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Effect of Integrated Nutrient Management on Fertilizer Use Efficiency in Wheat (*Triticum aestivum* L.) under Irrigated Condition

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Abstract: ***A field experiment was conducted during 2017-18 and 2018-19 at Agronomy Research Farm, CCS HAU Hisar to study the effect of integrated nutrient management on fertilizer use efficiency of wheat. The experiment was laid out in randomized block design with three replications and ten treatments. During both the years, the significantly highest agronomical nitrogen use efficiency, apparent recovery efficiency of nitrogen, utilization efficiency of nitrogen, economic nutrient use efficiency and nutrient removal ratio of wheat were recorded with application of 100% RDN. Application of 25% RDN + 75% N through FYM was noted to have the significantly higher physiological nitrogen use efficiency and nutrient efficiency ratio, being at par with application of 25% RDN + 75% N through vermicompost. The highest nutrient increment efficiency of nitrogen and lowest agro-physiological nitrogen use efficiency was observed with application of 100% RDN + 25% N through vermicompost.***

Keywords: Integrated nutrient management, nutrient use efficiency, wheat.

1. Introduction

Wheat is one of the most vital food grains in India, which is rich in vital ingredients such as proteins, carbohydrates, and vitamins. It is the primary staple of millions of Indians across the country. Which stands in second position next to rice, and contributes about 35% to the national food basket and accounts for 8.7% of world's wheat production and positioned just after Russia, USA, and China. India is the second largest producer of wheat next to china, which produces about 99.7 million tons of wheat from an area of 29.6 million hectare with an average productivity of 3371 kg ha^{-1} (Anonymous, 2018). Among plant nutrient nitrogen plays a key role in growth, development and boosting productivity of wheat crop and leaves higher residue in soil after harvest of the crop for soil fertility development. Wheat is generally grown under extensive cropping system with higher use of inorganic especially nitrogenous fertilizers. Continuous use chemical fertilizer for decades has increased the crops yield, but with passage of time the continuous use of large quantities of chemical fertilizers has resulted loss of soil organic matter, deterioration of soil health, environmental pollution and threatened the sustainable crop production. To ensure the sustainable wheat production with emphasis on ecologically friendly inputs the integrated plant nutrient supply systems is one of the solutions. The basic concept underlying the integrated plant nutrient supply system is the maintenance of soil fertility, sustaining agricultural productivity and improving farmer's profitability through judicious and efficient use of fertilizers, organic manures and biofertilizers to the possible extent. Currently it is estimated that only 30-50% of applied

nitrogen fertilizers and 45% of phosphorus fertilizers are used for crops (Ladha *et al.*, 2005 and Ghosh *et al.*, 2015). However, the efficiency of nutrient use may be enhanced by the combined use of organic and inorganic fertilizers (Kumar *et al.*, 2014). The increase in cost of chemical fertilizer results that the resource poor farmers cannot afford the high price of fertilizer, thus there is a need for complete or partial substitution of inorganic fertilizers, by locally available organic sources for sustaining crop production (Acharya and Mandal, 2010; Brahmachari *et al.*, 2011and Yadav *et al.*, 2013). Many long term experiments have been conducted in different locations in India and revealed that application of all the needy nutrients through chemical fertilizers have deleterious effect on soil health leading to unsustainable crop production (Jaga, 2013). Therefore, there is a need to improve nutrient supply system in terms of integrated nutrient management involving the use of chemical fertilizers in conjunction with organic manures. Considering the above facts, the two years experiment (2017-18 and 2018-19) have been conducted to study the effect of integrated nutrient management on fertilizer use efficiency in wheat (*Triticum aestivum* L.) under irrigated condition.

2. Material and Methods

The field experiment was conducted at Agronomy Research Farm of CCS Haryana Agricultural University, Hisar during *Rabi* season of 2017-18 and 2018-19 to study effect of integrated nutrient management on fertilizer use efficiency in wheat (*Triticum aestivum* L.) under irrigated condition. The experiment was laid out in randomized block design with three replications consisting of ten treatments viz. T_1.Control, T_2.100% recommended dose of nitrogen through inorganic fertilizer+25% nitrogen through farmyard manure, T_3.100% recommended dose of nitrogen through inorganic fertilizer+25% nitrogen through vermicompost, T_4.75% recommended dose of nitrogen through inorganic fertilizer+25% nitrogen through farmyard manure, T_5.75% recommended dose of nitrogen through inorganic fertilizer+25% nitrogen through vermicompost, T_6.50% recommended dose of nitrogen through inorganic fertilizer+50% nitrogen through farmyard manure, T_7. 50% recommended dose of nitrogen through inorganic fertilizer+50% nitrogen through vermicompost, T_8.25% recommended dose of nitrogen through inorganic fertilizer +75% nitrogen through farmyard manure T_9. 25% recommended dose of nitrogen through inorganic fertilizer through inorganic fertilizer+75% nitrogen through vermicompost and T_{10}. 100% recommended dose of nitrogen through inorganic fertilizer. The initial status of soil fertility was 172:17:270 kg NPK ha^{-1} and 0.44 percent organic carbon. The fertilizers were used as recommended package of practice in all treatments except control. The nutrient efficiencies were work out by using the following formulas given by Sarma (2018).

Agronomical nitrogen use efficiency (ANUE) = GY_n-GY_0 / N_a
Where,
GY_n = Grain yield with nitrogen
GY_0 = Grain yield without nitrogen
N_a = Nitrogen applied

Physiological nitrogen use efficiency (PNUE) = $BY_n - BY_0$ / $NU_n - NU_0$
Where,
BY_n = Biological yield with nitrogen
BY_0 = Biological yield without nitrogen
NU_n = Nitrogen uptake with nitrogen
NU_0 = Nitrogen uptake without nitrogen

Agro-physiological nitrogen use efficiency (APNUE) = GY_n-GY_0 / $NU_n - NU_0$
Apparent recovery efficiency of nitrogen (AREN) = $NU_n - NU_0$ / N_a * 100%
Utilization efficiency of nitrogen (UEN) = $BY_n - BY_0$ / N_a or PNUE * AREN
Nutrient efficiency ratio (NER) = BY/ NU
Nutrient increment efficiency of nitrogen (NIEN) = $Yn - Y_{n-1}$ / Y_{n-1}
Y_n = Biological yield with N_n amount of nitrogen
Y_{n-1} = Biological yield with N_{n-1} amount of nitrogen
Economic nitrogen use efficiency (ENUE) = Economic yield / Amount invested on the nutrient
Nitrogen removal ratio (NRR) = Nitrogen uptake by grain / Total nitrogen applied

3. Results and Discussion

Agronomical nitrogen use efficiency (ANUE)

Agronomical nitrogen use efficiency is the additional grain yield produced due to application of nitrogen over unfertilized control per unit of nitrogen applied. During both the years, the significantly higher agronomical nitrogen efficiency (22.34 and 22.70 kg/kg) of wheat was recorded with application of 100% recommended dose of nitrogen through inorganic fertilizer (T_{10}) over rest of the other treatments (table 1). This increase might be due to rapid release of nutrient particularly nitrogen through chemical fertilizer during all active growth stages of the wheat crop. This result is close to finding of Kaur *et al.* (2016) in wheat crop.

Physiological nitrogen use efficiency (PNUE)

Physiological nitrogen use efficiency is the additional biological yield produced by application of nitrogen over unfertilized control per unit of additional nitrogen uptake over unfertilized control. Application of 25% recommended dose of nitrogen through inorganic fertilizer+75% nitrogen through farmyard manure (T_8) had the significantly higher physiological nitrogen use efficiency(100.58 and 94.64 kg/kg) being at par with application of 25% recommended dose of nitrogen through inorganic fertilizer through inorganic fertilizer+75% nitrogen through vermicompost (T_9) during consecutive years of the experiment (table 1). The higher PNUE with T_8 and T_9 might be due to supply of macro and micro nutrient through contribution of 75 percent of nitrogen either through vermicompost or FYM. These results are in conformity with those reported by Ashutosh *et al*. (2013) and Patel *et a.l*, (2017).

Agro-physiological nitrogen use efficiency (APNUE)

The additional grain or economic yield produced due to application of nitrogen over unfertilized control per unit of additional nutrient uptake over unfertilized control treatment is called APNUE. It was noticed that during both the years the highest APNUE (54.90 and 54.17 kg/kg) was observed with T_8 whereas the minimum APNUE (48.70 and 46.54 kg/kg) was noticed with application of 100% recommended dose of nitrogen through inorganic fertilizer+25% nitrogen through vermicompost (T_3).

Table 1: Agronomical nitrogen use efficiency, physiological nitrogen use efficiency and gro-physiological nitrogen use efficiency as affected by integrated nutrient management

Treatments	ANUE (kg/kg)		PNUE (kg/kg)		APNUE (kg/kg)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1.Control						
T_2. 100% recommended dose of nitrogen through inorganic fertilizer + 25% nitrogen through farmyard manure	18.20	18.63	84.90	79.71	49.35	47.54
T_3.100 % recommended dose of nitrogen through inorganic fertilizer + 25% nitrogen through vermicompost	18.77	19.28	83.53	77.56	48.70	46.54
T_4. 75% recommended dose of nitrogen through inorganic fertilizer+ 25% nitrogen through farmyard manure	19.78	20.12	91.82	85.59	52.39	50.56
T_5. 75% recommended dose of nitrogen through inorganic fertilizer+ 25% nitrogen through vermicompost	20.65	21.08	90.23	84.28	51.84	50.15
T_6. 50% recommended dose of nitrogen through inorganic fertilizer+ 50% nitrogen through farmyard manure	17.04	17.44	96.04	88.59	52.73	50.70
T_7. 50% recommended dose of nitrogen through inorganic fertilizer+ 50% nitrogen through vermicompost	18.10	18.57	94.85	87.20	52.52	50.64

T_8. 25% recommended dose of nitrogen through inorganic fertilizer+75% nitrogen through farmyard manure	14.27	14.59	100.58	94.64	54.90	54.17
T_9. 25% recommended dose of nitrogen through inorganic fertilizer+75% nitrogen through vermicompost	15.23	15.57	99.15	92.50	54.57	53.01
T_{10}.100% recommended dose of nitrogen through inorganic fertilizer	22.34	22.70	87.06	81.71	50.19	48.50
C.D.	**0.98**	**0.78**	**4.51**	**4.73**	**3.56**	**3.86**
SE(m)	**0.32**	**0.26**	**1.49**	**1.56**	**1.18**	**1.28**

Apparent recovery efficiency of nitrogen (AREN)

The additional nitrogen uptake over unfertilized control per unit of nitrogen applied is called apparent recovery efficiency of nitrogen (AREN). During both the years, the significantly higher apparent recovery efficiency of nitrogen by wheat was recorded with T_{10} (table 2). This might be due to readily available form of nitrogen supplied through chemical fertilizer to wheat crop. Yadav *et al*. (2018) stated that inorganic fertilizer supply the nutrient directly and quickly for crop in available form, thereby increase AREN in wheat.

Utilization efficiency of nitrogen (UEN)

Utilization efficiency of nitrogen indicates the additional biological yield over unfertilized control per unit of nitrogen applied**.** Among the treatments T_{10} had the significantly higher UEN (51.05 and 51.74 kg/kg) during both the consecutive years, which might be due to sufficient availability of nitrogen through inorganic fertilizer at all active growth and development stages of the wheat crop (Table 2). Hafiz *et al*. (2011) stated recommended dose of NPK @ 150+115+60 kg ha^{-1} through inorganic fertilizer provides instant availability of nutrients to wheat crop and results to better UEN.

Nutrient efficiency ratio (NER)

The total biomass produced per unit of nutrient uptake is called nutrient efficiency ratio (NER). T_8 was noted to have the significantly higher nutrient efficiency ratio (106.19 and 103.70 kg/kg), being at par with T_9 during both the years (table 2). This might be due to bold role of organic manures, which supply the macro and micro nutrient to crop for full exploration of its potential yield. Devi *et al*. (2013) stated that in wheat production, micronutrients play a vital role for total biomass production. Micronutrients occupy a major portion as they are essential for increasing the growth and yield attributes of plant and soil fertility. Thus, judicious combinations of organics with chemical fertilizers besides improve the growth and yield of wheat, it also helps to maintain soil productivity, increase the nutrient use efficiency.

Table 2: Apparent recovery efficiency of nitrogen, utilization efficiency of nitrogen and nutrient efficiency ratio use efficiency as affected by integrated nutrient management

Treatments	AREN (%)		UEN (kg/kg)		NER (kg/kg)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1.Control					112.57	111.51
T_2. 100% recommended dose of nitrogen through inorganic fertilizer+ 25% nitrogen through farmyard manure	37.41	39.64	41.83	42.54	93.90	90.49
T_3.100 % recommended dose of nitrogen through inorganic fertilizer +25% nitrogen through vermicompost	39.06	41.91	43.03	43.85	92.67	88.54
T_4. 75% recommended dose of nitrogen through inorganic fertilizer+25% nitrogen through farmyard manure	38.38	40.22	45.86	46.18	99.54	95.92
T_5. 75% recommended dose of nitrogen through inorganic fertilizer+25% nitrogen through vermicompost	40.20	42.84	47.49	48.03	98.26	94.65

T_6. 50% recommended dose of nitrogen through inorganic fertilizer+50% nitrogen through farmyard manure	32.65	34.48	39.86	40.28	102.91	98.92
T_7. 50% recommended dose of nitrogen through inorganic fertilizer+50% nitrogen through vermicompost	34.97	36.94	42.19	42.59	101.90	97.63
T_8. 25% recommended dose of nitrogen through inorganic fertilizer+75% nitrogen through farmyard manure	26.27	27.08	33.65	33.91	106.19	103.70
T_9. 25% recommended dose of nitrogen through inorganic fertilizer+75% nitrogen through vermicompost	28.16	29.58	36.12	36.38	105.20	102.06
T_{10}. 100% recommended dose of nitrogen through inorganic fertilizer	45.23	47.22	51.05	51.74	95.61	92.25
C.D.	**3.50**	**4.34**	**1.54**	**1.40**	**3.10**	**3.62**
SE(m)	**1.16**	**1.43**	**0.51**	**0.46**	**1.03**	**1.21**

Nutrient increment efficiency of nitrogen (NIEN)

Nutrient increment efficiency is the additional grain or economic yield over the previous level of nitrogen per unit of preceding level of grain. The highest nutrient increment efficiency of nitrogen (1.61 kg/kg each during both years) was observed with T_3 and the lowest (1.01 and 1.00 kg/kg) with T_8 during both the consecutive years. It was observed that additional 25% nitrogen through vermicompost with 100% chemical fertilizer can improve the nutrient increment efficiency of nitrogen (table 3). Khan *et al.* (2006) studied the effect of INM practices on yield and nitrogen nutrition of rice and observed that integrated use of urea with organic sources has increased nutrient increment efficiency of nitrogen. Tabassum *et al.* (2010) reported that repeated application of nitrogen fertilizer alone or with organic manures led to significant increase in total nitrogen, hydrolysable nitrogen and non-hydrolysable nitrogen in both surface and subsurface soils as compared to initial values.

Economic nitrogen use efficiency (ENUE)

The grain or economic yield produced per rupees of invested is called economic nitrogen use efficiency (ENUE). During both the years, the significantly highest economic nitrogen use efficiency (7.23 and 7.34 kg/Rs.) was obtained with T_{10}, whereas the lowest ENUE was achieved with treatment T_9 (table 3).This might be attributed to lower price of inorganic fertilizer and higher prices of organic manures especially vermicompost along with their rapid and slow release and availability to wheat crop respectively. This finding is in line with Verma *et al.* (2015).

Nitrogen removal ratio (NRR)

The ratio of nitrogen uptake by grain to nitrogen applied is called nitrogen removal ratio. Among the treatments T_{10} had the significantly higher nitrogen removal ratio (0.69 and 0.72 kg/kg), whereas T_8 recorded to have lowest NRR, during both the consecutive years (table 3). This might be due readily available form of nitrogen through inorganic fertilizer which directly supplied the nitrogen in all active stages of the wheat crop and increased the nitrogen removal ratio through increased nitrogen uptake by wheat. The lower NRR with T_8 might be due to slower release of nitrogen through FYM. This finding is in accordance with Bhat (2013), who reported that inorganic fertilizers supply nutrients to synchronize with the crop nutrient demand but organic manures release the nutrient slowly and improve the soil properties at later stages. Similar results were observed by Kumar *et al* (2008) and Sharma (2012).

Table 3: Nutrient increment efficiency of nitrogen, economic nitrogen use efficiency and nitrogen removal ratio as affected by integrated nutrient management

Treatments	NIEN (kg/kg)		ENUE (Rs/kg)		NRR (kg/kg)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1.Control						
T_2. 100% recommended dose of nitrogen through inorganic fertilizer+ 25% nitrogen through farmyard manure	1.56	1.56	1.43	1.46	0.56	0.59
T_3.100 % recommended dose of nitrogen through inorganic fertilizer +25% nitrogen through vermicompost	1.61	1.61	0.67	0.68	0.58	0.61
T_4. 75% recommended dose of nitrogen through inorganic fertilizer+25% nitrogen through farmyard manure	1.37	1.36	1.65	1.66	0.62	0.65
T_5. 75% recommended dose of nitrogen through inorganic fertilizer+25% nitrogen through vermicompost	1.42	1.41	0.68	0.69	0.64	0.67
T_6. 50% recommended dose of nitrogen through inorganic fertilizer+50% nitrogen through farmyard manure	1.19	1.18	1.20	1.21	0.56	0.59
T_7. 50% recommended dose of nitrogen through inorganic fertilizer+50% nitrogen through vermicompost	1.26	1.25	0.40	0.40	0.59	0.61
T_8. 25% recommended dose of nitrogen through inorganic fertilizer+75% nitrogen through farmyard manure	1.01	1.00	1.07	1.08	0.50	0.51
T_9. 25% recommended dose of nitrogen through inorganic fertilizer+75% nitrogen through vermicompost	1.08	1.07	0.27	0.27	0.52	0.54
T_{10}. 100% recommended dose of nitrogen through inorganic fertilizer	1.53	1.52	7.23	7.34	0.69	0.72
C.D.	**0.054**	**0.048**	**0.33**	**0.32**	**0.033**	**0.041**
SE(m)	**0.018**	**0.016**	**0.11**	**0.11**	**0.011**	**0.014**

4. Conclusion

Application of 100% recommended dose of nitrogen through inorganic fertilizer brought out the significantly highest agronomical nitrogen use efficiency, apparent recovery efficiency of nitrogen, utilization efficiency of nitrogen, economic nutrient use efficiency and nutrient removal ratio in wheat during both the years of the study. The significantly highest physiological nitrogen use efficiency and nutrient efficiency ratio were obtained by application of 25% recommended dose of nitrogen through inorganic fertilizer+75% nitrogen through farmyard manure vermicompost during both the years. Application of 100% recommended dose of nitrogen through inorganic fertilizer+25% nitrogen through vermicompost had the highest nutrient increment efficiency of nitrogen but the lowest agro-physiological nitrogen use efficiency during both the years of the study.

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List of Publications

- One abstract entitled "Effects of integrated nutrient management on yield attributes and yield of wheat (*Triticum aestivum* L.) under irrigated condition" published in Golden Jubilee International Conference. Organized by Directorate of Research CCS Haryana Agricultural University on Nov-6-2019.
- One abstract entitled "Response of late sown wheat (*Triticum aestivum* L.) to organics" published in International Symposium: A need for sustainable Agriculture. Organized by Directorate of Research CCS Haryana Agricultural University on Feb-2-2019.
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