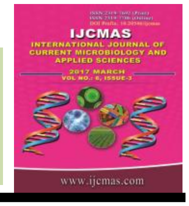
Int.J.Curr.Microbiol.App.Sci (2017) *6*(3): 152-163

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 3 (2017) pp. 152-163**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2017.603.017

Integrated Nutrient Management for Improving, Fertilizer Use Efficiency, Soil Biodiversity and Productivity of Wheat in Irrigated Rice Wheat Cropping System in Indo-Gangatic Plains of India

Suresh Kumar Kakraliya[1]* R.D. Jat[2], Sandeep Kumar[1], K.K.Choudhary[3], Jai Prakash[4] and L.K.Singh[2]

[1]CCS Haryana Agriculture University Hisar, Haryana, India
[2]International Maize and Wheat Improvement Center, India
[3]Central Arid Zone Research Institute RS Pali, Rajasthan, India
[4]SVBP University of Agriculture and Technology, Meerut UP, India
**Corresponding author*

A B S T R A C T

Keywords

Organic manures, Bio-fertilizer, Chemical fertilizers, Nutrient use efficiency, Wheat yield and Grain quality.

Article Info

Accepted:
08 February 2017
Available Online:
10 March 2017

A field experiment was conducted during rabi season of 2011-12 and 2012-13at C.S. Azad University of Agriculture and Technology, Kanpur to find out the combined effect of organic and inorganic fertilizers on grain yield, fertilizer use efficiency and grain quality of wheat crop. The treatments were -Control (T1), RDF (150:60:40 NPK Kg/ha) (T2),125% RDF (T3), RDF + Vermicompost (VC) at 2.5 t/ha (T4), RDF + VC at 5t/ha (T5), RDF + FYM at 5t/ha (T6), RDF + FYM at 10t/ha (T7), RDF + VC at 2.5 t/ha + Azotobacter (T8), RDF + FYM at 5t/ha + Azotobacter (T9), and RDF + VC at 2.5 t/ha + FYM at 5 t/ha + Azotobacter (T10). Result showed that the treatment T_{10} produced higher grain yield than the other treatments. The higher yield led to higher NPK uptake by wheat. Further, the available NPK and organic carbon (%) content of soil also increased with integration of organic and inorganic fertilizer along with bio-fertilizer strain over control. Different fertilizer- use efficiencies were significantly improved with the application of manures, chemical fertilizers and bio-fertilizer over control as well as chemical fertilizer alone. All the fertilizer use efficiency was maximum in treatment T10followed by treatment T_9 and the minimum value was quantified in T_3, T_2, T_1 (control). The highest grain protein content was obtained from the application of organic and inorganic fertilizer along with azotobacter and lowest from control as well as NPK fertilizer alone.

Introduction

In India, wheat is the second most important cereal crop after rice grown under sub-tropical environment during November to April, covering an area of 31.19 million ha. Total annual production of wheat in India is 95.91 million tonnes, with the productivity of 3.07 tonnes/ha (DES, 2014). India is the second largest producer of wheat with approximately 12% world's wheat production and it is also the second largest consumer of wheat after China. In 21st century, there will be a need of about more than 250 million ton of food grains to meet the demand of rapidly increasing human population. At present time, wheat production system are facing multiple challenges like lower factor productivity, stagnation of yield, multiple nutrient deficiencies and climate change (Jat *et al.*, 2016). As the global population grows, stress on natural resources increases, making it difficult to maintain food security for future. For long time food security requires a balance between increasing crop production, maintaining soil health and environmental sustainability. In India, nutrient management has played an important role in accomplishing the enormous increase in food grain production from 52 million tons in 1951-52 to 259 million tons during 2014-15. Since GR to till now the consumption rate of NPK (kg ha^{-1}) are increased by 5.5, 12.5, 16.7 and 28.5 million ton in 1970,1980,1990,2000, 2010 2010 respectively, (DES, 2014). However, application of imbalanced and/or excessive nutrients led to declining nutrient-use efficiency making fertilizer consumption uneconomical and producing combat effects on soil microorganism, soil enzymes activities, and atmosphere (Aulakh and Adhya, 2005) and groundwater quality (Aulakh *et al.*, 2009) causing health hazards and climate change.

Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems. It can be greatly impacted by fertilizer management as well as by soil- and plant-water management. The objective of nutrient use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop while minimizing nutrient losses from the field (Fixen *et al.*, 2014). Earlier, to meet the challenges intensive cropping patterns were adopted which resulted in declining nutrient status of soil (Balyan and Idnani, 2000). Indiscriminate use of fertilizers adversely affects the physicochemical properties of the soil resulting in poor rice-wheat production. The declining response to inputs has been received to be the major issue challenging the sustainability of wheat based cropping system (Mishra, 2006) (Table 1). Significant efforts have been made to economise the use of fertilizers in field crops through application of bio-fertilizer, vermicompost and farmyard manure (FYM). Integration of various sources of nutrients (organic, inorganic and bio-fertilizer) is more suitable because this reduces the application of chemical fertilizers and cost of cultivation, besides being an environment friendly approach (Ram and Mir, 2006).

Gupta *et al.*, (2006) also indicated that imbalanced use of fertilizers is an important issue in an Indian agriculture so now alternate option is combined use of organic and inorganic sources of essential nutrients increases the production and profitability of field crops and helps in maintaining the fertility status of the soil.

Organic manure and bio-fertilizers are needed along with chemical fertilizers for better yield and better soil health. Research indicates that bio-fertilizers like Azotobacter and Azospirillum alone or in combination have great prospect for increasing productivity of wheat (Kumar and Ahlawat, 2004). Therefore, the objectives of this study were to recognize the yield and nutrient use efficiency trends and to assess the N, P, K budget as influenced by application of NPK fertilizers in combination with or without organic manures over the years.

Materials and Methods

Experiment site description

A field experiment was conducted at Students Instructional Farm (SIF) in C. S. Azad University of Agriculture and technology, Kanpur (UP) during the winter (*rabi*) seasons of 2011–12 and 2012–13. The experimental farm falls under the Indo-Gangetic alluvial tract and irrigated by tube well.

Experiments design and treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications as summarised in table 2.

Application of manures and fertilizers

The source of nutrient was organic and inorganic fertilizers. Well-rotten FYM and VC as per treatment were incorporated before sowing. Recommended dose of phosphorus as DAP and potassium as muriate of potash (MOP) were applied at the time of sowing and one-third nitrogen was applied as basal and remaining in 2 equal splits-as urea at first irrigation and at boot stage as per treatments. Seed treatment was done with Azotobacter strain at the rate of 20g per 10 kg of wheat seed (Table 3).

Cultural practices

The wheat variety PBW-343 was sown on 4th and 1st of December 2011 and 2012 respectively. The seed was treated with the Azotobacter per treatments and seed sown with 20 cm rows spaced. The irrigations were given and other recommended packages of practices were adopted during the crop-growth periods in both the years.

Analysis of grain and straw samples

The grain and straw samples were analysed for N, P and K contents following standard methods. Then the nutrient uptake as well as nutrient use efficiency was calculated with the following equations.

Nutrient use efficiency

Grain yield increase in kg per kg nutrient applied is considered as nutrient use efficiency.

Partial factor productivity (PFP)

It is a simple production efficiency expression, calculated in units of crop yield per unit of nutrient applied (Fixen *et al.*, 2014) Equation (1)

$$\text{PFP} = \frac{\text{Yield of harvested portion of crop with nutrient applied (kg grain)}}{\text{Amount of nutrient applied (kg nutrient)}}$$

Agronomy efficiency (AE)

It is calculated in units of yield increase per unit of nutrient applied. It more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return (Fixen *et al.*, 2014and Alam *et al.*, 2007) Equation (2)

$$\text{AE} = \frac{\text{Yield of crop with nutrient applied} - \text{yield of crop with no nutrient applied}}{\text{Amount of nutrient applied(kg/ha)}}$$

Recovery efficiency (RE)

It is defined as the difference in nutrient uptake in above-ground parts of the plant between the fertilized and unfertilized crop relative to the quantity of nutrient applied. (Fixen *et al.*, 2014 and Alam *et al.*, 2007) Equation (3)

$$\text{RE} = \frac{\text{Nutrient uptake by crop with nutrient applied} - \text{Nutrient uptake by crop with no nutrient applied}}{\text{Amount of nutrient applied (kg nutrient)}} \text{X100}$$

Internal utilization efficiency

It is defined as the yield in relation to total nutrient uptake. It varies with genotype, environment and management. A very high Internal Efficiency (IE) suggests deficiency of that nutrient. Low IE suggests poor internal nutrient conversion due to other stresses (deficiencies of other nutrients, drought stress, heat stress, mineral toxicities, pests, etc.). (Fixen *et al.*, 2014) Equation (4)

$$IUE = \frac{\text{Yield of harvested portion of crop with nutrient applied (kg grain)}}{\text{Nutrient uptake by crop with nutrient applied (kg nutrient)}}$$

Physiological efficiency (PE)

It is defined as the yield increase in relation to the increase in crop uptake of the nutrient in above-ground parts of the plant (Fixen *et al.*, 2014) Equation (5)

$$PE = \frac{\text{Yield of crop with nutrient applied} - \text{yield of crop with no nutrient applied}}{\text{Nutrient uptake by crop with nutrient applied} - \text{Nutrient uptake by crop without nutrient applied}}$$

Partial Nutrient Balance (PNB)

It is expressed as nutrient output per unit of nutrient input (a ratio of "removal to use"). Less frequently it is reported as "output minus input. "Lower levels suggest changes in management could improve efficiency or soil fertility could be increasing. Higher levels suggest soil fertility may be declining. (Fixen *et al.*, 2014) Equation (6)

$$PNB = \frac{\text{Nutrient content of harvested portion of crop (kg nurient)}}{\text{Amount of nutrient applied (kg nutrient)}}$$

Results and Discussion

Grain yield, available N, P, K and total uptake of NPK

Grain yield

All fertilized treatments improve the productivity relative to control (unfertilized) (Tab 4.). Wheat yield with synthetic fertilizer (NPK) was 42 % more compared with control, and further increased with layering of organic and inorganic fertilizers along with bio-fertilizers. Grain yield in T_{10}, T_5, T_7, T_8, T_9, T_4 and T_6 was increased by 27, 20, 19, 16, 15, 12 and 11% respectively, compared to T_2 (4.11 t ha^{-1}). Alike grain yield, similar trend was also observed to straw yield (Table 4) Higher productivity in the T_4-T_{10} plots compared with synthetic fertilizers could be associated with advantages of organics apart from N, P, and K supply like as enhancements in soil microbial activities, supply of nutrients that were not supplied by inorganic fertilizers, and less losses of nutrients from the soil (Gopinath *et al.*, 2008). The increase in grain and straw yields might be due to adequate quantities and balanced proportions of plant nutrients supplied to the crop as per need during the growth period resulting in favourable increase in yield attributing characters which ultimately led towards an increase in economic yield. Improved physical and chemical properties of the soil through the application of organic manure might be the other possible reason for higher productivity. Similar obtained here compare with those in earlier reports (Bhattacharyya *et al.*, 2010; Sarma *et al.*, 2007; Devi *et al.*, 2011; Essam and El-Lattief, 2014), where The mean wheat yield under organic, inorganic and bio-fertilizer treated plots was ~27% higher than NPK (2.4 t ha^{-1}). Our similar result was also reported by Sarma *et al.*, (2007) who observed application of 150 kg N ha^{-1} + FYM (10 t ha^{-1}) + Azotobacter recorded significantly higher grain yield by ~10 % compared to 150 kg N ha-1and FYM 10 t ha^{-1} (4.34 t ha^{-1}).

Soil status after treatments

Application of FYM, vermicompost and inorganic fertilizers with azotobacter strain significantly (P= 0.05) increased the NPK uptake by the crop than the application of zero fertilizer as well as chemical fertilizers alone. Maximum NPK uptake by the crop was recorded from organic, inorganic and bio-fertilizer treated plots (Table 6) and decrease in available NPK status of soil was recorded in control where no fertilizer was applied to the crop. The increased uptake of the nutrients in treatments T_4-T_{10} the uptake of N,P and K was increased due to application of adequate quantity of nutrients in recommended doses with substitution of organics to added supply of nutrients and well developed root system resulting in better absorption of water and nutrient (Table 5). These results are in agreement with the findings of Devi *et al.*, (2011) who reported that integrated nutrient management (INM) produced higher yield attributes and grain yield than the alone NPK fertilizers, the higher yield led to higher NPK uptake by wheat. Further, the available NPK content of soil also increased in above INM treatment over control. Our study results revealed that the application of organic and inorganic fertilizer along with bio-fertilizer strain significantly increased the available nitrogen, phosphorus and potash status of the soil (Table 5). Similar result also confirm by Singh *et al.*, (2015) where, NPK, FYM and bio-fertilizers significantly increased the available nitrogen, phosphorus and potassium content at the harvest of wheat crop over control as well as 100% RDF alone. Experimental results showed that available NPK and organic carbon of soil after the harvesting of wheat were found to be maximum with the application of RDF + VC at 2.5 t/ha + FYM at 5 t/ha + Azotobacter, RDF + FYM at 10t/ha and RDF + VC at 5t/ha and the lowest from control. It might be due to the application of FYM, VC and azotobacter which enhances the activity of soil microbial populations and there was a high level of total NPK in experimental plot. These results are in agreement with the findings of Devi *et al.*, (2011) who reported that higher grain yield led to higher NPK uptake by wheat. Further, the available NPK content of soil also increased in integrated nutrient management treatments over control. Pandey *et al.*, (2009) also reported that addition of organic manure with fertilizer levels significantly increased the nutrient uptake by wheat, improved the organic carbon content N, P and K status as compare to chemical fertilizer alone.

Table.1 Physico-chemical status of soil at SIF, CSAUAT, Kanpur

Property (Unit)	value	Method used	Reference
pH	7.3	Digital pH meter	(Page *et al.*,1982)
Electrical conductivity (ds m^{-1})	0.26	EC meter	(Page *et al.*,1982)
Organic matter (%)	0.46	Wet oxidation method	(Walkley and Black1934)
Coarse sand (%)	0.72		
Sand (%)	54.5	Hydrometer method	(Bouyoucos1962)
Silt (%)	22.1	Hydrometer method	(Bouyoucos1962)
Clay (%)	22.68	Hydrometer method	(Bouyoucos1962)
Textural class	-	Triangular method	(Bouyoucos1962)
Bulk density (g cm^{-3})	1.28	Core method	(Piper 1966)
Available N (kg ha^{-1})	173	Alkaline permanganate method	(Subbiah and Asija1956)
Available P (kg ha^{-1})	16.8	Olsen's method	(Olsen *et al.*,1954)
Available K (kg ha^{-1})	164	Flame photometer method	(Jackson 1967)

Table.2 Details of different 10 treatments

Treatments	Details
T_1	Control
T_2	RDF(N,P,K 150:60:40 kg ha^{-1})
T_3	125 % RDF
T_4	RDF + Vermicompost (VC) at 2.5 t ha^{-1}
T_5	RDF + VC at 5 t ha^{-1}
T_6	RDF + FYM at 5 t ha^{-1}
T_7	RDF + FYM at 10 t ha^{-1}
T_8	RDF + VCat 2.5t ha^{-1} + Azotobacter
T_9	RDF+ FYM at 5 t ha^{-1} +Azotobacter
T_{10}	RDF + VC at 2.5 t ha^{-1}+ FYM at 5 t ha^{-1} + Azotobacter

Table.3 Nutrient content in organic manures and inorganic fertilizers

Manures/fertilizers	Nutrient content %		
	N	P	K
FYM	0.48	0.24	0.25
Vermicompost	1.87	1.12	1.25
Urea	46		
DAP	18	46	
MOP			60

Table.4 Effect of integrated use of organic and chemical fertilizers on grain yield, straw yield and grain protein of wheat (data over two seasons)

Treatments	Grain yield (q/ha)	Stover yield (q/ha)	Grain protein content %
T_1	2.90	4.06	10.48
T_2	4.11	5.72	11.32
T_3	4.37	5.98	11.35
T_4	4.67	6.45	11.78
T_5	5.19	7.16	11.93
T_6	4.65	6.42	11.78
T_7	5.09	7.02	11.89
T_8	4.91	6.77	11.86
T_9	4.82	6.64	11.80
T_{10}	5.62	7.53	11.96
SE± (d)	0.116	0.98	0.178
C.D. (P=0.05)	0.247	0.207	0.377

Table.5 Effect of integrated use of organic and chemical fertilizers on, nutrient uptake, available nutrient and organic carbon (data over two seasons)

Treatments	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total Kuptake (kg/ha)	Soil-fertility status after 2 years			
				Total available N(kg/ha)	Total available P(kg/ha)	Total available K(kg/ha)	Organic carbon (%)
T_1	67.85	15.46	52.88	165.2	15.16	158.59	0.45
T_2	91.30	22.08	75.54	176.2	16.73	169.15	0.46
T_3	96.52	22.82	78.05	179.4	16.92	172.22	0.46
T_4	101.49	24.51	83.84	184.8	17.83	180.12	0.47
T_5	112.09	27.20	93.04	192.3	20.04	184.29	0.48
T_6	101.28	24.39	83.45	185.5	18.31	182.10	0.48
T_7	108.30	26.66	91.22	197.2	22.16	189.31	0.5
T_8	106.37	25.72	87.98	188.3	17.71	180.77	0.47
T_9	103.86	25.26	86.42	190.4	18.55	182.15	0.48
T_{10}	116.11	28.21	97.88	196.5	21.21	188.64	0.49
SE± (d)	**1.72**	**0.38**	**1.33**	**1.31**	**0.190**	**0.55**	**0.006**
C.D. (P=0.05)	**3.65**	**0.82**	**2.82**	**2.77**	**0.402**	**1.16**	**0.012**

Table.6 Effect of integrated use of organic and chemical fertilizers on PFP (kg grain kg_1 applied nutrient), AE (kg grain kg_1 nutrient), Recovery efficiency, PNB(kg nutrient/ kg nutrient) and PEof applied NPK

Treatments	Total applied NPK kg/ha	Total uptake NPK kg/ha	PFPnpk (kg /kg)	AEnpk (kg grain/kg nutrient)	REnpk (%)	PNBnpk (kg nutrient/ kg nutrient)	PEnpk
T_1	0	126.1	-	-	-	-	
T_2	250	190.8	16.5	4.8	25.9	0.76	18.58
T_3	312	201	14	4.7	24	0.64	19.42
T_4	250	215.9	18.7	7	35.9	0.86	19.58
T_5	250	239.6	20.7	9.1	45.4	0.96	20.02
T_6	250	214.9	18.6	7	35.5	0.86	19.58
T_7	250	235	20.3	8.7	43.6	0.94	19.93
T_8	250	226.6	19.6	8	40.2	0.91	19.82
T_9	250	222.6	19.3	7.6	38.6	0.89	19.73
T_{10}	250	252.5	22.5	10.8	50.6	1.01	21.42
SE± (d)		2.38	0.97	0.314	1.36	0.012	0.147
C.D. (P=0.05)		7.16	1.92	0.664	2.88	0.025	0.312

Fig.1 Relationship between grain yield and PFP of N, P and K

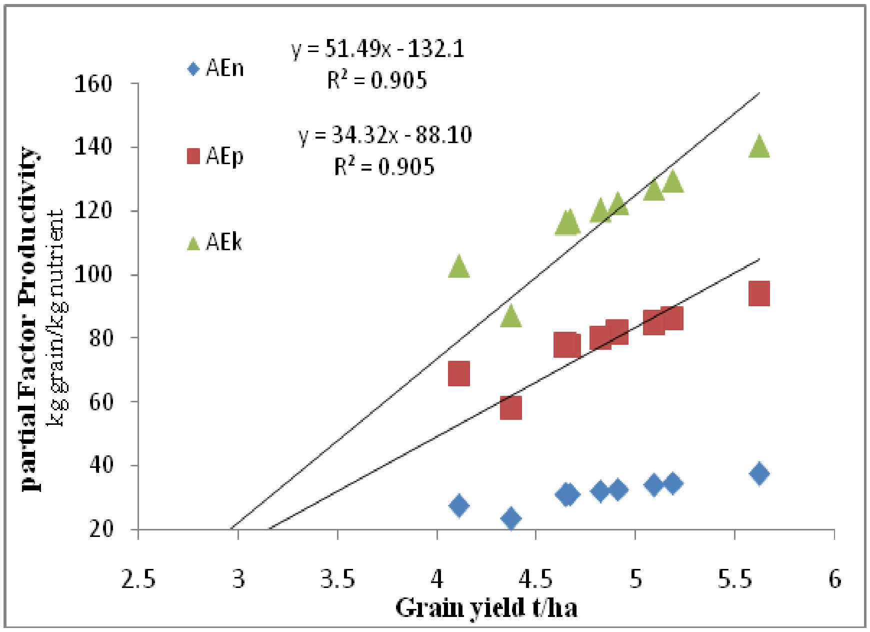


Fig.2 Relationship between grain yield and agronomic efficiency of N, P and K

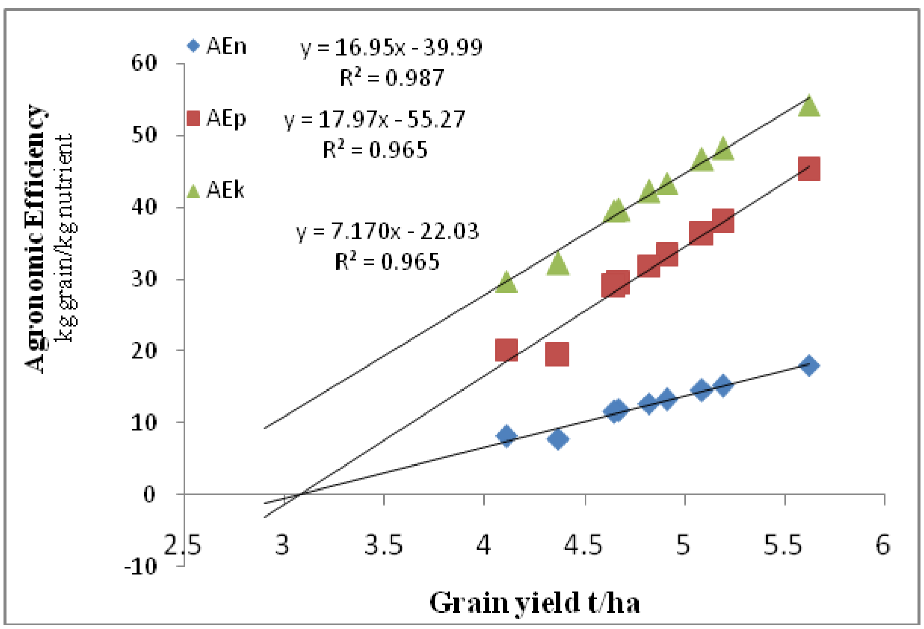
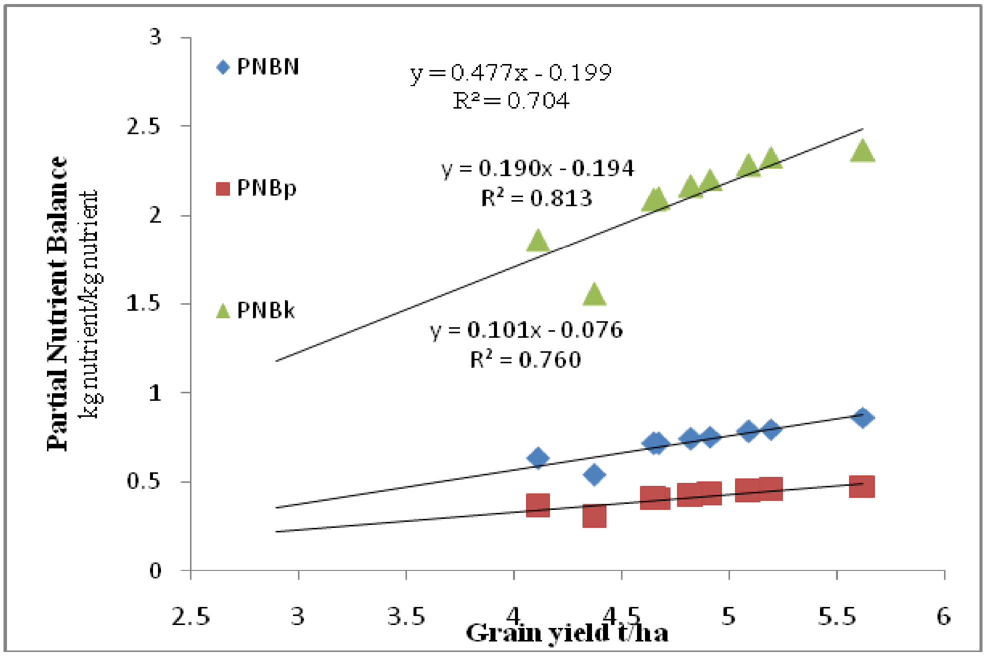


Fig.3 Relationship between grain yield and recovery efficiency of N, P and K



Effect of different levels of organic and inorganic fertilizers on Nutrient Use Efficiencies

Nitrogen, phosphorous and potassium

Application of FYM, VC and NPK fertilizers with azotobacter strain increased the nitrogen, phosphorus and potassium use efficiency by the crop than the application of zero fertilizer as well as chemical fertilizers alone. Fertilizer- use efficiency, i.e. Partial factor productivity (PFP) agronomic efficiency (AE), apparent recovery efficiency (RE), and physiological efficiency were significantly improved with the application of manures, chemical fertilizers and bio-fertilizer over control as well as chemical fertilizer alone. Both the fertilizers (organic and inorganic) remained at par in respect of fertilizer-use efficiency in both the years, N,P and K use efficiency retained in chemical fertilized plot in both the years but it increased from first year to second year due to effect of combined application of organic and inorganic fertilizer.

Our study indicated that different levels of organic fertilizers influenced fertilizers-use efficiency with the same level of Inorganic fertilizers i.e. the application of RDF + VC at 2.5 t/ha + FYM at 5 t/ha + Azotobacter gave maximum PFP, AE, RE and PE respectively, over the 125% RDF, RDF respectively. Similarly treatment T_4 to T_9 gave highest fertilizer efficiencies compare to 125% RDF and 100% RDF respectively.(Tab 6)Similar obtained here compare with those in earlier reports Malika *et al.*, (2015) and Alam *et al.*, (2007) where inorganic, organic and bio-fertilizer combinations significantly increased the agronomic efficiency and apparent N recovery similarly results was reported by Jat *et al.*, (2015) where nutrient use efficiency was greatly increased by balanced use of N, P, and K fertilizers, and by rational use of organic manures in wheat systems. It might be owing to beneficial effect of combined application of organic manures and inorganic fertilizers on crop growth, which influenced the growth and yield-attributing characters positively. Moreover, proper decomposition of FYM, VC which supplied available plant nutrients directly to plants and created favourable soil environment, ultimately increased the nutrients and water-holding capacity of soil for longer time, which resulted in better growth, yield attributes and ultimately grain and straw yields of wheat.

Effect of organic and inorganic fertilizers on quality

The two results in showed that grain protein content under integrated treatments was significantly higher than control (T_1) and chemical fertilizer alone. The maximum grain protein content was recorded under treatment T_{10} (11.96%) followed by treatment T_5, T_7, T_8, T_9 and T_4 respectively, and the minimum and significantly lower grain protein content was recorded in treatment T_1 (10.48%), T_2 and T_3 respectively (Table 4). The results are quite in line with El-Lattief (2014) and Abedi *et al.*, (2010) they concluded that grain protein contents responded to organic and inorganic fertilizer application. It was significantly higher under organic and inorganic fertilizer treated plots (11.65-11.98%) compared to control (11.01%).

In conclusion, for sustainably increasing agriculture productivity, research based recommendation must be focus on integrated use of organic manures, bio-fertilizer along with synthetic fertilizer rather than increase the rate of recommended synthetic fertilizers, that provide high yields, grain quality and adequate soil fertility. Our experimental results showed that addition of FYM,VC and azotobater with NPK fertilizers increased grain yield, nutrient uptake(NPK), available NPK, OC and protein content by 26, 32, 28, 6.5 and 5.6 % in RDF + VC at 2.5 t/ha + FYM at 5 t/ha + Azotobacter treated plot (T_{10}) respectively, over recommended NPK fertilizer. Whereas PFPnpk, AEnpk, REnpk, PNBnpk and PEnpk was improved by 22, 73, 60, 21 and 7.7 % (mean of T_4-T_{10}) in various combination of FYM, VC and Azotobacter along with recommended NPK fertilizer treated plots respectively, compared to that of recommended NPK fertilizer. Addition of FYM and VC with inorganic fertilizers improves organic matter content of soil and consequently water holding capacity of soil. Nutrient replenishment by merely adding chemical fertilizers is often not economically feasible and even in the technically, it may not be in balance with the supply of organic matter. Our study reflects those integrated use of chemical fertilizers, organic manures and azotobacter, assume greater significance of improving efficiency of chemical fertilizers in soil health or soil biodiversity, developing the biological activities, increasing the environmental hygiene, conservation and supporting the ecology. Integrated use of organic and inorganic fertilizer also increased grain protein content compare to use of chemical fertilizer alone.

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How to cite this article:

Suresh Kumar Kakraliya, R.D. Jat, Sandeep Kumar, K.K. Choudhary, Jai Prakash and Singh, L.K. 2017. Integrated Nutrient Management for Improving, Fertilizer Use Efficiency, Soil Biodiversity and Productivity of Wheat in Irrigated Rice Wheat Cropping System in Indo-Gangatic Plains of India. *Int.J.Curr.Microbiol.App.Sci*. 6(3): 152-163.
doi: https://doi.org/10.20546/ijcmas.2017.603.017