



Direct and Residual Effect of Integrated Nitrogen Management on Productivity of Rice-maize Cropping System

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Authors' contributions

This work was carried out in collaboration among all authors. Authors CSR, PVS, MML and VSR designed the study and wrote the protocol. Author DKDD performed the statistical analysis, wrote the first draft of the manuscript, managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To find out the direct and residual effect of application of organics, inorganics and their combination on yield and yield parameters of rice-maize cropping system.

Study Design: The experiment was laid out in randomized block design during *kharif* season and split plot design during *rabi*.

Place and duration of Study: At Agricultural college farm, Bapatla during 2018-19 and 2019-20.

Methodology: After the preliminary layout, paddy was sown in *kharif* and maize was sown in *rabi* season. Vermicompost and green leaf manure were applied two weeks before sowing of paddy. Treatments applied for paddy were considered as main plots and each main plot was divided into two sub plots during *rabi*.

Results: Higher grain yield, straw yield, drymatter production at tillering stage were recorded with the application of 50% RDN through vermicompost +50% RDN through inorganics (T₉) during both the years of study. However, in succeeding maize, the kernel yield, straw yield and yield attributing characters (drymatter, cob length and test weight) were significantly highest in the treatment which received 75% RDN through green leaf manure+ 25% RDN through inorganic (T₅). Among the fertilizer levels applied to maize, S₂ (100% RDF) recorded significantly higher dry matter production over S₁ (50% RDF) at all the stages of crop growth and during two years of experimentation.

Conclusion: Substitution of 50 % N through vermicompost improved rice yield and yield attributes whereas substitution of 75% N through GLM have shown better residual effect in terms of improvement of yield and yield attributing characters of maize. Among the subplots application of 100% RDF significantly increased the yield when compared to 50% RDF.

Keywords: Paddy; maize; grain yield; stover yield and dry matter.

1. INTRODUCTION

In India rice-maize cropping system assumes prime importance under irrigated conditions. In Andhra Pradesh, rice is grown in an area of 2.16 million ha with annual production of 7.49 million tonnes and productivity of 3466 kg ha⁻¹ and maize is grown in an area of 0.23 million ha with annual production of 1.41 million tonnes and productivity of 6069 kg ha⁻¹. However, the cultivation of two cereal crops like rice and maize in quick succession on the same piece of land is not advisable with respect to soil health, resulting in decline in the yield of both the crops. The continuous nutrient depletion from the agricultural fields is a severe threat to the soil health. Nutrient imbalance in soil results in low fertilizer use efficiency, low yields and low profits [1]. In South India, Andhra Pradesh has the highest acreage under rice-maize system where this system is rapidly increasing under resource-conserving technologies, mostly zero tillage [2].

A recent study by National Centre for Agricultural Economics and Policy Research (NCAP) in India has also shown an increasing demand for maize by the industry sector like textiles, paper, glue, alcohol, confectionery, food processing, and pharmaceutical industry, etc. [3]. Therefore, in the changing farming scenario in South Asia, maize is emerging as one of the potential crops in rice-based systems that can favorably address several issues like food and nutritional security, climate change, water scarcity, farming systems, bio-fuel demand and other industrial requirements.

However, not much is known about nitrogen management practices for the emerging rice-maize systems, particularly involving high-yielding maize hybrids. This system is complicated because the component crops are grown in sharply contrasting physical, chemical

and biological environments [4] where N losses are more pronounced. Here the role of soil organic matter becomes crucial, especially for maize as a supplier of secondary and micronutrients, and also as a natural "soil amendment" that creates a congenial soil physical environment for these crops. Organic matter becomes more important as most soils of South Asia currently have low organic matter contents. In this context, integrated nitrogen system, envisaging conjunctive use of inorganic and organic sources of nitrogen, could be considered for sustaining soil health and crop productivity [5].

2. MATERIALS AND METHODS

An experiment was conducted at Agricultural College Farm, Bapatla situated at 15° 54' N latitude and 80° 25' E longitude, at an altitude of 5.49 m above the mean sea level and is about 8 km away from the Bay of Bengal. The chemical analysis of soil showed that the soil is sandy clay loam in texture and low in available N (153.2 kg ha⁻¹), medium in P (36.7 kg ha⁻¹) and low in OC (0.44%) and K (341 kg ha⁻¹) during 2017-18 respectively. The experiment was carried out in the same field during both the years *i.e.*, 2018-19 and 2019-20. The experiment was laid out during *kharif* in a randomized block design with nine treatments *viz.*, T₁: Control, T₂: 100 per cent RDF through Inorganic fertilizers, T₃: 100% Organic (Beejamrutham + Jeevamrutham), T₄: 100% Organic (Beejamrutham and Jeevamrutham) + 25% RDN through inorganic fertilizers, T₅: 75% RDN through Green leaf manure (90 kg N ha⁻¹) + 25% RDN through inorganic fertilizers, T₆: 75% RDN through vermicompost (90 kg N ha⁻¹) + 25% RDN through inorganic fertilizers, T₇: 100% Organic (Beejamrutham and Jeevamrutham) + 50% RDN through inorganic fertilizers, T₈: 50% RDN through Green leaf manure (60 kg N ha⁻¹) + 50% RDN through

inorganic fertilizers, T₉: 50 % RDN through vermicompost (60 kg N ha⁻¹) + 50% RDN through inorganic fertilizers and replicated thrice and in *rabi* each plot was divided into two subplots viz., 100% RDF and 50% RDF during both the years of study. Organic manures viz., Green leaf manure (GLM), vermicompost were applied as per the treatments fifteen days before sowing. The inorganic nitrogen (120 kg N ha⁻¹) was applied through urea. Phosphorous (60 kg P₂O₅ ha⁻¹) and potassium (40 kg K₂O ha⁻¹) applied to all the plots except T₃ and T₁ considering their contents in the manures. Entire phosphorus and potassium and one third of the N were applied as basal dose. Remaining inorganic N fertilizer was applied in two equal splits at active tillering stage and panicle initiation stages.

The *rabi* experiment was continued on the same site without disturbing the soil with maize as test crop to the study residual effect of different nitrogen sources applied to preceding rice crop. During *rabi*, the treatments were consisted of two levels of fertilizers viz., S₁- 50% RDF and S₂- 100% RDF. Popular cultivars of rice and maize viz., BPT-5204 and Pioneer-3396 respectively, were chosen for the study.

3. RESULTS AND DISCUSSION

3.1 Effect of Organics, Inorganics and their Combined Application on Yield and Yield Attributes of Rice

3.1.1 Dry matter production in paddy

Dry matter production was considered to be the reliable index of crop growth. The effect of various treatments on the dry matter production (DMP) of rice was furnished in Table 1. At tillering stage, significantly higher drymatter production was observed in the treatment T₉ that received 50% RDN through vermicompost+50% RDN through inorganics (2673 and 2816 kg ha⁻¹) during both the years of study.

At panicle initiation stage, significantly higher drymatter production was observed in the treatment that received 50% RDN through vermicompost+50% RDN through inorganics (T₉- 6483.97 and 7242.00 kg ha⁻¹) during 2018 and 2019 respectively. At harvest, significantly higher dry matter production was observed in T₉ (13147 and 13507.7 kg ha⁻¹) which was 138% higher over control during both the years of study.

Significant increase in tiller number per unit area, plant height due to combined application of organics and inorganics might have increased

photosynthesis there by production of photosynthates which finally resulted in higher number of panicles per unit area and higher accumulation of dry matter [6].

Continuous slow release of nutrients might have increased the leaf area duration, thereby providing an opportunity for plants to increase the photosynthetic rate which could have led to higher accumulation of dry matter. The beneficial effect of organic manure on dry matter yield was also reported by Sangeetha et al. [7].

Treatment T₉ provides higher percentage of available nitrogen through high analysis inorganic fertilizers which provide nutrients to meet the immediate nutrient requirements of crop. When higher dose of inorganic fertilizer is applied, higher amount of fertilizer N could be converted into available form by the biochemical reaction of fertilizer N with soil organic matter [8]. Moreover, the persistent material in organic manures viz., cellulose, requires more time for its decomposition, hence, about 25 to 33% of nitrogen and small fraction of phosphorus and potassium may be available to immediate crop and the rest to subsequent crop [9]. Thus treatment T₉ where 50% N was substituted through inorganic fertilizers performed better during *kharif* when compared to T₆ where 25% N was substituted through inorganics.

The lowest drymatter production at all the stages of crop growth period was observed in T₁ i.e control (880.95, 2679.3, 5534.00 kg ha⁻¹ and 963.2, 2803.4, 5674.00 kg ha⁻¹) during both the years of experimentation. The drastic reduction in dry matter production without fertilization might be due to the depletion of nutrients with continuous cropping [10].

3.1.2 Grain yield

The data pertaining to grain yield was presented in Table 2. Significantly higher grain yield was recorded by the treatment T₉ that received 50% RDN through vermicompost + 50% RDN through inorganics (5921 and 6134 kg ha⁻¹) which was 159% over control during both the years of study.

The lowest grain yield was recorded in the treatment T₁ i.e control (2287 and 2327 kg ha⁻¹). The increase in yield with the combined application of organics and inorganics might be due to better and continuous availability of nutrients for plants [11], higher nutrient uptake and improvement of soil environment [12] which ultimately increased the grain yield.

Table 1. Effect of integrated use of inorganic fertilizers and organic manures on dry matter production (kg ha⁻¹) at different stages of rice

Treatments	Kharif (2018)			Kharif (2019)		
	Tillering	Panicle Initiation	Harvest	Tillering	Panicle Initiation	Harvest
T ₁	880.95	2679.30	5534.00	963.19	2803.40	5674.00
T ₂	2041.00	5612.00	12094.00	2163.00	6389.00	12203.00
T ₃	1176.00	2817.33	6390.00	1248.00	3248.67	6599.67
T ₄	1422.67	4106.00	8147.00	1576.00	4274.00	8269.00
T ₅	1555.00	4431.00	8357.00	1643.00	4438.00	8500.00
T ₆	1698.00	4628.00	9162.00	1821.00	4752.00	9349.00
T ₇	1814.00	5163.00	9836.00	1879.00	5298.00	10046.00
T ₈	2264.00	6037.00	12428.00	2427.00	6748.00	12829.00
T ₉	2673.67	6483.97	13147.00	2816.00	7242.00	13507.67
SEm ±	98.47	264.3	526.05	114.2	271.42	542.96
CD (P=0.05)	295.23	792.37	1580.08	342.36	813.71	1627.78
CV (%)	9.89	9.82	9.65	10.77	9.36	9.73

Table 2. Effect of integrated use of inorganic fertilizers and organic manures on yield (kg ha⁻¹), harvest index and test weight (g) of rice

Treatments	Kharif (2018)				Kharif (2019)			
	Grain yield	Straw yield	Harvest index	Test weight	Grain yield	Straw yield	Harvest index	Test weight
T ₁	2287.00	2881.00	44.4	13.60	2327.00	2979.00	43.8	13.90
T ₂	5466.00	6201.00	47.5	13.90	5625.00	6390.67	46.6	14.30
T ₃	2748.00	3387.00	44.6	13.70	2816.34	3493.00	44.2	13.97
T ₄	3384.00	4139.00	45.0	13.84	3481.00	4256.33	44.9	14.30
T ₅	3541.00	4274.00	45.3	14.20	3657.00	4443.00	45.6	15.10
T ₆	4085.00	4821.00	45.9	14.10	4187.00	4925.67	45.9	14.90
T ₇	4567.00	5326.00	46.2	14.01	4709.00	5467.00	46.3	14.40
T ₈	5615.00	6312.00	46.9	14.20	5802.00	6537.00	46.8	14.80
T ₉	5921.00	6530.00	47.1	14.30	6134.67	7008.22	47.0	15.00
SEm ±	256.22	272.6	2.16	0.43	235.46	319.23	1.47	0.43
CD(P=0.05)	768.14	817.26	NS	NS	705.91	957.05	NS	NS
CV (%)	10.62	9.69	8.16	6.34	9.47	10.94	6.58	6.11

Among the different organic sources applied vermicompost proved to be beneficial in enhancing crop productivity and soil fertility due to the reduced loss of organically supplied nutrients. Better supply of nutrients through incorporation of organic manures ascribed to congenial physical environment leading to better root activity and higher nutrient absorption, which resulted in higher yield [13].

Organics were beneficial in reducing the fixation or precipitation of nutrients with those of soil

components and played complementary role to boost the crop yield. Ramteke et al. [14] reported the superiority of the green leaf manure due to its decomposition, which probably led to better availability or release of nutrient as compared to other organic materials under wetland rice.

3.1.3 Straw yield

The data pertaining to straw yield was presented in the Table 2. Significantly higher straw yield

was recorded in the treatment T₉ that received 50% RDN through vermicompost +50% RDN through inorganics (6530.00 and 7008.22 kg ha⁻¹). Lowest straw yield was recorded in T₁ i.e., Control (2881 and 2979 kg ha⁻¹) during both the years of study.

The significant increase in straw yield in response to the combined application of organic and inorganic fertilizers could be attributed to increased nutrient availability and thus increased uptake of nutrients by plant. This might be attributed to the nutrient supplying capacity of the organics as well as their propensity to improve the soil physicochemical properties. Neither organics nor chemical fertilizers alone could be sufficient to increase yield sustainability under cropping system where nutrient turnover in soil plant system has been much higher [15]. However, in an integrated nutrient management, organics can maintain plant nutrients in the available forms for longer periods due to improved soil organic matter (SOM) and soil physico-chemical and biological characteristics. Similar results were reported by Aziz et al. [16].

In general, combined application of organic and inorganic fertilizers maintained wet soil NH₄ -N at higher levels throughout rice growth period than application of inorganic sources alone. Organics along with inorganic N supply NH₄ -N to the plant continuously through mineralization of organic N throughout the crop period and in turn increase nutrient use efficiency, ultimately giving higher yield [17]. These results were in confirmation with the findings of Manjappa [18], Amarpreet and Yashbirsingh [19] and Prathibhasree et al. [20].

3.1.4 Harvest index

The data on harvest index revealed that, application of inorganic fertilizers, organics and combined application of inorganic fertilizers and organic manures did not attain the level of significance in terms of harvest index (Table. 2) of rice crop during both the years of study.

However numerically maximum harvest index was recorded in the treatment T₉ that received 50% RDN through vermicompost+50% RDN through inorganics (47.5% and 47%) during both the years of experimentation. Nagaraj et al. [21] recorded non-significant effect on harvest index due to application of organic manures. Integrated nitrogen management treatments have recorded higher harvest index values when compared to

complete organic and control. This might be due to the positive response to the higher availability of nutrients and grain yields which could be ascribed to overall improvement in the crop growth enabling the plant to absorb more quantity of nutrients, increased photosynthetic activity and accumulating them in sink. These findings were in accordance with those of Naher and Paul [22].

3.1.5 Test weight

The data recorded on test weight of rice (Table. 2) revealed that addition of either organics or inorganics or combined application of organics and inorganics did not exhibit significant difference on test weight of rice. However combined application of organics and inorganics improved the test weight of rice when compared to complete inorganic, organic and control treatments. The test weight ranged from 13.6 g to 14.3 g and 13.9 g to 15.0 g in 2018 and 2019 respectively. The non significant differences in test weight with integrated nutrient management were also reported by Malviya et al. [23].

3.2 Residual effect of Organics Applied to Rice on Yield and Yield Attributes of Maize

3.2.1 Dry matter production

During the two years of study, among the different treatments applied to rice, combined application of organics and inorganics have shown prominent residual effect on succeeding maize (Tables 3 & 4). The substitution of 75% RDN through green leaf manure (T₅ -504.5, 3850.5, 12466.1 kg ha⁻¹ in 2019 and 526, 4072.5, 12857 kg ha⁻¹ in 2020) resulted in highest dry matter yield at all the three stages. The better residual effect of green leaf manure might be due to the more carrying over effect of green leaf manure when compared to other organics.

The maximum dry matter accumulation in INM treatments might be due to the continuous slow release of nutrients which have enabled extension of the leaf area duration there by providing an opportunity time for plants to increase the photosynthetic rate which in turn could have led to higher accumulation of dry matter. The findings were in conformity with Mounika et al. [24].

Table 3. Residual effect of INM practices in preceeding rice and NPK levels on dry matter yield (kg ha⁻¹) at different stages of maize (Rabi, 2019)

	Knee High		Mean	Silking		Mean	Harvest		Mean
	S1	S2		S1	S2		S1	S2	
T1	312	439	375.5	2529	3419	2974.0	8733.3	11692.9	10213.1
T2	361	491	426.0	2831	3769	3300.0	9429.5	12423.3	10926.4
T3	327	454	390.5	2607	3497	3052.0	8875.6	11818.4	10347.0
T4	338	468	403.0	2686	3584	3135.0	9072.3	11969.9	10521.1
T5	428	581	504.5	3373	4328	3850.5	11040.9	13891.3	12466.1
T6	409	563	486.0	3269	4171	3720.0	10606.3	13256.0	11931.2
T7	349	479	414.0	2754	3661	3207.5	9246.8	12181.2	10714.0
T8	397	551	474.0	3172	4058	3615.0	10501.8	12900.2	11701.0
T9	384	529	456.5	3059	3948	3503.5	10273.9	12736.6	11505.2
Mean	367	506.11		2920	3826.1		9753.36	12541.09	
	SEm±	CD	CV(%)	SEm±	CD	CV(%)	SEm±	CD	CV
		(p=0.05)		(p=0.05)			(p=0.05)		(%)
M	13.21	40	7.4	135.48	406.17	9.8	393.82	1180.67	9.2
S	7.64	23	9.1	40.10	119.13	6.2	212.76	632.15	9.9
M X S	20.91	60.7		159.97	NS		599.00	NS	
S X M	22.93	68.1		120.29	NS		638.28	NS	

Table 4. Residual effect of INM practices in preceeding rice and NPK levels on dry matter yield (kg ha⁻¹) at different stages of maize (Rabi, 2020)

	Knee High		Mean	Silking		Mean	Harvest		Mean
	S1	S2		S1	S2		S1	S2	
T1	323	456	389.5	2620	3561	3090.5	9021.4	12071.9	10546.6
T2	377	511	444.0	2943	3937	3440.0	9721.5	12807.1	11264.3
T3	341	472	406.5	2730	3683	3206.5	9164.3	12198.6	10681.4
T4	352	486	419.0	2809	3770	3289.5	9362.0	12350.2	10856.1
T5	447	605	526.0	3566	4579	4072.5	11398.2	14317.0	12857.6
T6	428	587	507.5	3462	4422	3942.0	10961.2	13677.4	12319.3
T7	363	497	430.0	2877	3847	3362.0	9537.6	12563.2	11050.4
T8	416	575	495.5	3365	4309	3837.0	10856.3	13318.3	12087.3
T9	403	553	478.0	3252	4199	3725.5	10626.7	13154.1	11890.4
Mean	383	526.9		3069.3	4034.1		10072.14	12939.75	
	SEm±	CD	CV(%)	SEm±	CD	CV(%)	SEm±	CD	CV
		(p=0.05)		(p=0.05)			(p=0.05)		(%)
M	16.82	50.4	9.1	138.79	416	9.6	375.77	1126.56	9.2
S	7.90	23.5	9.0	76.89	228	11.2	235.70	700.31	10.6
M X S	23.74	NS		214.16	NS		625.46	NS	
S X M	23.70	NS		230.66	NS		707.11	NS	

Among the subplot treatments, dry matter yield increased with increase in level of RDF *i.e.*, S₂ which received 100% RDF recorded significantly higher dry matter yield (506.1, 3826.1 kg ha⁻¹ in 2019 and 526.9, 4034.1 kg ha⁻¹ in 2020) when compared to 50% RDF. The interaction between mainplots and subplots was found to be non significant. The increase in dry matter production with increase in level of RDF might be owing to better uptake of different nutrients and their translocation to the sink [25].

The superiority of treatments T₅ and T₆ where 75% N was substituted through GLM and

vermicompost respectively, owes to slow decomposition and mineralization of major and minor nutrients from manures and their addition to soil nutrient pool left behind after their absorption by rice crop (Subbaiah et al., 2013). Urea which is most available form of nitrogen when applied to rice is subjected to leaching and volatilization losses in addition to crop uptake. Therefore the treatments which received higher dose of organic manures have shown better residual effect when compared to complete inorganic (T₂) and T₅, T₆ where only 50% N was substituted through GLM and vermicompost respectively.

3.2.2 Kernel yield

The data presented in the Tables. 5 & 6 revealed that among the different treatment applied to preceding rice, integrated nitrogen management treatments showed significant residual effect on kernel yield of maize when compared to other treatments during both the years of study.

Application of 75% RDN through green leaf manure + 25 % N through inorganics (T₅) to rice resulted in highest kernel yield (5354 and 5528 kg ha⁻¹ in 2019 and 2020 respectively). The manure was believed to increase yields of maize as a result of improved water holding capacity, soil aeration, soil structure, nutrient retention and microbial activities, all of which were known to play a significant role in enhancing crop performance [26]. The positive residual effect of organics applied to preceding crop on yield of second crop was also reported by Lokanath [27]. The lowest kernel yield was observed in treatment T₁ which did not receive any fertilizers (4422 and 4565 kg ha⁻¹) in 2019 and 2020 respectively. Complete inorganic treatment (T₂- 4422 and 4565 kg ha⁻¹) recorded higher kernel yield of maize when compared to the treatment which received 100% organic (beejamrutham + jeevamrutham) (T₃- 4483 and 4626 kg ha⁻¹) in 2019 and 2020 respectively. Among the different

organic sources applied to *kharif* rice, green leaf manure has shown better residual effect when compared to vermicompost and beejamrutham+jeevamrutham.

Irrespective of the nitrogen management treatments, kernel yield increased with increase in level of fertilizers. Application of 100% RDF (S₂) recorded significantly higher kernel yield (5653 and 5822 kg ha⁻¹ in 2019 and 2020 respectively) when compared to S₁ i.e 50% RDF.

The interaction between main plots and subplots was found non-significant. However treatment T₅S₂ that received 75% RDN through green leaf manure + 25 % N through inorganics in *kharif* and 100% RDF in *rabi* improved kernel yield and T₁S₁ i.e., Control in *kharif* and 50 % RDF in *rabi* recorded lesser kernel yield during both the years of study.

3.2.3 Stover yield

From the data furnished in Tables 5 & 6, it was inferred that straw yield of maize was significantly influenced by the treatments imposed in preceding rice crop and different levels of NPK application to maize. Their interaction effect was non-significant.

Table 5. Residual effect of INM practices in preceding rice and NPK levels on kernel & stover yield of maize (Rabi, 2019)

	Kernel yield (kg ha ⁻¹)		Mean	Stover yield (kg ha ⁻¹)		Mean
	S1	S2		S1	S2	
T1	3550	5294	4422	5791	7211	6501
T2	3810	5598	4704	6275	7689	6982
T3	3618	5348	4483	5875	7292	6583
T4	3685	5441	4563	6018	7361	6690
T5	4630	6077	5354	7178	8781	7980
T6	4612	5950	5281	6732	8228	7480
T7	3748	5517	4633	6142	7511	6826
T8	4537	5871	5204	6695	7926	7310
T9	4453	5785	5119	6535	7837	7186
Mean	4071	5653		6360	7760	
	SEm±	CD (p=0.05)	CV (%)	SEm±	CD (p=0.05)	CV (%)
M	196.56	589	9.9	265.89	797	9.2
S	112.49	334	12.0	174.09	517	12.8
M X S	309.16	897.9		455.06	NS	
S X M	337.47	1002.7		522.27	NS	

Table 6. Residual effect of INM practices in preceeding rice and NPK levels on kernel & stover yield of maize (Rabi, 2020)

	Kernel yield (kg ha ⁻¹)		Mean	Stover yield (kg ha ⁻¹)		Mean
	S1	S2		S1	S2	
T1	3677	5453	4565	5910	7376	6643
T2	3937	5757	4847	6394	7853	7124
T3	3745	5507	4626	5994	7456	6725
T4	3812	5600	4706	6137	7525	6831
T5	4797	6258	5528	7316	8957	8137
T6	4779	6131	5455	6870	8404	7637
T7	3875	5676	4776	6261	7675	6968
T8	4704	6052	5378	6833	8102	7467
T9	4620	5966	5293	6673	8013	7343
Mean	4216	5822		6488	7929	
	SEm _±	CD (p=0.05)	CV(%)	SEm _±	CD (p=0.05)	CV(%)
M	192.45	577	9.4	271.70	815	9.2
S	78.57	233	8.1	88.54	263	6.4
M X S	254.59	NS		330.30	NS	
S X M	235.70	NS		265.62	NS	

Table 7. Residual effect of INM practices in preceeding rice and NPK levels on yield attributes and harvest index of maize (Rabi, 2019)

	Cob length (cm)		Mean	Test weight (g/100 kernels)		Mean	Harvest index		Mean
	S1	S2		S1	S2		S1	S2	
T1	15.3	16.4	15.9	14.4	18.6	16.5	38.0	42.3	40.2
T2	15.9	18.0	17.0	15.9	20.2	18.1	37.8	42.1	39.9
T3	15.3	17.0	16.2	14.8	18.9	16.9	38.1	42.3	40.2
T4	15.4	17.2	16.3	15.1	19.3	17.2	38.0	42.5	40.2
T5	17.1	19.2	18.2	19.1	23.9	21.5	36.2	40.9	38.6
T6	16.9	18.8	17.9	18.4	23.3	20.9	40.7	42.0	41.3
T7	15.6	17.6	16.6	15.5	19.8	17.7	37.9	42.3	40.1
T8	16.6	18.5	17.6	17.8	22.2	20.0	40.4	42.6	41.5
T9	16.1	18.3	17.2	17.2	21.4	19.3	40.5	42.5	41.5
Mean	16.0	17.9		16.5	20.8		38.62	42.16	
	SEm _±	CD	CV(%)	SEm _±	CD	CV(%)	SEm _±	CD	CV
		(p=0.05)			(p=0.05)			(p=0.05)	(%)
M	0.5	1.4	7.0	0.5	1.5	6.4	0.87	NS	5.2
S	0.2	0.7	7.0	0.2	0.7	6.4	0.58	1.74	7.5
M X S	0.7	NS		0.7	NS		1.51	NS	
S X M	0.7	NS		0.7	NS		1.75	NS	

Application of 75% RDN through green leaf manure + 25% RDN through inorganics (T₅ - 7980 and 8137 kg ha⁻¹) to preceeding rice crop recorded significantly higher stover yield in *rabi* during both the years of the study. Continuous supply of NH₄ -N to the plant due to mineralization of organic N in INM treatments might have resulted in higher straw yield [28]. Similar findings were quoted by Malviya et al. [23], Shah et al. [29] and Patel et al. [9].

Among the levels of fertilizers applied to maize, the treatment S₂ (7760 and 7929 kg ha⁻¹) recorded significantly higher stover yield and when compared to S₁ i.e 50%RDF (6360 and 6488 kg ha⁻¹) However, the interaction was not significant. The straw yield was significantly increased due to different levels of fertilizers. The more growth and drymatter accumulation associated with higher levels of fertilizers could be the reason for the higher straw yield. Similar results were reported by Dwivedi et al. [30].

Table 8. Residual effect of INM practices in preceeding rice and NPK levels on yield attributes and harvest index of maize (Rabi, 2020)

	Cob length (cm)		Mean	Test weight (g/100 kernels)		Mean	Harvest index		Mean
	S1	S2		S1	S2		S1	S2	
T1	15.4	16.6	16.0	14.8	19.5	17.2	38.4	42.5	40.4
T2	16.0	18.2	17.1	16.8	21.8	19.3	38.1	42.3	40.2
T3	15.4	17.2	16.3	15.5	20.2	17.9	38.5	42.5	40.5
T4	15.5	17.4	16.5	15.8	20.6	18.2	38.3	42.7	40.5
T5	17.3	19.2	18.3	21.2	26.7	24.0	39.6	41.1	40.4
T6	17.1	19.1	18.1	20.5	26.1	23.3	41.0	42.2	41.6
T7	15.7	17.8	16.8	16.2	21.1	18.7	38.2	42.5	40.4
T8	16.8	18.8	17.8	19.9	25.0	22.5	40.8	42.8	41.8
T9	16.3	18.6	17.5	19.3	24.2	21.8	40.9	42.7	41.8
Mean	16.2	18.1		17.8	22.8		39.3	42.4	
	SEm±	CD	CV(%)	SEm±	CD	CV(%)	SEm±	CD	CV(%)
		(p=0.05)			(p=0.05)			(p=0.05)	
M	0.5	1.4	6.5	0.5	1.6	6.6	1.04	NS	6.2
S	0.2	0.6	6.4	0.2	0.7	6.3	0.56	1.7	7.1
M X S	0.6	NS		0.8	NS		1.57	NS	
S X M	0.6	NS		0.7	NS		1.67	NS	

3.2.4 Harvest index

Data pertaining to harvest index of maize was presented in Tables 7 and 8 and revealed that during both the years of study, the residual effect of organics, inorganics and their combination applied to rice had no significant influence on harvest index of maize. Combined application of organics and inorganics have resulted in better harvest index when compared to all other treatment. These results were also confirmed by Malviya et al. [23] and Patel et al. [9].

Among the different levels of fertilizers, harvest index increased significantly with increase in the level of fertilizers from 50% RDF to 100 % RDF (S₂-42.16 and 42.40%) in 2019 and 2020 respectively. The increase in harvest index with increase in the dose of fertilizers might be due to adequate supply of nutrients, besides enhanced carbohydrate synthesis and rate of metabolic activities through increased leaf area resulting in higher drymatter and finally the grain yield had favoured for higher harvest index. The interaction between main plot treatments and sub plot treatments was found to be insignificant during both the years of study.

3.2.5 Test weight

The data recorded on test weight of maize (Tables 7 and 8) revealed that treatments applied to the preceeding rice crop have shown significant impact on test weight of maize.

Significantly higher test weight of maize was recorded in the treatment (T₅) supplied with 75 % N through green leaf manure and 25 % N through inorganics in *kharif* season (21.5 and 24 g) in 2019 and 2020 respectively. Malviya et al., 2012 and Shah et al., 2017 also reported increase in test weight with combined application of organics and inorganics. The residual effect of organics through mineralization and improvement of physico-chemical properties of soil thereby improving water and nutrient holding capacity indirectly improved the availability of nutrients to plants from native pool of soil and thus improved the weight of grains [24]. The lowest test weight was recorded in T₁ i.e., control (16.5 and 17.2g) during both the years.

Among the sub plots, application of 100% RDF (20.8 and 22.8g in 2019 and 2020 respectively) recorded significantly higher test weight when compared to 50% RDF. Increase in 100 grain weight under increased NPK levels might be due to N induced enhancement photosynthetic activities and translocation of photosynthates, which might have promoted the growth, better partitioning of photosynthates into yield attributes and eventually produced large size of ear head, as well as more grain of higher weight that ultimately increased the yield. Similar results on yield attributes were also reported by Arun kumar et al. [31] and Mishra [32].

Table 9. Per cent increase in yield in treatment T9 during *kharif* and in treatment T5 during *rabi* over control

	% increase over control	
	2018 -19	2019-20
DMP in <i>kharif</i>	138	138
Grain yield in <i>kharif</i>	158	163
Straw yield in <i>kharif</i>	126	135
DMP in <i>rabi</i>	22	21
Grain yield in <i>rabi</i>	21	21
Straw yield in <i>rabi</i>	23	23

3.2.6 Cob length

From the data furnished in Tables 7 and 8, it was inferred that the cob length of maize following rice that received organics like green leaf manure and vermicompost together with 50 and 25% RDN through inorganic fertilizer was significantly higher than all other treatments and on par with each other during both the years of study. Application of 75% RDN through green leaf manure + 25% RDN through inorganics (T₅) to preceding rice crop recorded highest cob length (18.2 and 18.3 cm) and it was on par with T₆ (17.9 and 18.1 cm), T₈ (17.6 and 17.8 cm), T₉ (17.2 and 17.5 cm) and T₂ (17.0 and 17.1 cm) during both the years of the study. Organics applied might have released all macro and micro nutrients essential for plant growth as well as encouraged microbial population and improved physical condition of soil thereby effected yield contributing characters [33]. These results were in consonance with the findings of Bhat et al. [34] who reported the significant and consistent increase of cob length of maize with residual effect of organics.

Irrespective of the nitrogen management treatments given to preceding rice, the maize cob length increased significantly with increase in NPK level. Where S₂ (100% NPK- 17.9 and 18.1 cm) gave significantly higher cob length than that of S₁ (50% NPK- 16.0 and 16.2 cm). Kayani et al. [35] reported significant increase in cob length with higher levels of NPK.

4. CONCLUSIONS

Higher grain yield, straw yield, drymatter production at tillering stage were recorded with the application of 50% RDN through vermicompost +50% RDN through inorganics (T₉) (Table 9) and it was on a par with T₈ which received 50% RDN through green leaf manure +50% RDN through inorganics during both the years of study. However, in succeeding maize, the kernel yield, straw yield and yield attributing characters (drymatter, cob length and test

weight) were significantly highest where 75% RDN was substituted through green leaf manure (T₅- 21.1% increase over control) (Table 9) and it was on par with the treatments T₆ i.e, 50% RDN through vermicompost + 25% RDN through inorganic fertilizers (19.5%), T₈ i.e, 50% RDN through green leaf manure+ 50% RDN through inorganic fertilizers (17.7%) and T₉ i.e, 50% RDN through vermicompost+ 50% RDN through inorganic fertilizers (15.8%). Among the fertilizer levels applied to maize, S₂ (100% RDF) recorded significantly higher dry matter production over S₁ (50% RDF) at all the stages of crop growth and during two years of experimentation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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