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Customized fertilizers for improving yield and nutrient uptake of hybrid maize

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Abstract
Field experiments were conducted at two different locations of varying climate to study the effect of customized fertilizers on yield and nutrient uptake of hybrid maize. Two formulations of customized fertilizers viz., N: P: K mixture (CF I) and N: P: K: Zn mixture (CF II) have been developed based on the blanket recommendation (BR) of straight fertilizers being followed in the study area. Three levels of CF I and CF II *viz*., 50%, 75% and 100% of RDF were compared with 100% RDF through straight fertilizers. The results revealed that application of 100% RDF in the form of CF II increased the single cob weight (293 g) and number grains per cob (672 nos.). Application of 100% RDF in the form of CF II recorded the highest grain yield of 8554 kg ha^{-1}. Per cent increase in yield of 28.8 per cent over the application of straight fertilizers was recorded due to the application of 100% RDF in the form of CF II.

Keywords: Customized fertilizer, balanced fertilization, maize yield, nutrient uptake

Introduction
In India, fertilizers have contributed 60 percent of recent increases in food production. Balanced fertilization is the major strategy used with an ideal N: P_2O_5:K_2O ratio of 1:0.5:0.25 for grain-based production systems. (Tandon, 1997) [27]. When N, P and K applications are imbalanced, large quantities of the nutrients not applied in adequate amounts are mined from the soil until they become critically deficient. India is already in the era of multiple nutrient deficiencies with N, P, K, S and Zn being the most widespread. Nutrient depletion can be attributed to insufficient fertilizer use and unbalanced fertilization (Tan *et al*., 2005) [28]. The decline in productivity of rice and wheat with continuous cropping was related to deficiency of P, K, S, Zn and imbalanced nutrition (Kumar and Yadav, 2005) [12]. It was generally observed that maize fail to produce good grain in plots without adequate nutrients (Adediran and Banjoko, 2003) [1]. Inorganic fertilizer exerts strong influence on plant growth, development and yield (Stefano *et al*., 2004) [25].

The availability of sufficient nutrients from inorganic fertilizers leads to improved cell activities, enhanced cell multiplication and enlargement and luxuriant growth (Fashina *et al.*, 2002) [9]. Luxuriant growth resulting from fertilizer application leads to larger dry matter production (Obi *et al.*, 2005) [18] owing better utilization of solar radiation and more nutrient (Saeed *et al.*, 2001) [20]. Plants emerged from seeds with low concentration of Zn could be highly sensitive to biotic and abiotic stress (Obata *et al.*, 1999) [17]. Maize is more sensitive to Zn supply than any other crops. Moreover, the efficiency of fertilizer use is quite low. The efficiency of N-fertilizer is only 30–40% in rice and 50–60% in other cereals, while the efficiency of mineral P-fertilizer is 15–20% in most crops. The efficiency of K is 60–80%, while that of S is 8–12%. This leads to lower return on money spent per unit of fertilizer. The efficiency of micronutrients remains <5% (ref. 12). Hence, applying nutrients in the form of fertilizers requires suffi-cient quantities, the right form, the right time and right place for good management of Indian agriculture.

The main causes for low and declining crop response to fertilizers are : continuous use of fertilizer N alone or with inadequate P and K application leading to mining of native soil P and K; continued practice of intensive cropping systems with high yielding varieties even under recommended NPK use, use of high analysis fertilizers devoid of secondary and micronutrients leading to imbalanced fertilization. To improve the fertilizer use efficiency through balanced fertilization, customized fertilizers based on crop response are to be developed. For the present investigation, the customized fertilizers have been developed based on the blanket recommendation (BR) of straight fertilizers being followed in Tamil Nadu and evaluated through field trials.

Materials and methods

Field experiments were conducted in two different agro-climatic zones viz., Agricultural Research Station, Bhavanisagar (Lat 11° 41' N; Lon 77° 08' E) (location 1) and Farmer's field Vagarai (Lat 10° 22' N; Lon 78° 00' E) (location 2) with hybrid maize as test crop. The soils of the experimental sites were neutral and alkaline in soil reaction (pH: 7.41 and 8.54) and free from salt hazards with the electrical conductivity of 0.28 $dSm^{-1}$and 0.27 d Sm^{-1} and low in organic carbon status (0.47 and 0.34 per cent), while available N, P and K status were in low, high and high status respectively. At Agricultural Research Station, Bhavanisagar, DTPA extractable micronutrients viz., Zn, Fe, Cu and Mn were recorded at high levels. Low levels of DTPA extractable micronutrients viz., Fe and Cu were recorded in Farmer's field at Vagarai which were below the critical limit and were at deficient levels (Table 1).

Table 1: Initial soil analysis of the experimental sites

Parameter	Location I	Location II
pH	7.41	8.54
Electrical conductivity (dSm^{-1})	0.28	0.27
Organic carbon (%)	0.47	0.34
Available N (kg ha^{-1})	246	202
Available P (kg ha^{-1})	56.9	26.9
Available K (kg ha^{-1})	297	463
DTPA –Zn (mg kg^{-1})	6.40	2.84
DTPA –Fe (mg kg^{-1})	7.16	1.76
DTPA –Mn (mg kg^{-1})	5.78	3.11
DTPA –Cu (mg kg^{-1})	0.76	0.47

The treatments included straight fertilizers applied through urea, super phosphate and muriate of potash, customized fertilizer of N: P: K mixture (CF I) and N:P:K: Zn mixture (CF II) as follows : T_1-100% RD through straight fertilizers (250: 75 : 75 kg N, P_2O_5, K_2O ha^{-1}+ 25 kg $ZnSO_4$ ha^{-1} + 50 kg Fe SO_4 ha^{-1}) (Control) ; T_2-50% RD in the form of CFI + 25 kg $ZnSO_4$ ha^{-1} + 50 kg Fe SO_4 ha^{-1}, T_3-75% RD in the form of CFI+ 25 kg $ZnSO_4$ ha^{-1}+ 50 kg Fe SO_4 ha^{-1}, T_4-100% RD in the form of CFI+ 25 kg $ZnSO_4$ ha^{-1} + 50 kg Fe SO_4 ha^{-1},T_5-50% RD in the form of CFII, T_6-75% RD in the form of CFII, T_7-100% RD in the form of CFII.

For the preparation of CFI, N and P were supplied through ammonium phosphate and K through muriate of potash and for the preparation of CFII, N and P were supplied through ammonium phosphate, K through muriate of potash and Zn through Zinc sulphate. In CF I applied plots, basal application of 25 kg $ZnSO_4$ ha^{-1} and 50 kg Fe SO_4 ha^{-1}as straight fertilizers were carried out. Full dose of P was applied as basal and N, K were applied in 3 equal splits viz., basal, at vegetative and tasseling phases.

At the time of harvest, single cob weight, numbers of grains per cob and kernel row per cob were recorded. The grain and stover samples were processed and analyzed for N (Piper, 1966) [19] P and K (Jackson, 1973) [10] and micronutrient contents was determined using atomic absorption spectrophotometer (Varian model. AA240). The nutrient uptake was calculated by multiplying nutrient contents with dry matter production.

One -way analysis of variance (ANOVA) was done for all data set and the entire set of data had fulfilled the assumptions of ANOVA. The data collected from the field sites were pooled. Despite the fact that the experimental design had only three replications, care was taken to record the observations from 5 plants in each replication. Mean comparison test (Duncan's Multiple Range test, DMRT) was done for the significant values at $p<0.05$.Statistical procedures were carried out with the software package IRRI stat (IRRI, Manila, Philippines)

Results and Discussion

Yield attributes and grain yield

The highest single cob weight of 293 g was recorded in the treatment that received 100% RD as CF II which was on par with 75% RD as CF II (272 g) and 100% RD as CF I + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1}(282 g). Application of 50% RD as CF I + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1} recorded the lowest single cob weight of 219 g (Table 2).

The highest number grains per cob was registered in the treatment that received 100% RD as CF II (672 nos.) and was on par with the application of 100% RD as CF I + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1}. (Table 3). Moussa and Barsoum (1995) and Zuo *et al.* (1995) [16, 29] reported that number of seeds/cob increased due to Zn application. Similar results were also reported by various scientists like Das *et al.* (1993), Alam *et al.* (2000), Santi *et al.* (1997), Chowdhury and Islam (1993), Sankhyan and Sharma (1995) and Turambeker and Daftardar(1992). Sharma *et al.* (1992) [7, 6, 22, 3, 21, 26, 23] reported that the seed yield of maize increased by 11.4% up to Zn levels from 0 to 9 kg Zn ha^{-1}.

Application of 100% RD as CF I + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1} registered higher number of kernel rows per cob (17) and the lowest number of kernel rows per cob (14) was recorded in the treatment that received 50% RD as CF I+ 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1} (Table 2).

Table 2: Effect of customized fertilizers on single cob weight (g), no. of grains cob^{-1} and kernel row cob^{-1} of hybrid maize (Pooled mean of two locations)

Treatments	Single cob weight (g)	No. of grains cob^{-1}	Kernel Row cob^{-1}
T1: 100% RD– 250 : 75 :75 Kg N, P_2O_5,K_2O ha^{-1} + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1}	250	619	15
T2: 50% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	219	614	14
T3: 75% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	268	638	16
T4: 100% RD as CF I+ 25 kg $ZnSO_4$ ha^{-1} + 50 kg Fe SO_4 ha^{-1}	282	660	17
T5: 50% RD as CF II	250	605	15
T6: 75% RD as CF II	272	639	16
T7: 100% RD as CF II	293	672	16
CD	25.9**	25.8**	0.92**

The highest grain yield of 8554 kg ha^{-1} was recorded in the treatment that received 100% RD as CF II which was on par with 75% RD as CF II, 100% RD as CF I + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1} and 75% RD as CF I + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1}. While the lowest yield of 6065 kg ha^{-1} was recorded in the treatment that received 50% CF I + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1}. Banjoko and Adediran (2003) that showed that maize yield increased with the increasing rates of fertilizer. (Table 3)

Table 3: Effect of customized fertilizers on grain yield of Hybrid maize (Pooled mean of two locations)

Treatments	Grain yield (kg ha^{-1})	% increase over straight fertilizer
T1: 100% RD– 250 : 75 :75 Kg N, P_2O_5,K_2O ha^{-1} + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1}	6640	-
T2: 50% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	6065	-8.7
T3: 75% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	7844	18.1
T4: 100% RD as CF I+ 25 kg $ZnSO_4$ ha^{-1} + 50 kg Fe SO_4 ha^{-1}	8204	23.5
T5: 50% RD as CF II	6454	-2.8
T6: 75% RD as CF II	8221	23.8
T7: 100% RD as CF II	8554	28.8
CD	1067.4	

An increase in grain yield of 28.8 per cent over the application of 100% RD straight fertilizer was recorded due to the application of 100% RD as CF II. The increase in grain yield over 100% RD of straight fertilizer was 23.8 per cent in the treatment that received 75% RD as CF II. (Table 3) Abundant supply of nutrients through micronutrients with organics and RDF might have increased the protoplasmic constituents and accelerated the process of cell division and elongation. This in turn resulted in increased corn yield. Similar results were reported by Auti *et al*. (1999); Kamble and Kathmale (2015); Kumar and Singh (2015) [4, 11, 13].

An increase in grain yield of 23.5 per cent over 100% RD of straight fertilizer was observed due to the application of 100% CF I + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1} while the increase in grain yield of 18.1 per cent over 100% RD of straight fertilizer was observed in the treatment that received 75% RD as CF I + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1}. (Table 3)

Nutrient uptake by grain

The N uptake by grain ranged from 48.70 kg ha^{-1} to 99.33 kg ha^{-1}. The highest N uptake of 99.33 kg ha^{-1} was recorded in the treatment that received 100% RD as CF II and was on par with other treatments that supply 75% and 100% RD. The lowest N uptake by maize grain was recorded in the treatment that received 50% RD as CF I + 25 kg $ZnSO_4$ ha^{-1}+50 kg Fe SO_4 ha^{-1}. Application of 100% RD through straight fertilizer recorded the N uptake of 68.28 kg ha^{-1}. (Table 4)

Table 4: Effect of customized fertilizers on N, P and K uptake by maize grain (kg ha^{-1}): Harvest stage (Pooled mean of 2 locations)

Treatments	N	P	K
	(kg ha-1)		
T1: 100% RD– 250 : 75 :75 Kg N, P_2O_5,K_2O ha^{-1} + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1}	68.28	24.18	52.78
T2: 50% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	48.70	16.83	41.47
T3: 75% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	89.00	29.25	58.31
T4: 100% RD as CF I+ 25 kg $ZnSO_4$ ha^{-1} + 50 kg Fe SO_4 ha^{-1}	96.83	33.61	61.46
T5: 50% RD as CF II	60.81	18.57	46.15
T6: 75% RD as CF II	86.73	33.02	61.09
T7: 100% RD as CF II	99.33	34.09	63.94
CD	20.1**	9.02**	3.87**

The P uptake by grain varied from 16.83 kg ha^{-1} to 34.09 kg ha^{-1}. The lowest P uptake was recorded in the treatment that received 50% RD as CF I + 25 kg ha^{-1} $ZnSO_4$ ha^{-1}+50 kg Fe SO_4 ha^{-1}. Significantly higher P uptake (34.09 kg ha^{-1}) was registered in the treatment that received 100% RD as CF II as against 100% RD through straight fertilizers (24.18 kg ha^{-1}). (Table 4)

The K uptake ranged from 41.47 to 63.94 kg ha^{-1}. Application of 100% RD as CF I + 25 kg $ZnSO_4$ ha^{-1} +50 kg Fe SO_4 ha^{-1} recorded the K uptake of 61.46 kg ha^{-1} and was on par with 100% RD as CF II (63.94 kg ha^{-1}) and 75% RD as CF II (61.09 kg ha^{-1}). Lowest K uptake was observed in the treatment that received 50% RD as CF I + 25 kg $ZnSO_4$ ha^{-1}+50 kg Fe SO_4 ha^{-1}. (Table 4) Similar findings were reported by Dwivedi *et al*. (2014) and Meshram *et al*. (2015) [8, 14]

The Zn uptake by maize grain varied from 349 mg kg^{-1} to 606 mg kg^{-1}. Significantly higher Zn uptake (606 g ha^{-1}) was recorded in the treatment that received 100% RD as CF II which was on par with 75% RD as CF II (520 g ha^{-1}). The lowest Zn uptake (349 g ha^{-1}) was recorded in the treatment that received 50% RD as CF I + 25 kg $ZnSO_4$ ha^{-1} + 50 kg $FeSO_4$ ha^{-1}. (Table 5)

Table 5: Effect of FACTMIX on micronutrients uptake by maize grain (g ha^{-1}): Harvest stage (Pooled mean of 2 locations)

Treatments	Zn	Fe	Cu	Mn
	(g ha^{-1})			
T1: 100% RD– 250 : 75 :75 Kg N, P_2O_5,K_2O ha^{-1} + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1}	380	2517	252	559
T2: 50% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	349	1288	155	402
T3: 75% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	483	1974	241	590
T4: 100% RD as CF I+ 25 kg $ZnSO_4$ ha^{-1} + 50 kg Fe SO_4 ha^{-1}	493	2420	294	639
T5: 50% RD as CF II	367	965	257	481
T6: 75% RD as CF II	520	1546	317	703
T7: 100% RD as CF II	606	1990	345	710
CD	106.0	NS	70.9**	NS

No significant changes in the uptake of Fe and Mn were observed. The Cu uptake by grain varied from 155 g ha^{-1} to 345 g ha^{-1}. The highest Cu uptake (345 g ha^{-1}) was recorded in the treatment that received 100% RD as CF II. The Cu uptake was the lowest (155 g ha^{-1}) in the treatment that received 50% RD as CF I + 25 kg $ZnSO_4$ ha^{-1} + 50 kg $FeSO_4$ ha^{-1}. (Table 5)

Adiloglu and Saglam (2005) [2] observed that maize biomass yield, and its N and Zn contents were enhanced by increased N and Zn rates. However, Zn concentration in the plants was reduced by increased N application, while N concentration in plants declined with enhanced Zn rates. Singh and Steenberg (1974) [24] reported that increased application rates of Zn in maize and barley enhanced Zn content and uptake in the plant roots, sheaths and blades. Marschner (1993) [15] reported that uptake of zinc decreases sharply with increased P fertilization.

Nutrient uptake by stover

The N uptake by stover varied from 89.20 to 168.34 kg ha^{-1}. Highest uptake was recorded in the treatment that received 100% RD as CF II while the lowest uptake was recorded in the treatment that received 50% RD as CF I + 25 kg $ZnSO_4$ ha^{-1} + 50 kg $FeSO_4$ ha^{-1}. (Table 6)

Table 6: Effect of customized fertilizers on N, P and K uptake by maize stover (kg ha-1): Harvest stage (Pooled mean of 2 locations)

Treatments	N	P	K
	(kg ha-1)		
T1: 100% RD– 250 : 75 :75 Kg N, P_2O_5,K_2O ha^{-1} + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1}	117.75	39.76	138.94
T2: 50% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	89.20	28.87	99.86
T3: 75% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	131.21	46.58	144.97
T4: 100% RD as CF I+ 25 kg $ZnSO_4$ ha^{-1} + 50 kg Fe SO_4 ha^{-1}	149.86	51.45	178.69
T5: 50% RD as CF II	112.24	32.18	122.01
T6: 75% RD as CF II	146.10	48.40	178.47
T7: 100% RD as CF II	168.34	52.69	201.15
CD	27.5**	5.8**	22.9**

The P uptake by stover ranged from 28.87 to 52.69 kg ha^{-1}. Significantly higher P uptake was registered in the treatment that received 100% RD as CF II and was on par with 75% RD as CF II and 100% RD through CF I + 25 $ZnSO_4$ ha^{-1} + 50 kg $FeSO_4$ ha^{-1}. The P uptake was the lowest in the treatment that received 50% RD through CF I + 25 $ZnSO_4$ ha^{-1} + 50 kg $FeSO_4$ ha^{-1}. Application of 100% RD through straight fertilizers recorded a value of 39.76 kg ha^{-1}. (Table 6)

The K uptake by stover ranged from 99.86 kg ha^{-1} to 201.15 kg ha^{-1}. The highest K uptake was recorded in the treatment that received 100% RD as CF II and was on par with 75% RD as CF II and 100% RD through CF I + 25 $ZnSO_4$ ha^{-1} + 50 kg $FeSO_4$ ha^{-1}. Uptake of K was the lowest in the treatment that received 50% RD as CF I + 25 $ZnSO_4$ ha^{-1} + 50 kg $FeSO_4$ ha^{-1}. Application of 100% RD through straight fertilizers recorded a value of 138.94 kg ha^{-1} (Table 6)

The Zn uptake by stover ranged from 356 g ha^{-1} to 517 g ha^{-1}. Application of 100% RD as CF II registered the highest Zn uptake and was on par with 75% RD as CF II and 100% RD through CF I + 25 $ZnSO_4$ ha^{-1} + 50 kg $FeSO_4$ ha^{-1}.While application of 50% RD through CF I + 25 $ZnSO_4$ ha^{-1} + 50 kg $FeSO_4$ ha^{-1} recorded the lowest Zn uptake. (Table 7)

Table 7: Effect of customized fertilizers on micronutrients uptake by maize stover (g ha^{-1}): Harvest stage (Pooled mean of 2 locations)

Treatments	Zn	Fe	Cu	Mn
	(g ha^{-1})			
T1: 100% RD– 250 : 75 :75 Kg N, P_2O_5,K_2O ha^{-1} + 25 kg Zn SO_4 ha^{-1} +50 kg Fe SO_4 ha^{-1}	402	1661	283	677
T2: 50% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	356	952	204	468
T3: 75% RD as CF I+ 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1}	450	1568	298	775
T4: 100% RD as CF I+ 25 kg $ZnSO_4$ ha^{-1} + 50 kg Fe SO_4 ha^{-1}	488	1653	326	849
T5: 50% RD as CF II	382	695	273	577
T6: 75% RD as CF II	477	1511	360	871
T7: 100% RD as CF II	517	1612	380	880
CD	64.1**	NS	74.9**	347.4*

The Fe uptake by stover varied from 695 g ha^{-1} to 1653 g ha^{-1}. There was no significant variation in Fe uptake by maize stover. The Cu uptake ranged from 204 g ha^{-1} to 380 g ha^{-1}. The highest Cu uptake was observed in the treatment of 100% RD as CF II and was on par with 75% RD as CF II and 100% RD through CF I + 25 kg $ZnSO_4$ ha^{-1} + 50 kg $FeSO_4$ ha^{-1}. Application of 50% RD in the form of CF I +25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1} recorded the lowest Cu uptake. (Table 7)

The Mn uptake varied from 468 g ha^{-1} to 880 g ha^{-1}. The highest Mn uptake was recorded in the treatment that received 100% RD as CF II and was on par with 75% RD as CF II. Application of 50% RD in the form of CF I +25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1} recorded the lowest Mn uptake by stover. (Table 7)

Conclusion

Application of 100% RD as CF II recorded the highest maize grain yield, improved the soil available macro and micronutrients and nutrient uptake by hybrid maize. An increase of 28.8 per cent over the application of 100%RD through straight fertilizer was recorded due to the application of 100% RD in the form of CF II. Application of 100% RD in the form of CF I + 25 kg Zn SO_4 ha^{-1} + 50 kg Fe SO_4 ha^{-1} recorded an increase in maize grain yield of 23.5 per cent over the application of 100%RD through straight fertilizer.

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