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Research Paper

Effect of integrated nutrient management on yield and quality parameter of winter maize (*Zea mays*)-summer sesame (*Sesamum indicum*) cropping sequence in middle Gujarat condition

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ABSTRACT

A field experiment was conducted at College Agronomy Farm, Bansilal Amrutlal College of Agriculture, Anand Agricultural University, Anand, Gujarat, during the winter (*rabi*) and summer seasons 2019–20 and 2020–21, to study the effect of integrated nutrient management on yield of *rabi* maize (*Zea mays* L.) and its residual effect on succeeding summer sesame (*Sesamum indicum* L.) under irrigated condition. The experiment was laid out in a randomized block design with 12 treatments and 3 replications. Application of 75% recommended dose of fertilizer (RDF) + 25% recommended dose of nitrogen (RDN) through vermicompost + NPK consortium (soil application) resulted in the higher grain (5,742 kg/ha) and strover yield (8,518 kg/ha) as well as protein content (11.18%) maize crop. In succeeding sesame crop, residual effect of 75% RDF + 25% RDN through FYM + NPK consortium (soil application) along with 50% RDF (50 : 25 : 00 N : P : K kg/ha) recorded higher grain (1081 kg/ha) and stalk yield (2,370 kg/ha) along with oil content (47.77%) of crop.

***Key words*:** INM, Maize, Quality, Sesame, Yield

In India, after rice and wheat, maize (*Zea mays* L.) has emerged as the third most important cereal crop, occupying an area of 9.90 million ha, with the production of 31.51 million tonnes, having average productivity of about 3.18 t/ha (ANGRAU, Andhra Pradesh, 2021a). In Gujarat, maize is an important traditionally grown crop of tribal areas, comprising the districts of Panchamahal, Sabarkantha, Banaskantha and part of Vadodara and Kheda districts. *Rabi* maize is having an area of 13,2300 hectares with a production of 33,3600 million tonnes and productivity of 2,521 kg/ha in Gujarat (DoA, Gujarat, 2021b).

Integrated nutrient management (INM) is the combined use of mineral fertilizers with organic resources such as cattle manure, crop residues, urban/rural wastes, composts, green manures and bio-fertilizers. Its basic idea is sustaining soil and crop productivity through optimization of all probable sources of plant nutrients in an integrated manner. The supplementary and complimentary use of organic manures, viz. FYM, vermicompost and castor (*Ricinus communis* L.)- cake, and inorganic fertilizers, viz. nitrogen, and phosphorus nutrient play an important role in the growth and development of the crop. Integration of inorganic and organic manures not only sustain crop production but is also effective in improving soil health and enhancing nutrient-use efficiency (Verma *et al*., 2005).

The FYM seems to act directly by increasing crop yield by supplying 0.50, 0.17 and 0.55% of N, P and K respectively (Patel *et al.*, 1992). Castor-cake plays a vital role in the improvement of soil productivity because it supplies secondary and micro-nutrients in addition to major nutrients. it contains 5.5% nitrogen, 2.0% phosphorus and 1.5% potassium. It is fit for any type of soil, with its high content of organic matter and promotes root development and winter cold hardiness. Vermicompost is finely-divided mature peat-like materials with high porosity, aeration, drainage and water-holding capacity and microbial activity which are stabilized by interactions between earthworms and microorganisms in a non-thermophilic process (Edwards and Burrows, 1988).

Bio-fertilizers play a vital role in the increasing availability of nitrogen and phosphorus. It increases the biologi-

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cal fixation of atmospheric nitrogen and enhances phosphorus availability to crops. Therefore, the introduction of bio NPK consortium (*Azotobacter, Azospirillum* and 3 Bacillus species) may be helpful. It is a liquid bio-fertilizer that saves costly chemical fertilizers by 25–30% with a 10–15% increase in crop production.

The inclusion of pulses, oilseeds and vegetables in the system has been found more beneficial than cereal–cereal sequence for which maize–sesame (*Sesamum indicum* L.) sequence may be the example to avail the benefits of the cropping system (Surekha and Rao, 2001).

Sesame shares 0.9% area to the gross cropped area in India. A well-managed sesame crop can yield 1,200–1,500 kg/ha under irrigated conditions. In India, sesame is grown in 0.156 million ha area, with a production of 0.744 million tonnes, and productivity of 1,339 kg/ha (NFSM, 2018). In Gujarat, area under summer sesame is about 55,722 ha area, with production of 51,277 million tonnes and productivity of 920.22 kg/ha (DoA, Gujarat, 2021b).

Considering the importance of residual effect of INM on succeeding crop with a view to sustainable utilization of resources and reducing the cost of cropping system, present investigation was carried out to study the effect of integrated nutrient management on yield and quality of rabi maize and its residual effect on succeeding summer sesame under irrigated condition.

MATERIALS AND METHODS

A field experiment was conducted at College Agronomy Farm, Bansilal Amrutlal College of Agriculture, Anand Agricultural University Anand (22°35' N, 72° 55' E 45.1 m above the mean sea level), during *rabi* summer seasons 2019–20 and 2020–21 to study the effect of integrated nutrient management on yield of *rabi* maize (*Zea mays* L.). In winter season of 2019–20, a total of 63.4 mm rainfall was received during 43rd, 44th and 45th standard weeks, whereas a total of 26.8 mm of rainfall was recorded during 42nd and 50th standard weeks of *rabi* season and 16.4 mm of rainfall during 11th standard week summer season of 2020–21. In general, the climate remained congenial, providing a good and healthy environment for the successful cultivation of maize in winter and sesame in summer season during both the years of experimentation. The mean maximum temperature ranged from 22.5 to 34.5°C and 15.4 to 35.3°C and minimum temperature ranged from 9.7 to 23.7°C and 5.3 to 26.9°C during *rabi* crop season (October–January) 2019–20 and 2020–21 respectively. The mean maximum and minimum temperature during the summer season (February-May) ranged from 27.6 to 41.5°C and 29.6 to 39.5°C during 2020 and 12.1 to 27.8°C and 11.0 to 26.3°C during 2021 respectively, observed during both the years. The soil of the experimental field at 0–15 cm depth was low in organic carbon (0.35%) and available N (178.64 kg/ha), medium in available P_2O_5 (42.65 kg/ha) and high in available K_2O (282.36 kg/ha) and slightly alkaline (8.20 *p*H) in reaction. The maize variety 'GAYMH 3' (Gujarat Anand Yellow Maize Hybrid 3) was used in the investigation as a test crop. It is the first public, single cross hybrid (6,500–6,600 kg/ha) with early maturity (97–110 days), orange flint-grained cob and revealed 12.9% and 24.2% higher yield over 'HQPM 1' (Single cross hybrid) and 'GM 2' (variety) respectively. Sesame variety GT 3 (Gujarat Til 3), having 60 cm plant height, 1.70 branches/plant, 1 capsule/leaf axil, 47.3 % oil content and 1,706 kg/ha potential yield, was used.

Twelve integrated nutrient management treatments, viz. 100% RDF (T_1), 100% RDF + NPK consortium (seed treatment) (T_2), 100% RDF + NPK consortium (soil application) (T_3), 75% RDF + 25% RDN through FYM (T_4), 75% RDF + 25% RDN through castor cake (T_5), 75% RDF + 25% RDN through vermicompost (T_6), 75% RDF + 25% RDN through FYM + NPK consortium (seed treatment) (T_7), 75% RDF + 25% RDN through castor-cake + NPK consortium (seed treatment) (T_8), 75% RDF + 25% RDN through vermicompost + NPK consortium (seed treatment) (T_9), 75% RDF + 25% RDN through FYM + NPK consortium (soil application) (T_{10}), 75% RDF + 25% RDN through castor-cake + NPK consortium (soil application) (T_{11}) and 75% RDF + 25% RDN through vermicompost + NPK consortium (soil application) (T_{12}) were tested in randomized block design with 3 replications. Among total nitrogen doses, 25% nitrogen was given as a basal dose at the time of land preparation, 25% at 4-leaf stage, 25% at 8-leaf stage and the remaining 25% was applied at tasselling stage. Entire quantity of phosphorus (60 kg P_2O_5/ha) was applied basal in the furrow to all the plots in form of single superphosphate. The furrows were lightly covered with soil.

The organic manures, fertilizers and bio-fertilizers were applied in the experimental plots before sowing as per the treatments. Treatment-wise manures were manually incorporated in soil 10 days before sowing of the crop. Small furrows were opened manually in each plot, keeping the distance of 60 cm between the rows and fertilizers were applied uniformly in the furrows at the time of sowing. The NPK consortium was applied as per the treatments.

Maize 'GAYMH 3' was sown on 25 October 2019 and 28 October, 2020, with seed rate of 20 kg/ha and sesame 'GT 3' was sown on 20 February 2020 and 22 February, 2021, with seed rate of 2.5 kg/ha. Sowing was done with 1 pre-sowing irrigation. Total 6 irrigations in maize and 5 irrigations in sesame were given to maintain appropriate moisture level during crop period. Thinning of the crop was done manually at 15 days after sowing in both crops

during the experimentation to maintain proper plant stand as per geometry.

Cobs from all plants of each net plot were harvested separately and allowed to dry under the Sun for 10 days. After complete drying of cobs, grains were removed with a thresher. The produce so obtained was cleaned and weighed. The grain weight per plot was recorded and converted into kg/ha after adding grain weight of earlier selected 5 plants. After picking the cobs from the net plot, the stover was harvested from each net plot separately and was allowed to dry up to constant weight in the field. Then, it was tied into bundles of suitable size and yield of stover per net plot including 5 selected plants was recorded treatment-wise and converted into kg/ha. The protein content in the seeds was calculated by multiplying nitrogen content (%) of the seeds with the conversion factor of 6.25. Nitrogen content of the seeds was determined by Micro Kjeldahl's method (Jackson, 1973).

The harvested sesame crop of each net plot was threshed separately and the seeds were cleaned manually and weighed in kilogram per net plot and recorded separately for each net plot. Thereafter, the yield was converted into kg/ha. The stalk yield per each net plot was calculated by subtracting the seed weight from the crop dry biomass (biological yield) recorded earlier for each net plot and recorded separately for each net plot for further statistical analysis. Oil content in the kernels was determined by Nuclear Magnetic Resonance (NMR) method as described by Tiwari *et al*. (1974).

The statistical analysis was carried out as described by Cochran and Cox (1967). The values of calculated "F" were worked out and compared with the value of table "F" at 5 % level of significance. The pooled analysis of the 2 years data was carried out as per procedure suggested by Cochran and Cox (1967).

RESULTS AND DISCUSSION

Integrated nutrient management

Yield of winter maize: Among all the INM treatments, T_{12} [75% RDF + 25% RDN through vermicompost + NPK consortium (soil application)] resulted in higher grain (5,696, 5,789 and 5,742 kg/ha) and stover yield (8,405, 8,631 and 8,518 kg/ha) during

Table 1. Effect of integrated nutrient management on grain and stover yields of maize

Treatment	Grain yield (kg/ha)			Stover yield (kg/ha)		
	2019–20	2020–21	Pooled	2019–20	2020–21	Pooled
T_1, 100% RDF	4,754	4,849	4,802	6,631	6,924	6,777
T_2, 100% RDF + NPK consortium (seed treatment)	4,833	4,959	4,896	6,900	7,056	6,978
T_3, 100% RDF + NPK consortium (soil application)	5,374	5,472	5,423	7,712	7,858	7,785
T_4, 75% RDF + 25% RDN through FYM	4,153	4,377	4,265	5,879	6,223	6,051
T_5, 75% RDF + 25% RDN through castor cake	4,646	4,756	4,701	6,618	6,785	6,701
T_6, 75% RDF + 25% RDN through vermicompost	4,654	4,782	4,718	6,795	6,810	6,802
T_7, 75% RDF + 25% RDN through FYM + NPK consortium (seed treatment)	4,166	4,788	4,477	5,898	6,632	6,265
T_8, 75% RDF + 25% RDN through castor cake + NPK consortium, (seed treatment)	5,476	5,499	5,487	7,657	7,780	7,719
T_9, 75% RDF + 25% RDN through vermicompost + NPK consortium (seed treatment)	5,480	5,667	5,574	7,870	8,301	8,085
T_{10}, 75% RDF + 25% RDN through FYM + NPK consortium (soil application)	5,533	5,936	5,735	7,400	7,455	7,427
T_{11}, 75% RDF + 25% RDN through castor cake + NPK consortium (soil application)	5,502	5,674	5,588	7,904	8,311	8,107
T_{12}, 75% RDF + 25% RDN through vermicompost + NPK consortium (soil application)	5,696	5,789	5,742	8,405	8,631	8,518
Sem±						
Y			86			113
T	315	278	210	423	359	278
Y × T			297			393
CD (P=0.05)						
Y			NS			NS
T	924	815	599	1241	1053	791
Y × T			NS			NS
CV %	10.87	9.23	10.05	10.27	8.41	9.35

RDF, Recommended dose of fertilizer; RDN, recommended dose of nitrogen; year; Treatment; NS, non-significant

both the years and when pooled (Table 1). The results might be owing to the combined effect of growth parameters. However, enhancement of yield might be because of the effective utilization of applied nutrients thus, increased sink capacity and higher nutrient uptake by the crop. The results are in close conformity with those of Nagavani and Subbian (2014), Mukherjee (2015), Manjhi *et al*. (2016), Lakum (2017) and Verma *et al.* (2018).

Yield of succeeding summer sesame: Regarding residual effect, application of 75% RDF + 25% RDN through FYM + NPK consortium (soil application) (T_{10}) showed higher seed yield (1,080, 1,082 and 1,081 kg/ha respectively) and stover yield (2,361, 2,379 and, 2,370 kg/ha respectively) during both years and on pooled analysis (Table 2). It might be owing to the application of 75% RDF + 25% RDN through FYM + NPK consortium (soil application) to previous sown crop, inorganic fertilizer might be readily available to plant, so had not any residual effect observed. Vermicompost was also quickly available and almost 70–80% was decomposed and mineralized. But FYM was slowly decomposed and mineralized and about 40–50% nitrogen become available to the first crops and the remaining nitrogen become available to the next residual crop sesame. Adequate supply of most of the plant nutrients directly and made a favourable environment to increase microbial activity by easily available food for microorganisms. These microorganisms improve physical condition of soil and improve water-holding capacity, cation-exchange capacity and soil physico–chemical properties, which resulted in overall increased seed and stalk yields of sesame. It is in close agreement with the findings of Kumbhar *et al*. (2017) and Richard *et al*. (2018).

Quality of winter maize

Treatment T_{12} [75% RDF + 25% RDN through vermicompost + NPK consortium (soil application)] resulted in significantly higher protein content of grain during 2019–20, 2020–21 and pooled analysis (11.15, 11.21 and 11.18% respectively) over all the other treatments (Table 3). This might be possible owing to the higher content of nitrogen in grains because of adequate and perpetual

Table 2. Residual effect of integrated nutrient management treatments on seed and stalk yields of succeeding sesame

Treatment	Seed yield (kg/ha)			Stalk yield (kg/ha)		
	2020	2021	Pooled	2020	2021	Pooled
T_1, 100% RDF	828	853	841	1,854	1,859	1,857
T_2, 100% RDF + NPK consortium (seed treatment)	843	856	849	1,860	1,863	1,862
T_3, 100% RDF + NPK consortium (soil application)	869	876	873	1,927	1,929	1,928
T_4, 75% RDF + 25% RDN through FYM	997	1,020	1,009	2,119	2,125	2,122
T_5, 75% RDF + 25% RDN through castor cake	983	995	989	2,063	2,085	2,074
T_6, 75% RDF + 25% RDN through vermicompost	886	890	888	1,929	1,932	1,931
T_7, 75% RDF + 25% RDN through FYM + NPK consortium (seed treatment)	1,057	1,064	1061	2,274	2,280	2,277
T_8, 75% RDF + 25% RDN through castor cake + NPK consortium, (seed treatment)	996	1,000	998	2,146	2,153	2,150
T_9, 75% RDF + 25% RDN through vermicompost + NPK consortium (seed treatment)	873	882	877	1,908	1,916	1,912
T_{10}, 75% RDF + 25% RDN through FYM + NPK consortium (soil application)	1,080	1,082	1,081	2,361	2,379	2,370
T_{11}, 75% RDF + 25% RDN through castor cake + NPK consortium (soil application)	970	976	973	2,096	2,103	2,100
T_{12}, 75% RDF + 25% RDN through vermicompost + NPK consortium (soil application)	969	975	972	2,030	2,038	2,034
SEm±						
Y			15.39			29.95
T	54.06	52.55	37.70	105.77	101.68	73.36
Y × T			53.31			103.75
CD (P=0.05)						
Y			NS			NS
T	159	154	107	310	298	209
Y × T			NS			NS
CV %	9.91	9.47	9.69	8.95	8.57	8.76

RDF, Recommended dose of fertilizer; RDN, recommended dose of nitrogen; NS, non-significant

Table 3. Effect of integrated nutrient management on protein content of maize and its residual effect on oil content of succeeding sesame

Treatment	Protein content (%) of maize			Oil content (%) of succeeding sesame		
	2019–20	2020–21	Pooled	2020	2021	Pooled
T_1, 100% RDF	8.67	8.65	8.66	45.14	45.96	45.55
T_2, 100% RDF + NPK consortium (seed treatment)	9.00	9.13	9.06	45.96	46.03	46.00
T_3, 100% RDF + NPK consortium (soil application)	10.19	10.23	10.21	46.22	45.71	45.97
T_4, 75% RDF + 25% RDN through FYM	7.17	7.23	7.20	47.34	47.39	47.37
T_5, 75% RDF + 25% RDN through castor cake	8.08	8.09	8.09	46.52	46.61	46.57
T_6, 75% RDF + 25% RDN through vermicompost	8.33	8.23	8.28	45.50	46.63	46.06
T_7, 75% RDF + 25% RDN through FYM + NPK consortium (seed treatment)	7.56	7.75	7.66	47.18	47.61	47.39
T_8, 75% RDF + 25% RDN through castor cake + NPK consortium, (seed treatment)	9.94	9.90	9.92	46.83	47.18	47.00
T_9, 75% RDF + 25% RDN through vermicompost + NPK consortium (seed treatment)	10.54	10.56	10.55	47.05	46.48	46.76
T_{10}, 75% RDF + 25% RDN through FYM + NPK consortium (soil application)	9.69	9.58	9.64	47.61	47.93	47.77
T_{11}, 75% RDF + 25% RDN through castor cake + NPK consortium (soil application)	10.75	10.79	10.77	47.04	47.19	47.12
T_{12}, 75% RDF + 25% RDN through vermicompost + NPK consortium (soil application)	11.15	11.21	11.18	46.70	47.02	46.86
SEm±						
Y			0.112			0.42
T	0.388	0.390	0.275	1.48	1.39	1.02
Y × T			0.389			1.44
CD (P=0.05)						
Y			NS			NS
T	1.14	1.14	0.78	NS	NS	NS
Y × T			NS			NS
CV %	7.26	7.28	7.27	5.52	5.14	5.33

RDF, Recommended dose of fertilizer; RDN, recommended dose of nitrogen; NS, non-significant

availability of nitrogen throughout the growth period under treatment T_{12}. Similar results were obtained by Manjhi *et al*. (2016), Lakum (2017) and Chhetri and Sinha (2018).

Quality of succeeding summer sesame

Higher oil content of sesame was observed under application of 75% RDF + 25% RDN through FYM + NPK consortium (soil application) (T_{10}) during 2020 (47.61%), 2021 (47.93%) and when pooled (47.77%) (Table 3).

On the basis of the present findings, it can be concluded that the application of 75% RDF + 25% RDN through vermicompost + NPK consortium (soil application) resulted in higher yield (grain and strover yield) and protein content of maize crop. In succeeding sesame crop, residual effect of 75% RDF + 25% RDN through FYM + NPK consortium (Soil application) along with 50% RDF (50 : 25 : 00 N : P : K kg/ha) ensued in higher yield (grain and stalk yield) and oil content in grain of sesame.

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