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Precision nutrient and conservation agriculture practices for enhancing productivity, profitability, nutrient-use efficiencies and soil nutrient status of maize (*Zea mays*) hybrids

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ABSTRACT

A field experiment was conducted at New Delhi during *kharif* season to study the effect of precision nutrient and conservation agriculture practices for enhancing productivity, profitability, nutrient-use efficiencies and soil nutrient status of maize (*Zea mays* L) hybrids. Using nutrient expert system based site-specific nutrient management (SSNM) practices higher dose of K and N while lower dose of P were estimated for hybrid maize over recommended dose of fertilizers (RDF). Data of the previous crop, target yield, residue management and soil nutrient status were entered in the nutrient expert system. The significant interaction of SSNM and hybrids showed that hybrid PMH 3 along with site specific nutrient management (SSNM) produced significantly higher grain yield under conservation agriculture. The SSNM practice gave 14.7% higher grain yield (5 491 kg/ha) over RDF (4 182 kg/ha). Significantly higher gross return, net return (₹ 41 137) and B:C ratio (1.57) was obtained with SSNM and the net returns of the maize were improved by ₹ 7 856/ha by SSNM over RDF. Amongst genotypes, PMH 3 produced significantly higher gross, net return and B:C ratio over HQPM 1, however, it remained at par with PMH 1, S 6217 and CMH 08-292. Significantly higher partial factor productivity of applied N, P and K was obtained with 50% RDF while it remained at par for applied P by SSNM. Significantly highest agronomic efficiency of applied N and P was obtained with SSNM while for applied K it was significantly highest with 50% RDF. Initially before crop sowing, significantly highest organic carbon in soil was in 100% RDF plots. However, significantly higher organic carbon build up was obtained with SSNM which remained at par with 100% RDF, after crop harvest. In SSNM plots, significantly higher ammonical nitrogen and potassium was observed after maize harvest.

Key words: Agronomic efficiency, B:C ratio, Organic carbon, Partial factor productivity, Returns, Soil macro-nutrients,Yield

Nowadays, maize (*Zea mays* L.) is gaining importance in conservation agriculture as it is wide spaced crop, having slow growth rate in its early stage, which leads to more loss of water and nutrients through evaporation and heavy infestation of weeds. To overcome this problem, adoption of conservation agriculture practices is increasing in maize production area of peninsular India. But production is limited by low fertilizer efficiency, inadequacy in existing fertilizer recommendations and the ignorance of nutrients balance and hence pausing serious threat in maize production. There exists a significant opportunity to increase fertilizer efficiency and productivity of maize by adopting Nutrient Expert-based field specific fertilizer recommendations (Satyanarayana *et al.* 2013).

The Nutrient Expert^{TM} for Hybrid Maize is a new, computer-based decision support tool developed to assist local experts to quickly formulate fertilizer guidelines for tropical hybrid maize based on the principles of Site-Specific Nutrient Management (SSNM). It facilitates the development of recommendation in the form of a quick guide for each region enabling local experts to run multiple scenarios to identify the most common characteristics or factors affecting fertilizer rates in the region. Keeping all facts in view, an investigation to evaluate the performance of nutrient expert on hybrid maize under conservation agriculture with various hybrids was undertaken on sandy loam soil during *kharif* 2013.

MATERIALS AND METHODS

The present investigation was carried out at the research farm of the Indian Agricultural Research Institute,

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New Delhi. The geographical location of the site is located at a latitude of 28º40'N and longitude of 77º12'E, and an altitude of 228 m above the mean sea level. This location has a typical semi-arid and sub-tropical climate characterized by hot dry summers and cool winters. The mean annual rainfall of Delhi is 650 mm and more than 80% generally occurs during the south-west monsoon season (July to September) with mean annual evaporation of 850 mm. The rainfall received during the crop growing period from July to October 2013 was 416 mm. The experimental soil was sandy loam in texture having pH 8.2, low in organic carbon (0.3%) and available nitrogen, medium in available P and high in available K. The experiment was laid out in a factorial randomized block design (FRBD) with twenty treatments combinations having four nutrient management practices and five genotypes, replicated thrice. The five genotypes taken in the experiment were; PMH 1, PMH 3, HQPM 1, CMH 08-292 and S-6217. In order to evaluate current nutrient management practices and farmer practices the general recommended dose of fertilizer for Central Delhi region and half of the recommended dose of fertilizer were taken respectively.The nutrient management practices were: Absolute control, 100% RDF (150:60:40 kg/ha N:P_2O_5:K_2O), 50% RDF (75:30:20 kg/ha N:P_2O_5:K_2O), SSNM(170:40:48 kg/ha N:P_2O_5:K_2O) for hybrids PMH 1, PMH 3, CMH 08-292 and S 6217, SSNM (170:33:40 kg/ha N:P_2O_5:K_2O) for HQPM 1. This experiment was taken under permanent conservation agriculture trial in maize-wheat-mungbean cropping system, initiated during *kharif* 2012 in which mungbean straw @ 1.5 tonnes/ha was retained before maize planting. After shelling the cobs, the grain yield was recorded and the yield per hectare was computed. The straw yield per net plot area was weighed after complete sun drying and it was converted to per hectare. Economics of different treatments was worked out by taking into account the cost of inputs and income obtained from grain and straw yield. From these values, the gross and net returns as well as benefit: cost ratio was worked out as follows:

Gross returns (₹/ha) = (Economic yield × minimum support price)+(Straw yield × market price of produce)

Net returns (₹/ha) = Gross returns – Cost of cultivation

Benefit: cost ratio = Net returns/Cost of cultivation

The partial factor productivity and agronomic efficiency of applied NPK were computed as follows.

Partial factor productivity (PFP) of applied nutrient= Y_t/N_a (kg grain/kg nutrient applied) where, Y_t, Yield under test treatment (kg/ha); N_a, Amount of nutrient added (kg/ha).

Agronomic efficiency (AE) = Y_1-Y_0/A_1 (kg grain increased/kg nutrient applied)

where, Y_1, Yield under test treatment (kg/ha); Y_0, Yield under control (kg/ha); A_1, Units of nutrient applied in the test treatment (kg/ha).

Representative soil samples were collected prior to experimentation and after completion of study from 0-30 cm depth using core sampler. The composite soil samples were analyzed for the available major soil nutrients. Initial and final fertility status of soil nitrate, ammonical nitrogen and phosphate was determined by flow injection auto-analyzer. The organic carbon was estimated by Walkley and Black (1934) method. The soil potassium content was determined using Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

The results of experiment revealed that the grain yield increased significantly by site-specific nutrient management (SSNM) over 100% RDF (Table 1). However, straw yield were recorded significantly higher by 100% RDF over absolute control and 50% RDF and it remained at par with SSNM. Maize hybrids and nutrient management practices had a significant effect on grain yield (Table 2). Hybrid S 6217 gave significantly higher grain yield over all other hybrids at absolute control (no nutrient application). However, at 100% RDF, hybrid CMH 08-292 produced much higher grain yield as compared to all other hybrids. At 50% RDF, PMH 3 gave significantly higher grain yield over other hybrids. Further, at SSNM treatments maize hybrid PMH 3 produced higher grain yield which was statistically equivalent to S 6217, but significantly higher over other treatments.

Significantly increase in yield due to SSNM may have occurred due to the fact that the fertilizer requirement for a field or location is estimated from the expected yield response to each fertilizer nutrient, which is the difference between the attainable yield and the nutrient-limited yield. Nutrient-limited yields are determined from nutrient omission trials, while attainable yield is the yield in a typical year at a location using best management practices without nutrient limitation. Pampolino *et al.* (2012) showed that nutrient management using Nutrient Expert in wheat increased its yield and economic benefit (i.e. gross return

Table 1 Effect of nutrient management practices and hybrids on yields and economics maize

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
Nutrient management practices					
Absolute control	3 031d	5 344b	45 046d	26 352c	1.41ba
100% RDF*	4 027b	7 218a	59 976b	33 281b	1.25bc
50% RDF	3 654c	5 702b	53 565c	29 236cb	1.20c
SSNM#	4 619a	6 804a	67 312a	41 137a	1.57a
LSD (P=0.05)	337.21	693.26	4 705.3	4 705.3	0.202
Hybrids					
PMH 1	3 813b	7 059a	57 013a	33 027a	1.39a
PMH 3	4 247a	6 336ba	61 966a	37 981a	1.56a
HQPM 1	2 975c	5 647bc	44 622b	20 698b	0.86b
S 6217	4 180ba	5 303c	60 063a	36 077a	1.52a
CMH 08-292	3 948ba	6 990a	58 710a	34 725a	1.45a
LSD (P=0.05)	377.01	775.09	5 260.7	5 260.7	0.225

*RDF-Recommended dose of fertilizer; #SSNM- Site-specific nutrient management; Means followed by different letters are significantly different at LSD (P=0.05) in respective columns

Table 2 Interaction effect of nutrient management practices and hybrids on grain yield of maize

Hybrids	Nutrient management practices			
	Absolute control	100% RDF*	50% RDF	SSNM#
PMH 1	3 156	4 023	3 863	4 211
PMH 3	2 897	4 182	4 416	5 491
HQPM 1	2 280	3 307	2 563	3 751
S 6217	3 590	3 915	3 926	5 289
CMH 08-292	3 230	4 709	3 501	4 352
LSD (P=0.05)	1 145			

*RDF-Recommended dose of fertilizer; #SSNM- Site-specific nutrient management

above fertilizer costs) over Farmer Fertilizer Practices (FFP) and state recommendation. Compared with FFP, it increased yield by 0.9 tonnes/ha.

Satyanarayana *et al*. (2013) also reported that Nutrient Expert (NE)-based field specific fertilizer recommendations increased yield and cited the reason as yield improvement with NE-based fertilizer recommendation could primarily be attributed to a balanced application of nutrients rather than increasing nutrient rates. Similar results were also reported by Meena *et al.* (2014) in Udaipur, where they revealed that application of SSNM treatment recorded significantly higher grain and stover yield in maize. Similarly, Gilkes and Prakongkep (2010) also found that at 19 key production sites in Indonesia, Philippines, and Vietnam, compared to the farmers' practice, maize yield were improved by adoption of SSNM to about 0.9 to 1.3 tonnes/ha across different sites in each country.

Significantly higher gross return (₹ 67 312), net return (₹ 41 137) and B:C ratio (1.57) was obtained with SSNM over 100% RDF, 50% RDF and absolute control (Table 1). Amongst genotypes, PMH 3 gave significantly higher return and B:C ratio over HQPM 1, however, it remained at par with PMH 1, S 6217 and CMH 08-292. This was due to higher yield as compared with hybrid PMH 3 which resulted higher net income and net return/rupee invested. The high genetic potential of PMH 3 was also reported by Ashok (2013).The findings of Karthikeyan and Balasubramanian (2006) were also in close conformity of these results. Pampolino *et al*. (2012) also found in wheat that gross return above fertilizer costs were significantly higher with Nutrient Expert than state recommendation and FFP. Satyanarayana *et al*. (2013) also demonstrated in southern India that the Nutrient Expert-based field specific fertilizer recommendations were economically superior in maize.

The partial factor productivity (PFP) and agronomic efficiency (AE) differed significantly due to nutrient management practices. Significantly higher PFP values were obtained for P in SSNM, while N and K gave its significantly higher values with 50% RDF (Fig 1). Similarly higher AE was obtained by 50% RDF for applied potassium in maize. However, the AE of applied N and P nutrients were significantly higher by SSNM. These efficiencies in the

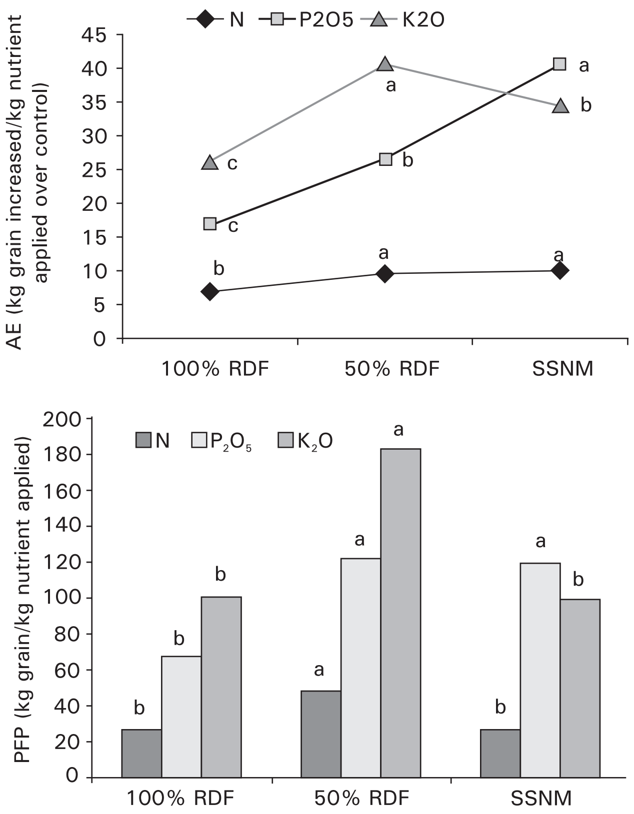

Fig 1 Effect of different nutrient management practices in maize on partial factor productivity (PFP) and agronomic efficiency (AE) of maize (bars/lines followed by different letters are significantly different at LSD (P=0.05).

study were in order of K> P > N. The lower dose of nutrient might have contributed for higher PFP and AE with 50% RDF and the higher amount of the nutrient application lower down these efficiencies. Due to this reason lower AE and PFP was observed compared to K and P. It clearly shows that balanced application in the form of SSNM resulted in significantly higher nitrogen and phosphorus agronomic efficiency because of higher grain yield produced with SSNM based nutrient management. Similar findings were also reported by Gilkes and Prakongkep (2010) where results showed that adoption of SSNM in maize increased the agronomic efficiency of N fertilizer by 53% compared to the FFP.

Organic carbon is the store house of nutrient which is considered as important soil health parameter. Initially, significantly higher organic carbon in soil was obtained with 100% RDF which remained at par with 50 % RDF (Table 3). While at final stage significantly higher organic carbon build up was obtained with SSNM which remained at par with 100% RDF. It clearly shows that balanced fertilization caused a buildup of organic carbon in soil. Amongst genotype initially organic carbon was significantly higher in PMH 1. However, driven high biomass production and soil health at final stage significantly higher organic carbon was obtained with CMH 08-292.

Table 3 Effect of nutrient management practices and hybrids on organic carbon and nitrogen status in soil

Treatment	Organic carbon (%)		Ammonical nitrogen (ppm)		Nitrate nitrogen (ppm)	
	Initial	Final	Before sowing	After harvesting	Before sowing	After harvesting
Nutrient management practices						
Absolute control	0.455c	0.487b	3.61ba	1.80ba	1.48a	1.39a
100% RDF*	0.487a	0.513a	3.41b	1.71b	1.49a	1.49a
50% RDF	0.475ba	0.511ba	3.39b	2.05ba	1.57a	1.36a
SSNM#	0.464bc	0.522a	3.79a	2.17a	1.61a	1.39a
LSD (P=0.05)	0.0151	0.0233	0.37	0.38	0.25	0.274
Hybrids						
PMH 1	0.481a	0.507ba	3.20b	1.83ba	1.51a	1.42ba
PMH 3	0.457c	0.492b	3.73a	2.25a	1.61a	1.61a
HQPM 1	0.479ba	0.504ba	3.57ba	1.85ba	1.41a	1.42ba
S 6217	0.462bc	0.517ba	3.63a	1.73ba	1.55a	1.18b
CMH 08-292	0.473bac	0.520a	3.61ba	2.01ba	1.60a	1.40ba
LSD (P=0.05)	0.0168	0.0261	0.4181	0.4343	0.2875a	0.308

*RDF-Recommended dose of fertilizer; #SSNM- Site-specific nutrient management; Means followed by different letters are significantly different at LSD (P=0.05) in respective columns.

It was also observed that by SSNM significantly higher ammonical nitrogen was observed before sowing as well as after harvest, however it remained at par with 50% RDF and absolute control (Table 3). Amongst genotypes, ammonical and nitrate nitrogen status in soil before sowing was significantly higher in PMH 3. After harvesting also similar trend of significantly higher build up of ammonical and nitrate nitrogen was observed with PMH 3, however, it remained at par with all other genotypes.

Non-significant effect on soil phosphate (PO_4) was observed before sowing and after harvest (Table 4). Similarly potassium status was also found non-significant before sowing, however after harvest significantly higher potassium status of soil was observed by SSNM, which shows that due to balanced application of fertilizer build up has taken place (Table 4). Amongst genotypes, phosphate status in soil before sowing as well as after harvest was significantly higher in S 6217. With regards to potassium status in soil, non-significant response by different genotypes was observed before sowing as well as after harvest.

The results of experiment showed that significant interaction on grain yield was observed and PMH 3 along with SSNM produced significantly highest grain yield, however, it remained at par with S 6217. Significantly higher gross return (₹ 67 312), net return (₹ 41 137) and B:C ratio (1.57) was obtained with SSNM over 100% RDF. Amongst genotypes, PMH 3 produced significantly highest gross, net return and B:C ratio over HQPM 1, however, it remained at par with PMH 1, S 6217 and CMH 08-292. Initially, significantly higher organic carbon in soil was obtained with 100% RDF and it remained at par with 50 % RDF. While at final stage significantly higher organic carbon build up was obtained with SSNM which remained at par with 100% RDF. By SSNM, significantly higher ammonical nitrogen and potassium were observed before sowing as well as after harvest. Amongst genotypes, ammonical and nitrate nitrogen status in soil before sowing was significantly higher in PMH 3. While phosphate status in soil before sowing as well as after harvest was significantly higher in S 6217 and potassium status in soil did not differ significantly by genotypes.

Table 4 Effect of nutrient management practices and maize hybrids on phosphate and potassium status in soil

Treatment	Phosphate (PO_4) (ppm)		Potassium (ppm)	
	Before sowing	After harvesting	Before sowing	After harvesting
Nutrient management practices				
Absolute control	4.095a	2.692a	31.99a	42.19b
100% RDF	4.389a	2.735a	30.58a	39.37b
50% RDF	4.164a	2.696a	32.03a	38.88b
SSNM	4.730a	3.350a	32.27a	52.55a
LSD (P=0.05)	1.2503	0.7766	5.255	6.6009
Hybrids				
PMH 1	4.615ba	3.061ba	32.66a	44.57a
PMH 3	4.078ba	2.840ba	29.82a	47.28a
HQPM 1	4.650ba	2.738ba	31.74a	40.86a
S 6217	4.923a	3.318a	33.45a	41.40a
CMH 08-292	3.457b	2.385b	30.93a	42.13a
LSD (P=0.05)	1.3978	0.8682	5.8753	7.38

*RDF-Recommended dose of fertilizer; #SSNM- Site-specific nutrient management; Means followed by different letters are significantly different at LSD (P=0.05) in respective columns

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