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Effect of integrated use of inorganic fertilisers, organic manure and biofertilizers on quality of maize

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Abstract
A field experiment was conducted at Agricultural College, Bapatla during the *rabi* season of 2020 in sandy loam soil. The objective of the research was to know the influence of different levels of inorganic nitrogen fertilization in combination with FYM and biofertilizers on quality, nutrient content of maize. The maize variety Pioneer - 3396 was taken as test crop. The study was carried out with eight treatments *viz*., T_1: Control, T_2: 100% RDN, T_3: 125% RDN, T_4: 75% RDN + 25% N through FYM, T_5: 75% RDN + 25% N through FYM + Biofertilizers, T_6: 100% RDN + 25% N through FYM, T_7: 100% RDN + Biofertilizers and T_8: 100% RDN + 25% N through FYM + Biofertilizers. The recommended dose of inorganic fertilizers were followed as 200:60:50 N-P_2O_5-K_2O kg ha^{-1} in all treatments except control treatment. The FYM @ 10 t/ha was taken as the organic component. The biofertilizers (*Azospirillum*, Phosphorus Solubilizing Bacteria (*Pseudomonas* sp.)) were applied @ 5 kg/ha each. The study revealed that there was a significant influence of INM on nutrient content and quality of maize. Among all the treatments imposed, the treatment which received 100% RDN + 25% N through FYM + Biofertilizers (T_8) performed best and it was found on par with the treatments 100% RDN + 25% N through FYM (T_6) and 125% RDN (T_3) in most cases. Among all the treatments the control (T_1) has recorded the least values for all parameters assessed.

Keywords: Inorganic fertilizers, organic manures, quality, maize

Introduction
Maize (*Zea mays* L.) is one of the most versatile emerging crops, having wide adaptability under varied agro-climatic conditions. Globally, maize is known as the "queen of cereals" because of its high genetic yield potential and photo-thermo insensitive character. It contributes 36% (782 metric tonnes) of the global grain production. The USA is the largest producer of maize, contributing nearly 34% of the total production in the world. World's maize production forecast has increased from 1,1186 lakh tonnes (2019-20) to 11578 lakh tonnes (2020-21). Global demand for maize is expected to hike over 16% by 2027. The overall productivity of maize in India is 2,583 kg ha^{-1}, which is lower when compared to other maize-producing countries. Maize is an extremely nutrient-exhaustive crop; continuous use of inorganic fertilizers in maize production may cause nutrient imbalances, lower the nutrient use efficiency, and also lead to low quality produce. There is also enough research evidence to suggest that prolonged use of inorganic fertilizers causes deterioration of soil properties and a drastic fall in soil fertility. Hence, there is an immense need to improve the maize productivity in the India by adopting sustainable management practices. In this scenario, sustainable agricultural efficiency can be achieved through the insightful utilisation of Integrated Nutrient Management (INM) practice, which can be characterised as the art of sensible utilisation of natural and inorganic sources of nutrients to crop fields for maintaining soil productivity. Since nitrogen has a key role in plant metabolism, the effect of different sources and amounts of nitrogen fertilization as well as other nutrients on the quality and macronutrient content of maize is presented in this paper.

Materials and Methods
Plant samples of maize were collected from five randomly selected plants at harvest stage. The samples were first dried in shade and then in a hot air oven at 65 °C. The plant samples were ground in a wiley mill and stored in labeled small brown paper bags for analysis. The kernel samples were also processed and stored in similar fashion. The nitrogen content in plant samples was estimated by micro Kjeldahl method (Piper, 1966) [13]. Di-acid extract was

prepared as per the method outlined by Jackson (1973) [6]. It was carried out using a 9:4 mixture of HNO_3: $HClO_4$. The pre digestion of the samples were done by using 10 ml of HNO_3 g^{-1} sample.This di-acid extract was used to determine phosphorus and potassium content in the plant and grain samples. Phosphorus and Potassium in the di-acid extract of plant samples was estimated by Vanado Molybdo phosphoric yellow color method as described by Jackson (1973) [6]. Sulphur in the di-acid extract of plant samples was estimated by the turbidimetric method by using a spectrophotometer at 420 nm (Chesnin and Yien, 1950)[3]. The nitrogen content from the grain samples was estimated by Microkjeldahl method (Wall *et al.* 1975) [19] and N content was multiplied by 6.25 to get percent crude protein. Total carbohydrate content was estimated by using the anthrone reagent (Hodge and Hofreiter, 1962) [5] as given by Thimmaiah (1999) [17]. The data on various parameters was statistically analysed by using Fisher's method of analysis of variance as suggested by (Panse and Sukhatme, 1978) [10] for the randomized block design adopted in this study. Statistical significance was tested by applying F-test at 0.05 level of probability. Critical differences at 0.05 levels were worked out for the effects, which were significant.

Table 1: Effect of INM on carbohydrate and protein content (%) of maize

Treatments	Carbohydrate content (%)	Protein content (%)
T_1: Control	64.23	10.11
T_2: 100% RDN	65.68	11.41
T_3: 125% RDN	66.81	12.60
: 75% RDN + 25% N through FYM	65.29	11.06
75% RDN + 25% N through FYM + Biofertilizers	65.67	11.56
100% RDN + 25% N through FYM	67.19	12.98
T_7: 100% RDN + Biofertilizers	66.26	12.04
100% RDN + 25% N through FYM + Biofertilizers	67.54	13.23
S.Em (±)	0.43	0.40
CD (P=0.05)	1.26	1.18
CV (%)	7.89	7.06

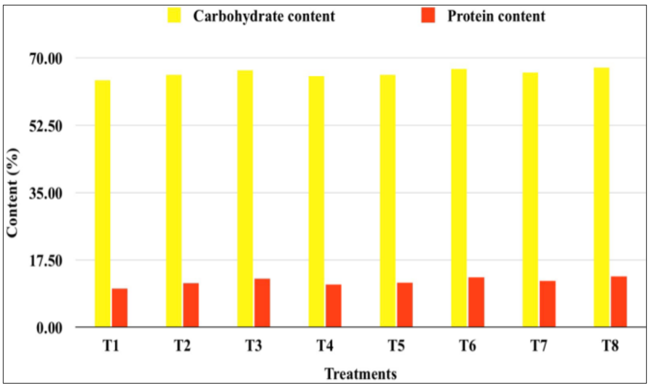

Fig 1: Effect of INM on carbohydrate and protein content (%) of maize

Results and Discussion

Protein content

The protein content of maize in table no.1 was significantly influenced by application of organic and inorganic sources of nutrients. The highest protein content (13.23) was observed in the treatment 100% RDN + 25% N through FYM + Biofertilizers (T_8) and it was found on par with the treatments 100% RDN + 25% N through FYM (T_6), 125% RDN (T_3). This might be due to combined application of inorganic, organic and biofertilizers which was associated with higher N availability in soil and thereby greater N uptake by crop. Nitrogen, being the principal constituent of protein, might have substantially increased the protein content of the kernel due to increased uptake of nitrogen under higher availability. The effective translocation of photosynthates from source to sink might have further improved the protein in kernels. Similar trend was also reported by (Yadav *et al.*, 2016) [20]. Role and efficiency of nitrogen fertilizers in improving maize protein content was also reported by (Ochieng *et al.*, 2021) [9]

The lowest values of protein content was observed in absolute control (T_1). Among the treatments that received inorganic sources of nutrients, the treatments 125% RDN (125% RDN (T_3) performed better than 100% RDN (T_2) due to higher supply of N. Also the performance of 125% RDN (T_3) was comparability higher than rest of the treatments but not than the treatment which received 100% RDN + 25% N through FYM + Biofertilizers (T_8) depicting the importance of integrated method of nutrition.

Carbohydrate content

The data pertaining to carbohydrate content of the maize kernel presented in the table no. 1 indicated that there was a significant difference among the treatments. The highest carbohydrate content (67.54) was observed in the treatment which received inorganic and organic sources combination of 100% RDN + 25% N through FYM + Biofertilizers (T_8) and it was found on par with the treatments 100% RDN + 25% N through FYM (T_6), 125% RDN (T_3) whereas the lowest (64.23) was observed in absolute control (T_1).

This might be due to the effect of FYM, which tended to favour higher accumulation of carbohydrate content of maize which might be the function of greater conversion of carbon dioxide to organic compounds and carbon dioxide fixation subsequently a greater carbon dioxide assimilation. The results obtained were in close agreement with the findings of (Singaram and Kamalakumari, 1995) [16]. Role of FYM in improving maize carbohydrate content was also reported by (Chauhan *et al.*, 2020) [2]. Further it was observed that biofertilizers receiving treatments were additionally benefited over the other treatments and this might be due to effective regulation of the metabolic functions leading to better synthesis of proximate constituents and subsequent improvement in the quality of the produce. Role of biofertilizers in increasing the quality of grain was also reported by (Gendy *et al.*, 2013) [4]. Role of *Azospirillum* in accumulating amino acids and sugars in maize was also confirmed by (Bano *et al*, 2013) [1]. The treatments 100% RDN (T_2) is higher than the control treatment depicting the role of inorganic sources of fertilization in plant metabolism. And hence the treatment 125% RDN (T_3) was found on a par with the integrated combination of 100% RDN + 25% N through FYM + Biofertilizers (T_8).

Table 2: Effect of INM on Nitrogen content (%) of maize

Treatments	Knee high	Tasseling	Grain	Stover
T_1: Control	1.72	1.48	1.20	0.53
T_2: 100% RDN	1.98	1.78	1.36	0.61
T_3: 125% RDN	2.29	2.01	1.58	0.65
75% RDN + 25% N through FYM	1.82	1.59	1.22	0.56
75% RDN + 25% N through FYM + Biofertilizers	1.86	1.64	1.28	0.58
00% RDN + 25% N through FYM	2.16	1.94	1.51	0.64
T_7: 100% RDN + Biofertilizers	2.04	1.81	1.38	0.62
100% RDN + 25% N through FYM + Biofertilizers	2.32	2.04	1.59	0.67
S.Em (±)	0.09	0.08	0.06	0.01
CD (P=0.05)	0.24	0.21	0.15	0.04
CV (%)	8.57	7.72	7.11	7.53

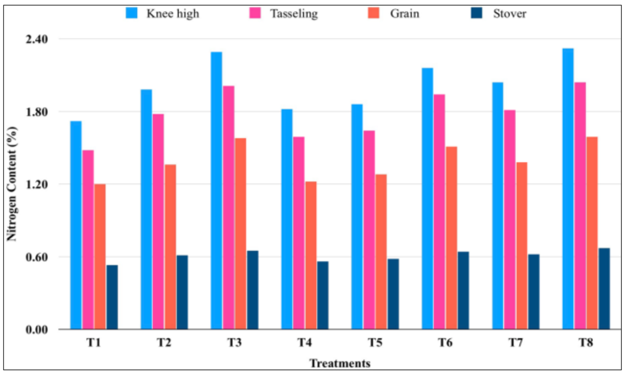

Fig 2: Effect of INM on Nitrogen content (%) of maize

Nitrogen content

The nitrogen content was higher at harvest stage (grain and stover) compared to knee high and tasseling stages. The treatments 125% RDN (T_3), 100% RDN + 25% N through FYM + Biofertilizers (T_8) and 100% RDN + 25% N through FYM (T_6) were found on par during all the three stages considered. The highest N concentration was recorded in sole inorganic treatment of 125% RDN (T_3) at knee height stage. However at tasseling and harvest stage, 125% RDN (T_3) has not recorded highest N concentration than that of 100% RDN + 25% N through FYM + Biofertilizers (T_8) which might be due to the fact that inorganic component provided nutrients during early stages of the crop growth while the organic component provided nutrients at the later stage of the crop development as it takes some time for the mineralization. Similar results were also reported by (Prabhavathi *et al*, 2021; Sarwar *et al*, 2012; Singh *et al*, 2011) [12, 14, 15].

At tasseling stage, the treatment 100% RDN + 25% N through FYM + Biofertilizers (T_8) has performed well among all treatments in which the highest nitrogen concentration of (2.04%) was recorded and it was significant among rest of the treatments due to balanced supply of nutrients by FYM and the benefits of biofertilizers in plant metabolism and also due to receiving of highest dosage of inorganic N than any other integrated treatments. At all stages the treatments which received 75% RDN had a comparably lower effect on plant N concentration than that of treatments receiving full dose of RDN (Mishra *et al*, 2019) [8].

The higher N content in treatments which are supplied with *Azospirillum* might be because of an increase in NUE (Nitrogen Use Efficiency) Zeffa *et al*., (2019) [21]. Also the increase in efficiency of *Azospirillum* with increase in N rates up to 200 kg/ha was also reported by (Galindo *et al*., 2019) [3]

The better performance of 75% RDN + 25% N through FYM + Biofertilizers (T_5) than 75% RDN + 25% N through FYM (T_4) might be because of additional effects of *Azospirillum*. The lowest N concentration at all stages of the crop growth was recorded in control treatment with no nitrogen application which has resulted in lowest plant nitrogen indicating the short supply of nitrogen.

Table 3: Effect of INM on Phosphorus content (%) of maize

Treatments	Knee high	Tasseling	Grain	Stover
T_1: Control	0.22	0.11	0.13	0.01
T_2: 100% RDN	0.23	0.12	0.16	0.02
T_3: 125% RDN	0.24	0.13	0.16	0.03
T_4: 75% RDN + 25% N through FYM	0.25	0.14	0.19	0.05
75% RDN + 25% N through FYM + Biofertilizers	0.31	0.18	0.21	0.09
T_6:100% RDN + 25% N through FYM	0.26	0.15	0.18	0.05
T_7: 100% RDN + Biofertilizers	0.30	0.15	0.20	0.08
100% RDN + 25% N through FYM + Biofertilizers	0.32	0.19	0.23	0.14
S.Em (±)	0.01	0.01	0.01	0.03
CD (P=0.05)	0.05	0.04	0.03	0.07
CV (%)	8.21	8.24	8.62	7.63

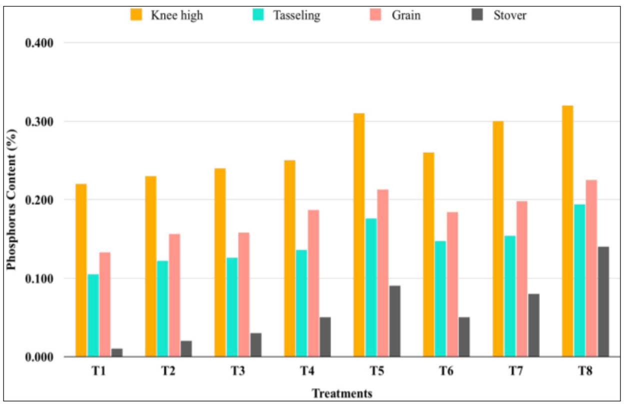

Fig 3: Effect of INM on Phosphorus content (%) of maize

Table 4: Effect of INM on Potassium content (%) of maize

Treatments	Knee high	Tasseling	Grain	Stover
T_1: Control	2.22	1.92	0.23	1.81
T_2: 100% RDN	2.36	2.08	0.24	1.86
T_3: 125% RDN	2.41	2.16	0.25	1.88
T_4: 75% RDN + 25% N through FYM	2.51	2.34	0.28	2.11
T_5: 75% RDN + 25% N through FYM + Biofertilizers	2.55	2.41	0.31	2.20
T_6: 100% RDN + 25% N through FYM	2.52	2.39	0.29	2.30
T_7: 100% RDN + Biofertilizers	2.43	2.18	0.26	1.93
T_8: 100% RDN + 25% N through FYM + Biofertilizers	2.65	2.43	0.32	2.24
SEm (±)	0.05	0.41	0.02	0.09
CD (P=0.05)	0.16	0.21	0.05	0.24
CV (%)	8.11	7.99	8.53	7.15

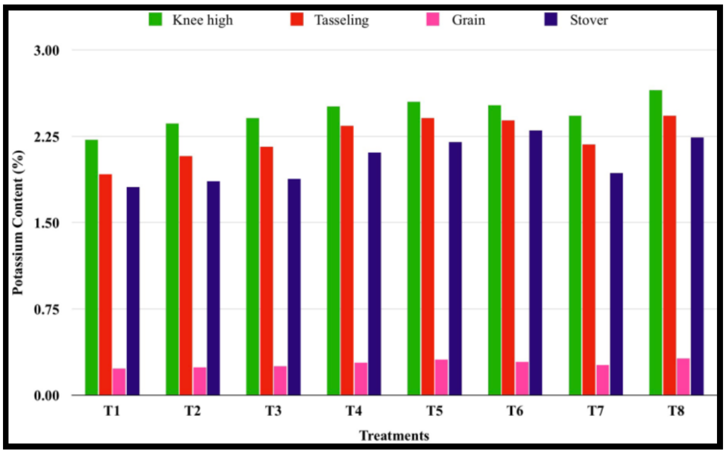

Fig 4: Effect of INM on Potassium content (%) of maize

Table 5: Effect of INM on Sulphur content (%) of maize

Treatments	Knee high	Tasseling	Grain	Stover
T_1: Control	0.14	0.11	0.20	0.04
T_2: 100% RDN	0.15	0.13	0.22	0.05
T_3: 125% RDN	0.17	0.14	0.24	0.05
T_4: 75% RDN + 25% N through FYM	0.19	0.17	0.27	0.06
T_5: 75% RDN + 25% N through FYM + Biofertilizers	0.20	0.16	0.28	0.07
T_6: 100% RDN + 25% N through FYM	0.19	0.18	0.27	0.05
T_7: 100% RDN + Biofertilizers	0.18	0.15	0.23	0.05
T_8: 100% RDN + 25% N through FYM + Biofertilizers	0.21	0.19	0.30	0.07
SEm (±)	0.06	0.04	0.03	0.02
CD (P=0.05)	NS	NS	NS	NS
CV (%)	9.60	8.62	8.91	8.24

Phosphorus content

The data pertaining to the phosphorus content (%) in maize was presented in table no.3. The ability of a plant to take up phosphorus largely depends on its root distribution relative to phosphorus availability in soil as it is very immobile in the soil and possesses low diffusion coefficient. The data indicated that phosphorus concentration of plants was significantly influenced by the imposed treatments at all stages of crop growth. Among all the treatments the treatment 100% RDN + 25% N through FYM + Biofertilizers (T_8) recorded the highest available phosphorus concentration in all stages which was on par with treatment 75% RDN + 25% N through FYM + Biofertilizers (T_5) and 100% RDN + Biofertilizers (T_7) at knee high, tasseling and harvest stage due to synergetic effect between N and P concentrations in the plant.

Application of organic manures might have been resulted in a favourable soil environment, which in turn enhanced activity of roots resulting in greater absorption of water and nutrients from lower layers. These findings are in conformity with (Jadhav *et al*. 2018) [7] who have reported an increase in root length due to applying of organic and inorganic fertilizers. (Thenmozhi and Paulraj, 2009) [18]. Moreover, FYM produces organic acids that liberate adsorbed phosphorus from iron and aluminum oxides thereby increasing its availability to plants. Similar results were also reported by (Pathak *et al.*, 2005) [11]. The lowest of all was recorded in control treatment at knee height tasseling and harvest stages. Due to the addition of PSB in the treatments 75% RDN + 25% N through FYM + Biofertilizers (T_5), 100% RDN + Biofertilizers (T_7), 100% RDN + 25% N through FYM + Biofertilizers (T_8) might have increased P availability in the soil of the respect to treatments due to the solubilizing effect which must have increased the absorption by plant roots and thereby the uptake by the plant have reflected in the increase in P concentration of the plant.

Potassium content

The data regarding the potassium content in maize presented in table no.4, reveals that there was a significant effect due to all the treatments imposed. Higher potassium content was observed at harvest stage compared to knee high and tasseling stages.

At all stages, the treatment which recieved 100% RDN + 25% N through FYM + Biofertilizers (T_8) has recorded higher content of potassium which was found to be on par with 75% RDN + 25% N through FYM (T_4), 75% RDN + 25% N through FYM + Biofertilizers (T_5) and 100% RDN + 25% N through FYM (T_6) treatments at all stages of crop growth. The lowest (2.22 per cent, 1.92 per cent, 0.23 per cent, 1.81 per cent) potassium content was observed in absolute control (T_1) in knee high, tasseling stages and grain, stover contents at harvest stage respectively. The higher buildup of available K in the soil treated with 100% RDN + 25% N through FYM + Biofertilizers (T_8) compared to sole 100% RDN (T_2) treated soil might have influenced the K absorption by plant (Kumar *et al.*, 2020) [9]. Also the additional effect of improvement in plant nutrition status might be due to organic component and also due to inorganic dose which in combination gave better result in integrated treatments.

Sulphur Content

The data pertaining to sulphur content in maize presented in table no.5, revealed that there were no significant differences in plant sulphur conten due to the different treatments imposed. Among various treatments 100% RDN + 25% N through FYM + Biofertilizers (T_8) has recorded numerically higher sulphur content (0.21 per cent 0.19 per cent, 0.30 per cent, 0.072 per cent) in knee high, tasseling, grain and stover respectively. Among all the treatments the lowest sulphur content was recorded in control with no fertilization (control). However the FYM treated plots has recorded slightly higher contents when compared to sole inorganic fertilizer treatment plots. However some traces of sulphur might have got added to soil through SSP, which must have absorbed by plant.

Conclusion

In a nutshell, the treatments which received a total of 125% nitrogen through integration of inorganic and organic sources of nutrients, had performed comparatively better. Among all the treatments imposed, the highest protein (13.23%) and carbohydrate content (67.54) in maize kernel and nitrogen content in plant at all stages was observed in the integrated treatment which received 100% RDN + 25% N through FYM + Biofertilizers (T_8) and it was found to be on par with the treatments 100% RDN + 25% N through FYM (T_6), 125% RDN (T_3). Regarding the phosphorus content of maize, the treatments that received additionally with PSB along with FYM has performed better. Whereas in case of potassium content of maize, the treatments supplied additionally with FYM showed a better performance. There was found a non-significant effect regarding the sulphur content of maize. The control (no fertilizers) treatment recorded the least values of all parameters assessed. Hence it can be concluded that, supplementing balanced and eco-friendly inputs like organic manure, biofertilizers, along with recommended dose of inorganic fertilizers would be a viable option to improve carbohydrate, protein and macronutrients content in maize in a sustainable way.

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