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Productivity and quality of maize (*Zea mays*) as influenced by integrated nutrient management under continuous cropping and fertilization*

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Amongst agricultural inputs, fertilizers have played a vital role in achieving the goal of food security in India. But having attained food security, the accentuate in recent times has shifted from productivity enhancement-based agricultural research to nutritional security and sustainability issues because the deteoration in soil health associated with global circumstance of energy crises and escalation in prices of chemical fertilizers have forced us supplement them with low priced organic and biosources of plant nutrients (Kumar and Dhar 2010). The use of readily available parochial farmyard manure and suitable strain of *Azotobacter* in a crop, like maize (*Zea mays* L.) in conjugation with chemical fertilizer can help in achieving the productivity and sustainability of production. Apart from integration of nutrient sources application of mineral nutrients in a proper balance also has a role to play in improving quality of maize. Balanced application of nutrients, ie N P K S Zn plays a vital role in bio-synthesis of proteins and amino acids. The quality parameters of maize, like sugar, starch and crude protein content increase by balanced and integrated application of organic manure with chemical fertilizers. No manuring, lack of K and use of S-free fertilizers decreases these parameters (Singaram and Kamla Kumari 2000). Similarly, protein, oil and amino acids, i e methionine, tryptophan and lysine content are also affected with continuous application of plant nutrients in organic and inorganic forms and their integration (Liu *et al*. 2004). Keeping the above facts under consideration, an experiment was carried out to study the response of continuous cropping and nutrient application on productivity and quality of maize with the objectives to assess the effect of integrated nutrient management on yield and quality of maize.

The field study was conducted during rainy *(kharif)* season 2008 in the long-term fertilizer experiments initiated in *kharif* 1997 at the Instructional Farm of the Rajasthan College of Agriculture, Udaipur situated in south-eastern part of Rajasthan at an altitude of 579.5 m above mean sea level, 24°35'N latitude and 74°42' E longitude with 'PEHM 2'maize. The soil was sandy clay loam in texture, slightly alkaline in reaction (*p*H 8.2), medium in available nitrogen (427 kg/ha) and phosphorus (22.4 kg/ha), and high in available potassium (671 kg/ha), sulphur (21.0 mg/kg) and zinc (3.76 mg/kg). Twelve treatments, viz T_1 100% NPK, T_2 100% NPK+Zn, T_3 100% NPK+S+Zn, T_4 100% NPK+S, T_5 100% NPK + seed treatment with *Azotobacter*, T_6 farmyard manure 10 tonnes/ha + 100% NPK (NPK content of farmyard manure), T_7 100% NPK + farmyard manure 10 tonnes/ha, T_8 farmyard manure 20 tonnes/ha,T_9 150% NPK, T_{10} 100% NP, T_{11} 100% N and T_{12} control were replicated four times in a randomized block design. The sources used for applying N, P and K were urea, di-ammonium phosphate (adjusted for its N content) and muriate of potash, respectively. Mineral gypsum and zinc sulphate ($ZnSO_4.7H_2O$) were used to supply S and Zn. The other sources of nutrients were farmyard manure and biofertilizer (*Azotobacter chroococcum*) as seed treatment. The biofertilizer for seed inoculation was used 600 g/ha. According to the soil-test fertilizer recommendation, the 100% NPK dose for maize was 120:60:30 kg/ha. The dose for sulphur and zinc were 40 kg and 5 kg/ha, respectively. A basal dose of well rotten farmyard manure was applied prior to sowing in the specific plots as per technical programme and thoroughly mixed with soil. Full dose of P and K along with ½ dose of N was given as a basal dose and thoroughly mixed with soil. The remaining ½ dose of the nitrogen was applied in two splits, first 30days after sowing and second 45 days after sowing. 'PEHM 2' maize was sown at the seed rate of 25 kg/ha in rows 60cm×20cm apart. Protein in grains was determined by

*Short note

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method described by AOAC (2002) and carbohydrate by Hedge and Hofreiter (1962). Oil content was estimated by Soxhlet apparatus petroleum ether method and lysine, methionine and tryptophan content were estimated as per Thimmaiah (1999).

Maximum weight/cob (119.56 g), cob length (17.45 cm), weight of grains/cob (92.66 g), test weight (208.18 g) and shelling percentage (77.59) was achieved by 100% NPK + farmyard manure 10 tonnes/ha, which was at par with 150% NPK or 100% NPK + Zn + S in weight of grain/cob (Table 1). While application of 100%NPK and its combination with Zn or Zn + S and farmyard manure 10 tonnes/ha + 100% NPK (–NPK of farmyard manure) achieved statistical equivalence in case of weight/cob. Test weight and shelling percentage of maize were increased significantly over unfertilized control. Compared to control application of N or NP or farmyard manure 20 tonnes/ha alone tended to result in significantly higher yield attributes in terms of weight/cob, cob length, and weight of grains/cob, test weight and shelling percentage.

Integrated nutrient management increased the grain yield of maize ranging from 56.71 to 162.85% and stover yield by 57.71 to 160% over the control (Table 1). Application of 100% NPK + farmyard manure 10 tonnes/ha resulted in highest grain yield (3 722 kg/ha) and sotver yield (5 447 kg/ha) yields. Application of 100%NPK was found superior over NP, N, farmyard manure 20 tonnes/ha and control but inferior to aforesaid treatments, while 100% NPK + Zn, Zn + S or *Azotobacter* seed treatment and 100% NPK through farmyard manure 10 tonnes/ha and fertilizer were found statistically equivalent in grain yield. Application of farmyard manure 20 tonnes/ha alone increased the grain yield over the control but yield levels were inferior to 100% NPK. Integrated uses of farmyard manure 10 tonnes/ha with 100% NPK resulted in potential and sustainable yields of maize. Continuous use of imbalanced fertilization gave low yields, underlining the importance of balanced and higher rate of fertilizer application. Similar yield trends have been reported by Singh and Swarup (2000) and Verma *et al*. (2006).

Maximum protein (10.13%), carbohydrate (69.98%) and tryptophan (0.64 g/16 g N) content were produced by the application of 100% NPK + farmyard manure 10 tonnes/ha (Table 2). Highest lysine content (3.91 g/16 g N) was found under the influence of 100% NPK + Zn, while maximum oil (5.21%) and methionine (2.09 g/16 g N) contents were recorded by use of S + Zn with 100% NPK. Integrated use of chemical fertilizers and organic manures (100% NPK + farmyard manure 10 tonnes/ha) significantly increased protein and tryptophan content by 9.40 and 52.3% respectively over 100% NPK. This treatment significantly increased carbohydrate content by 6% over the control. Use of 100% NPK with S + Zn significantly increased oil and methionine content by 21.44, 28.22% respectively, over the control and 13.50, 18.75% respectively, over 100% NPK. Application of 100% NPK + Zn significantly increased lysine content by 29.40% over 100% NPK and 59.60% over the control. Increase in protein content might be due to increased N concentration in grain which is integral part of protein synthesis. The increase in tryptophan and lysine might be due to the increase in the synthesis of globulin fraction which is rich in tryptophan and lysine (Dwivedi *et al*. 2002). The improvement in methionine content might be due to increase in S availability and consequently increases the synthesis of S containing amino acids and oil content.

The results of the present study infer that use of NPK based on soil test values with farmyard manure 10 tonnes/ha gave significantly highest values of yield attributes and yields of

Table 1 Effect of integrated nutrient management on yield and yield attributes of maize

Treatment	Yield (kg/ha)		Weight/ cob (g)	Cob length (cm)	Weight of grains/cob (g)	Test weight (g)	Per cent shelling
	Grain	Stover					
100%NPK	3 179	4 682	111	16.19	82.79	193	74.92
100%NPK + Zn	3 307	4 836	113	16.64	86.52	196	75.89
100%NPK + S + Zn	3 372	4 975	116	17.11	87.36	200	75.21
100%NPK + S	3 258	4 712	110	16.51	83.37	198	75.85
100%NPK + *Azotobacter*	3 279	4 795	111	15.93	83.35	191	75.02
100%NPK + FYM 10 tonnes/ha (– NPK of FYM)	3 230	4 817	114	16.07	86.03	194	74.98
100%NPK + FYM 10 tonnes/ha	3 722	5 447	119	17.45	92.66	208	77.59
FYM 20 tonnes/ha	2 219	3 304	102	15.10	72.64	183	70.95
150%NPK	3 537	5 293	117	17.37	89.02	189	75.89
100%NP	2 798	4 139	100	14.40	73.98	189	73.73
100%N	2 262	3 370	92	13.08	66.75	183	72.42
Control	1 416	2 095	78	10.12	45.91	161	58.80
C D (*P*=0.05)	340	509	8	1.83	5.95	22	7.41

FYM, Farmyard manure

Table 2 Effect of integrated nutrient management on quality of maize

Treatment	Protein (%)	Oil (%)	Carbohydrate (%)	Lysine (g/16 g N)	Methionine (g/16 g N)	Tryptophan (g/16 g N)
100%NPK	9.26	4.59	67.59	3.02	1.76	0.42
100%NPK + Zn	9.53	4.52	68.32	3.91	1.96	0.51
100%NPK + S + Zn	9.79	5.21	68.60	3.25	2.09	0.50
100%NPK + S	9.43	4.97	68.87	3.02	2.07	0.43
100%NPK + *Azotobacter*	9.37	4.63	68.92	3.21	1.77	0.47
100%NPK + FYM 10 tonnes/ha (– NPK of FYM)	9.32	4.88	69.02	3.46	1.87	0.55
100%NPK + FYM 10 tonnes/ha	10.13	4.95	69.98	3.52	1.88	0.64
FYM 20 tonnes/ha	9.15	4.72	66.18	3.02	1.99	0.60
150%NPK	10.09	4.50	69.78	3.34	1.76	0.54
100%NP	9.25	4.53	67.39	3.11	1.71	0.53
100%N	9.12	4.34	66.22	2.77	1.68	0.46
Control	7.62	4.29	66.01	2.45	1.63	0.38
C D (*P*=0.05)	0.65	0.29	2.55	0.22	0.12	0.03

FYM, Farmyard manure

maize yield. It improved the quality parameters of maize grain and maintained sustainability in crop production. Application of S and Zn with 100%NPK also resulted in improved grain quality indicating the importance of S and Zn nutrition in continuous cropping.

SUMMARY

A long-term fertilizer experiment initiated in 1997 at Udaipur to assess effect of continuous application of plant nutrients through organic and inorganic sources and its combination on yield and quality of maize. Results during *kharif* 2008 revealed that maximum grain (3 722 kg/ha) and stover (5 447 kg/ha) yields of maize (*Zea mays* L.) were obtained by conjoint application of farmyard manure 10 tonnes/ha with soil test recommended dose of NPK (120:60:30 kg/ha).This treatment also recorded highest values of protein (10.13%), carbohydrate (69.98%) and tryptophan (0.64 g 16 g/N), while lysine was found maximum (3.91 g/16 g N) with 100% NPK + Zn. Maximum methionine (2.09 g/16 g N) and oil (5.21%) content was recorded with the application of 100% NPK + S + Zn.

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