N (NH_4-N, NO_3-N) in soil samples, 20 g soil sample was extracted with 100 mL of 2 M KCl for 1 h on mechanical shaker and then filtered. Ten mL of the filtrate was distilled with MgO + Davarda's alloy to recover total mineral N in 5 mL of mixed boric acid indicator solution using the steam distillation method of Keeney and Nelson [5]. The distillate was titrated against 0.005 HCl, and the amount of mineral N was calculated as 1 mL of 0.005 HCl, which is equivalent to 70 µg N.

2.6.3. Soil Organic Matter

Organic matter content of the soil was determined by wet digestion method of Walkley and Black [6].

2.6.4. Plant Analysis

For determination of total N in plant, the method described by Kjeldahl method of Bremner [7] was used.

2.7. Statistical Analysis

The collected data was statistically analyzed using RCBD design with four replications (Gomez and Gomez, 1983). Treatments means were compared using LSD test of significance at 5% and 1% level of significance. The combined analysis of data was also performed over years.

3. Results

3.1. Nitrogen Content in Wheat Straw

Data on N concentrations in straw of wheat after each harvest for two consecutive years (2008–2009 and 2009–2010) are presented in Table 4. Statistical analysis of the data showed a significant effect of year and N fertilizer sources, while the effect of variety was not significant on the N content of wheat straw. In 2009–2010, a significantly higher N concentration in straw was found at 0.573% compared to 0.30% in 2008–2009 for both varieties. Planned mean comparisons showed a significant effect of both control vs. rest and 120 kg N ha^{-1} of vs. rest on nitrogen content in wheat straw.

Table 4. Straw nitrogen % of wheat as influenced by variety and N fertilizer sources.

Varieties (V)	Fertilizers (F)	Year (Y)		V × F
		2008–2009	2009–2010	
Uqab	Control	0.22	0.19	0.20
Uqab	120 kg N ha^{-1} from urea	0.35	0.77	0.56
Uqab	60 kg N ha^{-1} from urea	0.23	0.34	0.29
Uqab	50% N from urea + 50% N from FYM	0.30	0.55	0.43
Uqab	50% N from urea + 50% N from PM	0.29	0.52	0.40
Uqab	50% N from urea + 50% N from (FYM + PM)	0.31	0.57	0.44
Uqab	60 kg N ha^{-1} from urea + BM	0.26	0.41	0.34
Uqab	50% N from urea + 50% N from FYM + BM	0.37	0.81	0.59
Uqab	50% N from urea + 50% N from PM + BM	0.34	0.71	0.52
Uqab	50% N from urea + 50% N from (FYM + PM) + BM	0.36	0.75	0.56
F-S	Control	0.23	0.21	0.22
F-S	120 kg N ha^{-1} from urea	0.36	0.77	0.56
F-S	60 kg N ha^{-1} from urea	0.26	0.40	0.33
F-S	50% N from urea + 50% N from FYM	0.29	0.56	0.43
F-S	50% N from urea + 50% N from PM	0.30	0.55	0.42
F-S	50% N from urea + 50% N from (FYM + PM)	0.30	0.54	0.42
F-S	60 kg N ha^{-1} from urea + BM	0.26	0.46	0.36
F-S	50% N from urea + 50% N from FYM + BM	0.34	0.77	0.56
F-S	50% N from urea + 50% N from PM + BM	0.34	0.75	0.54
F-S	50% N from urea + 50% N from (FYM + PM) + BM	0.37	0.79	0.58
				Mean
	Uqab	0.30	0.56	0.43
	Fakhr-e-sarhad (F-S)	0.30	0.58	0.44
	Mean	0.30	0.57	
	Fertilizer Sources (FS)	Without BM	With BM	
	60 kg N ha^{-1} from urea	0.31	0.35	0.33 c
	50% N from urea + 50% N from FYM	0.43	0.57	0.50 a
	50% N from urea + 50% N from PM	0.41	0.53	0.47 b
	50% N from urea + 50% N from (FYM + PM)	0.43	0.57	0.50 a
	Mean	0.39	0.50	
	Planned mean comparison	Mean 1	Mean 2	p-value
	Control vs. rest	0.21	0.46	0.00
	120 kg N ha^{-1} from urea vs. rest	0.56	0.45	0.00

LSD Value for FS at $p \leq 0.05$ = 0.0299. Mean of the same category followed by different letters are significantly different ($p \leq 0.05$).

The effects of fertilizer treatments on wheat straw N concentration during both individual years (2008–2009 and 2009–2010) were significant. Mean values of the data from 2008–2009 showed that the highest straw N concentration of 0.586% was recorded for the treatment that received 50% N from urea + 50% N from FYM + BM (T_8), followed by a straw N concentration of 0.560% and 0.556% for the treatment with 120 kg N ha^{-1} from urea fertilizer (T_2) and 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}). The lowest straw N concentration of 0.205% was recorded In the control t plot (T_1). Similarly, in 2009–2010, the maximum straw N concentration of 0.579% was recorded for the treatment receiving 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}), followed by a straw N concentration of 0.564% and 0.556% for the treatment receiving 120 kg N ha^{-1} from urea fertilizer (T_2) and 50% N from urea + 50% N from FYM + BM (T_8), respectively, while the minimum straw N concentration of 0.221% was obtained in the control treatment plot (T_1).

Combined analysis of the data revealed significant effect of fertilizer treatments on straw N concentration. The highest straw N concentration of 0.571% was obtained in the treatment that received 50% N from urea + 50% N from FYM + BM (T_8), followed by a straw N concentration of 0.567% and 0.562% from the treatments receiving 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}) and 120 kg N ha^{-1} from urea fertilizer, respectively. The lowest straw N concentration of 0.213% was obtained in the control plot (T_1). Comparing the relevant treatments with and without BM, an increasing trend in straw N concentration in BM was noted. The application of BM with fertilizer sources increased straw N concentration by 0.11 (%). Fertilizer sources significantly affected wheat straw N concentration. A higher N concentration in straw was recorded in the treatment with 50% N from urea + 50% N from FYM and 50% N from urea + 50% N from (FYM + PM), while the lower concentration of N in wheat straw in treatment plots was found to absorb 60 kg N ha^{-1} from urea. The Y $\times$ F interaction was significant, where maximum straw N concentration was observed for the treatment receiving 50% N from urea + 50% N from FYM in both years, while the interactions of year $\times$ varieties, variety $\times$ N fertilizer sources and year $\times$ variety $\times$ N fertilizer sources were non-significant.

3.2. Total Nitrogen in Wheat Straw

The data relating to total straw N (kg ha^{-1}) in wheat plant after each harvest in two consecutive years (2008–2009 and 2009–2010) as affected by varieties and N fertilizer sources are presented in Table 5. Statistical analysis of the data indicated that the effect of years and N fertilizer sources on total straw N (kg ha^{-1}) was significant; however, the effect of varieties on total straw N (kg ha^{-1}) was non-significant. In 2009–2010, a significantly greater total straw N of 41.602 kg ha^{-1} was recorded compared to a lower total straw N of 19.036 kg ha^{-1} in 2008–2009. Planned mean comparisons revealed that control vs. rest and 120 kg N ha^{-1} from urea vs. rest significantly affected total nitrogen in wheat straw.

The effect of fertilization treatments on total N (kg ha^{-1}) in straw was significant in individual years (2008–2009 and 2009–2010). In 2008–2009, a maximum total N straw of 46.759 kg ha^{-1} was recorded in treatments receiving 120 kg N ha^{-1} from urea fertilizer (T_2), followed by 43.406 kg ha^{-1} and 40.843 kg ha^{-1} in treatments receiving 50% N from urea + 50% N from FYM + BM (T_8) and 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}). In the control plot (T_1), the minimum total straw N of 5.146 kg ha^{-1} was recorded. Almost the same trend was observed in 2009–2010. The highest straw total N of 43.690 kg ha^{-1} was noted for the 120 kg N ha^{-1} treatment from urea (T_2), followed by 43.293 kg ha^{-1} and 42.679 kg ha^{-1} straw total N in treatment with 50% N from urea + 50% N from PM + BM (T_9) and 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}), respectively. The lowest total straw N of 5.733 kg ha^{-1} was obtained in the control treatment plot (T_1). Combined analysis of the data exhibited significant effect of fertilizer treatments on straw total N (kg ha^{-1}). The highest straw total N of 45.224 kg ha^{-1} was recorded for the treatment receiving 120 kg N ha^{-1} from urea (T_2), followed by 41.761 kg ha^{-1} and 40.967 kg ha^{-1} in treatments receiving 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}) and 50% N from urea + 50% N from PM + BM (T_9). The lowest total N-straw content of 5.439 kg ha^{-1} was obtained in the control plot (T_1). Comparing the relevant treatments with and without BM, an increasing trend in total N (kg ha^{-1}) in straw with BM was observed. The application of BM with fertilizer sources increased total N in straw by 9.27 kg ha^{-1}. The effect of fertilizer sources was significant on straw total N. The maximum total N in straw was observed at a treatment receiving 50% N from urea + 50% N from FYM, and the minimum straw total N was noted in 60 kg N ha^{-1} from urea. The Interaction of Y × F was significant, where maximum total N in straw recorded for both years treated with 120 kg N ha^{-1} from urea and the minimum straw total N was noted in the control treatment, while the interactions of Yr × V, V × F and Y × Y × F were non-significant.

Table 5. Straw total N of wheat as influenced by variety and N fertilizer sources.

Varieties (V)	Fertilizers (F)	Year (Y)		V × F
		2008–2009	2009–2010	
Uqab	Control	6.01	4.28	5.15
Uqab	120 kg N ha^{-1} from urea	28.95	64.57	46.76
Uqab	60 kg N ha^{-1} from urea	12.92	21.59	17.25
Uqab	50% N from urea + 50% N from FYM	16.38	41.61	28.99
Uqab	50% N from urea + 50% N from PM	19.86	44.62	32.24
Uqab	50% N from urea + 50% N from (FYM + PM)	22.40	41.87	32.14
Uqab	60 kg N ha^{-1} from urea + BM	16.29	27.73	22.01
Uqab	50% N from urea + 50% N from FYM + BM	25.80	61.01	43.40
Uqab	50% N from urea + 50% N from PM + BM	22.89	54.39	38.64
Uqab	50% N from urea + 50% N from (FYM + PM) + BM	23.45	58.23	40.84
F-S	Control	6.13	5.33	5.73
F-S	120 kg N ha^{-1} from urea	26.83	60.55	43.69
F-S	60 kg N ha^{-1} from urea	16.53	28.19	22.36
F-S	50% N from urea + 50% N from FYM	18.40	34.14	26.27
F-S	50% N from urea + 50% N from PM	18.49	39.02	28.75
F-S	50% N from urea + 50% N from (FYM + PM)	16.55	38.32	27.44
F-S	60 kg N ha^{-1} from urea + BM	16.64	27.89	22.26
F-S	50% N from urea + 50% N from FYM + BM	20.13	52.77	36.45
F-S	50% N from urea + 50% N from PM + BM	23.37	63.21	43.29
F-S	50% N from urea + 50% N from (FYM + PM) + BM	22.64	62.72	42.68
				Mean
	Uqab	19.50	41.99	30.74
	Fakhr-e-sarhad (F-S)	18.57	41.21	29.89
	Mean	19.03	41.60	
	Fertilizer Sources (FS)	With out BM	With BM	
	60 kg N ha^{-1} from urea	19.81	22.14	20.97 b
	50% N from urea + 50% N from FYM	27.63	39.93	33.78 a
	50% N from urea + 50% N from PM	30.50	40.97	35.73 a
	50% N from urea + 50% N from (FYM + PM)	29.79	41.76	35.77 a
	Mean	26.93	36.20	
	Planned mean comparison	Mean 1	Mean 2	*p*-value
	Control vs. rest	5.44	33.08	0.00
	120 kg N ha^{-1} from urea vs. rest	45.22	31.56	0.00

LSD Value for FS at $p \leq 0.05$ = 3.3762. Mean of the same category followed by different letters are significantly different ($p \leq 0.05$).

3.3. Nitrogen Content in Wheat Grain

The result of N concentrations in wheat grains after each harvest for two consecutive years (2008–2009 and 2009–2010) is presented in Table 6.

Table 6. Grain Nitrogen (%) of wheat as influenced by variety and N fertilizer source.

Varieties (V)	**Fertilizers (F)**	**Year (Y)**		**V × F**
		2008–2009	**2009–2010**	
Uqab	Control	1.37	1.19	1.28
Uqab	120 kg N ha^{-1} from urea	1.53	1.86	1.69
Uqab	60 kg N ha^{-1} from urea	1.46	1.36	1.41
Uqab	50% N from urea + 50% N from FYM	1.48	1.65	1.57
Uqab	50% N from urea + 50% N from PM	1.49	1.66	1.58
Uqab	50% N from urea + 50% N from (FYM + PM)	1.50	1.52	1.51
Uqab	60 kg N ha^{-1} from urea + BM	1.45	1.41	1.43
Uqab	50% N from urea + 50% N from FYM + BM	1.56	1.90	1.73
Uqab	50% N from urea + 50% N from PM + BM	1.59	1.86	1.72
Uqab	50% N from urea + 50% N from (FYM + PM) + BM	1.62	1.84	1.73
F-S	Control	1.42	1.41	1.41
F-S	120 kg N ha^{-1} from urea	1.56	1.89	1.73
F-S	60 kg N ha^{-1} from urea	1.46	1.51	1.48
F-S	50% N from urea + 50% N from FYM	1.50	1.67	1.59
F-S	50% N from urea + 50% N from PM	1.48	1.73	1.60
F-S	50% N from urea + 50% N from (FYM + PM)	1.51	1.73	1.62
F-S	60 kg N ha^{-1} from urea + BM	1.47	1.61	1.54
F-S	50% N from urea + 50% N from FYM + BM	1.59	1.86	1.72
F-S	50% N from urea + 50% N from PM + BM	1.54	1.79	1.66
F-S	50% N from urea + 50% N from (FYM + PM) + BM	1.59	1.82	1.71
				Mean
	Uqab	1.50	1.62	1.56
	Fakhr-e-sarhad (F-S)	1.51	1.70	1.61
	Mean	1.51	1.66	
	Fertilizer Sources (FS)	With out BM	With BM	
	60 kg N ha^{-1} from urea	1.44	1.48	1.46 b
	50% N from urea + 50% N from FYM	1.58	1.73	1.65 a
	50% N from urea + 50% N from PM	1.59	1.69	1.64 a
	50% N from urea + 50% N from (FYM + PM)	1.56	1.72	1.64 a
	Mean	1.54	1.66	
	Planned mean comparison	Mean 1	Mean 2	*p*-value
	Control vs. rest	1.35	1.61	0.00
	120 kg N ha^{-1} from urea vs. rest	1.71	1.60	0.00

LSD Value for FS at $p \leq 0.05 = 0.0508$. Mean of the same category followed by different letters are significantly different ($p \leq 0.05$).

Statistical analysis of the data revealed significant effect of year, variety and N fertilizer source on wheat grain N content. A higher grain N concentration of 1.61 (%) was recorded in V_2 (Fakhr-e-sarhad) compared with lower grain N concentration of 1.57 (%) in V_1 (Uqab). Similarly, greater grain N concentration of 1.66 (%) measured for both varieties in 2009–2010 compared with lower grain N concentration of 1.57 (%) in 2008–2009. Planned mean comparisons indicated significant effects of both control vs. rest and 120 kg N ha^{-1} vs. rest on grain N concentration of wheat. The effects of fertilizer treatments on wheat grain N concentration during both individual years (2008–2009 and 2009–2010) were significant. Mean values of the data for 2008–2009 showed that the highest N concentration increase of 1.61 (%) was recorded in the treatment receiving 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}), followed by a grain N concentration of 1.58 (%) and 1.57 (%) in treatments receiving 50% N from urea + 50% N from FYM + BM (T_8) and 50% N from urea + 50% N from PM + BM (T_9), respectively. The lowest grain N concentration of 1.39 (%) was recorded in the control treatment plot (T_1). Similarly, in the year 2009–2010, a maximum grain N concentration of 1.88 (%) was recorded for the treatment receiving 50% N from urea + 50% N from FYM + BM (T_8), followed by a wheat grain N concentration of 1.83 (%) and 1.82 (%) in treatments receiving 50% N from urea + 50% (FYM + PM) + BM (T_{10}) and 50% N from urea + 50% N, respectively, was obtained from PM + BM (T_9),while the minimum grain N concentration of 1.30 (%) was obtained in the control treatment plot (T_1).

Combined analysis of the data revealed a significant effect of fertilizer treatments on grain N concentration. The highest grain N concentration of 1.73 (%) was obtained from the treatment that received 50% N from urea + 50% N from FYM + BM (T_8), followed by 1.72 (%) and 1.71 (%) from the treatments that received 50% N from urea + 50% N from FYM + 50% N from PM + BM (T_{10}) and 120 kg N ha^{-1} from urea fertilizer (T_2), respectively. The lowest grain N concentration of 1.35 (%) was obtained from the control treatment plot (T_1). Comparing the relevant treatments with and without BM, an increasing trend in grain N concentration with BM supplementation. Was noted. Application of BM with N fertilizer sources increases grain N concentration by 0.12 (%). Fertilizer sources significantly affected the grain N concentration. The maximum grain N concentration was recorded in the treatment receiving 50% N from urea + 50% N from FYM, while the minimum concentration was noted in the treatment receiving 60 kg N ha^{-1} from urea. The interaction between Y × V was significant. The maximum grain N concentration was recorded in both varieties during 2009–2010 as minimum concentration in 2008–2029. Similarly, the Y × F interaction was significant, where maximum grain N concentration was observed in the treatment received 50% N from urea + 50% N from (FYM + PM) + BM in the year 2008–2009, while the treatment receiving 50% N from urea + 50% N from FYM gives maximum grain N concentration. Interactions between V × F and Y × V × F were non-significant.

3.4. Total Nitrogen in Wheat Grain (kg ha^{-1})

Total grain N (kg ha^{-1}) data in wheat plants after each harvest for two consecutive years (2008–2009 and 2009–2010) influenced by varieties and N fertilizer sources are presented in Table 7.

Statistical analysis of the data indicated that the effect of years and N fertilizer sources on total grain N was significant while the effect of varieties on total grain N (kg ha^{-1}) was non-significant. In 2009–2010 a significantly higher total grain N of 78.20 kg ha^{-1} was recorded compared with lowest grain total N of 65.88 kg ha^{-1} in 2008–2009.

The effect of fertilizer treatments on total grain N (kg ha^{-1}) was significant in both individual years (2008–2009 and 2009–2010) was significant. In the year 2008–2009 maximum grain total N of 84.02 kg ha^{-1} was recorded in treatments with 120 kg N ha^{-1} from urea fertilizer (T_2), followed by a grain total N of 73.92 kg ha^{-1} and 73.02 kg ha^{-1} in treatments receiving 50% N from urea + 50% N from PM + BM (T_9) and 50% N from urea + 50% N from FYM + BM (T_{10}), respectively. In the control plot (T_1) the minimum total grain N of 26.56 kg ha^{-1} was recorded. Almost the same trend was observed in 2009–2010. The highest grain total N of 106.80 kg ha^{-1} was noted for treatment with 120 kg N ha^{-1} from urea (T_2), followed by a grain total N of 100.68 kg ha^{-1} and 94.00 kg ha^{-1} in treatment with 50% N from urea + 50% N from PM + BM (T_9) and 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}). The lowest grain total N of 23.78 kg ha^{-1} was obtained in the control plot (T_1). The combined analysis of the data exhibited significant effect of fertilizer treatments on grain total N (kg ha^{-1}). The highest grain total N of 95.41 kg ha^{-1} was recorded for treatment with 120 kg N ha^{-1} from the urea source (T_2), followed by a grain total N of 87.30 kg ha^{-1} and 83.49 kg ha^{-1} for treatment at 50% N from urea + 50% N from PM + BM (T_9) and 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}), respectively. Comparing the relevant treatments with and without BM, an increasing trend in grain total N (kg ha^{-1}) in grain with BM was observed. The supplementation of BM with fertilizer sources increases grain total N by 9.59 kg ha^{-1}. The effect of fertilizer sources was significant on grain total N. in the grain. The maximum total N in grain was observed at treatment with 50% N from urea + 50% PM whereas the minimum grain total N recorded at treatment with 60 kg N ha^{-1} from urea. The interaction between year × varieties, year ×

N fertilizer sources, variety × N fertilizer sources and year × variety × N fertilizer sources were non-significant.

Table 7. Grain total N (kg ha^{-1}) of wheat as influenced by variety and N fertilizer source.

Varieties (V)	Fertilizers (F)	Year (Y)		V × F
		2008–2009	2009–2010	
Uqab	Control	24.08	19.09	21.59
Uqab	120 kg N ha^{-1} from urea	88.84	106.87	97.85
Uqab	60 kg N ha^{-1} from urea	57.06	57.37	57.22
Uqab	50% N from urea + 50% N from FYM	57.43	83.19	70.31
Uqab	50% N from urea + 50% N from PM	70.35	87.48	78.91
Uqab	50% N from urea + 50% N from (FYM + PM)	74.92	75.47	75.19
Uqab	60 kg N ha^{-1} from urea + BM	66.56	65.08	65.82
Uqab	50% N from urea + 50% N from FYM + BM	77.42	97.98	87.70
Uqab	50% N from urea + 50% N from PM + BM	73.07	94.23	83.65
Uqab	50% N from urea + 50% N from (FYM + PM) + BM	72.25	85.38	78.82
F-S	Control	29.04	28.47	28.75
F-S	120 kg N ha^{-1} from urea	79.21	106.73	92.97
F-S	60 kg N ha^{-1} from urea	63.57	74.50	69.04
F-S	50% N from urea + 50% N from FYM	70.13	66.81	68.47
F-S	50% N from urea + 50% N from PM	65.36	74.67	70.01
F-S	50% N from urea + 50% N from (FYM + PM)	63.98	80.65	72.31
F-S	60 kg N ha^{-1} from urea + BM	67.26	65.63	66.44
F-S	50% N from urea + 50% N from FYM + BM	68.62	84.56	76.59
F-S	50% N from urea + 50% N from PM + BM	74.76	107.13	90.94
F-S	50% N from urea + 50% N from (FYM + PM) + BM	73.70	102.62	88.16
				Mean
	Uqab	66.20	77.21	71.71
	Fakhr-e-sarhad (F-S)	65.56	79.18	72.37
	Mean	65.88	78.20	
	Fertilizer Sources (FS)	With out BM	With BM	
	60 kg N ha^{-1} from urea	63.13	66.13	64.63 b
	50% N from urea + 50% N from FYM	69.39	82.15	75.77 a
	50% N from urea + 50% N from PM	74.46	87.30	80.88 a
	50% N from urea + 50% N from (FYM + PM)	73.75	83.49	78.62 a
	Mean	70.18	79.77	
	Planned mean comparison	Mean 1	Mean 2	*p*-value
	Control vs. rest	25.17	77.25	0.00
	120 kg N ha^{-1} from urea vs. rest	95.41	74.97	0.00

LSD Value for FS at $p \leq 0.05$ = 7.4217. Mean of the same category followed by different letters are significantly different ($p \leq 0.05$).

3.5. Total N Uptake in Wheat Crop

The data relating to total N uptake of wheat crop (kg ha^{-1}) after each harvest for two consecutive years (2008–2009 and 2009–2010) as affected by varieties and N fertilizer sources is summarized in Table 8.

Statistical analysis of the data indicated that the effect of years and N fertilizer sources on total N uptake of wheat was significant, however the effect of varieties on total N uptake of wheat crop (kg ha^{-1}) was non-significant. Significantly greater total N uptake of 119.80 kg ha^{-1} was recorded in 2009–2010 compared with total N uptake of 84.92 kg ha^{-1} in 2008–2009. Planned mean comparisons revealed that the control vs. rest and 120 kg N ha^{-1} from urea vs. rest significantly affected total N uptake of wheat crop.

Table 8. Total N uptake (kg ha^{-1}) of wheat as influenced by variety and N fertilizer.

Varieties (V)	Fertilizers (F)	Year (Y)		V × F
		2008–2009	**2009–2010**	
Uqab	Control	30.10	23.37	26.73
Uqab	120 kg N ha^{-1} from urea	117.78	171.44	144.61
Uqab	60 kg N ha^{-1} from urea	69.98	78.96	74.47
Uqab	50% N from urea + 50% N from FYM	73.81	124.80	99.30
Uqab	50% N from urea + 50% N from PM	90.20	132.10	111.15
Uqab	50% N from urea + 50% N from (FYM + PM)	97.33	117.34	107.33
Uqab	60 kg N ha^{-1} from urea + BM	82.85	92.81	87.83
Uqab	50% N from urea + 50% N from FYM + BM	103.22	158.99	131.11
Uqab	50% N from urea + 50% PM + BM	95.96	148.62	122.29
Uqab	50% N from urea + 50% N from (FYM + PM) + BM	95.70	143.61	119.66
F-S	Control	35.17	33.80	34.48
F-S	120 kg N ha^{-1} from urea	106.04	167.27	136.66
F-S	60 kg N ha^{-1} from urea	80.10	102.69	91.40
F-S	50% N from urea + 50% N from FYM	88.53	100.94	94.74
F-S	50% N from urea + 50% N from PM	83.84	113.69	98.77
F-S	50% N from urea + 50% N from (FYM + PM)	80.54	118.97	99.75
F-S	60 kg N ha^{-1} from urea + BM	83.89	93.52	88.70
F-S	50% N from urea + 50% N from FYM + BM	88.75	137.33	113.04
F-S	50% N from urea + 50% N from PM + BM	98.13	170.34	134.24
F-S	50% N from urea + 50% N from (FYM + PM) + BM	96.34	165.34	130.84
				Mean
	Uqab	85.69	119.20	102.45
	Fakhr-e-sarhad (F-S)	84.13	120.39	102.26
	Mean	84.91	119.80	
	Fertilizer Sources (FS)	With out BM	With BM	
	60 kg N ha^{-1} from urea	82.93	88.27	85.60 b
	50% N from urea + 50% N from FYM	97.02	122.08	109.55 a
	50% N from urea + 50% N from PM	104.96	128.26	116.61 a
	50% N from urea + 50% N from (FYM + PM)	103.54	125.25	114.39 a
	Mean	97.11	115.96	
	Planned mean comparison	Mean 1	Mean 2	*p*-value
	Control vs. rest	30.61	110.33	0.00
	120 kg N ha^{-1} from urea vs. rest	140.63	106.54	0.00

LSD Value for FS at $p \leq 0.05$ = 10.0770. Mean of the same category followed by different letters are significantly different ($p \leq 0.05$).

The effect of fertilization treatments on total N uptake of wheat crop (kg ha^{-1}) during the two individual years (2008–2009 and 2009–2010) was significant. In 2008–2009, a maximum total N uptake of 111.91 kg ha^{-1} was recorded treated with 120 kg N ha^{-1} from urea fertilizer (T_2), followed by a total N uptake of 97.05 kg ha^{-1} and 96.02 kg ha^{-1} in treatments receiving 50% N from urea + 50% N from PM + BM (T_9) and 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}), respectively. The minimum total N uptake of 30.61 kg ha^{-1} was recorded in the control plot (T_1). Almost the same trend was observed in 2009–2010. The highest total N uptake of 169.36 kg ha^{-1} was noted when treated with 120 kg N ha^{-1} from urea fertilizer (T_2), followed by a total N uptake of 159.48 kg ha^{-1} and 154.47 kg ha^{-1} in treatment received 50% N from urea + 50% N from PM + BM (T_8) and 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}), respectively. The lowest total N uptake of 28.59 kg ha^{-1} was obtained in the control treatment plot (T_1). Combined analysis of the data exhibited significant effect of fertilizer treatments on total N uptake of wheat crop (kg ha^{-1}). The highest total N uptake of 140.64 kg ha^{-1} was recorded for treatment with 120 kg N ha^{-1} from urea (T_2), followed by a total N uptake of 128.27 kg ha^{-1} and

125.25 kg ha^{-1} in the treatment with 50% N from urea + 50% N from PM + BM (T_8) and 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}). The lowest total N uptake of 30.61 kg ha^{-1} was noted in the control treatment plot (T_1).

Comparing the relevant treatments with and without BM, an increasing trend in total N uptake was noted with BM supplementation. The application of BM with any fertilizer sources increases the total N uptake of wheat crop by 18.85 kg ha^{-1}. Fertilizer sources significantly affected total N uptake of wheat crop. The maximum total N uptake was observed at 50% N from urea + 50% N from PM treatment, and the lowest total N uptake of wheat crop was observed in the treatment receiving 60 kg N ha^{-1} from urea. The interaction of Y × F was significant. The maximum total N uptake of wheat crop was recorded in the treatment with 120 kg N ha^{-1} compared to the control in both years, while interactions of Y × V, V × F and Y × V × F were non-significant.

3.6. Soil Total N (g kg^{-1})

The data relating to soil total N (g kg^{-1}) in soil after each harvest of wheat crop for two consecutive years (2008–2009 and 2009–2010) as affected by varieties and N fertilizer sources is presented in Table 9.

The statistical analysis of the data indicated that the effect of years and N fertilizer sources on soil total N was significant, whereas the effect of varieties on soil total N (g kg^{-1}) was non-significant. Significantly greater soil total N of 0.867 g kg^{-1} of soil was recorded in 2009–2010 compared to a lower soil total N of 0.780 g kg^{-1} of soil in 2008–2009.

The effect of fertilizer treatments on soil total N (g kg^{-1} soil) during both individual years (2008–2009 and 2009–2010) was significant. In 2008–2009, the maximum soil total N of 0.884 g kg^{-1} soil was recorded in treatments receiving 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}) and 50% N from urea + 50% N from FYM + BM (T_8), followed by 0.883 g kg^{-1} soil in the treatment receiving 50% N from urea + 50% N from PM + BM (T_9). The minimum soil total N of 0.606 g kg^{-1} soil was recorded in the control treatment plot (T_1). Almost the same trend was observed in 2009–2010. The highest total soil N of 1.27 g kg^{-1} soil was noted for the treatment receiving 50% N from urea + 50% N from FYM + BM (T_8), followed by a total soil N of 1.041 g kg^{-1} soil for treatment 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}). The lowest total soil N of 0.580 g kg^{-1} soil was obtained in the control treatment plot (T_1).

The combined analysis of the data exhibited an significant effect of fertilizer treatments on total soil N (g kg^{-1} soil). The highest total soil N of 1.006 g kg^{-1} soil was recorded for the treatment receiving 50% N from urea + 50% N from FYM + BM (T_8), followed by 0.962 g kg^{-1} soil and 0.961 g kg^{-1} soil for treatments receiving 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}) and 50% N from urea + 50% N from PM + BM (T_9), respectively. The lowest total soil N of 0.593 g kg^{-1} soil was obtained in the control treatment plot (T_1). Comparing the relevant treatments with and without BM, an increasing trend in soil total N (g kg^{-1} soil) was noted with application of BM. Supplementation of BM with any fertilizer sources increases soil total N by about 0.08 g kg^{-1} soil. The interactions of Y × F was significant, where the maximum total soil N (g kg^{-1} soil) in both years was recorded for the treatment receiving 50% N from urea + 50% N from FYM + BM. The interactions of Y × V, V × F and Y × V × F were non-significant.

Table 9. Soil total N (g kg^{-1} soil) of wheat as influenced by wheat variety and N fertilizer.

Varieties (V)	Fertilizers (F)	Year (Y)		V × F
		2008–2009	2009–2010	
Uqab	Control	0.61	0.58	0.59
Uqab	120 kg N ha^{-1} from urea	0.70	0.68	0.69
Uqab	60 kg N ha^{-1} from urea	0.67	0.68	0.67
Uqab	50% N from urea + 50% N from FYM	0.84	0.91	0.87
Uqab	50% N from urea + 50% N from PM	0.83	0.87	0.85
Uqab	50% N from urea + 50% N from (FYM + PM)	0.83	0.92	0.87
Uqab	60 kg N ha^{-1} from urea + BM	0.70	0.74	0.72
Uqab	50% N from urea + 50% N from FYM + BM	0.86	1.23	1.04
Uqab	50% N from urea + 50% N from PM + BM	0.87	1.04	0.95
Uqab	50% N from urea + 50% N from (FYM + PM) + BM	0.87	1.03	0.95
F-S	Control	0.61	0.59	0.60
F-S	120 kg N ha^{-1} from urea	0.67	0.72	0.70
F-S	60 kg N ha^{-1} from urea	0.67	0.69	0.68
F-S	50% N from urea + 50% N from FYM	0.84	0.95	0.90
F-S	50% N from urea + 50% N from PM	0.83	0.93	0.88
F-S	50% N from urea + 50% N from (FYM + PM)	0.84	0.94	0.89
F-S	60 kg N ha^{-1} from urea + BM	0.70	0.74	0.72
F-S	50% N from urea + 50% N from FYM + BM	0.91	1.03	0.97
F-S	50% N from urea + 50% N from PM + BM	0.90	1.05	0.97
F-S	50% N from urea + 50% N from (FYM + PM) + BM	0.90	1.06	0.98
				Mean
	Uqab	0.78	0.87	0.82
	Fakhr-e-sarhad (F-S)	0.79	0.87	0.83
	Mean	0.78	0.87	
	Fertilizer Sources (FS)	Without BM	With BM	
	60 kg N ha^{-1} from urea	0.68	0.72	0.70 b
	50% N from urea + 50% N from FYM	0.89	1.01	0.95 a
	50% N from urea + 50% N from PM	0.86	0.96	0.91 a
	50% N from urea + 50% N from (FYM + PM)	0.88	0.96	0.92 a
	Mean	0.83	0.91	
	Planned mean comparison	Mean 1	Mean 2	*p*-value
	Control vs. rest	0.59	0.85	0.00
	120 kg N ha^{-1} from urea vs. rest	0.69	0.87	0.00

LSD Value for FS at $p \leq 0.05$ = 0.0406. Mean of the same category followed by different letters are significantly different ($p \leq 0.05$).

3.7. Soil Mineral N (mg kg^{-1} Soil)

Data concerning to soil mineral N (mg kg^{-1} soil) in soil after each harvest of wheat crop for two consecutive years (2008–2009 and 2009–2010) are summarized in Table 10. Statistical analysis of the data showed non-significant effect of varieties on soil mineral N (mg kg^{-1} soil); however, the effect of years and N fertilizer sources on soil mineral N (mg kg^{-1} soil) was significant. Significantly greater soil mineral N of 19.53 mg kg^{-1} soil was recorded in the year 2009–2010 compared with 16.72 mg kg^{-1} soil in the year 2008–2009 for both varieties.

Table 10. Soil mineral N (mg kg^{-1} soil) of wheat as influenced by wheat variety and N fertilizer sources.

Varieties (V)	Fertilizers (F)	Year (Y)		V × F
		2008–2009	2009–2010	
Uqab	Control	9.63	6.56	8.09
Uqab	120 kg N ha^{-1} from urea	14.88	18.38	16.63
Uqab	60 kg N ha^{-1} from urea	11.81	16.63	14.22
Uqab	50% N from urea + 50% N from FYM	17.06	21.00	19.03
Uqab	50% N from urea + 50% N from PM	17.06	20.56	18.81
Uqab	50% N from urea + 50% N from (FYM + PM)	17.94	22.75	20.34
Uqab	60 kg N ha^{-1} from urea + BM	15.31	19.69	17.50
Uqab	50% N from urea + 50% N from FYM + BM	21.00	23.63	22.31
Uqab	50% N from urea + 50% N from PM + BM	20.13	22.31	21.22
Uqab	50% N from urea + 50% N from (FYM + PM) + BM	21.44	24.94	23.19
F-S	Control	8.75	9.19	8.97
F-S	120 kg N ha^{-1} from urea	14.88	18.38	16.63
F-S	60 kg N ha^{-1} from urea	12.69	16.63	14.66
F-S	50% N from urea + 50% N from FYM	17.06	21.00	19.03
F-S	50% N from urea + 50% N from PM	16.63	18.81	17.72
F-S	50% N from urea + 50% N from (FYM + PM)	18.38	21.88	20.13
F-S	60 kg N ha^{-1} from urea + BM	16.63	19.25	17.94
F-S	50% N from urea + 50% N from FYM + BM	21.00	23.19	22.09
F-S	50% N from urea + 50% N from PM + BM	21.00	22.75	21.88
F-S	50% N from urea + 50% N from (FYM + PM) + BM	21.00	23.19	22.09
				Mean
	Uqab	16.63	19.64	18.13
	Fakhr-e-sarhad (F-S)	16.80	19.43	18.11
	Mean	16.71	19.53	
	Fertilizer Sources (FS)	Without BM	With BM	
	60 kg N ha^{-1} from urea	14.44	17.72	16.08 c
	50% N from urea + 50% N from FYM	19.03	22.20	20.62 ab
	50% N from urea + 50% N from PM	18.27	21.55	19.91 b
	50% N from urea + 50% N from (FYM + PM)	20.23	22.64	21.44 a
	Mean	17.99	21.03	
	Planned mean comparison	Mean 1	Mean 2	*p*-value
	Control vs. rest	8.53	19.19	0.00
	120 kg N ha^{-1} from urea vs. rest	16.63	19.51	0.00

LSD Value for FS at $p \leq 0.05 = 0.89$. Mean of the same category followed by different letters are significantly different ($p \leq 0.05$).

The effects of fertilizer treatments on soil mineral N (mg kg^{-1} soil) during both individual years (2008–2009 and 2009–2010) was significant. Mean values of the data for 2008–2009 showed that the highest mineral N of 21.22 mg kg^{-1} soil was recorded for treatment with 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}), this was statistically at par with treatment with 50% N from urea + 50% N from FYM + BM (T_8) and 50% N from urea + 50% N from PM + BM (T_9) with soil mineral N value of 21.00 mg kg^{-1} soil and 20.56 mg kg^{-1} soil, respectively. The lowest soil mineral N of 9.19 mg kg^{-1} soil was recorded in the control treatment plot (T_1). Similarly, in 2009–2010, maximum soil mineral N value of 24.06 mg kg^{-1} soil was recorded for treatment with 50% urea + 50% N from (FYM + PM) + BM (T_{10}), which was statistically on par with T_8 (50% N from urea + 50% N from FYM + BM), and the minimum soil mineral N of 7.88 mg kg^{-1} soil was recorded in the control treatment plot (T_1).

Significant influence observed from combined analysis of fertilization treatment data on soil mineral N (mg kg^{-1} soil). The highest soil mineral N value of 22.64 mg kg^{-1} soil was obtained from treatment with 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}), which was statistically on par with treatments receiving 50% N from urea + 50% N from FYM + BM (T_8) and 50% N from urea + 50% N from PM + BM (T_9) with soil mineral N of 22.20 mg kg^{-1} soil and 21.55 mg kg^{-1} soil. The lowest soil mineral N of 8.53 mg kg^{-1} soil was obtained from control treatment plot (T_1). Comparing the relevant treatments with and without BM, an increasing trend in soil mineral N (mg kg^{-1} soil) was noted with BM. The application of BM with any fertilizer sources increases soil mineral N value by 3.04 mg kg^{-1} soil. Among the fertilizer sources, the treatment with 50% N from urea + 50% N from (FYM + PM) obtained a significantly higher content of soil mineral N (mg kg^{-1} soil), whereas a lower content of soil mineral N (mg kg^{-1} soil) was noted in the treatment with 60 kg N ha^{-1} from urea. The interactions of Y × F was significant, while the interactions of Y × V, V × F and Y × V × F were non-significant.

3.8. Soil Organic Matter (g kg^{-1} Soil)

Data on soil organic matter (g kg^{-1} soil) in the soil after each wheat harvest for two consecutive years (2008–2009 and 2009–2010) are given in Table 11. Statistical analysis of the data showed a significant effect of year and N fertilizer sources on soil organic matter (g kg^{-1} soil); however, the effect of varieties on soil organic matter (g kg^{-1} soil) was non-significant. Significantly greater soil organic matter content of 10.96 g kg^{-1} soil was recorded in 2009–2010 compared with soil organic matter content of 9.76 g kg^{-1} soil for both varieties in 2008–2009. Planned mean comparisons indicated that the control vs. rest and 120 kg N ha^{-1} from urea vs. rest significantly affected soil organic matter (g kg^{-1} soil).

The effect of fertilizer treatments on soil organic matter (g kg^{-1} soil) was significant in both individual years (2008–2009 and 2009–2010). Mean values of the data for 2008–2009 showed that the highest soil organic matter of 11.34 g kg^{-1} soil was recorded for the treatment receiving 50% N from urea + 50% N from FYM + BM (T_8), followed by soil organic matter of 11.04 g kg^{-1} soil for the treatment receiving 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}). The lowest soil organic matter of 8.31 g kg^{-1} soil was recorded in the control plot (T_1). Similarly, in 2009–2010, a maximum soil organic matter of 12.69 g kg^{-1} soil was recorded for the treatment receiving 50% N from urea + 50% N from FYM + BM (T_8), followed by soil organic matter of 12.39 g kg^{-1} soil for the treatment receiving 50% N from urea + 50% N from (FYM + PM) + BM (T_{10}), while the minimum soil organic matter of 8.21 g kg^{-1} soil was obtained in the control treatment plot (T_1).

The combined analysis of the data showed a noteworthy effect of fertilizer treatments on soil organic matter (g kg^{-1} soil). The highest soil organic matter of 12.01 g kg^{-1} soil was obtained from the treatment with 50% N from urea + 50% N from FYM + BM (T_8); this was statistically on par with soil organic matter of 11.71 g kg^{-1} soil for the treatments with 50% urea + 50% N from (FYM + PM) + BM (T_{10}). The lowest soil organic matter of 8.26 g kg^{-1} soil was obtained in the control plot (T_1). Comparing the relevant treatments with and without BM, an increasing trend in soil organic matter (g kg^{-1} soil) was noted with BM. The application of BM with any fertilizer sources increases soil organic matter by 3.04 g kg^{-1} soils. The effect of fertilizer source was significant on soil organic matter. The maximum soil organic matter content was recorded in the treatment with 50% N from urea + 50% N from (FYM + PM), and the minimum soil organic matter content was recorded at 60 kg N ha^{-1} from urea. The interactions of year × variety, year × N fertilizer sources, variety × N fertilizer sources and year × variety × N fertilizer sources were non-significant.

Table 11. Soil organic matter (g kg^{-1} soil) as influenced by wheat variety and N fertilizer.

Varieties (V)	Fertilizers (F)	Year (Y)		V × F
		2008–2009	2009–2010	
Uqab	Control	0.88	0.86	0.87
Uqab	120 kg N ha^{-1} from urea	0.92	1.01	0.97
Uqab	60 kg N ha^{-1} from urea	0.91	0.97	0.94
Uqab	50% N from urea + 50% N from FYM	1.04	1.17	1.10
Uqab	50% N from urea + 50% N from PM	1.01	1.12	1.06
Uqab	50% N from urea + 50% N from (FYM + PM)	1.02	1.15	1.08
Uqab	60 kg N ha^{-1} from urea + BM	0.99	1.05	1.02
Uqab	50% N from urea + 50% N from FYM + BM	1.14	1.28	1.21
Uqab	50% N from urea + 50% N from PM + BM	0.81	1.22	1.01
Uqab	50% N from urea + 50% N from (FYM + PM) + BM	1.12	1.26	1.19
F-S	Control	0.79	0.79	0.79
F-S	120 kg N ha^{-1} from urea	0.89	0.99	0.94
F-S	60 kg N ha^{-1} from urea	0.88	0.98	0.93
F-S	50% N from urea + 50% N from FYM	1.01	1.16	1.09
F-S	50% N from urea + 50% N from PM	0.98	1.11	1.04
F-S	50% N from urea + 50% N from (FYM + PM)	0.92	1.14	1.03
F-S	60 kg N ha^{-1} from urea + BM	0.97	1.01	0.99
F-S	50% N from urea + 50% N from FYM + BM	1.13	1.26	1.19
F-S	50% N from urea + 50% N from PM + BM	1.05	1.20	1.12
F-S	50% N from urea + 50% N from (FYM + PM) + BM	1.09	1.22	1.15
				Mean
	Uqab	0.98	1.11	1.05
	Fakhr-e-sarhad (F-S)	0.97	1.09	1.03
	Mean	0.98	1.10	
	Fertilizer Sources (FS)	without BM	With BM	
	60 kg N ha^{-1} from urea	0.94	1.00	0.97 c
	50% N from urea + 50% N from FYM	1.10	1.20	1.15 a
	50% N from urea + 50% N from PM	1.05	1.07	1.06 b
	50% N from urea + 50% N from (FYM + PM)	1.06	1.17	1.11 ab
	Mean	1.03	1.11	
	Planned mean comparison	Mean 1	Mean 2	*p*-value
	Control vs. rest	0.83	1.06	0.00
	120 kg N ha^{-1} from urea vs. rest	0.95	1.07	0.00

LSD Value for FS at $p \leq 0.05$ = 0.0639. Mean of the same category followed by different letters are significantly different ($p \leq 0.05$).

4. Discussion

Plants are living things, and their growth and production are largely determined by nutrient availability. Among the essential plant nutrients, nitrogen is the most important element and is required in maximum quantity for better growth and yield of wheat [8]. In order to meet N needs of plants, farmers apply chemical fertilizers to overcome the N deficiency problem and obtain the maximum yield. However, the price of chemical fertilizer is very high, and poor farmers cannot use it in a balanced proportion; as a result, the farmer obtains a low yield compared to the potential of the crop [8]. In order to increase the crop yield and improve soil fertility, the integration of organic and mineral N can play an important role [9–12]. Organic amendments are considered an important soil productivity parameter [13]. It plays an important role in the physical structure and biological activities of soil. Productivity of the soil is greatly influenced by organic amendments. It not only supplies the soil with nutrients, but also increases the water holding capacity of the soil. It also improve soil tilth as well as seeds germination through better aeration and root development of plants [14]. Organic amendments in the soil increase aggregate size, promote cation exchange capacity, and also improve soil adsorbing power. During decomposition, cations such as Ca^{2+}, Mg^{2+} and K^{+} are formed [15]. Farmyard manure and poultry manure are the main sources of organic fertilizer in Pakistan. According to estimates, farmyard manure provides about 1.5 million tons of plant nutrients every year; similarly, 101 thousand tons of nitrogen, 58 thousand tons of P_2O_5 and 26 thousand tons of K_2O are available from poultry manure annually [16]. Unfortunately, most of the organic materials remain unutilized in Pakistan, which not only poses a serious threat to water, air and soil pollution, but it also causes the loss of valuable nutrients that plants need.

Effective microorganisms/beneficial microorganisms (EM/BM) technology of nature management was introduced by Higa [17], who isolated some beneficial microorganisms from the soil and called them EM. EM culture consists of co-existing beneficial microorganisms, the main being the species of photosynthetic bacteria, lactic acid bacteria, fermenting fungi, yeasts and *actenomycetes* (*Strptomyces* spp.), which improve crop growth and yield by increasing photosynthesis, producing bioactive substances such as hormones and enzymes, controlling soil-borne diseases and accelerating decomposition of lignin materials in the soil [18].

In addition, total NPK levels in plants were significantly increased in response to combined application of chemical fertilizer and organic N sources. Mixing N fertilizer with organic fertilizer reduced leaching and nitrification in the soil, resulting in better nitrogen utilization by the plants. The composted organic materials increase the efficiency of the fertilizer use by slowly releasing nutrients, thus minimizing losses, especially nitrogen.

Hussain et al. [19] and Moe et al. [20] reported that the integrative use of organic and inorganic N resulted in greater N uptake by plants than when applied alone. In the previous chapter, our study presented revealed significantly higher straw and grain nitrogen concentrations in straw and grain in the 50% urea + 50% FYM + BM treatment, followed by the 50% N from urea + 50% N from (FYM + PM) + BM treatment or the full dose of N (120 kg ha^{-1}) from urea fertilizer. The lowest straw and grain N concentrations were obtained from control plots. Comparing the relevant treatments with and without BM, an increasing trend N concentrations in straw and grain was observed with BM. These observations are in line with those of Fikry et al. [21], who found that combination of organic and inorganic nitrogen sources resulted in higher apparent net N release values. They also found that the N requirements of wheat could not be met from FYM alone. According to them, the best mixture ratio between organic and inorganic N sources was 1:1. These findings confirmed that combined use of urea and FYM performed better than the use of FYM and urea alone in terms of improving crop and N yields of wheat. Effective microorganisms/beneficial microorganisms applied in combination with NPK, GM (Green Manure) and FYM caused a significant increase in nutrient uptake by the straw and grain of wheat and rice. Our findings further indicated markedly highest grain total nitrogen, straw total nitrogen and total nitrogen uptake by wheat crop for the treatments receiving T_2 (120 kg N ha^{-1} from urea), followed by the treatments receiving 50% N from urea + 50% N from PM + BM and 50% N from urea + 50% N from (FYM + PM) + BM. The lowest values for these parameters were noted in the control treatment plot. Moreover, after comparing the relevant treatments with and without BM for the parameters mentioned, an increasing trend in nitrogen uptake was observed.

Grzebisz et al. [22] reported that nitrogen fertilization is very important to improve soil fertility and maximize crop productivity. The application of nitrogen fertilizer contributes to an 18–34% increase in soil residual N [23] and a 4–9.4% increase in mineralization from total soil N [24]. In the previous chapter, our study presented showed a significantly higher total soil nitrogen (g kg^{-1} soil) for treatment with 50% N from urea + 50% N from FYM + BM, followed by the treatment receiving 50% N from urea + 50% N from (FYM + PM) + BM and 50% N from urea + 50% N from PM + BM, respectively, as compared to the control treatment plot. Similarly, our results showed a significantly higher soil mineral nitrogen (mg kg^{-1} soil) for the 50% N from urea + 50% N from (FYM + PM) + BM treatments, followed by the

50% N treatments from urea + 50% N from FYM + BM and 50% N from urea + 50% N from PM + BM compared with control treatment plot. Comparing the relevant treatments with and without BM, an increasing trend in total soil N (g kg^{-1} soil) and soil mineral N (mg kg^{-1} soil) was noted with the application of BM. Residue incorporation in combination with chemical nitrogen fertilizers had positive impacts on plant growth and production and on soil physiochemical properties. The synergistic effects of mineral nitrogen with organic fertilizers (FYM or residue) accumulate more total N in the soil [25]. The greater amount of mineral nitrogen in the nitrogen fertilized plots as compared to the control plot was due to organic nitrogen mineralization and/or residual nitrogen action. The treatments with both inorganic nitrogen fertilizer and organic fertilizer resulted in more mineral nitrogen. The greater mineralization potential would be the possible explanation for the higher mineral nitrogen value. The degradation and mineralization of the organic materials added to the soil was positively influenced by the use of effective microorganisms (EM/BM). Our study, relating to soil organic matter status (g kg^{-1} soil), revealed significantly higher values for the 50% N from urea + 50% N from FYM + BM treatment as compared to the untreated control plot. Our study further revealed an increasing trend in soil organic matter status (g kg^{-1} soil) when comparing the relevant treatments with and without BM. Comparatively higher biomass production in various treatments contributed to the enhancement of soil organic matter status [26]. Li et al. [27] reported a significant increase in soil organic matter with the integrated application of organic and chemical fertilizers. Effective microorganisms/beneficial microorganisms suspension consists of a selection of various grouping of microorganisms, in particular, photosynthetic bacteria, lactic acid bacteria and yeast, which plays vital role in food production. Among other things, it is claimed that effective microorganisms modify the biological status of the soil, increase soil organic matter improve germination and root development, enhance photosynthesis and improve plant growth and yield [28]. As our results confirmed, Fakhr-e-Sarhad performed better among the strains studied across different yields and biochemical characteristics. This may be due to the genetic efficiency of the Fakhr-e-Sarhad cultivar to perform better than Uqab.

5. Conclusions

In summary, a combination of 50% N from mineral source (Urea) and 50% N from organic sources either from farmyard manure (T_8) or from poultry manure (T_9) and combination of organic N sources (T_{10}) (25% farmyard manure and 25% poultry manure) with beneficial microbes has increased grain N (%) and straw N (%). In addition to that, T_8 (50% N from urea and 50% N from FYM + BM) also delivered the maximum total soil N, soil mineral N and soil organic matter. BM supplementation increased soil mineral N. Beneficial microbe technology is economically feasible and environmentally friendly. Therefore, it is strongly recommended to be used with organic N sources; this will not only reduce the import bill of mineral N but will also reduce the input cost. Further research work is needed to ascertain the effect of BM above 25 L ha^{-1} and application of BM as sprayer before sowing on farmyard manure and poultry manure as bio-kasht.

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