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Integrated nutrient management in Quality Protein Maize (*Zea mays*) planted in rotation with wheat (*Triticum aestivum*): Effect on productivity and nutrient use efficiency under different agro-ecological conditions

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ABSTRACT

Field experiments were conducted during two consecutive years 2007 and 2008 at seven locations, viz. Ambikapur, Bahraich, Banswara, Chhindwara, Ranchi, Udaipur and Varanasi of different agro-ecologies to evaluate the effect of integrated nutrient management on productivity of quality protein maize (*Zea mays* L.) sown in sequence of wheat (*Triticum aestivum* L.). Integrated application of total nutrient doses from both organic and inorganic sources (225 N+ 105 P_2O_5 + 90 K_2O kg/ha) to maize resulted in maximum grain yield of quality protein maize hybrid (HQPM 1) during both the years at all the locations studied. The pooled analysis also showed that the application of FYM@ 6 tonnes/ha at N_4 level resulted into significantly higher grain yield during both the years across the locations. However the response of FYM application was higher at Ambikapur, Chhindwara, Ranchi and Varanasi as compared to other three locations. The pooled analysis of the nutrient productivity across the locations showed that it was highest with the application of O_0N_1 treatment. The productivity gained with the application of O_0N_4 can be obtained with the application of O_1N_2 although there is less than 50% of the nutrients applied through the FYM are utilized by the first crop. Hence the application of the organic manure up to the N_2 fertility levels leads to enhance the overall productivity of the land in the system as compared to sole application of N_4 levels. The SREG biplot analysis by SAS software for the yield and nutrient productivity also showed the similar trend in the results.

Key words: Inorganic fertilizer, Multi-location, Nutrient productivity, Organic manure, Quality protein maize, Yield

Maize (*Zea mays* L.) – wheat (*Triticum aestivum* L.) cropping system becoming important in northern and central India and occupies 1.8 million ha. This system mainly spread into maize eating tribal belts of Rajasthan, Himachal Pradesh, Madhya Pradesh and Jharkhand. As animals and people of these areas depend on maize for their dietary protein and unfortunately normal maize has significant flaws; it lacks the full range of amino acids, namely lysine and tryptophan causing serious threats to nutritional insecurity. QPM produces 70-100% more of lysine and tryptophan than the most modern varieties of tropical maize. These two amino acids allow the body to manufacture complete proteins, thereby eliminating wet-malnutrition. In this context growing of QPM will play a pivotal role for eliminating protein-calorie malnutrition. Nutrient management plays key role in sustaining the productivity of this system, as both the crops are high nutrient-requiring ones and respond well to higher levels of chemical fertilizers. But deterioration in soil health associated with global crises of energy, escalation in the prices of chemical fertilizers and environmental hazards due to excessive use of fertilizers, lead to emphasize on supplementation or substitution of chemical fertilizers with low priced nutrient sources such as organic manures. However, judicious combination of manures and chemical fertilizers depending upon the availability, nature and properties of the soil and crops to be grown would not only maximize the crop

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production and improve the quality of agricultural produces but would also help in maintaining the soil fertility (Shaikh *et al*. 1994), optimum productivity and overall health and quality of the soil for posterity and also to sustain the system productivity (Singh and Yadav 1992). Application of these nutrient sources alone or in combination with inorganic sources had been found beneficial not only in enhancing the productivity of maize and wheat (Jamwal 2005) but also had the beneficial impact on soil properties (Pathak *et al.* 2005). The beneficial effect of organic sources applied in preceding crops was recorded in succeeding wheat crop (Yadav *et al.* 2005, Yadav *et al*. 2008). The carry over effect of fertilizers and manures applied to maize had also been reported in wheat (Jamwal 2005, Kumar and Ahlawat 2004, Tiwari *et al.* 2004). Therefore, an attempt was made to study the effects of inorganic and organic fertilizers on the productivity of QPM grown in maize–wheat cropping system.

Table 1 Nutrient composition of farmyard manure (FYM) at different locations used in the experiment (averaged over 2 years)

Nutrients	Content	Average content
N%	0.47 – 0.53	0.50
P%	0.23 – 0.27	0.25
K%	0.43 – 0.57	0.50

MATERIALS AND METHODS

A multi-location field experiment was carried out at Ambikapur (Chhattisgarh), Chhindwara (MP), Banswara (Rajasthan), Udaipur (Rajasthan), Ranchi (Jharkhand), Baharaich and Varanasi (UP) under partially irrigated conditions during 2007-08. The treatment comprises control (without organic manure O_0) and application of FYM @ 6 tonnes/ha (O_1) in main plots and four levels of inorganic nutrients, ie 100:40:30 (N_1), 150:60:40 (N_2), 187:75:50(N_3) and 225:90:60 N: P_2O_5: K_2O kg/ha (N_4) in subplots. Nutrient composition of farm yard manure (FYM) at different locations used in the experiment is summarised in Table 1. The total amount of nutrient added in various treatment combinations are given in Table 2. The experiment was conducted in split-plot design with three replications.

The soil characteristics and rainfall during cropping season at different experimental sites are given in Table 3. Soil texture is sandy loam at Ambikapur, Bahraich and Varanasi, whereas at all other locations the soil texture is clay loam. The soil pH range from 5.6 at Ambikapur to 8.5 at Bahraich. With regards to soil fertility status, except Chhindwara (medium N), all other centres were having low N level. Similarly phosphorus was also low in all centres. Potassium status was high in Chhindwara and Banswara, medium in Ambikapur, Udaipur, Bahraich and Varanasi and low in Ranchi.

Table 2 Nutrient added in various treatments of different agro-ecologies

Treatment	FYM (t/ha)	Nutrients from FYM (kg/ha)			Nutrients from chemical fertilizers (kg/ha)			Total Nutrients (kg/ha)			Total N+P_2O_5 +K_2O (kg/ha)
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	
O_0N_1	0	0	0	0	100	40	30	100	40	30	170
O_0N_2	0	0	0	0	150	60	40	150	60	40	250
O_0N_3	0	0	0	0	187	75	50	187	75	50	312
O_0N_4	0	0	0	0	225	90	60	225	90	60	375
O_1N_1	6	30	15	30	100	40	30	130	55	60	245
O_1N_2	6	30	15	30	150	60	40	180	75	70	325
O_1N_3	6	30	15	30	187	75	50	217	90	80	387
O_1N_4	6	30	15	30	225	90	60	255	105	90	450

Table 3 Rainfall and soil characteristics of experimental site located in different agro ecologies

Experimental site	Soil type	Organic carbon (%)	Available soil nutrients (kg/ha)			Soil pH	Rainfall (mm)	
			N	P_2O_5	K_2O		2007	2008
Ambikapur	Sandy loam	0.40	218.0	14.7	276.0	5.6	1 167	1 470
Chhindwara	Clay loam	0.78	318.0	21.2	402.0	7.4	762	745
Banswara	Clay loam	0.36	180.5	14.9	509.4	7.8	1 380	686
Udaipur	Clay loam	0.65	270.5	19.5	280.5	7.8	504	714
Ranchi	Clay loam	0.38	212.0	20.0	115.0	5.8	1 380	1 306
Bahraich	Sandy loam	0.28	115.0	12.5	175.0	8.5	1 150	1 535
Varanasi	Sandy loam	0.66	275.0	12.8	114.0	7.5	903	1 045

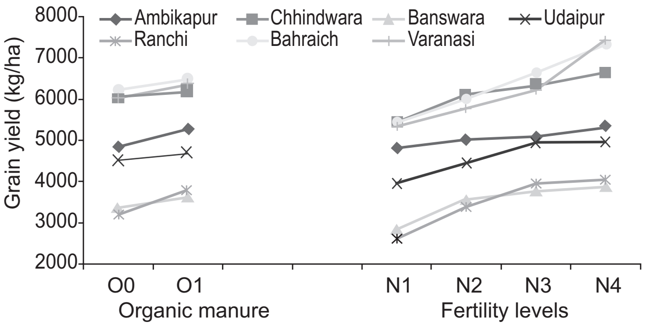

Fig 1 Effect of organic and inorganic source of nutrients on productivity of quality protein maize in different agro-ecologies during 2007

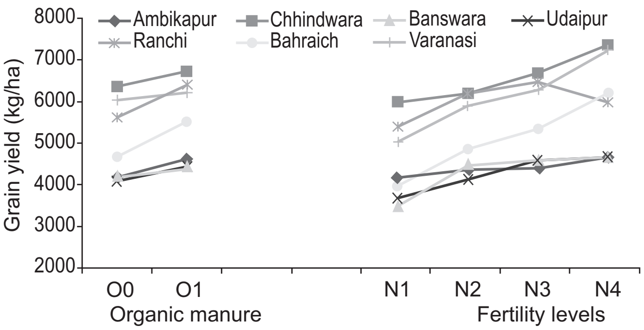

Fig 2 Effect of organic and inorganic source of nutrients on productivity of quality protein maize in different agro-ecologies during 2008

Due to climate change lot of variability was found in rainfall at the same centre. Ambikapur, Chhindwara, Banswara and Ranchi received higher rainfall in 2007, while Udaipur, Bahraich and Varanasi received higher rainfall during 2008 (Table 3). Rainfall ranges from 504.3 mm (Udaipur) to 1535.0 mm (Bahraich). The crop of maize was grown using HQPM 1 variety with standard package of practices in rotation with wheat. The pooled analysis of data was done using SAS software programme with general linear model.

RESULTS AND DISCUSSION

Grain yield

The application of 6 tonnes/ha FYM resulted into significant increase in grain yield of QPM over no organic manure application (Fig 1 and 2). The percent increase ranged from 4.3 (Bahraich) to 17.1 (Ranchi) during 2007 and 6.9 (Banswara) to 18.0 (Bahraich) during 2008. However due to higher initial available N status in the soil the response of the organic matter was not reached to the level of significance at Chhindwara and Varanasi during both the years and at Udaipur in first year.

The application of inorganic sources of nutrients resulted significantly higher productivity of QPM at Bahraich and Varanasi where yield increased significantly up to N_4 level over all previous levels. At other centres also highest yield was obtained with N_4 level though it was non-significant with N_3 level; however at Udaipur during first year and at Ranchi during second year significant response was observed only up to N_3 level.

Grain yield is the end result of morphological and physiological processes occurring during growth and development of a crop. The increase in grain yield due to farmyard manure and optimal fertilizer treatments was mainly due to more number of cobs/plant and better grain development due to adequate nutrient supply. Use of farmyard manure and sometimes in combination with inorganic fertilizers gave maximum grain yields (Tasneem *et al*. 2004, Tamayo *et al*. 1997, Balai *et al.* 2011).

Interaction effect on yield

The varied response was found with respect to integrated application of organic and inorganic nutrient levels application at different locations (Table 4). Application of 6 tonnes/ha FYM with N_4 fertility levels of inorganic fertilizers was recorded the highest yield at Bahraich, Banswara and Varanasi during both the years while at Ranchi in first year. At Udaipur, application of FYM along with N_3 levels resulted into highest grain yield in 2007.

The pooled analysis result also showed that the application of FYM@ 6 tonnes/ha at N_4 level resulted into highest grain yield during both the years which was on par with sole inorganic fertilizer application at N_3 and N_4 levels. The application of O_1N_4 resulted in 21.5 and 25.2; 14.4 and 13.6; 9.2 and 11.6; 5.1 and 6.8; 20.0 and 16.8; 11.1 and 9.0 and 5.6 and 4.6 % increase over O_0N_1 , O_0N_2 , O_0N_3 , O_0N_4, O_1N_1 , O_1N_2 and O_1N_3 in the pooled grain yield of all the locations during 2007 and 2008, respectively. The interaction effect of integrated nutrient management was found non-significant at Ambikapur and Chhindwara during both the years while at Udaipur during second year of the experimentation.

Nutrient productivity

The response in terms of nutrient productivity was more with the application of organic sources as compared to without FYM application at all the chemical fertilized nutrient levels (Table 5). The nutrient productivity was higher up to F_3 levels with the application of FYM. At N_4 levels however it was higher without FYM application and it was due to more nutrients in O_1F_4 compared to all other INM combination which has diminishing returns in the productivity per unit nutrient applied. The same trend was noticed with the application of higher nutrient but still the response was more than 10 kg maize grain/kg nutrient applied at all the locations. Although the maximum nutrient productivity was obtained when N_1 was applied without application of FYM at all the locations during both the years. The pooled analysis of the nutrient productivity across the locations during both the

Table 4 Effect of Integrated Nutrient Management on productivity (kg/ha) of quality protein maize in different agro-ecologies

Treatment	Ambikapur (Chhatisgarh)		Bahraich (UP)		Banswara (Rajasthan)		Chhindwara (MP)		Ranchi (Jharkhand)		Udaipur (Rajasthan)		Varanasi (UP)		Pooled	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
O_0N_1	4566^{a}	3900^{a}	5286^{e}	3522^{e}	2703^{d}	3556^{e}	5367^{a}	5988^{a}	2496^{d}	5333^{b}	3827^{d}	3426^{a}	5333^{e}	5037^{d}	4226^{f}	4395^{f}
O_0N_2	4900^{a}	4222^{a}	5822^{d}	4414^{d}	3379^{bc}	4067^{d}	6067^{a}	6040^{a}	3018^{c}	5857^{b}	4327^{bcd}	3943^{a}	5630de	5963^{c}	4735^{e}	4930de
O_0N_3	4922^{a}	4255^{a}	6558^{b}	4894^{cd}	3624^{ab}	4267^{cd}	6196^{a}	6377^{a}	3658^{b}	5841^{b}	4843^{ab}	4430^{a}	6148^{cd}	6148^{bc}	5136^{cd}	5173^{cd}
O_0N_4	5033^{a}	4366^{a}	7194^{a}	5867^{b}	3757^{ab}	4333^{bcd}	6585^{a}	7051^{a}	3760^{b}	5460^{b}	5043^{a}	4543^{a}	7000^{b}	6963^{ab}	5482^{b}	5512^{bc}
O_1N_1	5077^{a}	4411^{a}	5600^{d}	4478^{d}	2976^{cd}	4022^{d}	5496^{a}	6014^{a}	2771^{cd}	5460^{b}	4117^{cd}	3940^{a}	5333^{e}	5037^{d}	4482^{ef}	4766^{ef}
O_1N_2	5166^{a}	4500^{a}	6161^{c}	5288^{bc}	3707^{ab}	4489^{abc}	6093^{a}	6300^{a}	3800^{b}	6556^{a}	4627^{abc}	4346^{a}	5926^{cde}	5852^{cd}	5069^{d}	5333^{c}
O_1N_3	5233^{a}	4555^{a}	6714^{b}	5778^{b}	3940^{a}	4711^{ab}	6481^{a}	6974^{a}	4238^{a}	7064^{a}	5130^{a}	4723^{a}	6296^{c}	6407^{bc}	5433^{bc}	5745^{ab}
O_1N_4	5611^{a}	4944^{a}	7467^{a}	6514^{a}	4003^{a}	4800^{a}	6715^{a}	7622^{a}	4340^{a}	6524^{a}	4883^{ab}	4733^{a}	7852^{a}	7556^{a}	5839^{a}	6099^{a}
SEm±	334.7	337.1	134.8	301.2	234.8	185.8	507.3	500.7	149.3	285.2	298.9	325.8	306.5	391.2		
LSD (P=0.05)	717.9	723.1	289.1	646.1	503.7	398.5	1088.0	1073.9	320.2	611.6	641.3	698.86	657.3	839.1		
p value	0.2103	0.2167	<0.0001	<0.0001	0.0006	0.0002	0.1549	0.0433	<0.0001	0.0002	0.0058	0.0144	<0.0001	0.0002	<0.0001	<0.0001

Means with at least one letter common are not statistically significant using Fisher's Least Significant Difference

Table 5 Effect of Integrated Nutrient Management on nutrient productivity (kg grain/kg nutrient applied) in quality protein maize

Treatment	Ambikapur (Chhatisgarh)		Bahraich (UP)		Banswara (Rajasthan)		Chhindwara (MP)		Ranchi (Jharkhand)		Udaipur (Rajasthan)		Varanasi (UP)		Pooled	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
O_0N_1	26.8^{a}	22.9^{a}	31.1^{a}	20.7^{a}	15.9^{a}	20.9^{a}	31.6^{a}	35.2^{a}	14.7^{a}	31.4^{a}	22.5^{a}	20.2^{a}	31.4^{a}	29.6^{a}	28.1^{a}	26.1^{a}
O_0N_2	19.6^{bc}	16.9^{b}	23.3^{b}	17.7^{ab}	13.5^{b}	16.3^{bc}	24.3^{b}	24.2^{b}	12.1^{b}	23.4^{b}	17.3^{b}	15.8^{bc}	22.5^{b}	23.9^{ab}	20.8^{b}	20.5^{b}
O_0N_3	15.8^{cd}	13.6^{bc}	21.0^{c}	15.7^{b}	11.6^{bc}	13.7^{d}	19.9^{bcd}	20.4^{bc}	11.7^{b}	18.7^{cd}	15.5^{bc}	14.2^{bcd}	19.7^{bcd}	19.7^{bc}	17.7^{bcd}	16.8^{c}
O_0N_4	13.4^{d}	11.6^{c}	19.2^{d}	15.6^{b}	10.0^{cd}	11.6^{de}	17.6^{bcd}	18.8^{bc}	10.0^{cd}	14.6^{d}	13.5^{cd}	12.1^{cd}	18.7^{bcd}	18.6^{bc}	15.4^{cd}	14.7^{cd}
O_1N_1	20.7^{b}	18.0^{ab}	22.9^{b}	18.3^{ab}	12.2^{bc}	16.4^{b}	22.4^{bc}	24.6^{b}	11.3^{bc}	22.3^{bc}	16.8^{bc}	16.1^{b}	21.8^{bc}	20.6^{bc}	19.9^{bc}	20.1^{b}
O_1N_2	15.9^{bcd}	13.9^{bc}	18.9^{d}	16.3^{b}	11.4^{bc}	13.8^{cd}	18.8^{bcd}	19.4^{bc}	11.7^{b}	20.2^{bc}	14.2^{bcd}	13.4^{bcd}	18.2^{bcd}	18.0^{c}	16.6^{bcd}	16.6^{c}
O_1N_3	13.5^{d}	11.8^{c}	17.4^{e}	14.9^{b}	10.2^{cd}	12.2^{de}	16.8^{cd}	18.0^{bc}	11.0^{bcd}	18.3^{cd}	13.3^{cd}	12.2^{cd}	16.8^{d}	16.6^{c}	14.9^{d}	14.6^{cd}
O_1N_4	12.5^{d}	111.0^{c}	16.6^{e}	14.5^{b}	8.9^{d}	10.7^{e}	14.9^{d}	16.9^{c}	9.6^{d}	14.5^{d}	10.9^{d}	10.5^{d}	17.5^{cd}	16.8^{c}	13.5^{d}	13.2^{d}
SEm±	1.40	1.43	0.36	1.20	0.64	0.71	1.90	1.97	0.44	1.24	1.06	1.08	1.42	1.64	0.29	0.41
LSD (P = 0.05)	2.99	3.07	0.77	2.57	1.36	1.53	4.08	4.22	0.94	2.66	2.27	2.32	3.06	3.53	0.88	1.23
p value	<0.0001	<0.0001	<0.0001	0.0023	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Note: Means with at least one letter common are not statistically significant using Fisher's Least Significant Difference

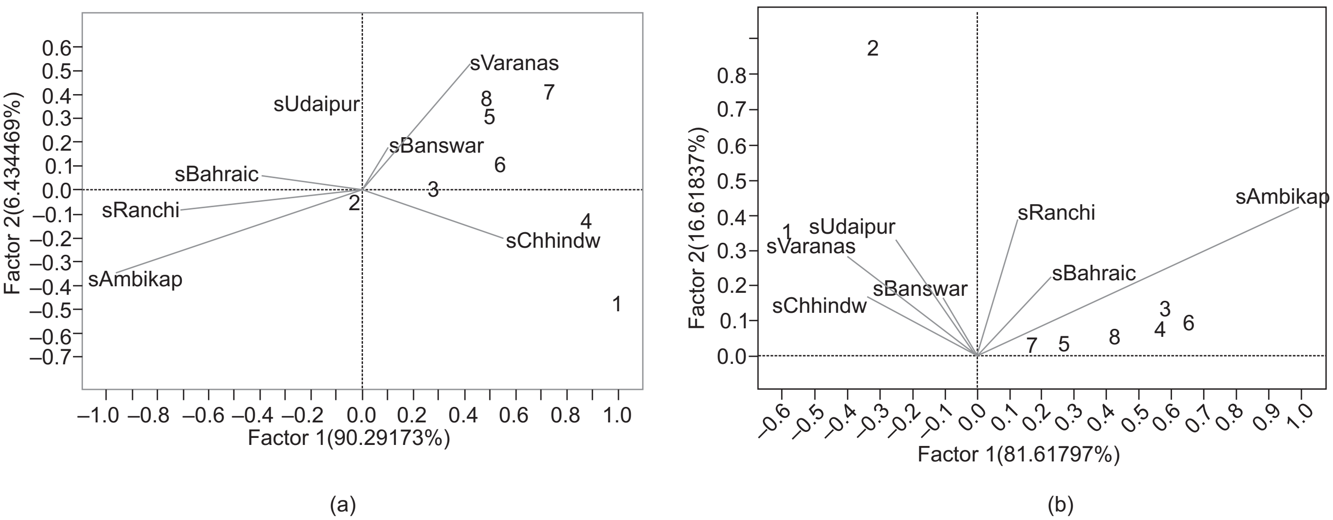

Fig 3 SREG biplot of the grain yield (a) and nutrient productivity (b) under different INM practices in QPM during 2007

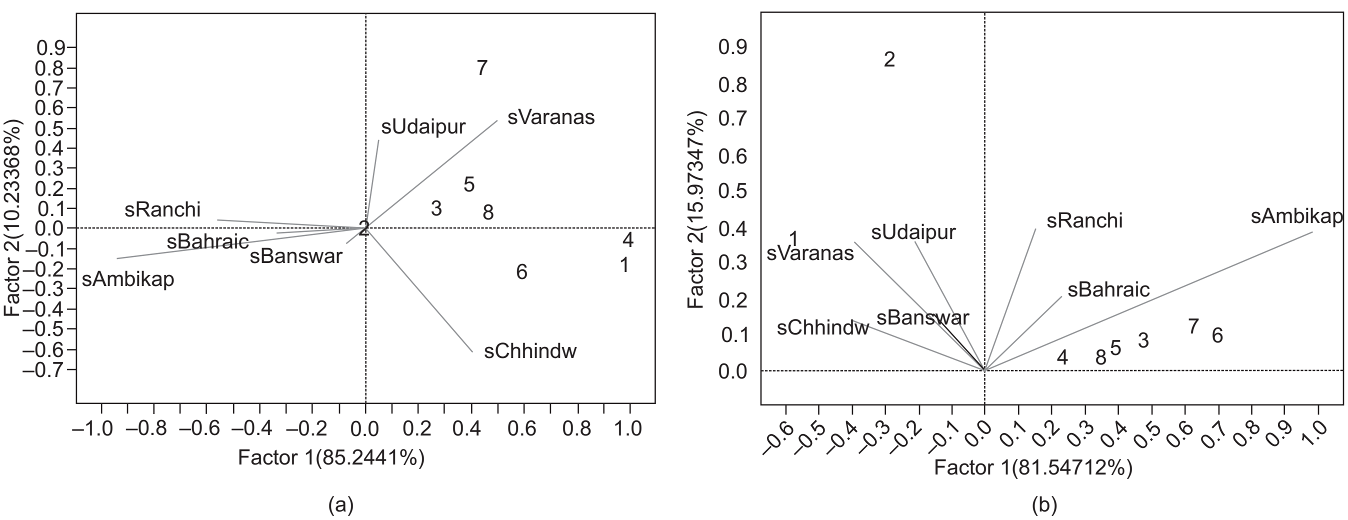

Fig 4 SREG biplot of the grain yield (a) and nutrient productivity (b) under different INM practices in QPM during 2008

years showed that it was highest with the application of O_0N_1 treatment. The productivity gained with the application of O_0N_4 can be obtained with the application of O_1N_2 although there is less than 50% of the nutrients applied through the FYM are utilized by the first crop. Hence the application of the organic manure up to the N_2 fertility levels leads to enhance the overall productivity of the land in the system as compared to sole application of N_4 levels.

The organic manure has the properties of enhanced soil quality by the way of increasing soil organic carbon and microbial activities. Beside this organic manures are the storehouse of the micronutrients and other growth promoters that enhances the plant growth which in turn makes better source-sink relationship and enhances economic yield of the crop. The application of the organic manures enhances microbial activity that releases different organic acids which helps in solubilization of the native soil nutrients and makes available for the uptake by plants.

SREG biplot analysis

The SAS software analysed SREG biplot for the environment × treatment interaction fort the yield and nutrient productivity of quality protein maize sown in rotation with wheat also showed the similar treatment consistency as discussed earlier across the locations and the years of different agro-ecologies (Fig 3 and 4).

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