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Profiling nitrogen use efficiency in QPM, hybrid and composite maize cultivars

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Abstract
A two year investigation during *rabi* seasons between 2017-2019 at Mondouri farm, BCKV, West Bengal, was conducted in split plot design, replicated thrice. Main plot treatments comprised maize cultivars - i) V_1: HQPM4 (QPM), ii) V_2: Shresta (Single cross hybrid) and (iii) V_3: NAC 6004 (Composite); in the sub plot there was 6 nutrient schedules *viz*- i) T_1: control, ii) T_2: RDF, iii) T_3: RDN_{75} + Vermicompost @ 2 t/ha, iv) T_4: T_3+ Azotobacter @ 2kg/ha, v) T_5: T_4+ Zn, vi) T_6: RDN_{50} + Vermicompost @ 2 t/ha + Azotobacter @ 2kg/ha + Zn. NUE trends of PFP, AUE and PE for both years followed in ARE values of grain and total biomass. Addition of vermicompost in T_3 resulted in improved NUE over RDF in second year. T_5 had highest yield and NUE indices. T_6 bettered its own NUE indices over the first year which underpins compounding effects in organic nutrients.

Keywords: Maize cultivars, N schedules, NUE, uptake, yield

Introduction
Cereals cater the key sustenance in most of the diets and comprise over 73% of the total world harvested area supporting 60% of the global food production (Das *et al*., 2012) [3]. The spectrum of uses for cereals 43.47% figure out as food, 32.61% as feed and 21.73% for other industrial uses (FAO 2013) [5]. Maize, a C4 plant, enjoys more efficient photosynthates conversion. Maize also finds application in industry in a host of non-food applications (Murdia *et al*., 2016) [15]. In the shrinking water scenario natural resource management pivots more on the issue and Maize is the potential crop with a water productivity of 0.363 kg/M^3 which is more than that of summer rice 0.25 kg/M^3 (Kumari *et al*., 2017) [13]. By growing Maize farmers save 90% of water, 70% of power compared to paddy). To address the protein malnutrition among children in the developing countries, breeding for enhanced protein content in maize resulted in advent of Quality Protein Maize (Prasanna *et al*., 2001) [17] while also improving its agronomic and consumer characteristics (Gunaratna *et al*., 2019) [8]. India would require 45 MMT of Maize by year 2022 and Maize qualifies as potential crop for doubling farmer's income Maize a source of more than 3,500 products including specialized Maize like QPM “Quality Protein Maize” (FICCI 2018) [6].

After the promulgation of New Seed Policy in late 1980s, many private seed companies came into operation and started producing and marketing hybrid maize. The overall Seed Replacement Rate (SRR) in maize crop in India is about 60 per cent. The Government of India has set the goal of 100 per cent seed replacement in hybrid crops like maize. Some of the states have already reached the level of 100 per cent SRR, particularly where the farmers have adopted hybrid maize while the unaffordable farmers in many states still prefer to grow local or composite varieties, which are mainly retained for domestic consumption. In Rajasthan and Gujarat, it is almost equal preference for composite and hybrids, as in tribal or underdeveloped regions, farmers prefer local/composite varieties, and in developed regions, hybrids are cultivated for commercial purposes (Kumar *et al*., 2013) [11].

The rapid diffusion of maize hybrids as well as relatively high dose of fertilizers application are often considered to be the driving force for better yield in high potential zone. When fertilizer was applied to hybrids, the resulting yield grain was much higher (120%) than that of OPVs grown with fertilizer (Kumar *et al*., 2013) [11]. Nitrogen addition through inorganics has its due effect on environment and emissions as reported by many workers.

Again Poor farmers using suboptimal fertilizer level also harm the environment through soil mining. Use of renewable and non- renewable nutrient not only improves the physico-chemical characteristics and fertility of soil but also increase the crop yields by enhancing the efficiency of applied non-renewable sources (Lal and Shing, 1998) [14]. Ramesh (2018) [18] also reported nitrogen use efficiency changes in rice resorting to addition of renewable nutrient sources including vermicompost.

In the above premise, there is a need to understand the improvement in nitrogen use efficiency through nutrient schedules incorporating organics and at the same time to generate information on how the different types of maize varieties under cultivation *viz*- single cross hybrid, and quality protein maize and compare the response with composite maize. Such information is scanty in the archives. The information on nitrogen use efficiency studies across the different types and its comparison becomes important to understand the issues of allocation of nutrients, through both sustainable and inorganic formats. This work has been tried to present, comprehensively, the nitrogen nutrient issue of different types of maize growers in the country towards more rationalized nutrient schedules and lower wastage of nitrogen to reduce environmental costs.

Materials and Method

The experiment was conducted during *rabi* season of 2017-2018 and 2018-2019 at Mondouri experimental farm, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, with bearing of 22°56' N latitude, 88°32' E longitude falling under Lower gangetic plains of West Bengal and enjoying sub-tropical humid climate with short and mild winter. The location has a pooled mean rainfall of 1460 mm skewed between June and September, and mean monthly temperature ranged from 10 °C-37 °C. The experimental soil comes under the order of Entisol in the USDA modern taxonomical classification with sandy loam in texture consisting of 35.5% clay, 39.7% silt, and 24.8% sand with a bulk density of 1.40 g/cc (0-15cm depth of soil), almost neutral pH, good drainage capacity and low available N and P, and medium organic carbon as well as K status. Standard analytical procedures were followed for carrying out the chemical analysis of soil and plant samples by taking concentrated sulfuric acid as decomposer of organic substance for digestion, 40% NaOH and 4% Boric acid for distillation and finally 0.1 N H_2SO_4 for titration (Jackson, 1973) [9].

The experiment was conducted in split plot design and replicated thrice, where the main plot treatments comprised maize cultivars in i) V_1: HQPM4 (QPM hybrid maize), ii) V_2: Shresta (Single cross hybrid) and (iii)V_3: NAC 6004 (Composite variety); in the sub plot there was 6 nutrient schedules in i) T_1: control, ii) T_2: RDF, iii) T_3: RDN_{75} + Vermicompost @ 2 t/ha, iv) T_4: T_3+ Azotobacter @ 2kg/ha, v) T_5: T_4+ Zn, vi) T_6: RDN_{50} + Vermicompost @ 2 t/ha + Azotobacter @ 2kg/ha + Zn. A recommended fertilizer dose of 180:80:80 kg NPK $ha^{-1}$of which P, K, 20% N were applied as basal dose and remaining dose of N was administered in the following manner as top dressing *viz*. 25% N applied as 1st top dressing at 4 leaf stage, 30% as 2nd top dressing at 8 leaf stage, 20% as 3rd top dressing at tasselling stage and 5% was top dressed at the grain filling stage. The required quantity of vermicompost @ 2 t/ha as per treatment were applied for each respective plots a day before sowing, on the soil surface and mixed into the soil. Soil application of $ZnSO_4$ @ 20 kg/ha was done 3 days before sowing.

Indices of nitrogen use efficiency studied were

Partial factor productivity (kg/kg): It is calculated by grain yield (kg/ha) dividing it with total amount of nitrogen applied through fertilizer (kg/ha). It measures how much amount of yield can be obtained through unit amount of extraneous N fertilizer application.

Partial factor productivity (PFP) (kg/kg) = (Grain yield/Amount of fertilizer N applied)

Agronomic use efficiency (kg/kg): It is calculated by difference of grain yield in between N fertilizer treated plot and control (untreated) plot divided by total amount of nitrogen applied through fertilizer (kg/ha). It is the efficiency with which plant uses each additional unit of nitrogen.

Agronomic use efficiency (AUE) (kg/kg) = (Grain yield in N treated plot – Grain yield in untreated plot) / Amount of fertilizer N applied

Apparent recovery efficiency (grain) (kg/kg): It is calculated by difference of grain N uptake in between N fertilizer treated plot and control (untreated) plot divided by total amount of nitrogen applied through fertilizer (kg/ha). It is a measure of incremental grain uptake per unit of N applied. It depends on the congruence between plant demand and nutrient release from fertilizer.

Apparent recovery efficiency $_{grain}$ (ARE $_{grain}$) (kg/kg) = (Grain N uptake in N treated plot – Grain N uptake in untreated plot) / Amount of fertilizer N applied.

Apparent recovery efficiency (Total biomass) (kg/kg)

It is calculated by difference of total biomass N uptake in between N fertilizer treated plot and control (untreated) plot divided bytotal amount of nitrogen applied through fertilizer (kg/ha). It is a measure of incremental total biomass N uptake per unit of n applied. It depends on the congruence between plant demand and nutrient release from fertilizer.

Apparent recovery efficiency $_{Total\ biomass}$ (ARE $_{Total\ biomass}$) (kg/kg) = (Total biomass N uptake in N treated plot – Grain N uptake in untreated plot) / Amount of fertilizer N applied.

Production efficiency: It is calculated by agronomic use efficiency divided by apparent recovery efficiency of a n fertilizer treated plot.

Production efficiency = Agronomic use efficiency (AUE)/apparent recovery efficiency (ARN)

The chemical analysis for soil and plant N was done resorting to composite sampling and uptake and NUE values were estimated by using previously obtained plot wise grain yield and stover yield data and the same were statistically analysed using online OP Stat Statistical Software Package for Agricultural Research (Sheoran *et al*., 1998) [20].

Results and Discussion

Grain and stover yield

Hybrid Shresta recorded highest significant yield of 7.19 and 8.26 t/ha in the successive years at par with HQPM4 (6.77 t/ha) in the first year and significantly higher than the latter (7.66 t/ha) in the 2nd year. (Among nutrient schedules T_5

(RDN_{75}+ Vermicompost @ 2 t/ha + Azotobacter @ 2kg/ha+ Zn) had the best mean yields of 8.61 and 9.74 t/ha; Rajasingh *et al*., 2014 [18] reported greater grain yield through integrated sources using compost. The stover yield of both the hybrid cultivars (HQPM4 and Shresta) were at par in both the seasons. In both the seasons, among the N management schedules, T5 performed the best with 9.61 t/ha and 10.10 t/ha of stover yield respectively. Improvement of stover yield by N administration through compost was reported by Shinde *et al*., 2011 [21] and Khan *et al*., 2008 [10]. Biofertilizer application significantly improved stover yield in experiments conducted by Balyan *et al*., 2006 [1]. Treatments were responsive towards the three varieties having TXV interaction values for grain yield significant in both the years. The grain yields were at par with treatment T_5 when compared between Shresta and HQPM4 in their behavior towards T_5, but were significant over corresponding values of V_3T_5.

Table 1: Yield and uptake pattern in Maize cultivars

	Grain Yield (t/ha)		Stover Yield (t/ha)		Grain	Shoot	Total	Grain	Shoot	Total
	2017-2018	2018-2019	2017-2018	2018-2019	(N Uptake kg/ha) 2017-2018			(N Uptake kg/ha) 2018-2019		
	Variety									
V1	6.77	7.66	8.72	9.04	119.66	46.63	166.11	135.02	50.86	188.35
V2	7.19	8.26	8.88	9.20	90.40	48.74	139.25	103.71	52.37	157.58
V3	5.26	5.82	7.68	8.11	61.44	38.62	100.07	68.25	41.70	109.67
S.Em±	0.12	0.13	0.15	0.16	0.505	0.107	0.570	0.579	0.099	0.685
CD (0.05)	0.48	0.55	0.59	0.66	2.035	0.432	2.298	2.335	0.399	2.760
	Nutrient schedules									
T1	3.52	3.43	6.16	5.77	37.07	27.03	64.10	36.13	23.10	56.94
T2	7.35	7.61	8.87	9.28	105.63	48.91	154.77	109.07	49.32	158.40
T3	6.37	7.04	8.43	9.21	89.34	45.70	134.45	97.95	51.82	151.15
T4	7.29	8.10	9.25	9.85	108.31	52.23	160.71	119.82	59.82	182.62
T5	8.61	9.74	9.61	10.10	130.39	53.23	183.69	148.20	61.63	213.43
T6	5.31	7.56	8.22	8.50	72.25	40.87	113.14	102.78	44.16	148.66
S.Em±	0.21	0.22	0.17	0.20	0.345	0.116	0.440	0.394	0.145	0.547
CD (0.05)	0.59	0.66	0.49	0.58	1.002	0.337	1.276	1.142	0.420	1.588

V_1: QPM (HQPM4); V_2: Shresta (hybrid) V_3: NAC 6004 (composite), T_1: Control; T_2 RDF; T3 RDN_{75} + Vermi; T4: T_3+ Azo; T_5: T_4+ Zn; T_6: RDN_{50} + Vermi + Azo + Zn

Table 2: Interaction of variety and nutrient schedules in grain and stover yield of maize

	Grain yield (t/ha)		Stover yield (t/ha)	
	2017-2018	2018-2019	2017-2018	2018-2019
V_1T_1	3.48	3.36	6.53	5.99
V_1T_2	7.93	8.06	9.18	9.53
V_1T_3	6.30	6.92	9.04	9.78
V_1T_4	7.81	8.43	9.64	10.22
V_1T_5	8.94	10.41	9.89	10.54
V_1T_6	6.18	8.74	8.03	8.15
V_2T_1	4.11	4.02	6.81	6.27
V_2T_2	7.84	8.18	9.31	9.65
V_2T_3	7.69	8.43	8.55	9.55
V_2T_4	7.99	9.00	9.47	10.12
V_2T_5	9.76	10.92	9.92	10.16
V_2T_6	5.75	9.02	9.20	9.43
V_3T_1	2.97	2.92	5.14	5.03
V_3T_2	6.28	6.59	8.12	8.65
V_3T_3	5.12	5.76	7.70	8.29
V_3T_4	6.07	6.87	8.64	9.20
V_3T_5	7.12	7.89	9.03	9.59
V_3T_6	4.00	4.92	7.44	7.90
	V X T		V X T	
S.Em±	0.35	0.39	0.30	0.33
CD (0.05)	NS	1.16	NS	0.98
	T X V		T X V	
S.Em±	0.39	0.43	0.36	0.39
CD (0.05)	1.92	2.01	NS	NS

V_1: QPM (HQPM4); V_2: Shresta (hybrid) V_3: NAC 6004 (composite), T_1: Control; T_2 RDF; T3 RDN_{75} + Verma; T4: T_3+ Azo; T_5: T_4+ Zn; T_6: RDN_{50}+ Vermi + Azo + Zn

Uptake N in grain and shoot

Initial and final available soil nitrogen in the first and second season is shown as Fig no. 1 and 2. An uniform available soil N status of 174 kg/ha at the start of the experiment, as a result of treatment additions and uptake responses culminated in trend of available soil N as $V_1 < V_2 < V_3$ with corresponding 2nd season final means of 109.15, 165.75 and 256.43 kg/ha of N. This clearly reflects that the nature of consumption of N was most in QPM and it was followed by hybrid maize. The difference across final N status was more pronounced in the 2nd year. Among the various nitrogen schedules the organic supplemented treatments had registered higher final available soil N in both the years with greater residual fertility in the second year. RDN_{75} + Vermi and RDN_{75} + Vermi + Azo ended up with maximum and next best final N status with respective means of 239.38 and 218.13 kg/ha. As evidenced from Fig no. 1 & 2, the final fertility status in 2018-2019 is appreciably higher over 2017-2018 for respective sub plots sown with composite variety. This improved fertility does not account itself in the growth and yield of the crop and lower NUE values, discussed later, and also implies that composite variety should not be suggested to farmers.

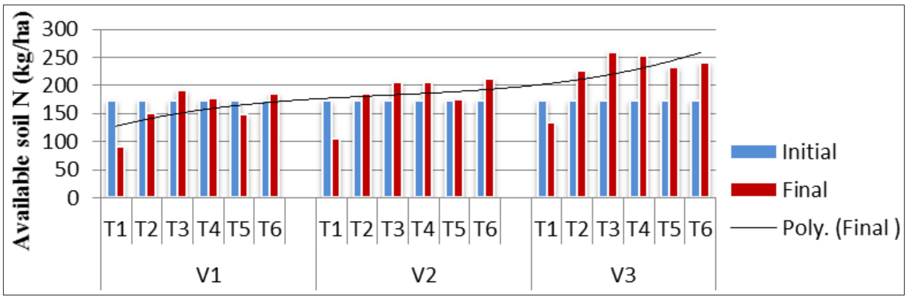

Fig 1: Available soil N status (2017-2018)

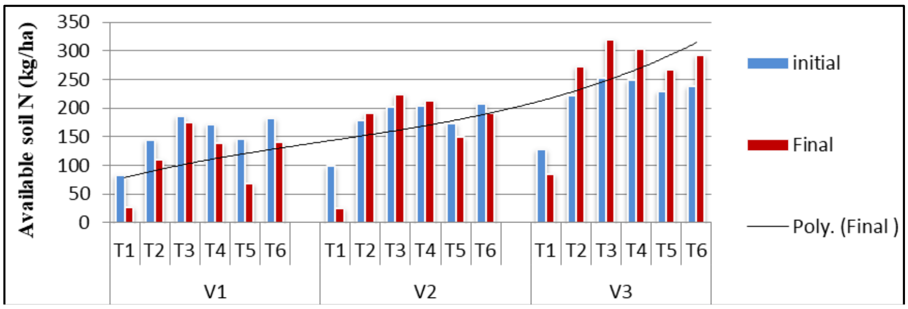

Fig 2: Available soil N status (2018-2019)

The estimated N content in the economic part of maize were more than that of shoot N and the second season means were most in HQPM4 (1.72%) followed by Shresta (1.25%) and NAC6004 (1.13%), which can be attributed to the higher N uptake pattern of quality protein maize. Total uptake of N was most for V_1 followed by V_2 and V_3 subsequently, in both the years and the corresponding second year means were significant and having values of 188.35, 157.58 and 109.67 in kg/ha respectively. Treatment uptake was also significant for total N and the second season means were 213.43 kg/ha in T_5 followed by T_4 (182.62 kg/ha). Among the nutrient schedules RDN_{75} + Vermi +Azo + Zn had resulted in the most N content in both grain followed by RDN_{75} + Vermi +Azo treatments with second season final grain content being 1.53 and 1.50 percent respectively. Shoot N content followed the same trend with much lower values. Interaction values for N uptake in grain and stover were not significant.

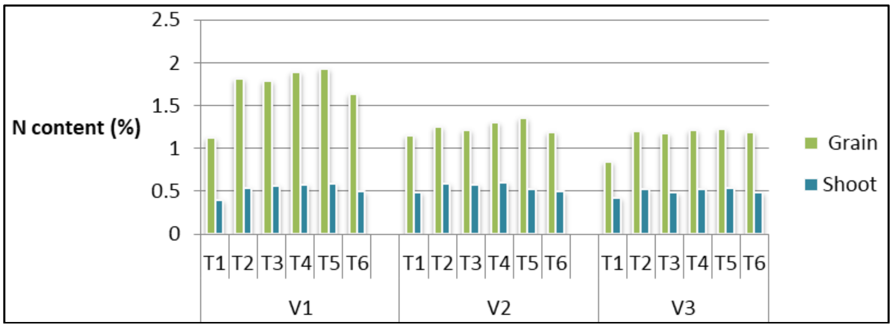

Fig 3: N content in plant (2017-2018)

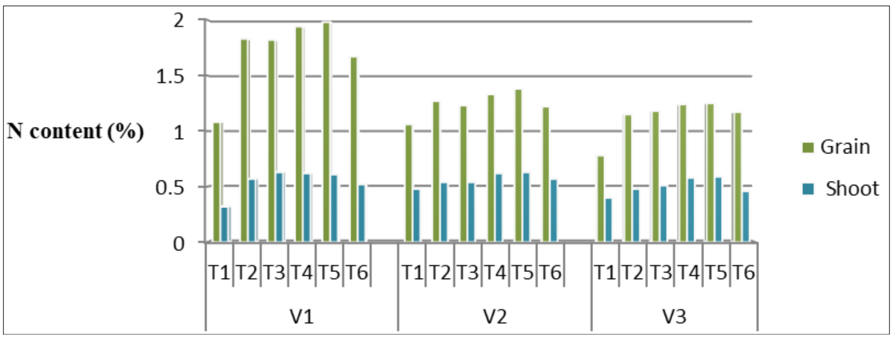

Fig 4: N content in plant (2018-2019)

Nitrogen use efficiency

Going through the literature, it is found that soil changes owing to treatment response are usually unstable and difference method of NUE calculation from soil data is usually considered over long trends. So NUE indices derivatives of to grain and biomass along with added nutrient and uptake were considered to indices of the various NUE indices estimated are Partial factor productivity (PFP), Agronomic use efficiency (AUE), apparent recovery efficiency (ARE) in grain and stover, and production efficiency (PE).Considering this the entire NUE calculations were based upon total nutrient added from different composition of treatments, plant uptake of N in grain and shoot along with stover and grain tonnage.

Among the NUE indices, across varieties, hybrid Shresta had highest values for Partial factor productivity (PFP) in both the seasons (34.51% and 40.67% respectively) and for Production efficiency (PE) in 1st year with the value of 60.78%. The partial factor is a very important measure as it indicates the fertility of a particular cultivation practice and how it responds changes across time. Among the nutrient the PFP of N is most important because it indicates that over time, the productivity is declining. Necessary use of organic sources and use of biofertilizer to improve PFP by facilitating more microbial health is being considered as the most important interventions of the present day. The rest of the indices in AUE (17.50% and 22.99% in first and second season respectively), ARE $_{grain}$ and ARE $_{total}$ calculated significantly greater values in HQPM4, ARE $_{grain}$ (0.43 and 0.52 in successive years), ARE $_{total}$ of 0.53 and 0.69 in the respective years. This evidence the QPM varieties are more responsive and justify the added nitrogen.

Among the nutrient schedules in T_5, all the indices are having the significantly higher value respectively in PFP (42.11% in first year and 47.65% in the second year), AUE (24.89 and 30.86% in successive years), ARE$_{grain.}$ (0.45 and 0.58). Are $_{total}$ (0.59 and 0.74) and PE of 56.47 in the first year only. These values evidence that RDN75 + Vermi +Azo + Zn has best utilization of the added nitrogen. Kumar *et al*., 2016 also reported better nitrogen use efficiency in successive year for integrated nutrient management schedules. The source comprises integrated nutrient use of supplemental organics and biofertilizers and the second year value of the indices are always higher indicating compounding positive effects (Kumar *et al*., 2016) [12]. More so, the partial factor productivity values were at par between T_5 (RDN_{75} + Vermi +Azo + Zn) and T_6 (RDN_{50} + Vermi +Azo + Zn) in the second year 47.65 (T_5) and 47.43 (T_6) and production efficiency of 56.47 (T_5) and 57.25 (T_6) which signify that compounding effect of organic supplementation over sustained periods, and supported by It can be supported through the results of the experiment conducted by Duan *et al*. (2011) [4]. Reports prevail by Ciampatti *et al.* (2011) [2] and Paramasivan *et al.*, (2014) [16] for better ARE $_{grain}$ values with integrated N sources. Literature suggests that values for ARE, AUE and PFP all conform to range suggested for well managed soils (Fixen *et al*., 2014) [7]. Interaction values for NUE indices in PFP, AUE, ARE $_{grain,}$ ARE$_{total,}$ PE were not significant.

Table 3: Nitrogen Use Efficiency indices influenced by N management schedules across different maize cultivars

	2017-2018	2018-2019	2017-2018	2018-2019	2017-2018	2018-2019	2017-2018	2018-2019	2017-2018	2018-2019
	PFP	PFP	AUE	AUE	ARE (grain)	ARE (grain)	ARE (total)	ARE (total)	PE	PE
	Variety									
V1	33.10	38.05	17.50	22.99	0.43	0.52	0.53	0.69	34.28	36.81
V2	34.51	40.67	16.09	22.65	0.22	0.39	0.31	0.42	60.78	47.73
V3	25.27	28.35	11.96	15.26	0.19	0.23	0.29	0.35	50.45	54.69
S.Em±	0.087	0.128	0.051	0.075	0.002	0.002	0.002	0.002	0.232	0.158
CD $_{(0.05)}$	0.349	0.516	0.204	0.304	0.009	0.009	0.008	0.10	0.937	0.635
	Nutrient schedules									
T1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T2	40.84	42.28	21.28	23.20	0.38	0.44	0.52	0.55	60.58	55.14
T3	33.82	37.15	15.23	19.02	0.28	0.36	0.38	0.48	59.15	54.95
T4	35.68	39.63	18.45	22.83	0.35	0.44	0.46	0.59	57.44	54.64
T5	42.11	47.65	24.89	30.86	0.45	0.58	0.59	0.74	58.26	56.47
T6	33.32	47.43	11.24	25.89	0.22	0.46	0.30	0.55	55.57	57.25
S.Em±	0.158	0.213	0.090	0.112	0.002	0.002	0.002	0.003	0.250	0.233
CD $_{(0.05)}$	0.459	0.617	0.262	0.325	0.006	0.007	0.006	0.008	0.725	0.675

V_1: QPM (HQPM4); V_2: Shresta (hybrid) V_3: NAC 6004 (composite), T_1: Control; T_2 RDF; T3 RDN_{75} + Vermi; T4: T_3+ Azo; T_5: T_4+ Zn; T_6: RDN_{50}+ Vermi + Azo + Zn

Where, PFP= Partial factor productivity, AUE= Agronomic use efficiency, ARE =Apparent recovery efficiency, PE= Production efficiency

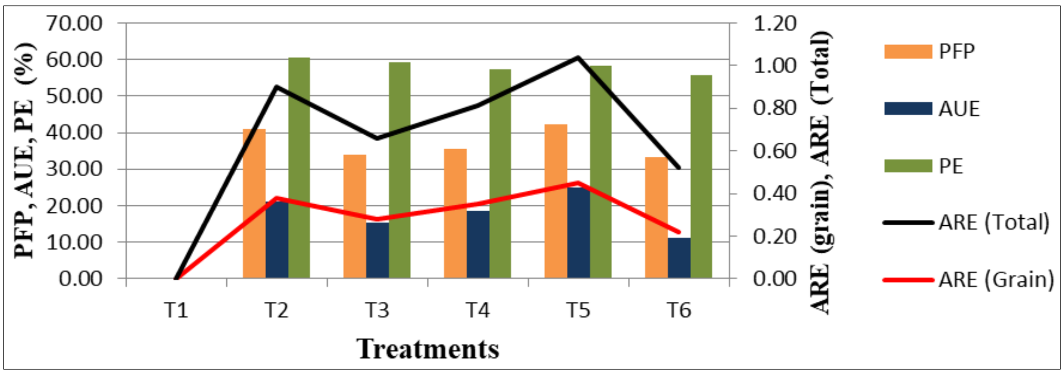

Fig 5: NUE indices across treatments in 2017-2018

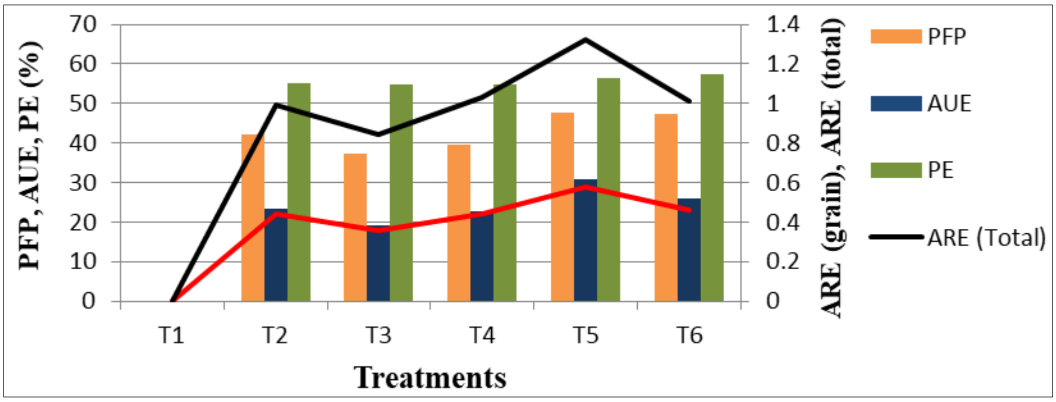

Fig 6: NUE indices across treatments in 2018-2019

The graphical representation of NUE values involving PFP, AUE and PE for both 2017-2018 (Fig 5.) and 2018-2019 (Fig 6.) follows the same trend in better indicators of recovery efficiencies of grain and total biomass. Among the nutrient schedules, the apparent setback of T_3 over RDF in the 1st year has been recovered, to some extent, in the successive year. The overall trend signifies better recovery values for both grain and biomass in T_5 as expected, again with an improved value for the corresponding 2nd year. Another spectacular finding for the recovery efficiencies corresponding to T_6 reflects that over a longer period of experimentation the RDF_{50} plots along with organics and Zn may be able to hold at par yield values with T_5. This essentially may signify scope for reducing inorganic N use to the extent of 50% of recommendation even for exhaustive nutrient miners like maize. This underpins the efficacy of organics in the long run.

Conclusion

The investigation concludes with the finding that QPM cultivars provide better utilization of added nitrogenous fertilizers over hybrid and composite cultivars and also the NUE indices reflects that schedules with organic supplementation along with vermicompost, zinc and Azotobacter have better compounding effects over successive effects and effectively discounts inorganic use of N to the extent of 25% in the initial year with further improvements in such replacements over time.

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