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Maize Grain Quality as Influenced by Chemical, Organic and Natural Farming Systems in an Acid Hill Soil of North-Western Himalayas

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Abstract: An understanding of nutritional quality response to different nutrient management practices is important to counter the widespread deficiencies of nutrients among humans. This study aimed to evaluate the effect of chemical fertilizers, lime, organic farming and natural farming practices on the yield and quality of maize (*Zea mays* L.) The experiment consisted of 11 treatments *viz.,* 100% NPK , 100% NPK+FYM (Farmyard manure) , 100% NPK + lime , organic farming practices , NFS (Natural Farming System)-*Desi* cow ; NFS-Crossbred cow , NFS-buffalo , organic farming practices + 25% NPK , NFS-*Desi* cow + 25% NPK , NFS-Crossbred cow + 25% NPK , NFS-buffalo + 25% NPK) The 100% NPK+ FYM @ 10 t ha^{-1} recorded highest maize grain equivalent yield (42.25 q ha^{-1}), reducing sugars (1.01%), non-reducing sugars (0.64%), crude protein (9.88%) and ash content (1.34%). Organic farming recorded highest total carbohydrate (72.65%) as well as starch content (68.68%). The calcium content in maize grains was highest in 100% NPK+ lime, whereas, phosphorus, magnesium, zinc and iron content were highest in 100% NPK+ FYM. The study concluded that higher crop yield and better nutritional quality can be achieved with a balanced application of NPK fertilizers along with FYM and lime, and organic manures plays a significant role in enhancing carbohydrate and starch content of maize grains.

Keywords: Grain quality, Maize, Chemical fertilizers, Lime, Organic farming, Natural farming

Maize (*Zea Mays*) is the third leading cereal crop across the globe after rice and wheat. It is a staple food for a huge section of the world's population, accounting for more than one-third of total calorie and protein intake in various countries. However, maize is inherently poor in protein and mineral content; particularly zinc. It is a high nutrient intensive crop which is sensitive to micronutrient deficiency. It is cultivated on an average of 9.5 million hectares area, with a total production of 28.7 million tons and a productivity of 3.0 tons per hectare (Agricultural Statistics at a Glance 2018). Intensive, high-input agriculture reliant on chemical fertilizers, insecticides, irrigation and other chemicals has resulted in deterioration of soil health leading to poor grain production and quality. According to the Food and Agriculture Organization of the United Nations (FAO 2017), about 190.7 million people in India are malnourished, with zinc (Zn) and iron (Fe) being the most often deficient micronutrients. To meet the nutritional needs of such a large population, the country needs to boost the production as well as nutritional quality of food grains. Proper nutrient management practices is one of the key factors for maintaining soil health and ultimately obtaining higher yields with increased nutrient content in grains. The integrated use of organic manures and balanced fertilizers has been reported to improve yield and nutritional quality of maize. Soil acidity limits agricultural production by affecting plant growth and restricting the absorption of water and nutrients (mainly micronutrients) by plant roots. Reclamation of soil acidity by use of lime is very effective in enhancing crop yield particularly in acidic regions. In addition to this, it is equally important to grow food grains of superior nutritional quality to address the wide-spread nutritional deficiencies among people. However, little is known about the effects of lime application on the nutritional quality of maize.

Recently, with the increasing concern of environment and human health, the scientists across the world are focusing on the adoption of alternate nutrient management practices which can improve crop yield and nutritional quality of food grains sustainably. In India, about 2.78 million hectare of farmland is under organic cultivation which accounts only 2 per cent of the net sown area in the country (Anonymous 2020). In organic farming, soil fertility is maintained through the use of organic amendments *viz.,* compost, manures and cover crops.. The soil has a critical role in organic farming and therefore, soil quality has a direct influence on the quality of food grown in it. When compared to conventional farming, organic farming brings minimal or no changes in starch quality, protein content, antioxidant activities and secondary metabolites of grains (Kesarwani et al 2021). Therefore, the effect of organic farming on nutritional quality of grains is still a matter of debate.

Natural farming is another alternative farming system to raise food crops that counters commercial expenditure and farmers' dependency on market for inputs. It involves the use of formulations (Jeevamrit, Beejamrit etc.) generally prepared from the dung and urine of indigenous cows (*Desi*) and are used as a replacement for the chemical fertilizers. These formulations are the quality natural sources which can supply the essential nutrients for the plant growth, and economical in preparation as all the ingredients are naturally available on farm. Government of India as well as the state government has laid emphasis on evaluation and popularization of natural farming system. The Himachal Pradesh government hopes to bring 9.61 lakh farmers under natural farming by the end of 2022. However, very little is known about the effect of natural farming practices using products of indigenous cow, and crossbred cow and buffalo in particular on yield and grain quality of maize. Keeping this in view, the present study was carried out with the aim to evolve a more efficient nutrient management practices in terms of yield and grain quality of maize.

MATERIAL AND METHODS

The present study was carried out on maize during 2020 at CSK Himachal Pradesh Agricultural University, Palampur, Himachal Pradesh, India (32°6´N latitude and 76°3´E longitude, 1290 m above the mean sea level). The research site falls under the mid-hills sub-humid agro-climatic zone and its climate is characterized as wet temperate. Nearly 80% of annual rainfall is received during July–September months. During the study period, total rainfall of 1449.0 mm was received and weekly relative humidity ranged between 57.95 to 92.05%. The maximum and minimum weekly temperatures varied from 26.0 to 30.5 °C and13.0 to 20.1°C, respectively. 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 before sowing of maize have been depicted in Table 1.

Experimental details: The experiment comprised of eleven treatments in three replications which were laid out in a randomized block design. These treatments were 100% NPK (T_1), 100% NPK+FYM (Farmyard manure) (T_2), 100% NPK + lime (T_3), organic farming practices (T_4), NFS (Natural Farming System)-*Desi* cow (T_5); NFS-Crossbred cow (T_6), NFS-buffalo (T_7), organic farming practices + 25% NPK (T_8), NFS-*Desi* cow + 25% NPK (T_9), NFS-Crossbred cow + 25% NPK (T_{10}), NFS-buffalo + 25% NPK (T_{11}). 100% NPK corresponding to 120 kg nitrogen (N), 60 kg phosphorus (P), and 40 kg potassium (K) ha^{-1} for maize. Urea, single super phosphate, and muriate of potash were used to supply N, P, and K, respectively. One pre-sowing irrigation was given and thereafter, water requirement of crop was met through rainfall. The whole quantity of FYM, containing 0.98, 0.47 and 0.85 % N, P and K, respectively on a dry weight basis, was added at the time of sowing in 100% NPK + FYM @ 10 ha^{-1} treatment. Lime @ 3.2 t ha^{-1} was applied about four weeks prior to sowing of the maize in specified plots comprising 100% NPK + 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 N was top-dressed in two equal splits at knee high and pre-tasseling stages. In organic farming plots, 60 kg N ha^{-1} was supplied through FYM and another 60 kg N ha^{-1} was supplemented through vermicompost containing 29.4% moisture with average nutrient content of 1.83, 0.97 and 0.73% of N, P and K, respectively on dry weight basis. In NFS plots, before sowing, the seeds were treated with beejamrit for a period of 30 minutes. At sowing, *Ghan-jeevamrit* (@ 250 kg ha^{-1}) was applied along with sieved FYM (@ 250 kg ha^{-1}), followed by application of *Jeevamrit* (@ 500 l ha^{-1}), and sprays of *Jeevamrit* @ 10% were given five times at 21days interval during crop growth. Soybean was intercropped in between the rows of maize plants in the ratio of 2:1. Mulching

Table 1. Initial physico-chemical characteristics of the surface soil

Soil property	Value
Mechanical analysis	
Mechanical separates (%)	
Sand	18.80
Silt	41.40
Clay	34.90
Chemical analysis	
Bulk density (g cm^{-3})	1.36
Water holding capacity (%)	44.42
Mean weight diameter (mm)	2.12
Soil pH (1:2.5)	5.56
Organic carbon (g kg^{-1})	8.31
Available nutrients (kg ha^{-1})	
N	257.4
P	33.17
K	211.36
Exchangeable cations (c mol (p$^+$) kg^{-1})	
Ca	2.51
Mg	1.32

with locally available organic residues was also done. The crop was harvested manually on 9th October, 2020 and yield was recorded at the time of harvesting. The NPK composition of beejamrit and jeevamrit prepared using dung of different cattle is given in Table 2.

Sampling and analysis: After the harvesting, the maize grain samples were collected and dried in an electric oven at 60°C to a constant weight. The dried grain samples were finely ground in a mixer grinder in stainless steel jar, sieved through 1 mm sieve and stored under moisture-free conditions in plastic bags. The reducing sugar content was estimated by the Dinitrosalicylic acid reagent method as proposed by Miller (1959). Non-reducing sugar content was determined as per the standard procedure (Malhotra and Sarkar 1979). To estimate crude protein, ash content, and total carbohydrate content, the standard procedure for proximate analysis given by AOAC (2005) was followed. The starch content was estimated using the Anthrone method given by Hedge and Hofreiter (1962).

Statistical analysis: The data recorded was analysed using MS-Excel, OPSTAT and SPSS 16.0 package as per design of the experiment.

RESULTS AND DISCUSSION

Maize grain equivalent yield: The highest maize grain equivalent yield (42.25 q ha^{-1}) was in 100% NPK + FYM (T_2) which was statistically at par (40.51 q ha^{-1}) with 100% NPK + lime (T_3). Addition of FYM, and lime along with 100% NPK fertilizers recorded 15.9% and 11.1% higher maize grain equivalent yield than sole application of 100% NPK, respectively. The lowest maize grain equivalent yield (23.07 q ha^{-1}) was in NFS-Buffalo (T_7) (Table 3). Among organic treatments, organic farming treatment resulted in higher maize grain equivalent yield (29.13 q ha^{-1}) which was statistically at par (26.54 q ha^{-1}) with NFS-*Desi* cow (T_5). Among integrated organic treatments, higher maize grain equivalent yield (33.99 q ha^{-1}) was in NFS-*Desi* cow + 25% NPK (T_9) with non-significant differences with NFS-Crossbred cow + 25% NPK , NFS-Buffalo + 25% NPK and organic farming + 25% NPK. NFS-*Desi* cow recorded 15% higher grain equivalent yield than NFS-Buffalo treatment, whereas NFS-*Desi* cow + 25% NPK 8.9% higher maize grain equivalent yield over NFS-Buffalo + 25% NPK treatments**.** The significant increase in maize grain equivalent yield with integrated use of FYM and inorganic fertilizers could be due

Table 2. NPK content (%) of *Beejamrit* and *Jeevamrit* prepared using dung of different cattle

Dung used	*Beejamrit*			*Jeevamrit*		
	N	P	K	N	P	K
Desi cow	0.457	0.115	0.273	0.203	0.048	0.078
Cross-bred cow	0.485	0.119	0.297	0.220	0.049	0.085
Buffalo	0.476	0.118	0.270	0.216	0.046	0.069

Table 3. Effect of conventional, organic and natural farming treatments on maize grain equivalent yield and quality parameters in maize grains

Treatments	Maize grain equivalent yield (q ha^{-1})	Reducing sugars (%)	Non-reducing sugars (%)	Crude protein (%)	Total carbohydrates (%)	Starch (%)	Ash (%)
100%NPK (T_1)	36.46	0.96	0.59	9.77	69.21	64.84	1.23
100%NPK+FYM (T_2)	42.25	1.01	0.64	9.88	70.92	65.12	1.34
100%NPK+Lime (T_3)	40.51	0.99	0.62	9.83	70.12	65.04	1.28
Organic farming (T_4)	29.13	0.90	0.51	9.52	72.65	68.68	1.05
NFS-*Desi* cow (T_5)	26.54	0.88	0.49	9.48	72.12	68.50	1.04
NFS-Crossbred cow (T_6)	24.15	0.88	0.46	9.45	72.09	68.23	1.02
NFS-Buffalo (T_7)	23.07	0.87	0.44	9.43	71.82	68.15	1.01
Organic farming +25% NPK (T_8)	31.64	0.93	0.57	9.70	70.82	66.94	1.17
NFS-*Desi* cow +25% NPK (T_9)	33.99	0.92	0.55	9.67	70.64	66.70	1.15
NFS-Crossbred cow +25% NPK (T_{10})	33.06	0.92	0.53	9.65	70.29	66.42	1.12
NFS-Buffalo +25% NPK (T_{11})	31.21	0.91	0.52	9.63	70.14	66.21	1.11
LSD (P=0.05)	4.32	0.03	0.02	0.08	1.60	1.07	0.04

to the improved physical, biological and chemical properties of soil as well as supply of higher quantity of nutrients with FYM and fertilizer which consequently resulted in better growth and higher crop yields (Ghosh et al 2022).

Reducing sugars: The reducing sugar content varied from 0.87 to 1.01% (Table 3). The highest reducing sugar content was in 100% NPK+ FYM @ 10 t ha^{-1} (1.01%) which was statistically at par with 100% NPK + lime treatment (0.99%). Addition of FYM, and lime along with 100% NPK fertilizers resulted in 5.2 and 3.1% higher reducing sugar content than sole application of 100% NPK, respectively. NFS-buffalo recorded the lowest reducing sugar content (0.87%) in maize grains among all the treatments. Among organic treatments, organic farming recorded higher reducing sugar content (0.90%) which was statistically at par with NFS-*Desi* cow (0.88%), NFS-Crossbred cow (0.88%) and NFS-Buffalo treatments (0.87%). Among integrated organic treatments, organic farming + 25% NPK recorded higher reducing sugar content (0.93%) which produced non-significant differences with NFS-*Desi* cow + 25% NPK (0.92%), NFS-Crossbred cow + 25% NPK (0.92%) and NFS-Buffalo + 25% NPK treatments (0.91%). The significant increase in reducing sugar content of maize grain with conjunctive use of FYM and inorganic fertilizers could be attributed to good nutrient status, improved plant conditions, more efficient functioning of leaf area and increased photosynthetic activity (Sharma et al 2018). .

Non-reducing sugars : The 100% NPK + FYM (T_2) recorded the highest non-reducing sugar content (0.64%) which was statistically at par with 100% NPK + lime (0.62 %), while the lowest non-reducing sugar content (0.44%) was in NFS-Buffalo (T_7) (Table 3). Integration of FYM, and lime with NPK fertilizers recorded 8.5% and 5.1% higher non-reducing sugar content than application of 100% NPK (T_1) alone, respectively. Integration of 25% NPK with organic farming recorded 11.8% higher non-reducing sugar content when compared to organic farming treatment only. Among organic treatments, organic farming recorded higher non-reducing sugar content (0.51%) which was statistically at par with NFS-*Desi* cow treatment (0.49%). The significant increase in non-reducing sugar content with combined application of FYM and inorganic fertilizers could be due to balanced supply of essential nutrients, growth promoting substances such as hormones, enzymes, etc. and effective regulation of metabolic functions which might have led to better synthesis of sugars (Safiullah et al 2018).

Crude protein: Integrated use of fertilizers with organic manure or lime influenced the crude protein content of maize grain significantly over sole use of fertilizers (Table 3). The highest crude protein content (9.88%) was in 100% NPK + FYM (T_2), followed by 9.83% under 100% NPK+ lime (T_3), and the lowest (9.43%) in NFS-Buffalo (T_7). Addition of FYM, and lime along with inorganic fertilizers recorded 1.1 and 0.6% higher crude protein content than sole use of 100% NPK, respectively. The significant higher crude protein content was in integration of FYM with inorganic fertilizers which might be due to the increased nitrogen availability, uptake as well as its storage in maize grains (Liu et al 2016). The positive effect of lime use on the crude protein content of maize grain could be due to the enhanced activity of nitrifying bacteria resulting in higher availability of N for uptake (Castro and Crusciol 2015). Among organic treatments, organic farming recorded higher crude protein content (9.52%) which produced non-significant differences with NFS-*Desi* cow (9.48%) and NFS-Crossbred cow treatments (9.45%). Among integrated organic treatments, organic farming + 25% NPK recorded higher crude protein content (9.70%) which was statistically at par with NFS-*Desi* cow + 25% NPK (9.67%), NFS-Crossbred cow + 25% NPK (9.65%) and NFS-Buffalo + 25% NPK treatment (9.63%). Organic farming resulted in higher crude protein content which could be due to better supply of macro and micro nutrients by vermicompost along with FYM and thereby, better nitrogen absorption and transformation in crops (Manjhi et al 2016).

Total carbohydrates: The total carbohydrate content of maize grains ranged from 69.21 to 72.65% (Table 3). The organic farming (T_4)recorded the highest carbohydrate content which was statistically at par with NFS-*Desi* cow , NFS-Crossbred cow and NFS-Buffalo treatments (Organic farming recorded 4.97% higher carbohydrate content than sole application of inorganic fertilizers. The lowest total carbohydrate content was in 100% NPK (T_1) (69.21%). The significantly higher total carbohydrate content with organic farming practices could be due to the slow and continuous supply of both micro and macro nutrients from manures (vermicompost), which might have helped in improved root growth, higher dry matter accumulation with adequate supply of nutrients to the plants leading to increase in the accumulation of carbohydrates. Addition of FYM, and lime along with NPK fertilizers showed 2.5% and 1.3% higher total carbohydrate content than sole application of 100% NPK, respectively. Integration of FYM, and lime with chemical fertilizers provided the adequate and balanced supply of nutrients required for several metabolic activities within the plants, resulting in high carbohydrate content over sole application of inorganic fertilizers (Chauhan et al 2020).

Among integrated organic treatments, organic farming + 25% NPK (T_8) recorded higher total carbohydrate content (70.82%) which was statistically at par with NFS-*Desi* cow + 25% NPK (70.64%), NFS-Crossbred cow + 25% NPK

(70.29%) and NFS-Buffalo + 25% NPK (70.14%) treatments which might be due to balanced and continuous supply of nutrients provided by both organic and inorganic sources of nutrients.

Starch content: The significant difference in starch content in maize grains due to different nutrient management practices was recorded (Table 3). The highest starch content in maize grains (68.68%) was recorded under organic farming treatment (T_4), while the lowest (64.84%) was in 100% NPK treatment (T_1). The treatment, 100% NPK + FYM (T_2) as well as 100% NPK + lime (T_3) also recorded higher starch content than sole application of 100% NPK which was 65.12% and 65.04%, respectively. Among integrated organic treatments, organic farming + 25% NPK (T_8) recorded higher starch content (66.94%) which produced non-significant differences with NFS-*Desi* cow + 25% NPK (66.70%), NFS-Crossbred cow + 25% NPK (66.42%) and NFS-Buffalo + 25% NPK treatments (66.21%). The beneficial effect of organic farming practices on starch content could be attributed to the organic manures that contain significant amounts of macro and micronutrients which help in improving the grain chemical constituents, as well as the effect of organic acids produced during soil mineral decomposition in enhancing grain quality (Anjum et al 2020). Combined application of NPK fertilizers and FYM resulted in significant increase in starch content over sole application of inorganic fertilizers which could be due to release of hormones, nutrients and other growth promoting substances from organic manures. Liming also resulted in significant improvement in starch content over 100% NPK which could be attributed to the increased nutrient availability due to the neutralization of soil acidity.

Ash content: There was a significant effect of application of fertilizers and amendments on ash content of maize grains. Highest ash content of 1.34% was in 100% NPK + FYM (T_2), followed by 100% NPK + lime (1.28 %), while the lowest ash content (1.01%) was in NFS-buffalo treatment (Table 3). Integration of FYM, and lime along with NPK fertilizers recorded 8.9% and 4.1% higher ash content than sole application of 100% NPK fertilizers (T_1), respectively. Among integrated organic treatments, organic farming + 25% NPK (T_8) recorded higher ash content (1.17%) which was statistically at par (1.15%) with NFS-*Desi* cow + 25% NPK treatment (T_9). Integration of FYM with inorganic fertilizers resulted in significant increase in ash content which might be due to improved availability of mineral nutrients from the soil and enhancement in the microbial activity as well, which in turn, would have helped in better absorption of macro and micro nutrients from the soil thereby resulting in higher mineral content in maize grains. Chauhan et al (2020) also reported higher ash content in FYM amended plots as compared to other treatments due to the presence of higher amount of bran portion in it.

Nutrient content: The significant difference in nutrient content of maize grains was recorded under different nutrient management practices (Table 4). Highest P, Mg, Zn and Fe content of maize grain were recorded under organic farming (T_4). However, 100% NPK + lime (T_3) recorded the highest Ca content. Addition of FYM, and lime with 100% NPK increased the P content by 39.3% and 21.1%, Mg content by 40 and 30% , Zn content of maize grains by 18.9% and 4.5% when compared to 100% NPK (T_1), respectively. The Ca content of maize grain recorded a significant increase with lime over 100% NPK, the increase being 21.9%. The significant increase in phosphorus, magnesium and zinc content of maize grains with organic farming might be due to positive

Table 4. Effect of conventional, organic and natural farming treatments on P, Ca, Mg, Zn and Fe content in maize grains

Treatments	P (%)	Ca (%)	Mg (%)	Zn (mg kg^{-1})	Fe (mg kg^{-1})
100% NPK (T_1)	0.48	0.32	0.10	24.09	54.01
100% NPK+FYM (T_2)	0.52	0.37	0.14	28.64	56.99
100% NPK+Lime (T_3)	0.49	0.39	0.13	25.17	53.97
Organic farming (T_4)	0.55	0.38	0.15	31.36	58.32
NFS-*Desi* cow (T_5)	0.53	0.37	0.14	29.03	56.99
NFS-Crossbred cow (T_6)	0.52	0.36	0.14	28.36	56.38
NFS-Buffalo (T_7)	0.51	0.36	0.13	27.03	55.89
Organic farming + 25% NPK (T_8)	0.48	0.34	0.13	24.69	55.66
NFS-*Desi* cow + 25% NPK (T_9)	0.47	0.35	0.13	24.36	55.01
NFS-Crossbred cow + 25% NPK (T_{10})	0.45	0.33	0.12	24.69	55.23
NFS-Buffalo + 25% NPK (T_{11})	0.44	0.33	0.12	24.02	54.10
LSD (p=0.05)	0.03	0.02	0.01	2.77	1.62

effect of vermicompost on soil physical-chemical properties, root growth, its ability to release plant growth regulators, phytohormones, mineral nutrients and also humic substances that prolonged the bioavailability of micro nutrients and thereby improved the uptake of nutrients. Addition of organic manures also resulted in significant increase in iron content of maize grains which could be due to decrease in leaching losses and increase in the availability of nutrients with the use of organic manures (Joshi et al 2019). The significant improvement in calcium content of maize grains due to application of lime might be attributed to increase in soil pH and improved availability of calcium in the soil.

CONCLUSION

The present study demonstrated that balanced use of fertilizers in conjunction with FYM or lime significantly improved the maize grain quality in terms of reducing and non-reducing sugars, crude protein, ash and nutrient content. Application of organic manures significantly enhanced the total carbohydrates and starch content of maize grains. Thus, it can be concluded from the study that combined use of inorganic fertilizers and FYM, and organic manures and amelioration of soil acidity are essential to improve yield and nutritional quality of maize grains.

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