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Influence of integrated nutrient management on yield and economics of *rabi* maize (*Zea mays* L.)

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Abstract

A field experiment was conducted at College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India during *rabi*-summer seasons of the years 2019-20 and 2020-21 to study the influence of integrated nutrient management on yield and economics of *rabi* maize (*Zea mays* L.) with different integrated nutrient management practices *viz.*, 100% RDF, 75% RDF + 25% RDN through FYM, 50% RDF + 50% RDN through FYM, 75% RDF + 25% RDN through vermicompost, 50% RDF + 50% RDN through vermicompost, 100% RDF + NPK Consortium, 75% RDF + 25% RDN through FYM + NPK Consortium, 50% RDF + 50% RDN through FYM + NPK Consortium, 75% RDF + 25% RDN through vermicompost + NPK Consortium, 50% RDF + 50% RDN through vermicompost + NPK Consortium, 50% RDF + 25% RDN through FYM + 25% RDN through vermicompost and 50% RDN through FYM + 50% RDN through vermicompost + NPK Consortium. The soil of the experimental plot was loamy sand in texture, deficient in available nitrogen, medium in organic carbon and available phosphorus and high in available potassium. Results revealed that 75% RDF + 25% RDN through vermicompost + NPK Consortium recorded significantly higher growth and yield attributes *viz.*; plant height and dry matter accumulation at 60 DAS and at harvest, cob length and cob girth. They also produced significantly higher grain and stover yield over rest of the treatments. Higher net monetary returns of ₹ 104736/ha were fetched under 75% RDF + 25% RDN through vermicompost + NPK Consortium while, the highest benefit cost ratio of 4.97 was recorded under application of 100% RDF + NPK Consortium.

Keywords: Maize, RDF, RDN, FYM, vermicompost, NPK consortium

Introduction

Being C_4 plant, maize has the highest genetic yield potential amongst the cereals owing to its better dry matter accumulation efficiency in a unit area and time, which is why, it often refers to as "Miracle Crop", "King of Grain Crops", "Backbone of America" and "Queen of Cereals", as together with rice and wheat, it provides approximately 30% of the food calories to more than 4.5 billion people in 94 developing countries and the demand for maize in these countries is assumed to double by 2050 (Johnston *et al.*, 2011) [9]. Worldwide it occupies an area of about 184 million ha covering 160 countries providing around 36 per cent towards the global food grain production. In India maize has been emerged as the third most important cereal crop, after rice and wheat, occupying an area of 9.60 million ha with the production of 27.15 million tones, having average productivity of about 2.8 tones/ha, whereas in Gujarat, 0.44 million ha area is covered with a production of 0.68 million tones having productivity of 1659 kg/ha (Anon., 2020) [1], which is quite below the national and world average. Nutrient management is an important factor for achieving the potential yield in maize production systems (Singh *et al.*, 2021) [19]. Plant nutrients can be supplied from different sources *viz.*, chemical fertilizers, organic manures and crop residues. For better utilization of resources and to produce crops with less expenditure, integrated nutrient management is the best approach. The supplementary and complementary use of different organic manures *viz.*, FYM and vermicompost and inorganic fertilizers *viz.*, nitrogen and phosphorus play major role in growth and development of crop. Application of organic manure like compost, vermicompost, bio-fertilizer alone or in combination improves soil fertility, growth and yield of maize.

In recent years there has been serious concern about long-term adverse effect of continuous and indiscriminate use of inorganic fertilizers on deterioration of soil structure, soil health and environmental pollution (Singh, 2000) [18]. Use of organic manures alone, as a substitute to inorganic fertilizer is not profitable and will not be enough to maintain the present levels of crop productivity of high yielding varieties.

Application of organic manures along with inorganic fertilizers into soil increases the productivity of the system and also sustained the soil health for a longer period (Gawai and Pawar, 2007) [6]. Integrated nutrient management includes the intelligent use of organic, inorganic and biological resources so as to sustain optimum yields, improve or maintain the soil physical and chemical properties as well as microbial properties and provide crop nutrition packages which are technically sound, economically attractive, practically feasible and environmentally safe (Tandon, 1995) [21]. However, information pertaining to integrated nutrient management in maize through different inorganic fertilizer, organic manures and biofertilizer is unknown. With this background present study was conducted to know the effect of different integrated nutrient management practices on yield and economics of maize crop.

Materials and Methods

A field experiment was conducted at Agronomy Farm, Anand Agricultural University, Anand during the years 2019-20 and 2020-21 to find out influence of different integrated nutrient management practices on yield and economics of *rabi* maize (*Zea mays* L.). The experimental site was loamy sand in texture, alkaline in nature (8.19 pH) with low soluble salts (0.17 dS/m) and available nitrogen (177.25 kg/ha), medium in organic carbon (0.29%) and available phosphorus (43.53 kg/ha) and high in available potassium (284.81 kg/ha). Twelve integrated nutrient management treatments comprising of 100% RDF, 75% RDF + 25% RDN through FYM, 50% RDF + 50% RDN through FYM, 75% RDF + 25% RDN through vermicompost, 50% RDF + 50% RDN through vermicompost, 100% RDF + NPK Consortium, 75% RDF + 25% RDN through FYM + NPK Consortium, 50% RDF + 50% RDN through FYM + NPK Consortium, 75% RDF + 25% RDN through vermicompost + NPK Consortium, 50% RDF + 50% RDN through vermicompost + NPK Consortium, 50% RDF + 25% RDN through FYM + 25% RDN through vermicompost and 50% RDN through FYM + 50% RDN through vermicompost + NPK Consortium were studied under Randomized Block Design (RBD). The maize variety GAYMH 3 (Gujarat Anand Yellow Maize Hybrid 3) was taken for the experiment. Recommended dose of nutrients *i.e.*, 150: 60:00 NPK kg/ha were applied through fertilizers uniformly in the furrows as per the treatments, wherein, 50% of recommended dose of nitrogen (RDN) and 100% recommended dose of phosphorus were applied as basal, whereas remaining 50% RDN was applied in two equal splits at 30 and 60 DAS. The nitrogen was applied through urea and phosphorus was applied through single super phosphate. Bio-fertilizers (NPK Consortium) treatment was given to the seeds before sowing as per treatment. Maize crop was sown at 60 cm x 20 cm spacing in experimental plot.

Shelling percentage was calculated using following formula.

$$\text{Shelling percentage} = \frac{\text{Weight of grain}}{\text{Weight of cob with shells}} \times 100$$

The harvest index for each treatment was worked out by using formula given by Donald and Hamblin (1976) [5].

$$\text{HI (\%)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

The benefit: cost ratio was calculated on the basis of formula given below.

$$\text{BCR} = \frac{\text{Total income (₹/ha)}}{\text{Total expenditure (₹/ha)}} \times 100$$

Results and Discussion

The data pertaining to various growth parameter, yield attributes, yield and economics of maize as influenced by different integrated nutrient management practices with their statistical inference are presented and discussed as under:

A. Growth parameters

The mean data pertaining to periodical plant height of maize measured periodically at 30, 60 DAS and at harvest as influence by different integrated nutrient management practices.

The plant height (Table 1) at 30 DAS did not exert any significant effect in different integrated nutrient management treatments. However, at later stages, significantly higher plant height of 154.83 cm and 216.33 cm was recorded with application of 75% RDF + 25% RDN through vermicompost + NPK Consortium at 60 DAS and at harvest, respectively. This treatment exhibited at par relations under the treatments T_1, T_2, T_4, T_6, T_7 and T_{10} at 60 DAS and with treatments T_4 and T_6 at harvest.

The higher plant height may be due to the positive effects of application of NPK consortium along with vermicompost which had accelerated microbial activities resulted into hastened various metabolic processes and resulted in increasing vegetative growth. It might be also possible that due to constant supply of nitrogen throughout the growth period of maize due to blending of inorganic (75% N) and organic source (25% vermicompost) along with microbial culture ascribing the synergistic effect of nitrogen on cell division and expansion, generating thin cell wall, promoting vegetative growth, increasing the formation of foliage by producing more carbohydrates which might be utilized in building up of new cells. Biofertilizers might enhance the plant height and productivity by synthesizing phyto-hormones, increasing in local availability of nutrients, facilitating the uptake of nutrients by the plants and decreasing the heavy metal toxicity in the plant antagonizing plant pathogens. This could be resulted in to higher plant height in maize crop. These are in conformity with the results of Mued *et al.* (2019) [11], Rajashekhar *et al.* (2019) [14], Jeevabharathi *et al.* (2020) [8], Vaghela *et al.* (2020) [22], Bezboruah and Dutta (2021) [3] and Singh *et al.* (2021) [19].

Table 1: Periodical plant height and dry matter accumulation of maize as influenced by different treatments (pooled over two years)

Treatments	Plant height (cm)			Plant dry matter accumulation (g/plant)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1: 100% RDF	68.37	151.72	197.86	18.73	83.96	147.60
T_2: 75% RDF + 25% RDN through FYM	68.22	147.29	192.85	18.11	81.26	138.70
T_3: 50% RDF + 50% RDN through FYM	67.58	131.58	176.98	17.18	74.59	130.88
T_4: 75% RDF + 25% RDN through vermicompost	68.50	153.17	204.67	18.90	89.54	155.24

T_5: 50% RDF + 50% RDN through vermicompost		68.06	139.00	187.05	17.86	79.03	136.22
T_6: 100% RDF + NPK Consortium		68.43	151.81	201.55	18.78	86.09	149.49
T_7: 75% RDF + 25% RDN through FYM + NPK Consortium		68.29	147.63	194.66	18.48	81.78	142.05
T_8: 50% RDF + 50% RDN through FYM + NPK Consortium		67.69	131.86	178.85	17.61	76.77	132.97
T_9: 75% RDF + 25% RDN through vermicompost + NPK Consortium		68.78	154.83	216.34	19.02	94.65	163.30
T_{10}: 50% RDF + 50% RDN through vermicompost + NPK Consortium		68.11	143.89	189.43	17.95	79.73	137.03
T_{11}: 50% RDF + 25% RDN through FYM + 25% RDN through vermicompost		68.03	135.08	185.31	17.82	76.95	134.40
T_{12}: 50% RDN through FYM + 50% RDN through vermicompost + NPK Consortium		67.29	127.69	164.43	16.87	74.07	129.60
S.Em. ±	Y	0.81	1.44	2.75	0.21	1.001	1.42
	T	1.79	4.72	5.58	0.51	2.03	4.76
	Y × T	2.82	4.99	9.52	0.73	3.47	4.91
CD (P=0.05)	Y	NS	NS	NS	NS	NS	NS
	T	NS	13.59	16.06	NS	5.87	13.66
	Y × T	NS	NS	NS	NS	NS	NS
CV %		7.44	6.99	8.27	7.91	7.07	9.49

The plant dry matter accumulation (Table 1) at 30 DAS did not exert any significant effect in different integrated nutrient management treatments. However, at later stages, significantly higher dry matter accumulation of 94.65 g and 163.30 g was recorded with application of 75% RDF + 25% RDN through vermicompost + NPK Consortium at 60 DAS and at harvest, respectively. This treatment exhibited at par relations under the treatments T_4 at 60 DAS and at harvest. It might be due to favorable conditions during the crop growth period and slow release of nutrients associated with vermicompost might have resulted in higher concentration of nutrients in plant cells coupled with high photosynthetic rates and excellent vegetative growth resulting in higher dry matter accumulation. Similar results were reported by Baradhan and Kumar (2018) [2], Raman and Suganya (2018) [15], Verma *et al.* (2018) [24], Subbaiah and Ram (2019) [20] and Jeevabharath *et al.* (2020) [8].

B. Yield attributes

Data pertaining to yield attributes of maize as influenced by different integrated nutrient management on pooled basis are presented in Table 2.

Results revealed that though seed index, harvest index and shelling percentage of maize did not differ remarkably due to different integrated nutrient management practices on pooled basis, significant differences on cob length, cob girth and number of grains per cob were observed. During pooled analysis significantly higher cob length (23.18 cm) was recorded under application of 75% RDF + 25% RDN through vermicompost + NPK Consortium, but it was comparable with T_1, T_4, T_6 and T_7 treatments. Same trend was observed for cob girth and being at par for the treatments T_3, T_5, T_8, T_{10}, T_{11} and T_{12} significantly higher cob girth (16.37 cm) was reported under the same treatment. Number of grains per cob was also observed significantly higher under application of 75% RDF + 25% RDN through vermicompost + NPK Consortium. The significant increase in cob girth under the treatment might be due to adequate supply of the plant nutrient quickly and directly and made a congenial environment to increase microbial activity by easily available food for microorganisms. These microorganisms improve physical condition of the soil and improve water holding capacity, soil physico-chemical properties, cation exchange capacity, which was resulted in to overall increase in yield attributes like cob length and cob girth. The results were in conformity with Jadav *et al.* (2018) [7], Chhetri and Sinha (2018) [4], Preetham *et al.* (2018) [13], Rajashekhar *et al.* (2019) [14], Nayak *et al.* (2020) [12], Rao *et al.* (2020) [16] and Vaghela *et al.* (2020) [22].

In pooled analysis, significantly higher number of grains per cob of maize (310.13) was recorded under the same treatment of 75% RDF + 25% RDN through vermicompost + NPK Consortium (T_9). However, it was found to be substantially at par with all the treatments except T_4 and T_6. It might be due to perpetual supply of nutrient from diversified sources and their persistent availability of nutrients to the growing plant, which resulted into tissue differentiation from somatic to reproductive meristematic activity and increase in development of floral primordial, bringing in higher number of seeds per cob. These results are in agreement with those observed by Preetham *et al.* (2018) [13], Mued *et al.* (2019) [11], Kumar *et al.* (2020) [10], Bezboruah and Dutta (2021) [3] and Singh *et al.* (2021) [19].

Table 2: Influence of different integrated nutrient management practices on yield attributes of maize (pooled over two years)

Treatments	Cob length (cm)	Cob girth (cm)	Number of grains per cob	Seed index (g)	Harvest index (%)	Shelling percentage
T_1: 100% RDF.	22.31	15.62	274.50	27.00	40.76	76.13
T_2: 75% RDF + 25% RDN through FYM.	21.90	15.21	265.37	25.88	41.10	74.90
T_3: 50% RDF + 50% RDN through FYM.	20.73	14.02	249.38	24.47	41.67	72.38
T_4: 75% RDF + 25% RDN through vermicompost.	22.97	16.06	295.62	27.39	42.86	78.63
T_5: 50% RDF + 50% RDN through vermicompost.	21.42	14.63	256.00	25.30	41.55	74.24
T_6: 100% RDF + NPK Consortium.	22.62	15.81	290.62	27.19	40.88	77.78
T_7: 75% RDF + 25% RDN through FYM + NPK Consortium.	22.14	15.50	273.25	26.75	41.56	75.81
T_8: 50% RDF + 50% RDN through FYM + NPK Consortium.	20.92	14.25	250.87	24.72	41.31	72.93
T_9: 75% RDF + 25% RDN through vermicompost + NPK Consortium.	23.18	16.37	310.13	27.75	40.32	79.34
T_{10}: 50% RDF + 50% RDN through vermicompost + NPK Consortium.	21.60	14.94	263.50	25.45	41.27	74.63

T_{11}: 50% RDF + 25% RDN through FYM + 25% RDN through vermicompost.		21.19	14.46	250.62	24.87	41.00	73.98
T_{12}: 50% RDN through FYM + 50% RDN through vermicompost + NPK Consortium.		20.52	13.96	246.13	24.18	41.40	71.00
SEm ±	Y	0.17	0.17	3.86	0.25	0.44	0.71
	T	0.43	0.38	9.78	1.12	1.16	2.15
	Y × T	0.60	0.58	13.37	0.86	1.53	2.45
CD (P=0.05)	Y	NS	NS	NS	NS	NS	NS
	T	1.20	1.07	28.14	NS	NS	NS
	Y × T	NS	NS	NS	NS	NS	NS
CV %		5.53	7.04	10.29	12.22	7.91	8.08

C. Grain and Stover yields

Data pertaining to grain and stover yield of maize as influenced by different integrated nutrient management practices are presented in Table 3. Data showed that different integrated nutrient treatments significantly influenced the grain yield of maize during both the years (2019-20 and 2020-21) as well as in pooled analysis. Among all the treatments tested, treatment with 75% RDF + 25% RDN through vermicompost + NPK Consortium had produced apparently higher grain yield of 5697 kg/ha and 5791 kg/ha during the year 2019-20 and 2020-21, respectively. However, it remained comparable with treatments T_1, T_2, T_4, T_6 and T_7 and treatments T_1, T_2, T_4, T_6 and T_7 during the year 2019-20 and 2020-21, respectively.

Results of pooled analysis followed the same trend and revealed that significantly higher grain yield of 5744 kg/ha was recorded under the application of 75% RDF + 25% RDN through vermicompost + NPK Consortium (T_9), which was closely related to the treatments T_1, T_2, T_4, T_6 and T_7. An increase in grain yield over T_{12} was reported to the tune of 31.97%, 29.31% and 30.63% under T_9 during the year 2019-20, 2020-21 and pooled data, respectively.

Grain yield is a consequential effect of cumulative impact of all the growth and yield attributes. This impact was reflected in higher growth and yield attributes like plant height, cob length, cob girth, number of rows per cob and seed index obtained under the same treatment T_9. These results are in conformity with findings of Rajashekhar *et al.* (2019) [14], Verma and Bindra (2019) [23], Jeevabharathi *et al.* (2020) [8], Vaghela *et al.* (2020) [22], Wanniang and Singh (2020) [25] and Bezboruah and Dutta (2021) [3] on maize.

The results of pooled analysis showed that significantly higher stover yield (8519 kg/ha) of maize recorded under application of 75% RDF + 25% RDN through vermicompost + NPK Consortium (T_9). However, it was closely related to treatments T_1, T_2 and T_6. An increase in stover yield over T_{12} was reported to the tune of 30.07%, 27.85% and 28.95% under T_9 during the year 2019-20, 2020-21 and pooled data, respectively. An increase in stover yield under the treatments is mainly attributed to growth attributing parameter like plant height. The results are in close conformity with those of Rathod *et al.* (2019) [17], Subbaiah and Ram (2019) [20], Rajashekhar *et al.* (2019) [14], Verma and Bindra (2019) [23], Nayak *et al.* (2020) [12], Vaghela *et al.* (2020) [22] and Bezboruah and Dutta (2021) [3].

D. On economics

Economics as influenced by different integrated nutrient management practices for maize crop comprised of cost of cultivation, gross income, net realization and B:C ratio obtained on hectare basis during the course of investigation are presented in Table 4.

An appraisal of data presented in Table 4 revealed that maximum net realization of ₹ 104736/ha was fetched under application of 100% RDF + NPK Consortium (T_6) followed by treatment T_1 (₹ 104354/ha). The lowest net realization/ of ₹ 38411/ha was realized under treatment 50% RDN through FYM + 50% RDN through vermicompost + NPK Consortium (T_{12}).

In case of benefit cost ratio, the highest benefit cost ratio of 4.97 was recorded under application of 100% RDF + NPK Consortium (T_6) followed by T_1 *i.e.*, 100% RDF (4.96).

Conclusion

In light of the two years field experiment, it can be concluded that higher growth, yield attributes, yield and economics of *rabi* maize could be achieved with an application of 75% RDF + 25% RDN through vermicompost + NPK Consortium, however, application of 100% RDF (150-60-00 NPK kg/ha) with NPK consortium gave higher net realization and BCR, followed by 100% RDF.

Table 3: Grain yield and stover yield of maize as influenced by different integrated nutrient management treatments

Treatments	Grain yield (kg/ha)			Stover yield (kg/ha)		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1: 100% RDF.	5486	5659	5573	7874	8309	8091
T_2: 75% RDF + 25% RDN through FYM.	5375	5474	5424	7715	7863	7789
T_3: 50% RDF + 50% RDN through FYM.	4264	4696	4480	6055	6496	6275
T_4: 75% RDF + 25% RDN through vermicompost.	5637	5734	5686	7501	7650	7575
T_5: 50% RDF + 50% RDN through vermicompost.	4752	4855	4804	6631	6925	6778
T_6: 100% RDF + NPK Consortium.	5509	5674	5591	7905	8314	8110
T_7: 75% RDF + 25% RDN through FYM + NPK Consortium.	5478	5502	5490	7657	7791	7724
T_8: 50% RDF + 50% RDN through FYM + NPK Consortium.	4649	4757	4703	6624	6784	6704
T_9: 75% RDF + 25% RDN through vermicompost + NPK Consortium.	5697	5791	5744	8406	8632	8519
T_{10}: 50% RDF + 50% RDN through vermicompost + NPK Consortium.	4835	4963	4899	6908	7056	6982
T_{11}: 50% RDF + 25% RDN through FYM + 25% RDN through vermicompost.	4653	4788	4721	6793	6813	6803
T_{12}: 50% RDN through FYM + 50% RDN through vermicompost + NPK Consortium.	4157	4376	4266	5879	6228	6053

SEm ±	Y			69			77
	T	243	239	166	325	345	275
	Y × T			240			268
CD (P=0.05)	Y			NS			NS
	T	700	688	477	936	991	792
	Y × T			NS			NS
CV %		9.65	9.22	9.17	9.09	9.31	10.68

Table 4: Economics as influenced by various integrated nutrient management treatments (Average of two years)

Treatments	Yield (kg/ha)		Fixed cost (₹/ha)	Treatment cost (₹/ha)	Total cost of cultivation (₹/ha)	Gross realization (₹/ha)	Net realization (₹/ha)	BCR
	Grain	Stover						
T_1	5573	8091	21457	4881	26338	130692	104354	4.96
T_2	5424	7789	21457	11161	32618	127122	94504	3.90
T_3	4480	6275	21457	17441	38898	104827	65929	2.69
T_4	5686	7575	21457	16164	37621	132656	95035	3.53
T_5	4804	6778	21457	27441	48898	112455	63557	2.30
T_6	5591	8110	21457	4921	26378	131114	104736	4.97
T_7	5490	7724	21457	11204	32661	128493	95832	3.93
T_8	4703	6704	21457	17481	38938	110170	71232	2.83
T_9	5744	8519	21457	16201	37658	134882	97224	3.58
T_{10}	4899	6982	21457	27481	48938	114754	65816	2.34
T_{11}	4721	6803	21457	22441	43898	110657	66759	2.52
T_{12}	4266	6053	21457	40040	61497	99908	38411	1.62

Selling price: Grain: ₹ 22/kg, **Stover:** ₹ 1.0/kg.

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