International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2021; 9(6): 70-76

Received: 02-11-2021
Accepted: 29-12-2021

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Effect of nutrient management and Bio-inoculants on the nutrient uptake and nutrient use efficiencies of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was carried out for doctoral research. It was conducted in Split Plot Design with three replications during the Rabi seasons of 2018-19 and 2019-20 in the Research Farm, College of Agriculture, JNKVV, Jabalpur to study the effect of nutrient management and bio-inoculants on nutrient uptake and nutrient use efficiencies of Wheat (*Triticum aestivum* L.). Different treatments of recommended dose of fertilizers and bio-inoculums with their interactions *viz*., F_0=control, F_1=50% RDF, F_2=75% RDF, F_3= 100% RDF; Bio-inoculums; B_0=without bio-inoculums, B_1=VAM 10 kg ha^{-1}, B_2=Pseudomonas 5 kg ha^{-1}, B_3= VAM 10 kg ha^{-1} + Pseudomonas 5 kg ha^{-1}. A pooled analysis of both years revealed that application of F_3 and B_3 and their combinations recorded significantly increased in the uptake of N, P, K by grain and straw and agronomic efficiency of nutrient, apparent recovery of nutrient NPK. But in physiological efficiency, interactions are non-significant, and F_2 was significantly superior over other treatments and at par with F_3, B_3.

Keywords: Nutrient uptake by grain and straw, agronomic efficiencies of NPK, physiological efficiencies of NPK, apparent recovery efficiencies of NPK, wheat.

Introduction
Wheat (*Triticum aestivum* L.) is one of the most extensively grown cereal crops worldwide that has known as the “king of cereals,” emanating as the keystone of India’s food security and depicts the primary food for about one-third of the world population (Thakur and Agrawal 2020) [15]. India is the top major producer and consumer of wheat globally. Microbial inoculants are carrier-based preparations containing beneficial microorganisms in a viable state intended for seeds or soil treatment and designed to improve soil fertility and help plants grow by increasing the number and biological activity of desired microorganisms in the vicinity of the root zone. Bio-fertilizers/ bio-inoculums are inputs containing microorganisms capable of mobilizing nutritive elements from complex and non-usable form to simple and usable form through biological processes (Cakmakc *et al*., 2007). The bio-inoculants can be applied to seeds, plant surfaces, or the soil. Fertilizers directly increase soil fertility by adding nutrients to the soil.

In contrast, bio-fertilizers/ bio-inoculums are helpful in nutrient uptake as their main function in the soil is to either fix a nutrient in the soil that was subjected to more loss or to solubilize a nutrient that did not available to plants because of fixation in the soil. The potential bio-fertilizers play an important role in maintaining productivity and soil sustainability and helps in increasing the production potential of crops. Microbial inoculants have a growing interest in their potential role in improving soil health, fertility, and increasing crop yields and their nutrient contents. When applied to seeds, soil and Microbial inoculants improve directly or indirectly the nutrient availability to the host plant and promote plant growth to enhance crop yield. The most important beneficial effect of Mycorrhizae is the increase in the phosphorus uptake by the plant. Biofertilizers are cost-effective and environmentally eco-friendly and serve as a supplement to fertilizers. Thus, it can be concluded that biofertilizers and bio-inoculums are intended to improve nutrient uptake and their use efficiency without applying extra doses of inorganic chemicals. Therefore, it can be hypothesized that applying biofertilizers with chemical fertilizer will enhance the growth, yield, and nutrient use efficiency. Generally believed that the efficiency of N, P, K fertilizers for increasing wheat yield is under proper nutrient management with bio-inoculums. This present study reports N, P, K uptake (both grain and straw), Agronomic efficiency, Physiological efficiency and Apparent recovery efficiency.

Materials and Methods

The field experiment was carried out for doctoral research at Research Farm, College of Agriculture, JNKVV, Jabalpur (M.P.), during the Rabi season of the year 2018-19 and 2019-20, situated at 23' 90" N latitude and 79' 58"E longitude at an altitude 411.78 meters over the mean sea level. The area was rich in sandy clay loam soil, having a pH of 7.1. The experiment was laid out in a split-plot design with three replications and four different nutrient management (F_0=control, F_1=50% RDF, F_2=75% RDF, F_3= 100% RDF, {RDF=120:60:40 N, P_2O_5,K_2O kg ha^{-1}}) as main plot and four application of bio-inoculums (B_0=without bio-inoculums, B_1=VAM 10 kg ha^{-1}, B_2=Pseudomonas 5 kg ha^{-1}, B_3= VAM 10 kg ha^{-1} + Pseudomonas 5 kg ha^{-1}) as subplots. The total treatment combinations were sixteen. The crop was grown with all recommended cultural operations as per requirement. The seed was sown in lines at spacing of 20cm with recommended seed rate, i.e., 100 kg ha^{-1}.

DAP, MOP, and urea applied the recommended dose of nutrients. The basal dose of fertilizers was applied per nutrient management in the plots and mixed in the soil. A full dose of P_2O_5, K_2O, and 50% Nitrogen was applied at the time of sowing as per nutrient management. The remaining nitrogen was top-dressed in two splits as per treatment after first and second irrigation. The amount of VAM and Pseudomonas were applied treatment-wise. The field was kept free from weeds by hand weeding. Five irrigations were applied at critical stages in the same manner for all the treatments.

Estimating N, P, and K contents in the crop (Grain & Straw) was done at the maturity stage. Therefore, the sample seeds and straw were taken at the time of harvesting for each plot, and then they were allowed to dry in an oven at 60 C till constant weight. After this, these samples were grinded into fine powder for chemical analysis. From each ground sample, 1g was weighed separately for N, P, and K analysis.

Nitrogen was estimated by Micro Kjeldahl digestion method (Amma 1989) [1], Phosphorus by Vanadomolybdo phosphoric yellow color method (Koenig and Johnson, 1942), and potassium by Flame Photometer (Black, 1965) [2]. The values of NPK contents for grains and straw were recorded treatment-wise, and then N, P, and K uptake were determined separately for the Grain and straw yield of each treatment. The total Uptake of these nutrients was workout by summation of Uptake by Grain and straw for each treatment separately.

For the determination of N, P, and K uptake by crop, the obtained values were multiplied by corresponding dry weight (grain and straw yield) under each treatment and expressed in mg/kg.

Nutrient use efficiency can be expressed in several ways (Moiser *et al*., 2004). Agronomic indices commonly used to describe nutrient use efficiency are agronomic efficiency (A.E.), physiological efficiency, Apparent recovery efficiency etc.

- Agronomic efficiency is the economic yield per unit of nutrient applied. It is also referred to as crop response or crop response ratio and is very useful in determining the benefits derived from the fertilizer applied. It is expressed in terms of kg grain per kg nutrient applied and was worked out by using the following formulas as proposed by cross well and Godwin (1984) [5] and Duncan and Baligar (1990) [7].

$$\text{Agronomic efficiency (kg grain per kg nutrient applied)} = \frac{(Yf - Yc)}{Fa}$$

Where, Yf = Grain yield in the fertilized plot (kg/ha)
Yc = Grain yield in control plot (kg/ha)
Fa = Amount of nutrient applied (kg/ha)

- Apparent recovery is the utilization of nutrients by the crop per unit of nutrient applied. It is useful in preparing nutrient balance sheets. Apparent recovery of each treatment was calculated by using the following formula as suggested by Crosswell and Godwin (1984) [5] as well as by Duncan and Baligar (1990) [7].

$$\text{Apparent recovery (nutrient uptake per kg nutrient applied)} = \frac{(Uf - Uc)}{Fa}$$

Where,
U_f = Uptake of nutrient by crop in the fertilized plot (kg/ha)
U_c = Uptake of nutrient by crop in the control plot (kg/ha)
F_a = Amount of nutrient applied (kg/ha)

Physiological efficiency is the grain yield in relation to the nutrient uptake. It is expressed as kg grain per kg nutrient absorbed by the crop. P.E. was determined by using the following formula as given by Duncan and Baligar (1990) [7].

$$\text{Efficiency (kg grain per kg nutrient absorbed)} = \frac{(Yf - Yc)}{(Uf - Uc)}$$

Or

$$\text{Physiological efficiency} = \frac{AE}{AR}$$

Where,
Yf = Grain yield in fertilized plot (kg/ha)
Yc = Grain yield in control plot (kg/ha)
Uf = Uptake of nutrient by crop in the fertilized plot (kg/ha)
Uc = Uptake of nutrient by crop in the control plot (kg/ha)
AE = Agronomic efficiency (kg grain per kg nutrient applied)
AR = Apparent recovery (%)

Result and Discussion

Grain and Straw Nutrient content

The uptake of nutrients by wheat crop depends on the biomass (grain and straw yield) and concentrations of a particular nutrient in the produce. In general, the concentration of major nutrients (N, P, and K) in grain and straw of wheat differ markedly. Therefore, uptake of each nutrient is directly related to grain and straw yields of wheat in a particular treatment under the present investigation. On considering the nutrients uptake in grain and straw, there was the appreciable influence of nutrient management on nitrogen, phosphorus, and potassium uptake by grain and straw. Wheat under nutrient management had significantly maximum N, P, and K uptake by grain and straw, which exhibited superiority over the rest of the treatments. A similar trend was noted in bio-inoculums to that of nutrient uptake by wheat.

Grain and straw samples of wheat grown under different levels of nutrient management and bio-inoculums treatments were drawn after winnowing for analyzing the nitrogen, phosphorus, and potassium contents. Accordingly, their grain and straw uptake was carried out under different applications. Data about nutrient uptake (mg/kg) by grain and straw are presented in Table 1. And their interaction is shown in Table 3.

Pooled data analysis reveals that grain and straw nitrogen uptake was significantly higher in treatment F_3 (100% RDF) (9416.54 and 4329.61 mg/kg) respectively under nutrient management application. On the other hand, no fertilizer treatment (7816.77 & 3591.34 mg/kg) showed minimum nitrogen uptake by grain and straw. Concerning bio-inoculums as a soil application, nitrogen uptake by grain and straw was observed to be significantly higher for treatment VAM 10 kg/ha + Pseudomonas 5 kg/ha (8912.52 & 4176.35 mg/kg). No bio-inoculums treatment (8129.15 & 3649.38 mg/kg) respectively showed the lowest nitrogen uptake by grain and straw. Regarding interactions, the combination of F_3B_3 (9944.67 & 4694.6 mg/kg) maximum nitrogen uptake over other treatments might be due to the bio-inoculums effect.

The nutrient management application enhanced phosphorus uptake by grain and straw was significantly observed in treatment F_3 (3185.50 & 877.32 mg/kg). On the other hand, treatment without nutrient management F_0 (2676.80 & 681.51 mg/kg) showed minimum phosphorus uptake. To bio-inoculums soil application, phosphorus uptake by grain & straw was observed to be significant; treatment VAM 10 kg/ha + Pseudomonas 5 kg/ha (3012 & 825.53 mg/kg) showed more phosphorus uptake. On the other hand, treatment without bio-inoculums B_0 (2805.91 & 711.34 mg/kg) respectively, showed minimum phosphorus uptake. Regarding interactions, maximum uptake was observed in 100% RDF+ VAM + Pseudomonas treatment (F_3B_3) (4694.6 & 946.06 mg/kg) than control F_0B_0 (2598.96 & 648.91 mg/kg).

Potassium uptake by grain and straw was significantly higher in treatment VAM 10 kg/ha + Pseudomonas 5 kg/ha B_3 (3528.90 & 9161.31 mg/kg) respectively, showed more potassium uptake. Potassium uptake by grain and straw was significantly superior in full dose RDF F_3 (3611.51 & 10692.34 mg/kg) over the rest of the treatments. On the other hand, treatment without nutrient management F_0 (3362.01 & 8375.44 mg/kg) respectively showed minimum potassium uptake. On the other hand, B_0 (3412.30 & 8587.75 mg/kg) without bio-inoculums showed minimum potassium uptake. Interactions showed similar trend, i.e., more potassium uptake by combined application F_3B_3 (3687 & 12186.27 mg/kg) respectively, than other treatments.

The crop's significant difference in grain, straw yields, and NPK content under different nutrient management with bio-inoculums may be the reason for higher nutrient uptake in the presence of bio-inoculums in soil flora. Similar results were also noticed by Devi *et al*. (2011) [19], Khandare *et al*. (2020) [18] Gogoi *et al*. (2004) [17]. Nutrient management treatments significantly influenced nutrient uptake by grain and straw. The average N, P, and K uptake by grain and straw was minimum under control plots and was significantly increased with all plots receiving increasing nutrient management levels and bio-inoculums or alone. Among all nutrient management practices, N, P, and K uptake were maximum with 100% nutrient management + VAM + Pseudomonas, followed by 100% nutrient management + Pseudomonas. The increased uptake of the nutrients in the respective plot was due to added nutrients and a well-developed root system because of bio-inoculums resulting in better water and nutrient absorption. The corresponding increase in nutrient uptake was owing to higher yields and nutrient content in plant tissues. These results are similar to the findings of Khandare *et al*. (2020) [18], Hussain *et al*. (2016).

Table 1: Nutrient content in Grain and Straw of wheat as affected by various nutrient management and bio-inoculum

Treatments	Nutrient content in Grain and Straw					
	Grain N (mg/kg)	Straw N (mg/kg)	Grain P (mg/kg)	Straw P (mg/kg)	Grain K (mg/kg)	Straw K (mg/kg)
	Pooled data of both years					
Fertilizer (nutrient management) F						
F_0	7816.77	3591.34	2676.80	681.51	3362.01	8375.44
F_1	8215.63	3761.19	2834.09	740.54	3432.95	9086.81
F_2	8616.69	4039.81	3017.01	810.35	3509.16	9711.77
F_3	9416.54	4329.61	3185.50	877.32	3611.51	10692.34
Mean	8516.41	3930.49	2928.35	777.43	3478.91	9466.59
SEm±	14.69	39.22	18.07	5.55	4.24	121.83
CD(P=0.05)	50.84	135.71	62.5	19.2	14.7	421.57
Bioinoculants (soil application) B						
B_0	8129.15	3649.38	2805.91	711.34	3412.30	8587.75
B_1	8414.02	3910.93	2932.60	777.04	3473.72	9291.93
B_2	8609.94	3985.29	2962.64	795.80	3500.71	9641.22
B_3	8912.52	4176.35	3012.25	825.53	3528.90	10345.46
Mean	8516.41	3930.49	2928.35	777.43	3478.91	9466.59
SEm±	6.55	26.25	5.17	4.76	2.14	103.93
CD(P=0.05)	19.13	76.61	15.1	13.9	6.2	303.36

Nutrient use Efficiencies

The nutrient use efficiency under different nutrient management and bio-inoculums applications are discussed in terms of agronomic efficiency (AE), apparent-recovery (AR) and physiological efficiency.

The agronomic efficiency of nitrogen, phosphorus, and potassium in wheat did vary significantly due to different nutrient management with bio-inoculums applications during pooled data analysis of both years. But the apparent recovery of N, P, and K was remarkably higher under nutrient management with both VAM and Pseudomonas treatment over alone treatment or control. However, differential responses of wheat crops towards the physiological efficiency of N, P, and K were observed due to different nutrient management. It is apparent from the results presented in Tables 2 and 4. that the various nutrient management treatments and bio-inoculums did influence the efficiency.

Agronomic efficiency (AE)

It is apparent from the results presented in Tables, that the various nutrient management treatments and bio-inoculums did influence the agronomic efficiency of nitrogen significantly. However, it varied between 3.4 to 21.4 kg grain/kg N applied during the mean of both years (pooled).

Agronomic efficiency of nitrogen in wheat under different nutrient management level treatments differed markedly, and it ranged from 9.28 to 18.31 kg grain kg/N applied in pooled data, respectively. Maximum agronomic efficiency of nitrogen in wheat 18.31 and 15.17 kg grain/kg N applied was observed in treatment where F_3 (100% nutrient management) and VAM 10 kg/ha + Pseudomonas 5 kg/ha (VAM + Pseudomonas) respectively. Maximum agronomic efficiency of nitrogen in wheat 21.5kg grain/kg N applied was observed in treatment wherein combination 90:45:30 N:P:K kg/ha + VAM 10 kg/ha + Pseudomonas 5 kg/ha (75% nutrient management and VAM 10 kg/ha + Pseudomonas 5 kg/ha). The lowest NAE in wheat was observed with the treatment received without bio-inoculums and fertilizer. Hence, the agronomic efficiency of nitrogen in wheat declined steadily with a successive decreased rate of nutrient management levels without combining VAM and Pseudomonas application both or alone. Interaction between nutrient management levels and bio-inoculums applications did cause significant influence on the agronomic efficiency of nitrogen in pooled data.

The agronomic efficiency of phosphorus did vary significantly due to different nutrient management levels and bio-inoculums applications in pooled data. However, PAE varied from 6.8 to 42.9 kg grain/kg P applied in pooled experimentation data, respectively. Different nutrient management practices affected the agronomic efficiency of phosphorus identically during both years. The plots receiving 100% nutrient management F_3 (36.64 kg grain/kg P applied) and VAM 10 kg/ha + Pseudomonas 5 kg/ha (21.05 kg grain/kg P applied), did cause significant variations on agronomic efficiency of phosphorus in pooled data. However, these treatments had significantly higher agronomic efficiency of phosphorus than control.

The marked influence of nutrient management was observed on the agronomic efficiency of potassium in pooled data. The plots receiving 100% RDF nutrient management (54.95 kg grain/kg K applied) and VAM 10 kg/ha + Pseudomonas 5 kg/ha (31.57 kg grain/kg K applied) did not apply cause significant variations on agronomic efficiency of potassium. However, KAE ranged from 10.2 to 64.4 kg grain/kg K applied in the mean of both the years' data. This was owing to the synergistic relationship between grain yield and nutrient uptake by grain. These results conform with the findings of Delogu *et al.* (1998) [6]; Piccinin *et al.* (2011) [12]; Choudhary and Behera (2013) [4], Elias *et al.* (2020) [8].

Table 2: Nutrient use Efficiencies of wheat as affected by various nutrient management and bio-inoculums.

Treatments	Agronomic Efficiency of Nutrient			Physiological efficiency of Nutrient			Apparent Recovery Efficiency of Nutrient		
	AE N	AE P	AE K	PE N	PE P	PE K	AR N	AR P	AR K
	Pooled data of both years								
Fertilizer (nutrient management) F									
F_0	-	-	-	-	-	-	-	-	-
F_1	9.28	18.58	27.88	54.73	178.33	40.54	0.16	0.10	0.65
F_2	13.98	27.98	41.97	57.99	191.06	47.79	0.24	0.15	0.90
F_3	18.31	36.64	54.95	55.62	192.31	46.36	0.33	0.19	1.22
Mean	13.858	27.733	41.599	56.113	187.230	44.897	0.25	0.145	0.921
SEm±	0.523	1.239	1.859	1.575	11.092	2.256	0.01	0.003	0.034
CD(P=0.05)	1.810	4.288	6.433	5.452	38.382	7.806	0.02	0.009	0.119
Bioinoculants (soil application) B									
B_0	-	-	-	-	-	-	-	-	-
B_1	6.99	14.00	21.00	43.62	141.70	35.96	0.16	0.07	0.40
B_2	8.89	17.80	26.70	41.57	135.66	33.41	0.19	0.10	0.59
B_3	10.52	21.05	31.57	41.22	137.44	32.12	0.27	0.11	0.73
Mean	8.80	17.62	26.43	42.14	138.27	33.83	0.21	0.09	0.57
SEm±	0.363	0.725	1.088	2.059	8.116	2.480	0.003	0.002	0.020
CD(P=0.05)	1.058	2.116	3.174	NS	NS	NS	0.01	0.007	0.057

Physiological efficiency (PE)

Different nutrient management levels and bio-inoculums influenced the physiological efficiency of nitrogen. Under different nutrient management levels it was highest Under F_2 (75% nutrient management) (57.99 kg grain/kg N absorbed) and lowest F_1 kg/ha (50% nutrient management) (54.73 kg grain/kg N absorbed). But physiological efficiency of nitrogen in wheat was varied non-significantly due to different bio-inoculums applications. Wheat is sown under 75% nutrient management without bio-inoculums (F_2 + no bio-inoculums) registered the highest physiological efficiency of nitrogen (64.5 kg grain/kg N absorbed) which was at par with 100% nutrient management without bio-inoculums 100% RDF + no bio-inoculums (62.7 kg grain/kg N absorbed). However, both treatments were statistically similar as they did not significantly affect the physiological efficiency of nitrogen in wheat. The varying nutrient management levels caused marked variation in the physiological efficiency of nitrogen in pooled data. Hence, NPE in wheat was increased steadily with successively increased levels of nutrient management. Therefore, plots receiving nutrient management alone had significantly higher physiological efficiency of nitrogen than the plots where bio-inoculums were applied. The physiological efficiency of phosphorus differed significantly due to different nutrient management levels in pooled data. However, PPE varied from 143.0 to 214.0 kg grain/kg P absorbed in pooled data. Different nutrient management practices affected physiological efficiency of phosphorus in pooled data. It was also increased steadily with a successively increased proportion of nutrient management levels with bio-inoculums but only nutrient management showing higher PPE. The plots receiving 100% nutrient management, 100% RDF (192.31 kg grain/kg P absorbed), and 75% nutrient management F_2 (191.06 kg grain/kg P absorbed) did cause non-significant variations on the physiological efficiency of phosphorus in wheat. These treatments had significantly higher PPE than 50% nutrient management and without nutrient management. The physiological efficiency of phosphorus did not differ significantly due to different bio-inoculums.

Different nutrient management levels and bio-inoculums did influence the physiological efficiency of potassium. However, with respect to nutrient management levels, it was highest under F_2 (75% nutrient management) (47.79 kg grain/kg K absorbed) and lowest F_1 (50% nutrient management) (40.54 kg grain/kg K absorbed). But physiological efficiency of potassium in wheat was non-significant due to different bio-inoculums applications. Wheat sown under 75% nutrient management without bio-inoculums (F_2 + B_0) registered the highest physiological efficiency of potassium (57.8 kg grain/kg K absorbed), which was at par with 100% nutrient management with without bio-inoculums F_3 + B_0 (52.1 kg grain/kg K absorbed). However, both of the treatments were statistically similar as they did not significantly affect the physiological efficiency of potassium in wheat. The varying nutrient management levels caused marked variation in the physiological efficiency of potassium in pooled data. Hence, KPE in wheat was increased steadily with successively increased levels of nutrient management. Therefore, plots receiving nutrient management alone had significantly higher physiological efficiency of potassium than the plots where bio-inoculums were applied. The physiological efficiency of potassium was not markedly affected due to the interaction of nutrient management and bio-inoculums in pooled data.

These results are similar to the work of Mahanta and Rai (2008) [10], Tamas and Zoltan (2012) [14], and Sharma *et al.* (2013) [13].

Apparent-Recovery Efficiency (AR)

Nutrient management and bio-inoculums treatments influenced the apparent recovery of nitrogen significantly. However, it varied between 0.07 to 0.42 N uptake per kg N applied during the mean of the year's data (pooled). Apparent recovery of nitrogen in wheat under different nutrient management treatments differed markedly, and it ranged from 0.16 to 0.33 N uptake per kg N applied in pooled data, respectively. Maximum apparent nitrogen recovery in wheat 0.33 and 0.27 N uptake per kg N applied was observed in treatment where F_3 (100% nutrient management) and VAM 10 kg/ha + Pseudomonas 5 kg/ha (VAM+ Pseudomonas) respectively. Maximum apparent nitrogen recovery in wheat 0.42 N uptake per kg N applied was observed in treatment wherein combination F_3+ B_3. The lowest N-AR in wheat was observed with the treatment which received the without bio-inoculums with 50% nutrient management + no bio-inoculums 0.07N uptake per kg N applied. Hence, apparent recovery of nitrogen in wheat was declined steadily with a successive decreased rate of nutrient management levels without the combination of VAM and Pseudomonas application. Interaction between nutrient management levels and bio-inoculums applications did cause significant influence on the apparent recovery of nitrogen.

Apparent recovery of phosphorus varied between 0.04 to 0.23 P uptake per kg P applied during the mean of both the year's data (pooled). Apparent recovery of phosphorus in wheat under different nutrient management treatments differed markedly, and it ranged from 0.10 to 0.19 P uptake per kg P applied, respectively. Maximum apparent phosphorus recovery in wheat 0.19 and 0.11 P uptake per kg P applied was observed in treatment where F_3 (100% nutrient management) and VAM 10 kg/ha + Pseudomonas 5 kg/ha respectively. Maximum apparent recovery of phosphorus in wheat 0.23 P uptake/ kg P applied was observed in treatment wherein combination F_3B_3. The lowest PAR in wheat was observed with the treatment which received the without bio-inoculums with 50% nutrient management (F_1) + no bio-inoculums 0.04 P uptake per kg P applied. Hence, apparent phosphorus recovery in wheat declined steadily with a successive decreased rate of nutrient management levels without the combination of VAM and Pseudomonas application. Interaction between nutrient management levels and bio-inoculums applications caused significant influence on the apparent recovery of phosphorus.

Apparent Recovery of Potassium varied between 0.25 to 1.62 K uptake per kg K applied during the mean of both the years' respectively apparent recovery of potassium in wheat under different nutrient management treatments differed markedly. It ranged from 0.65 to 1.22 K uptake per kg K applied in pooled data, respectively. Maximum apparent recovery of potassium in wheat 1.22 and 0.73 K uptake per kg K applied was observed in treatment where F_3 (100% RDF) and VAM 10 kg/ha + Pseudomonas 5 kg/ ha (VAM + Pseudomonas) respectively. Maximum apparent recovery of potassium in wheat 1.62 K uptake per kg K applied was observed in treatment wherein combination F_3B_3. The lowest KAR in wheat was observed with the treatment which received the without bio-inoculums with 50% nutrient management F_1B_0 0.25 K uptake per kg K applied. Hence, apparent recovery of potassium in wheat declined steadily with a successive decreased rate of nutrient management levels with no combination of VAM and Pseudomonas application. Interaction between nutrient management levels and bio-inoculums applications did cause significant influence on the apparent recovery of potassium.

The nutrient management treatments caused noticeable variation on Agronomic efficiency, apparent recovery, and physiological efficiency of N, P, and K in wheat. Among all the nutrient management practices, the plots receiving 100% nutrient management + VAM + Pseudomonas reflected higher agronomic efficiency of N, P, and K in wheat, while lower was observed under control plots. The agronomic efficiency of N, P, and K in wheat was steadily progressive with successive increases in the recommended fertilizer dose with supplementation of bio-inoculums. Apparent recovery of N, P and K in wheat also follows the same trend observed in agronomic and physiological efficiency. But the just reverse trend was obtained in physiological efficiency.

Table 3: Nutrient content in Grain and Straw of wheat as affected by various nutrient management and bio-inoculums their interactions.

Treatments	Nutrient content in Grain and Straw					
	Grain N (mg/kg)	Straw N (mg/kg)	Grain P (mg/kg)	Straw P (mg/kg)	Grain K (mg/kg)	Straw K (mg/kg)
	Pooled data of both years					
Interactions (FxB)						
F_0B_0	7433.33	3446.7	2598.96	648.91	3329.83	7600.09
F_0B_1	7789.58	3533.6	2660.53	665.00	3348.47	8449.06
F_0B_2	7942.92	3614.4	2703.75	690.89	3371.12	8733.40
F_0B_3	8101.25	3770.7	2743.97	721.26	3398.61	8719.19
F_1B_0	7985.75	3546.5	2732.83	697.11	3379.49	8298.55
F_1B_1	8184.42	3722.0	2839.19	734.59	3429.87	9102.28

F_1B_2	8164.25	3787.3	2867.79	749.86	3455.45	9181.28
F_1B_3	8528.08	3988.9	2896.55	780.58	3466.98	9765.11
F_2B_0	8319.17	3677.2	2875.85	727.42	3431.07	8711.66
F_2B_1	8449.83	4119.9	3020.73	823.01	3505.21	9472.08
F_2B_2	8621.67	4110.9	3049.15	836.75	3537.40	9952.08
F_2B_3	9076.08	4251.3	3122.29	854.20	3562.98	10711.26
F_3B_0	8778.33	3927.1	3015.99	771.93	3508.79	9740.68
F_3B_1	9232.25	4268.2	3209.94	885.57	3611.32	10144.29
F_3B_2	9710.92	4428.5	3229.86	905.70	3638.89	10698.11
F_3B_3	9944.67	4694.6	3286.21	946.06	3687.02	12186.27
Mean	8516.41	3930.5	2928.35	777.43	3478.91	9466.59
SEm±	13.10	52.5	10.3	9.5	4.3	207.90
CD(P=0.05)	38.30	153.2	30.2	27.8	12.5	606.70

Table 4: Nutrient use Efficiencies of wheat as affected by various nutrient management and bio-inoculums their interaction.

Treatments	Agronomic Efficiency of Nutrient			Physiological efficiency of Nutrient			Apparent Recovery Efficiency of Nutrient		
	AE N	AE P	AE K	PE N	PE P	PE K	AR N	AR P	AR K
	Pooled data of both years								
Interactions (FxB)									
F_0B_0	-	-	-	-	-	-	-	-	-
F_0B_1	-	-	-	-	-	-	-	-	-
F_0B_2	-	-	-	-	-	-	-	-	-
F_0B_3	-	-	-	-	-	-	-	-	-
F_1B_0	3.39	6.81	10.22	47.28	142.97	33.90	0.07	0.04	0.25
F_1B_1	6.67	13.36	20.04	56.02	180.12	40.77	0.12	0.07	0.50
F_1B_2	9.28	18.58	27.86	56.86	182.88	40.62	0.16	0.10	0.69
F_1B_3	17.79	35.59	53.39	58.75	207.33	46.89	0.30	0.17	1.16
F_2B_0	9.51	19.04	28.57	64.46	209.83	57.83	0.14	0.09	0.48
F_2B_1	11.42	22.86	34.29	53.59	175.00	43.48	0.21	0.13	0.79
F_2B_2	13.54	27.09	40.63	56.01	182.53	43.73	0.24	0.15	0.93
F_2B_3	21.45	42.92	64.39	57.90	196.86	46.12	0.37	0.22	1.40
F_3B_0	15.07	30.15	45.22	62.73	214.01	52.11	0.24	0.14	0.87
F_3B_1	17.49	34.99	52.48	56.69	187.52	49.39	0.31	0.19	1.07
F_3B_2	19.26	38.53	57.79	52.02	184.33	44.12	0.37	0.21	1.31
F_3B_3	21.43	42.88	64.31	51.05	183.37	39.81	0.42	0.23	1.62
Mean	13.86	27.73	41.60	56.11	187.23	44.90	0.25	0.14	0.92
SEm±	0.7250	1.4501	2.1751	4.1179	16.2319	4.9605	0.0067	0.0047	0.0391
CD(P=0.05)	2.1162	4.2325	6.3487	NS	NS	NS	0.0196	0.0139	0.1142

4. Conclusions
Based on the results summarized above, it can be concluded that the use of RDF with bio-inoculums to plant along maintained the nutrient availability and increased the nutrient uptake of wheat. Application of 100% RDF (F_3) and (B_3) gave the best results regarding agronomic efficiency, apparent recovery, and uptake of N, P, K by the plant. F_3B_3 was proved the combined application of nutrient management and bio-inoculums, the most effective wheat quality grain production and essential nutrient in grain.

References

1. Amma MK. Plant and soil analysis. Rubber Research Institute. Rubber Board, Kottayam, Kerala. 1989.
2. Black CA. Methods of soil analaysis part 1 American Society of Agronomy. Publication. Madison Wisconsin, USA. 1965.
3. Cakamkc R, Donmez MF and Erdogan. The effect of plant growth promoting rhizobacteria on barley seedling growth, nutrient uptake, some soil properties and bacterial counts. Turkey Journal of Agriculture and Forestry. 2007;31:189-199.
4. Choudhary RL, Behera UK. Effect of sequential tillage practices and N levels on energy relations and use-efficiencies of irrigation water and N in maize (Zea mays)–wheat (*Triticum aestivum*) cropping system. Indian Journal of Agronomy. 2013;58(1):27-34.
5. Crosswell ET, Godwin DC. The efficiency of N-fertilizers applied to cereals. In: Avances in plant nutrition. PB. Tinker, (ed). New York. 1984, 1-55.
6. Delogu G, Cattivelli L, Pecchioni N, De Falcis D, Maggiore T, Stanca AM. Uptake and agronomic efficiency of nitrogen in winter barley and winter wheat. European Journal of Agronomy. 1998;9(1):11-20.
7. Duncan RR, Baligar VC. Genetic, breeding and physiological mechanisms of nutrient uptake and use efficiency: An overview. Ins: crop as Enhancers of Nutrient use, Baligar VCand Duncan RR (Eds), Academic Press Inc. San Diego, California. 1990, 3-35.
8. Elias E, Teklu B, Tefera T. Effect of blended fertiliser application on bread wheat yield, agronomic efficiency and profitability on Nitisols of Southern Ethiopia. South African Journal of Plant and Soil. 2020;37(4):292-299.
9. Koenig RA Johnson CR. Colorimerric determination of Phosphorus in biological materials. Indian Engineering and Chemistry Anlas. 1942;14:155-156.
10. Mahanta D, Rai RK. Effect of sources of Phosphorus and biofertilizers on productivity and profitability of soybean-wheat system. Indian Journal of Agronomy. 2008;53(4):279-284.
11. Mosier AR, Syers JK, Frency. Agriculture and the nitrogen cycle. Assessing the impacts of fertilizer use on food production and the environment, scope-65. Island Press Londo. 2004.

12. Piccinin GG, Dan LD, Braccini AD, Mariano DD, Okumura RS, Bazo GL. Agronomic efficiency of Azospirillum brasilense in physiological parameters and yield components in wheat crop. Journal of Agronomy. 2011;10(4):132-5.
13. Sharma GD, Thakur Risikesh, RAJ SOM, Kauraw DL, Kulhare PS. Impact of integrated nutrient management on yield, nutrient uptake, protein content of wheat (Triticum aestivam) and soil fertility in a typic haplustert. The Bioscan. 2013;8(4):1159-1164.
14. Tamas Kand Zoltan Toth. Mineral and Organic Fertilization to Improve Soil Fertility and Increase biomass Production and N Utilization by Cereals, Soil Fertility Improvement and Integrated Nutrient Management -A Global Perspective, Dr. Joann Whalen (Ed.), ISBN: 978-953-307-945-5, 2012, 183-200.
15. Thakur M, Agrawal HP. Effect of bio-inoculant, organic manure and chemical fertilizer on growth and yield of wheat (*Triticum aestivum* L.). IJCS. 2020;8(3):2293-2296.
16. Hussain S, Sharif M, Khan S, Wahid F, Nihar H, Ahmad W, *et al*. Vermicompost and *Mycorrhiza* Effect on Yield and Phosphorus Uptake of Wheat Crop. Sarhad Journal of Agriculture. 2016;32(4):372-381.
17. Gogoi D, Kotoky U, Hazarika S. Effect of biofertilizers on productivity and soil characteristics in banana. Indian Journal of Horticulture. 2004;61:354-356.
18. Khandare RN, Chandra R, Pareek N, Raverkar KP. Carrier-based and liquid bioinoculants of Azotobacter and PSB saved chemical fertilizers in wheat (*Triticum aestivum* L.) and enhanced soil biological properties in Mollisols. Journal of Plant Nutrition. 2020;2;43(1):36-50.
19. Devi KN, Singh MS, Singh NG, Athokpam HS. Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.). Journal of Crop and Weed. 2011;7(2):23-27.