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Effect of Longterm Fertilization and Manuring on Nutritional Quality of Maize Grain

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A study on Effect of long term fertilization and manuring on soil quality and nutritional quality of maize (*Zea mays* L.) under finger millet-maize cropping system was carried out in LTFE plots which has been in progress since 1986 at UAS, GKVK, Bengaluru. Eleven treatments were laid in

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randomized block design with three replications. The hybrid maize was grown in LTFE plots during *Rabi* 2021-2022 (35th crop cycle) and qualities of grain were assessed. Application of 100 per cent NPK+ FYM+ lime recorded significantly higher grain quality *viz.,* geometric mean diameter (7.63 mm), bulk density (791 kg m^{-3}), 1000 grain mass (444.10 g), colour (L*72.91, a*4.68, b*27.48), crude protein (10.35%), ash (1.73%), moisture (8.19%) and crude fibre (1.85%). Inorganic fertilization alone, 100% N, 100% NP and control treatments recorded poor quality grain of maize. The conjoint use of organic manures along with chemical fertilizers in balanced form is essential to maintain good soil quality and for quality maize production.

Keywords: Fertilization; maize; carbon accumulation; soil quality.

1. INTRODUCTION

Maize (*Zea mays* L.) belongs to the family, Poaceae, has wider adaptability under varied agro-climatic conditions it is the most versatile emerging crop that has been successfully cultivated in diverse seasons and ecologies for various purposes. It is recognized globally as queen of cereals, due to its highest yield potential among cereals. However, maize has greater potential than rice and wheat to provide gainful employment and doubling farmers income.

“Maize consists of three main parts- fiber-rich bran or husk, oil-rich germs,and starchy endosperm. Normal maize grain under Indian conditions has an average 14.9 percent moisture content, 11.1 percent protein, 3.6 percent fat, 2.7 percent fibre, 66.2 percent other carbohydrates and 1.5 percent minerals” (National Institute of Nutrition, 2002). “Every part of the maize plant has economic value. Grains, leaves, stalks, tassels , and cobs can all be used in the production of a variety of food and non-food products. It is widely processed into various types of products such as starch, flour, cornmeal, grits, tortillas, snacks ,and breakfast cereals. Maize flour is used to make chapatis or flatbreads” [1,2].

Maize grain is a rich source of carbohydrates which possesses diverse usage as an industrial raw material. Corn oil is also gaining popularity due to its desirable fatty acid composition; rich source of linoleic acid (18:2), oleic acid (18:1), palmitic acid (16:2), stearic acid (18:0), small amounts of linolenic acid (18:3), and traces of other fatty acids. Compared with other edible oils, maize oil has the advantage of having a low proportion of monosaturated fatty acids. This means that if you meet all the energy requirements from maize, you need about nearly 600 g per day. Starch is composed of amylase and amylopectin and variants of amylose and amylopectin have been reported up to a maximum of about 80 and 100 percent, respectively.

In the current Indian agricultural scenario, sustainability is an issue, and food security as well as nutritional quality is the need of the hour. This challenge becomes even more difficult as the population increases and agricultural land becomes narrower and smaller. In such a situation, it is essential to add fertilizers, manures, amendments, etc. according to the requirements of the soil and crops.

Long term use of inorganic fertilizers with FYM is an excellent management system for soil organic carbon accumulation, sustaining yield improving soil quality, and increasing crop production. Long term fertilizer experiments (LTFEs) are the experiments conducted on the same set of experimental units over a sequence of treatments or crops or both for a better understanding of the effect of nutrient management on crop productivity, soil health, and economics. Long term fertilizer experiments play an important role in understanding the complex interactions involving crops, soils, climate, and management practices and their influence on crop production and soil quality. It provides valuable information on agricultural sustainability, environmental quality and nutrient uptake, and physio-chemical changes of soil. The primary objective of any LTFE study is to assess changes in soil quality based on physical, chemical, and biological parameters of soil on the continuous use of manuring and fertilizer application on long term basis in a given cropping systems.

Modern agricultural systems have traditionally focused primarily on increasing productivity on the one hand and the nutritional quality of the produce on the other hand. Maize is a staple food for human beings and feeds for animals. Human and animal health depends on the quality of food. Food quality inturn depends on the soil quality. The Nutritional quality of grains is a highly complex trait. This is the collective result of nutritional, physiological, biochemical factors [3]. In addition to productivity, balanced nutrition also influences the nutritional quality of produce. Keeping in the view, its importance of soil health to crop production and human and animal nutrition, need to produce maize grain of superior nutritional quality is undeniable.

2. MATERIALS AND METHODS

2.1 Experimental Location and Climate

The present investigation was carried out during 30th November 2021- April 2022 in an ongoing long term fertilizer experiment started in 1986 at the "E-18" block, Zonal Agricultural Research Station of GKVK campus of the University of Agricultural Sciences, Bengaluru. In this long-term fertilizer experiment (LTFE), the 11 treatments listed earlier were imposed every year for the last 35 years. The research station is located at an altitude of 930 meters above MSL, latitude of 13° north, longitude of 77° 33" east.

2.2 Normal Climatic Condition

The normal mean annual rainfall of the station (1972-2021) is 921.0 mm. The Major portion of rainfall was received from May to October with two peaks, the first peak in the month of May (107.6 mm) and the second peak in September to October (195.6 mm). The normal mean monthly maximum air temperature ranged between 26.3°C to 33.8°C and the monthly minimum air temperature ranged between 14°C to 20.5°C. The highest monthly temperature was recorded during (33.8°C) and it was followed by May and March (33°C and 32.7°C, respectively). The mean monthly relative humidity ranged from 77 percent in March to 89 percent in August and September. The mean monthly bright sunshine hours were maximum during February (9.60) followed by March (9.30). The mean monthly wind speed was maximum during June (11.9 km hr^{-1}) followed by July (11.6 km hr^{-1}).

2.3 Actual Weather Conditions During the Cropping Season

Actual rainfall was received during the cropping season from November 2021 to April 2022 was 76.5 mm. The highest rainfall was obtained during November month (367.4 mm) and no rainfall was received till March 2022. The actual rainfall was lower than normal in December and January and higher in November. The average maximum air temperature also ranged from 33.5°C to 27.5°C. The average minimum air temperature ranged from 25.6°C to 26.5°C. The mean maximum temperature was lower in November and December (2021), while the same as normal in January, February, March and April (2022). The mean monthly relative humidity ranged from 87 percent in November (2021) to 57.5 percent in April (2022). The average relative humidity was more than normal in all the months of the cropping period. The mean bright sunshine hours ranged from 2.0 hours in November (2021) to 7.8 hours in April (2022). The mean wind speed ranged from 4.5 km hr^{-1} in November (2021) to 5.7 km hr^{-1} in April (2022). The soil of the study site has been classified as Typic Hapludalf and the texture is silty loam. The soil properties at the initiation of the experiment in 1972 and before of sowing of maize have been depicted in Table 1.

2.4 Soil Characteristics, Treatments and Crop

The soil of the study area was sandy loam texture with red colour and was classified as Isohyperthermic family of the sub group typic kandicpaleustalfs as per the Taxonomic System of Soil Classification. The soil properties at the initiation of the experiment in 1986 have been depicted in Table 1. The experiment consists of eleven treatments which are replicated three times in a Randomized Block Design and the plot size was 144 m2 (16 m * 9 m). The treatments were 50% NPK; 100% NPK; 150% NPK; 100% NPK + Hand Weeding (HW); 100% NPK + Lime; 100% NP; 100% N; 100% NPK + FYM; 100% NPK (-S); 100% NPK + FYM + lime; control. "100% NPK corresponding to 100 kg nitrogen (N), 33 kg phosphorus (P), and 82 kg potassium (K) ha^{-1} for maize. Urea, single super phosphate, and muriate of potash were used to supply N, P, and K, respectively, except in 100% NPK(-S), diammonium phosphate was used to supply P" [4].

"Maize (MAH 14-5) was sown on 30th November 2021 in 60 cm × 30 cm spacing. One presowing irrigation was given and thereafter, crop water requirement was met through rainfall. The FYM, containing 1.01% N, 0.26% P, and 0.40% K on a dry weight basis, was added @ 15 t ha^{-1} on a dry weight basis. Lime @ 500 kg ha^{-1} was applied at

Table 1. Initial soil characteristics of the experimental site, GKVK, Bangalore

Subgroup	:	*Kandi Paleustalfs*
Series	:	Vijayapura
Taxonomy	:	Fine, mixed *Isohyperthermic Kandicpaleustalfs*
Physical properties		
Bulk density (Mg m^{-3})		1.51
Max. water holding capacity (%)		30.00
Field capacity moisture (%)		22.70
Wilting point moisture (%)		8.40
Pore space (%)		40.10
Infiltration rate(cmh^{-1})		4.20
Water stable aggregates (%) (2 mm)		23.70
Chemical properties		
pH (1:2.5, soil: water suspension)		6.17
Electrical conductivity (EC, dS m^{-1})		0.059
CEC [cmol (p+) kg^{-1}]		12.20
Organic carbon (g kg^{-1})		4.6
Available nitrogen (kg ha^{-1})		256.7
Available phosphorus (kg ha^{-1})		34.3
Available potassium (kg ha^{-1})		123.1
Total calcium (%)		0.46
Total magnesium (%)		0.35
Total sulphur (%)		0.028
Exchangeable calcium (kg ha^{-1})		1456.00
Exchangeable magnesium (kg ha^{-1})		415.20
Available sulphur (kg ha^{-1})		20.34
DTPA extractable micronutrients (mg kg-1)		
Zinc		2.34
Copper		2.30
Manganese		108.40
Iron		5.22

the time of sowing in 100 percent NPK + lime, 100 percent NPK + FYM + lime treatment. The full doses of P and K and half dose of N were applied at the time of sowing and the remaining half of N was top-dressed in two equal splits at knee-high and pre-tasseling stages. Tembotrione was sprayed as early post-emergence @143 ml ha^{-1} and Atrazine was sprayed as pre-emergence herbicide @ 1.25 kg ha^{-1}, except in 100% NPK + HW in which weeds were removed manually and incorporated in the same plot. The crop was harvested manually on 14th April 2022" [4].

2.5 Quality Analysis

Plant samples and grain samples from each treatment were collected at harvest, oven-dried, powdered, and used for the analysis of quality parameters. All the oven-dried samples were grounded in a Willey mill using a 2 mm sieve for crude protein and ash content.

2.5.1 Different physical properties of maize grain quality were as follows

The physical characteristics like size geometric mean diametre, sphericity index, bulk density, true density, 1000 grams mass and color of the maize grains were determined.

2.5.1.1 Geometric mean diameter

Size is the geometric mean diameter was calculated by using the expression [5]

Geometric mean diameter, $D_m = [LBT]^{1/3}$

Where,

L = longest intercept (Length)
B = longest intercept normal to L (Width) and
T = longest intercept normal to L and B (Thickness)

2.5.1.2 Sphericity

The sphericity is used to describe the shape of the grain. It is a measure of how closely the shape of an object resembles that of a perfect sphere. The sphericity was calculated using the relationship [5];

$$\text{Sphericity, } \Phi = \frac{\text{Dm}}{\text{L}}$$

Dm = Geometric mean diameter and
L = Longest intercept (Length)

2.5.1.3 Bulk density

Bulk density was determined by using a container of known volume. The sample was taken into the container and weighed. The bulk density was determined using the formula given below [6]. Average of three replications was taken as the bulk density.

$$\text{Bulk density}, \frac{\text{kg}}{\text{m}^3} = \frac{\text{Weight of grains (kg)}}{\text{Volume of grains including pore space (m}^3)}$$

2.5.1.4 True density

True density was determined by the toluene displacement method. 50 mL of toluene was taken in a measuring jar. A known weight of the grain sample was poured into the measuring jar and a rise in the toluene level was recorded. The true density of the grain was calculated by using the following formula [6].

$$\text{True density, kg/m}^3 = \frac{\text{Weight of grains (kg)}}{\text{Volume of grains excluding voids (m}^3)}$$

2.5.1.5 1000 grain weight

The grain samples from the produce of each plot were taken. From this sample, a thousand grains were randomly counted, and weighed and the weight was recorded as 1000 grain weight in grams.

2.5.1.6 Colour

Tristimulus color measurement of the sample was made using spectrophotometer (Make: Konica Minolta Instruments, Osaka, Japan; Model-CM5). The color of the sample was measured in CIELAB (L*a* b*) coordinate system where L* indicate lightness of the sample; a* value indicate greenness (-) or redness (+) of the sample; and b* value indicate blueness (-) or yellowness (+) of the sample. Before testing the sample, the instrument was calibrated with standard black and white tiles supplied with the instrument. Three readings were taken for a sample and the mean value was recorded.

2.5.2 Different chemical properties of maize grain quality were as follows

The grain samples were collected after the harvest of maize crop and then dried to constant weight at 50± 1 °C in hot air oven. “Maize grain samples were digested in a di-acid mixture (HNO_3:$HClO_4$ in 9:4 ratio) and the aqueous extract was used to determine contents of P with the vanado-molybdophosphoric acid method [7], calcium (Ca) with a flame photometer [7] and magnesium (Mg), Zn, and Fe content with Atomic Absorption Spectrophotometer” [7].

2.5.3 Proximate composition of grains

The standard procedure for proximate analysis by AOAC (2005) was followed to estimate crude protein, ash, crude fat, crude fiber, and total carbohydrate content.

2.5.3.1 Crude protein content (%)

The crude protein (CP) content of dried samples as mentioned in 3.8.1 was calculated by multiplying nitrogen per cent with 6.25 [8].

Crude Protein (%) = Nitrogen (%) x 6.25

2.5.3.2 Ash content

Five grams oven dried sample grounded in Willey mill using 2 mm sieve was de-smoked on a heater and ignited at 550 °C in muffle furnace for 2 hours and cooled in desiccator [9]. The weight of residual ash in previously weighed crucible was taken as total mineral. The mineral content was calculated and expressed in per cent as follows;

$$\text{Total Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample taken for ashing}} \times 100$$

2.5.3.3 Moisture content (%)

A known weight of powdered sample was taken in moisture cups and subjected to 90°C (±5°C) temperature in a well-ventilated hot air oven for 5 to 6 hours and cooled in desiccator. The weight of sample in moisture cups was taken and calculated the moisture percentage by determining the loss in weight of the sample during drying by using the following formula;

$$Moisture\ (\%) = \frac{Original\ weight\ of\ sample\ (g) - Final\ weight\ of\ sample\ (g)}{Original\ weight\ of\ sample\ (g)} \times 100$$

2.5.3.4 Ether extractable fat (%)

The ether extractable fat was estimated by petroleum ether extraction method. The crude fat was calculated by using the formula given by Mahadevan [10] and expressed in percentage.

$$\text{Ether extractable fat (\%)} = \frac{\text{Weight of ether extract}}{\text{Weight of the dried plant sample taken}} \times 100$$

2.5.3.5 Crude fibre content (%)

Crude fibre (CF) content in grain was estimated by acid-alkali digestion method. The crude fibre was calculated by using the formula given by Mahadevan [10] and expressed in percentage.

$$\text{CF (\%)} = \frac{\text{(Weight of sample before ashing)} - \text{(Weight of sample after ashing)}}{\text{Weight of the dried plant sample taken}} \times 100$$

2.5.3.6 Carbohydrate content (%)

Carbohydrate (CHO) content was calculated by using the following formula and expressed in percentage [11].

CHO (%) = 100- [CP (%) + Crude fat (%) + CF (%) + Ash (%) + moisture (%)]

2.6 Statistical Analysis

The data generated from the field and laboratory studies will be subjected to statistical analysis using the technique of analysis of variance for randomized block design for the interpretation of results as described by Gomez and Gomez [12]. The level of significance used in “F” and “t” test was P = 0.05. Critical difference (CD) values were calculated for the P = 0.05 whenever “F” test was found significant.

3. RESULTS AND DISCUSSION

3.1 Effect of Longterm Fertilization and Manuring on Physical Properties of Maize Grain

3.1.1 Geometric mean diameter

The data on geometric mean diametre of maize grain showed significant differences among the treatments due to the long-term application of the fertilizers and are presented in Table 2.

Among the different treatments, a higher geometric diameter mean (7.63 mm) was recorded in the treatment receiving 100 percent NPK + FYM + lime followed by 150 percent (7.83 mm), 100 per cent NPK + FYM (6.95 mm). While lowest geometric mean diameter was recorded in the treatment 100 per cent NP (5.32 mm) followed by 100% N (5.71 mm). Increasing the rate of N application through FYM increased geometric mean diameter and it reached the level of significance in FYM treatment. These results are in agreement with the findings of [13], [14] and [15].

3.1.2 Bulk density

The data on the bulk density of maize showed significant differences among the treatments due to the long-term application of the fertilizers and manures which are presented in Table 2.

Among the different treatments, a higher bulk density (791 kg m^{-3}) was recorded in the treatments receiving 100 percent NPK + FYM + lime followed by 150 percent NPK (780 kg m^{-3}), 100 per cent NPK + FYM (774 kg m^{-3}). While lowest bulk density was recorded in the treatment 100 percent NP (627 kg m^{-3}) followed by 100 percent N (645 kg m^{-3}). This lower content of bulk density was due to low compactness and increased moisture content in the grain *vice versa*. These results are in agreement with the findings of [14,15].

3.1.3 1000 grain mass

The data on 1000 grain weight (gm) of maize showed significant differences among the treatments due to the long-term application of the fertilizers and are presented in Table 2.

Among the different treatments, significantly higher 1000 grain weight (444.10 g) was recorded in the treatments receiving 100 percent NPK + FYM + lime which followed by treatments receiving 100 percent NPK + FYM (392.80), 100 per cent NPK + lime (349.40 g), 150 percent NPK (367.40 g), 100 percent NPK + Hand weeding (338.40 g) and 100 per cent NPK (350.60 g). While the lowest 1000 grain weight was recorded in the treatment 100 per cent NP (152.90 g). Therefore, the application of organic manures improved the quality of wheat grain. Shah et al*.* (2010) reported that thousand-grain weight was significantly increased on applying organic manures along with mineral fertilizers. The large accumulation of proteins and other reserved food in the seed due to which 1000 grain weight was increased may be due to the

Table 2. Effect of long term fertilization and manuring on geometric mean diameter, bulk density 1000 grams mass, Sphericity, True density, Colour of maize grain

Treatments	Geometric mean diameter (mm)	Bulk density (kg m^{-3})	1000 grain mass(g)	Sphericity (%)	True density (kg m^{-3})	Colour		
						L*	a*	b*
T1: 50% NPK	6.01	678	309.20	62.80	1143.85	63.54	3.14	21.11
T2: 100% NPK	6.58	743	350.60	64.83	1199.52	67.38	3.97	22.45
T3: 150% NPK	7.27	780	367.30	67.31	1234.52	70.52	4.34	24.97
T4: 100% NPK + HW	6.56	749	338.40	64.44	1133.86	67.02	3.41	22.59
T5: 100% NPK +Lime	6.80	756	349.40	66.47	1204.32	69.17	4.17	23.78
T6: 100% NP	5.32	627	152.90	65.08	1106.23	62.24	2.94	20.73
T7: 100% N	5.71	645	241.50	66.72	1124.56	60.41	2.75	19.89
T8: 100% NPK +FYM	6.95	774	392.80	66.44	1222.62	70.78	4.38	25.47
T9:100% NPK(S-free)	6.24	683	335.10	63.22	1154.79	64.72	3.37	21.63
T10:100% NPK +FYM +Lime	7.63	791	444.10	68.80	1258.62	72.91	4.68	27.48
T11: Control	5.48	697	313.90	65.52	1136.00	63.05	3.57	21.49
SEm±	**0.23**	**3.62**	**4.66**	**2.38**	**42.65**	**2.41**	**0.13**	**0.81**
CD at 5%	**0.68**	**10.63**	**13.68**	**NS**	**NS**	**7.06**	**0.39**	**2.38**

Table 3. Effect of long term fertilization and manuring on nutrient content of maize grain

Treatments	phosphorus	Calcium	Iron	Copper	Manganese	Magnesium	Zinc
T1: 50% NPK	211	4.8	4.38	0.177	1.84	168	1.24
T2: 100% NPK	233.2	6.1	4.93	0.185	2.26	181	1.50
T3: 150% NPK	256.4	6.66	5.23	0.223	2.40	192	2.04
T4: 100% NPK + HW	261.3	6.74	5.25	0.224	2.52	199	2.09
T5: 100% NPK +Lime	6.80	7.56	5.42	0.226	2.61	202	2.12
T6: 100% NP	197.4	5.6	4.65	0.193	2.18	160	1.49
T7: 100% N	179.5	5.54	4.56	0.176	1.93	154	1.34
T8: 100% NPK +FYM	274.1	7.04	5.58	0.227	2.72	210	2.2
T9:100% NPK(S-free)	231.6	5.84	4.87	0.183	2.23	177	1.47
T10:100% NPK +FYM +Lime	290.6	7.46	5.65	0.229	2.91	234	2.34
T11: Control	207.6	5.01	4.24	0.171	2.11	170	1.41
SEm±	**14.26**	**0.30**	**0.28**	**0.02**	**0.18**	**10.63**	**0.12**
CD at 5%	**41.85**	**0.88**	**0.82**	**0.08**	**0.55**	**31.18**	**1.30**

easy availability of nitrogen and other soil nutrients from fertilizers where 50% N was applied from organic sources and 50% from a mineral source

3.1.4 Sphericity

The data on the sphericity of maize showed non-significant differences among the treatments due to the long-term application of the fertilizers and manures which is presented in Table 2.

Among the different treatments, a higher sphericity (65.08%) was recorded in the treatments receiving 100 percent NPK + FYM + lime followed by 150 percent NPK (67.31 %), 100 percent NPK + FYM (66.44%). While lower sphericity was recorded in the treatment 100 percent NP (65.08%) followed by 100 percent N (66.72%). Increasing the rate of N application through FYM increased Sphericity. These results are in agreement with the findings of [13,14,15].

3.1.5 True density

The true density was non significantly varied from 1106.23 kg m^{-3}in 100 percent NP treatment to 1258.62 kg m^{-3} percent in 100 percent NPK + FYM + lime treatment (Table 2). 100 percent NPK + FYM and 100 per cent NPK + lime treated plots were at par. Comparison among different treatments revealed that true density under 100 per cent NPK treatments was non significantly higher than 100 percent NP and 100 percent N treatment. The addition of FYM along with NPK (T_{10} and T_8) increased the true density of over 100 percent NPK (T_2).

The higher true density of grain under the treatment 100 per cent NPK + FYM + Lime in comparison to 100 percent NPK. This corroborates the findings of [14,15].

3.1.6 Colour

The colour significantly varied from (L*60.41, a*2.75, b*19.89**)** in 100 per cent N treatment to (L*72.91, a*4.68, b*27.48**)** in 100 per cent NPK + FYM + lime treatment (Table 3). 100 percent NPK + FYM and 100 percent NPK + lime treated plots were at par. Comparison among different treatments revealed that colour developed under 100 per cent NP and 100 percent NPK treatments was significantly higher than 100 percent N treatment. The addition of FYM along with NPK (T_{10} and T_8) increased the colour significantly over 100 percent NPK (T_2).

Higher colour of grain under the treatment 100 percent NPK + FYM + Lime in comparison to 100 percent NPK. This corroborates with the findings of Barnwal et al. [14] and Yenge et al. [15]. In plots receiving 100 per cent NPK + FYM + lime, 100 per cent NPK + FYM, 100 per cent NPK + lime the colour of the grain increased to (L*72.91, a*4.68, b*27.48), (L*70.78, a*4.38 b*25.47), (L*69.17, a*4.17, b*23.78) respectively. Application of a graded dose of fertilizers from 50 percent NPK to 150 percent NPK increased the colour of the grain.

3.2 Effect of Longterm Fertilization and Manuring on Nutrient Content of Maize Grain

The continuous application of fertilizers and amendments (FYM or lime) significantly influenced the nutrient content of maize grain (Table 3). “The highest P, Mg, Cu, Mn, Zn and Fe content of maize grain were recorded under 100% NPK + FYM+ lime treatment. However, 100% NPK + lime recorded the highest Ca content”. [4] The addition of FYM or lime with 100% NPK increased the P content of maize grain compared to 100% NPK, respectively. The Ca content of maize grain recorded a significant increase with lime over 100% NPK, the increase being 23.9%. “Significant reduction in P, Ca, Mg, Fe, Cu, Mn and Zn content of maize grain was recorded with imbalanced fertilization (100% NPK (-S) and 100% NP) in comparison to 100% NPK” [4].

3.3 Effect of Long Term Fertilization and Manuring on Proximate Composition Maize Grain

3.3.1 Crude protein

The application of fertilizers and manures had a significant impact on the crude protein content of maize grain (Table 4). The protein content varied from 7.68% in control to 10.35% in 100% NPK + FYM + lime which could be attributed to a better supply of macro and micronutrients as well as other beneficial elements through decomposition of FYM which promotes better nitrogen absorption and transformation in crops [16] and [17]. The gradual increase in NPK doses from 50 to 150 percent resulted in an increase in crude protein content, which could be attributed to increased available nitrogen content [18,19]. (Kumar et al., 2007). “The positive effect of lime treatment on the crude protein content of maize grain could be due to the increased activity of nitrifying bacteria leading to higher availability of N for uptake" [20]. Over 100% NPK, FYM, and lime treated plots recorded significantly higher crude protein content to an extent of 8.5 and 3.4%, respectively, over 100% NPK. The lowest value of protein (8.27%) was noted in the control and it increased to 9.31% due to the application of 100% NPK. Omission of K and S resulted in significantly lower protein content when compared to optimal fertilization of NPK, the reduction being 6.6% and 5.3%, respectively because of the deficiency of S in the soil, leading to poor S uptake and thereby, reduced synthesis of S-containing amino acids [3] and Potassium plays a complex role in nitrogen metabolism and protein synthesis in plants, which is well explained by the low crude protein content under 100% NP treatment. Similar findings were reported in the maize crop by Radulov et al. [21].

3.3.2 Moisture content

From the nutrition point of view, active ingredients are present in the dry matter, hence determination of moisture content is an important factor. It is an index of yield, storability and quality of food.

Moisture content of maize grain (Table 2) ranged from 8.19 percent in 100 percent NPK + FYM + lime to 13.2 percent in control. Application of FYM along with 100 percent NPK (T_8) and application of lime along with recommended NPK (T_5) recorded 22.93 and 17.44 percent less moisture content in maize grains respectively, as compared to 100 percent NPK. 100 percent NPK(-S) and 100 percent NP recorded 17.39 and 17.6 percent higher moisture content than 100 percent NPK.

The lowest moisture content of maize grain in 100 percent NPK + FYM + lime might be attributed to the positive effect of organic manure on the grain quality of maize by improving soil properties which enhanced the root development, water, and nutrient uptake (Habashy and Hemeid, 2011). Moisture content in grain mainly depends on drying efficiency rather than the quality of the soil. Low moisture content in grain, inhibits the growth and multiplication of microorganisms, and thus might be useful in grain storage for a relatively longer period Cisse et al. (2013) and Shobha et al. (2011). On the other hand, due to the high moisture content of grain under control plots, there might be the risk of rot due to the proliferation of moulds *etc*. or self-digestion by enzymes in grain. The presence of high moisture content in grain reduces the shelf-life.

3.3.3 Ash content

"The total amount of minerals present in produce is measured by ash content. The treatments containing NPK fertilisers, FYM, and lime had a higher ash content than the control. The addition of FYM, and lime along with NPK fertilizers increased the availability and uptake of mineral nutrients leading to the higher mineral content of maize grain since there is a positive relationship between available soil nutrients and ash content of maize grain" (Thakur et al*.* 2019). Karforma et al. [22] and Nwite et al. [23] have also reported "the positive effect of organic manure on the ash content of maize". "In comparison, the control, 100%N, 100%NP, and 100% NPK (-S) showed a decrease of 18.1%, 13.1%, and 11.9%, respectively, over 100% NPK. The low ash content of maize grain under control could be attributed to continuous cropping without fertilization resulting in low soil fertility" (et al*.* 2016).

3.3.4 Crude fat

"The fat content ranged from 1.56% in control to 1.80% in 100% NPK þ FYM. The fat content of wheat grain in 100% NPK increased significantly by 12.2% over control. FYM and lime treated plots recorded significantly higher fat content than the other treatments. Application of 100% NPK, 100% NPK +HW recorded 1.75%, 1.74% and 1.75% fat content, respectively, and these treatments were statistically at par with each other. FYM application in conjugation with the recommended dose of fertilizers resulted in better grain quality parameters, indicating the importance of balanced nutrition for quality production of maize. Lower fat content is associated with imbalanced fertiliser addition and in control, which could be a result of lower fat metabolism associated with imbalanced and low nutrition level, while, it is accelerated under a supply of balanced nutrition" (Singh, Ghosh, and Ajay 2003) [24]. "S deficiency in soil due to the continuous use of S-free fertilizers in 100% NPK (-S) may have resulted in lower crude fat content because S is required for fat biosynthesis" [17].

3.3.5 Crude fibre

"Crude fiber is an important constituent of the human diet. Fiber content in wheat grains varied significantly from 1.41% in control to 1.87% in

Table 4. Effect of long term fertilization and manuring on crude protein, moisture and ash content of maize grain

Treatment	Crude protein (%)	Moisture (%)	Ash (%)
T1:50% NPK	8.47 (-7.91)	12.33 (+11.6)	1.47 (-5.44)
T2: 100% NPK	9.14	11.04	1.55
T3: 150% NPK	9.83 (+7.54)	11.06 (+0.18)	1.5 (-3.33)
T4: 100%NPK + HW	9.24 (+1.09)	10.83 (-1.93)	1.63 (+5.16)
T5: 100%NPK +Lime	9.36 (+2.40)	9.40 (-17.44)	1.68 (+8.38)
T6: 100%NP	8.05 (-13.54)	12.99 (+17.6)	1.41(-9.92)
T7: 100% N	8.04 (-13.68)	13.11 (+18.75)	1.32 (-17.42)
T8: 100% NPK +FYM	9.67 (+5.79)	8.98 (-22.93)	1.71(+10.32)
T9: 100%NPK(S-free)	7.97 (-15.01)	12.96 (+17.39)	1.48 (-4.72)
T10: 100%NPK +FYM + Lime	10.35 (+13.23)	8.19 (-20.92)	1.73 (+11.61)
T11: Control	7.68 (-19.01)	13.2 (+29.56)	1.45 (-6.89)
SEm±	**0.32**	**0.41**	**0.06**
CD at 5%	**0.93**	**1.20**	**0.17**

Table 5. Effect of long term fertilization and manuring on crude fat, crude fibre and carbohydrates content of maize grain

Treatment	Crude fat (%)	Crude fibre (%)	Carbohydrates (%)
T1:50% NPK	4.39 (-0.9)	1.71 (-2.33)	71.61(-0.64)
T2: 100% NPK	4.43	1.75	72.07
T3: 150% NPK	4.48 (+1.12)	1.73 (-1.15)	71.36 (+0.99)
T4: 100%NPK + HW	4.51 (+1.80)	1.77 (+1.14)	71.99 (-0.11)
T5: 100%NPK +Lime	4.61 (+4.06)	1.80 (+2.85)	73.12 (+1.45)
T6: 100%NP	4.32 (-2.54)	1.65 (-6.06)	71.56 (-0.71)
T7: 100% N	4.41 (-0.45)	1.42 (-23.23)	71.68 (-0.54)
T8: 100% NPK +FYM	4.63 (+4.51)	1.83 (+4.57)	73.18 (+1.54)
T9:100% NPK(S-free)	4.24 (-4.48)	1.63 (-7.36)	71.70 (-0.51)
T10:100% NPK +FYM + Lime	4.65 (+4.96)	1.85 (+5.71)	73.22 (+1.59)
T11: Control	4.2 (-5.47)	1.61(-8.69)	71.70 (-0.51)
SEm±	**0.15**	**0.06**	**0.77**
CD at 5%	**NS**	**0.19**	**NS**

100% NPK + FYM+ lime. Maximum fiber content was noted when 100% NPK was applied with FYM which might be due to the better growth and uptake of nutrients, resulting from the balanced use of fertilizer with FYM. Nutrient availability greatly affects the crude fiber content of plants" [25]. Thakur et al. (2019) have reported "a positive correlation between available soil nutrients and crude fiber content of maize grain". "Liming significantly improved the crude fiber content of maize grain, which might be due to the positive effect of lime application on physical, chemical and biological properties of soil" [26,27]. Control, 100% NPK (-S) and 100% NP registered a decline of 17.5%, 12.9% and 9.9% in fiber content, respectively, over 100% NPK.

3.3.6 Total carbohydrates

A perusal of data (Table 5) revealed that carbohydrate content of wheat grains varied from 75.53% in 100% NPK (-S) to 76.27% in 100% NPK +FYM. The adequate and balanced supply of nutrients required for various metabolic activities within the plants [20,28,29] might have resulted in high carbohydrate content under 100% NPK + FYM. "Application of graded doses of fertilizer from 50% to 150% NPK, 100% NPK þ HW and 100% NPK þ Zn resulted in the carbohydrate content of 75.80%, 76.02%, 75.61%, 75.94% and 76.10%, respectively, and these values were statistically at par with each other. Increasing levels of fertility from 50% to 100% increased the carbohydrate content" (Misra, Singh, and Rajput 2001) [30-33]. The omission of K in 100% NP led to K starvation in plants (Hernández-Pérez et al. 2019), impairing the synthesis of carbohydrates and their translocation from leaves to the grains (Cakmak 2005). Kamalakumari and Singaram (1996) and Sujith, Sudhir, and Shivraj [3] have also reported "a significant reduction in the total carbohydrate content of maize grain due to the omission of potassium fertilizers. Inadequate plant nutrition led to low carbohydrate content in control" [34,35].

4. CONCLUSION

The result of the present study indicates that the application of FYM in combination with balanced chemical fertilizers and lime recorded higher maize grain quality parameters in terms of crude protein content, ash content, crude fat content, crude fiber content, total carbohydrate content, and nutrient content. The application of 100% NPK along with FYM and lime significantly improved the physical parameters of maize grain than rest of the treatments. Absolute control and application of imbalanced use of fertilizers (100% N, 100% NP, 100% NPK (-S) had the most deleterious effect on grain quality. Thus, it can be concluded from the study that conjective use of organic manures along with chemical fertilizers in balanced form is very much essential to maintain a good quality of maize grain production.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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