

Response of maize (*Zea mays*) hybrids to nutrient management practices for enhancing productivity and profitability under sub-humid condition of Southern Rajasthan

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ABSTRACT

A field experiment was conducted during 2 consecutive years of 2013 and 2014 to find out the response of nutrient expert-decision support systems based on the principle of site-specific nutrient management (SSNM) for achieving targeted yield of maize (*Zea mays* L.). This approach estimated high dose of N and K and low dose of P over recommended dose of fertilizer (RDF) to evaluate the response of hybrid under this experiment. Growth parameters, yield, nutrient uptake, harvest index and partial factor productivity of P and K and apparent recovery of N and P and economics were significantly higher with SSNM over RDF and farmer's fertilizer practices (FFP). Yield attributes, harvest index and partial factor productivity of N and apparent recovery of K were found at par with RDF. Among the hybrids, 'CMH-08-292' recorded maximum plant growth parameters, yield attributes, yield and nutrient uptake, which was found statistically at par with 'CMH-08-350'. SSNM gave significantly higher net returns (₹ 66,350/ha) and benefit: cost ratio (2.60) over RDF and FFP. Among the hybrids, 'CMH-08-292' recorded maximum gross returns (₹ 84,686/ha), net returns (₹ 60,120/ha) and benefit: cost ratio (2.41), which was at par with 'CMH-08-350'. The interaction effect revealed that the highest grain yield (7.90 t/ha), net returns (₹ 84,723/ha), and benefit: cost ratio (3.27) obtained with 'CMH-08-292' under SSNM. Hence, it is concluded that SSNM along with suitable high yielding hybrids are recommended for enhancing yield and profitability of maize under sub-humid condition of Southern Rajasthan and similar ecologies elsewhere.

Key words : Economics, Nutrient harvest index, Nutrient uptake, Partial factor productivity, Yield

Maize is one of the most versatile crop, has the highest genetic yield potential and known as queen of cereals in the world. Maize is considered as the third most important food crop among the cereals in India that contributed to nearly 9% of the national food security (Jat *et al*, 2013). Maize is a staple food, and quality feed, and used as a basic raw material for thousands of industrial products. Currently, it is cultivated over an area 9.23 million ha with 24.2 million tonnes production having an average productivity of 2,560 kg/ha (ICAR-IIMR 2015). Growing market demand for the feed and starch industry and increase in minimum support price from ₹ 5,400/t in the year 2006–07 to ₹ 13,100/t in 2013–14 led to make maize as a more

profitable crop and encouraged farmers to grow maize to a large extent (DACNET, 2015). However, maize productivity has not increased proportionately and significant yield gaps are evident across the maize growing areas in the country. High yielding maize hybrids, with very high biomass production, extracts higher amounts of mineral nutrients from the soil than other major cereals like rice or wheat. Nutrient requirement of maize varies from field to field due to high variability in soil fertility across farmer's fields and also varies with the yield potential of hybrids. Therefore, single homogenous nutrient recommendations may not be very useful for improving maize yield. To overcome this problem from adoption of the emerging concept of precision agriculture wherein the input variables such as fertilizers are applied in the right amount, at the right place and at the right time (variable rate application) as per the demand of the crop. It helps to improve input-use efficiency, economy, and ensures sustainable use of natural resources, as it minimizes wastage. Nutrient expert is a

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decision support tool based on principles of site-specific nutrient management (SSNM), in which optimum fertilizer management for a crop field is tailored to specific local condition, growth duration of the variety, crop residue management, past fertilizer use and input of nutrients from external sources. It is computer-based decision tool that provides fertilizer recommendations with consideration of yield response and targeted agronomic efficiency in addition to the contribution of nutrients from indigenous sources. It also considers other important parameters of the growing environment, which effect nutrient management recommendations in a particular location. Keeping these in views, a field experiment was undertaken to improve the productivity, nutrient-use efficiency and economics of maize in Southern Rajasthan by altering the fertilizer prescription using SSNM as compared to existing fertilizer recommendation and farmer's fertilizer practice.

MATERIALS AND METHODS

A field experiment was conducted during 2 consecutive years of 2013 and 2014 to find out the response of nutrient expert-decision support system assisted SSNM for achieving targeted yield of maize hybrids under precision agriculture at Agricultural Research Station (MPUAT), Banswara. It is geographically situated at 23°33' N, 74°27' E and altitude 220 m above mean sea-level, covered under humid southern plain agro-climatic zone of Rajasthan, which falls under sub-humid climate with dry, hot summer and mild winters. The average annual rainfall is about 862 mm of which more than 80% is generally received during the monsoon season (June–October). The average rainfall received during the crop growing period of experiment from July to October was 784.1 mm. The soil of experimental field was clay loam in texture, slightly alkaline in reaction, low in organic carbon (0.41%) and available nitrogen (218 kg/ha), medium in available phosphorus (26 kg/ha) and high in available potassium (345 kg/ha). The experiment was laid out in a split-plot design (SPD) with fifteen treatment combinations of three nutrient management practices and five hybrids and replicated thrice. The five hybrids taken in the experiment were 'PMH 1', 'PMH 3', 'HQPM 1', 'CMH-08-292' and 'CMH-08-350'. Current nutrient management practices (RDF), site-specific nutrient management (SSNM) practices based on target yield of hybrids and farmer fertilizer practices (FFP) were tested. The nutrient management practices were RDF (120-26.2-33.2 kg N-P-K/ha), SSNM based on target yield of hybrids as 'PMH 1' and 'PMH 3' (140-40:46 kg N: P₂O₅:K₂O/ha) for target yield (6.0 t/ha), 'HQPM 1' (130:37:41 kg N:P₂O₅:K₂O/ha) for target yield (5.0 t/ha) and 'CMH-08-292' and 'CMH-08-350' (160:44:51 kg N:P₂O₅:K₂O/ha) for target yield (7.0 t/ha) and farmer's

fertilizer practice (78:23:00 kg N: P₂O₅:K₂O/ha). Nutrient management practices and hybrids were randomized in main-plots and sub-plots, respectively. The planting was done at spacing of 60 cm × 25 cm. A representative soil samples were collected prior to experimentation and after completion of study from 0–30 cm depth using core sampler. The different plant parts, viz. grain and straw were grinded and analyzed for N, P and K at harvest. From each replication 0.5 g grain and stover samples were taken for chemical analysis to determine the N, P and K concentrations. The nutrient uptake was calculated by multiplying dry matter production with corresponding values of their concentrations and expressed in kg/ha. The nutrient harvest indexes, apparent recoveries and partial factor productivity (PFP) of applied nutrients were calculated as follows:

$$\text{Apparent recovery (AR)} = \frac{N_t - N_f}{N_a}$$

Where, N_t = Amount of nutrient taken from test treatment plot (kg/ha), N_f = Amount of nutrient taken from the farmer fertilizer practices (kg/ha), N_a = Amount of nutrient added (kg/ha)

$$\text{Partial factor productivity (PFP)} = \frac{\text{Economic yield (kg/ha)}}{\text{Nutrient (kg/ha)}}$$

Where, PFP= Partial factor productivity of nutrient (kg grain/kg nutrient applied)

The economic analysis parameters, viz. gross returns, net returns and benefit cost ratio were worked out on the basis of prevailing market prices of inputs and outputs. The data were subjected to analysis of variance technique as per the statistical procedure and the treatment pooled means were compared at 5% level of significance.

RESULTS AND DISCUSSION

Growth parameters

Significantly higher growth characters were recorded in SSNM over RDF and FFP (Table 1). It seems that SSNM based balanced dose provided nutrient as per the crop requirement, hence the better plant height was observed with SSNM. With regards to different hybrids, significantly the highest plant height at harvest was recorded in 'CMH 08-292' over all other hybrids and significantly the lowest plant height was recorded by 'HQPM 1'. The dry-matter accumulation and leaf area index have direct correlation with grain yield of the crop. Leaf area indicates the photosynthetic efficiency, while dry-matter accumulation shows the crop health. Dry-matter accumulation and leaf-area index at 90 days after sowing (DAS) were significantly increased with SSNM, followed by RDF and significantly

lowest recorded in the FFP (Table 1). Among different hybrids, 'CMH-08-292' recorded significantly the highest dry matter accumulation and leaf area index at 90 DAS compared to other hybrids and 'HQPM 1' recorded significantly the lowest dry matter accumulation and leaf area index at 90 DAS. It clearly indicated that owing to better leaf-area and higher growth parameters, SSNM proved better than other nutrient applications. Kumar *et al.* (2014) also reported that 'CMH-08-292' recorded the highest dry-matter accumulation/plant compared to other hybrids.

The crop growth rate (CGR) was recorded significantly higher with SSNM over RDF and FFP at all growth stages (Table 1). It might be owing to better availability of nutrients to crop-growth. Among the hybrids, 'CMH-08-292' was recorded significantly higher CGR over other hybrids at all growth stages except 'CMH-08-350' at 60–90 DAS. While significantly lowest CGR obtained by 'HQPM 1' at all growth stages, which show the limitation of hybrids to perform for dry-matter enhancement. It also indicates the difference in the growth potential of maize hybrids used in the experiment.

Yield attributes and yield

All the yield attributes, viz. cobs/plant, grain rows/cob, grains/row, test weight (g) and shelling percentage were influenced significantly by different nutrient management practices (Table 1). Cobs/plant (0.96), grain rows/cob (14.9), grains/row (38.6), test weight (327.6 g) and shelling percentage (85.0%) were the recorded the highest with SSNM, followed by RDF and significantly the lowest re-

corded in FFP. The highest yield attributes under SSNM practice might be due to higher nutrient availability, which lead to more growth and development compared to other practices. While, cob yield (7.25 t/ha), grain yield (6.56 t/ha) and stover yield (8.61 t/ha) were recorded significantly higher with SSNM over RDF and FFP (Table 2). The highest grain yield in SSNM practice might be due to positive correlation of yield and yield attributes, which were found higher in this treatment. The similar findings were reported by Ameta and Hargilas (2014) and Hargilas (2016).

With regards to hybrids, 'CMH-08-292' recorded significantly higher cobs/plant over 'PMH 1' and 'HQPM 1', however, it remained at par with 'CMH-08-350' and 'PMH 3'. The maximum grain rows/cob recorded in 'CMH-08-292' but it was not found significant with other hybrids. Significantly superior grains/row recorded in 'PMH 3' over rest hybrids. Maximum test weight obtained in 'CMH-08-292' and it found at par with 'CMH-08-350' and significantly superior over rest hybrids. Maximum shelling (83.5%) was observed in 'CMH-08-292', however, it remained at par with 'PMH 1' and 'PMH 3'. Cob, grain and stover yields were recorded maximum in 'CMH-08-292' and found significantly superior over rest hybrids except 'CMH-08-350'. Significantly the lowest yield attributes and grain yield were recorded by 'HQPM 1' (Table 2). Enhancement in growth and yield attributes leads to better photosynthetic partitioning and source–sink relationship, which gave higher yield in such hybrids. The similar findings were reported by Kumar *et al.* (2014).

Table 1. Effect of nutrient management practices and hybrids on growth parameters and yield attributes (mean data of 2 years)

Treatment	Plant height (cm)	Dry matter (g/plant) at 90 DAS	LAI at 90 DAS	CGR (g/plant/day)			Cobs/plant	Grain rows/cob	Grain/row	Test weight (g)	Shelling (%)
				0–30 DAS	30–60 DAS	60–90 DAS					
<i>Nutrient management practice</i>											
RDF	209	289	2.6	1.3	1.7	7.8	0.92	13.9	38.4	315.1	83.3
SSNM	220	329	3.3	1.6	2.1	9.9	0.96	14.9	38.6	327.6	85.0
FFP	201	235	1.9	0.9	1.2	5.6	0.75	13.4	33.7	307.6	74.1
SEm±	1.7	3.0	0.3	0.02	0.01	0.08	0.01	0.5	0.9	9.1	1.7
CD (P=0.05)	4.7	8.4	0.7	0.04	0.04	0.23	0.04	1.3	2.5	25.3	4.7
<i>Hybrid</i>											
'PHM 1'	213	293	2.7	1.3	1.7	7.9	0.81	13.4	34.6	312.6	83.4
'PMH 3'	217	292	2.7	1.3	1.7	8.0	0.91	14.4	41.7	311.5	80.1
'HQPM 1'	174	217	2.0	1.0	1.3	5.9	0.80	14.3	35.6	289.6	79.8
'CMH-08-350'	222	305	2.8	1.4	1.8	8.4	0.92	13.5	35.7	327.5	77.2
'CMH-08-292'	225	316	2.8	1.4	1.8	8.6	0.94	14.8	36.9	342.6	83.5
SEm±	2.9	5.2	0.5	0.03	0.03	0.14	0.04	1.20	1.25	13.5	1.5
CD (P=0.05)	6.0	10.8	1.0	0.06	0.06	0.29	0.08	2.48	2.57	27.8	3.2

RDF, Recommended dose of fertilizers; SSNM, site-specific nutrient management; FFP, farmer's fertilizer practice; LAI, leaf-area index; CGR, crop growth rate; DAS, days after sowing

Nutrient uptake

The data of 2 years indicated that the uptake of NPK by grain and stover and biomass was significantly higher with SSNM over RDF and FFP (Table 2). It clearly shows that application of balanced fertilization based on target yield resulted in significantly higher nitrogen uptake by grain and stover. Among the hybrids, 'CMH-08-292' recorded significantly higher NPK uptake by grain over rest hybrids, however, NPK uptake by stover and biomass of 'CMH-08-292' was obtained at par with 'CMH-08-350'. Better timing and splitting of fertilizer N application and biomass of hybrids were probably the major reasons in higher N uptake, while balanced fertilization lead to enhanced uptake of PK under SSNM and higher uptake by 'CMH-08-292' might be due to higher yield performance. Similar finding was also reported by Kumar *et al.* (2015).

Nutrient harvest index

The harvest index of the nutrient shows, how nutrient partitioning influenced by agronomic management practices and higher index shows more recovery of nutrient in economic yield. The optimum dose of P and K by SSNM has influenced their partitioning in the plant (Table 3). The N harvest index was significantly higher in FFP over RDF and SSNM, whereas phosphorus harvest index was obtained significantly higher in SSNM over RDF and FFP. However, the potassium harvest index was obtained significantly higher in SSNM over RDF, but it remained at par with FFP because lower dose of potassium applied in SSNM compared to RDF and no use of potassium by FFP. Among hybrids, 'HQPM 1' recorded the highest harvest index of N and P, which remained at par with 'CMH-08-

292' and 'PMH 3', whereas, the maximum K harvest index recorded in 'PMH 3', which remained at par with 'HQPM 1' and significantly superior over rest hybrids.

Apparent nutrient recovery

Apparent nutrient recovery in maize was significantly influenced by different nutrient management practices and hybrids (Table 3). Apparent recovery of nitrogen and phosphorus recorded significantly higher with SSNM over RDF. Whereas, apparent recovery of potassium in SSNM was recorded at par with RDF, might be owing to high level of K in the soil. The balanced application of nutrient by SSNM obtained significantly higher apparent recovery (%) of nutrient applied, because, all these nutrients are synergistic in nature. Among the hybrids, 'CMH-08-292', resulted in significantly higher apparent recovery (N, P & K) over 'HQPM 1' and 'PMH 1' and it remained at par with 'CMH-08-350' and 'PMH 3'.

Partial factor productivity (PFP)

The maximum PFP of N recorded in SSNM, followed by RDF and it's recorded significantly higher over FFP. The PFP of phosphorus in SSNM was found significantly higher over rest treatments. The highest PFP of K in SSNM, followed by RDF. It clearly shows that balanced nutrient application by SSNM increases partial factor productivity compared to the RDF and FFP. Among the hybrids, maximum partial factor productivity of N (49.4 kg/ha), P (154.8 kg/ha) and K (152.3 kg/ha) recorded with 'CMH-08-292', which recorded significantly higher over rest hybrids. It indicates that 'CMH-08-292' was efficient in the utilization of nutrients and genetic diversity exists

Table 2. Effect of nutrient management practices and hybrids on yield and nutrient uptake (mean data of 2 years)

Treatment	Cob yield (t/ha)	Grain yield (t/ha)	Stover yield (t/ha)	Nutrient uptake by grain (kg/ha)			Nutrient uptake by stover (kg/ha)			Total uptake (kg/ha)		
				N	P	K	N	P	K	N	P	K
<i>Nutrient management practice</i>												
RDF	6.68	5.29	7.93	66.7	16.8	25.8	24.9	11.7	146.8	91.8	30.6	172.6
SSNM	7.25	6.56	8.61	86.3	21.0	35.3	31.1	11.9	158.7	117.4	34.8	185.6
FFP	4.98	3.48	5.55	42.5	10.3	16.9	12.9	6.6	82.1	55.5	17.9	105.4
SEm±	0.12	0.07	0.09	1.01	0.24	0.40	0.36	0.17	2.21	0.68	0.48	3.65
CD (P=0.05)	0.34	0.20	0.24	2.8	0.67	1.12	1.00	0.46	6.13	1.89	1.33	10.14
<i>Hybrid</i>												
'PHM 1'	5.38	4.52	6.96	57.1	14.0	23.0	21.3	10.8	124.1	79.1	25.4	147.9
PMH 3'	6.58	5.21	7.60	64.9	16.3	28.9	22.1	9.0	125.1	86.2	27.4	153.8
'HQPM 1'	5.26	4.24	5.61	55.5	13.9	20.6	18.1	8.3	101.7	73.7	23.4	120.9
'CMH-08-350'	7.09	5.54	8.19	70.4	17.1	28.9	26.4	11.5	147.6	97.2	30.0	174.9
'CMH-08-292'	7.19	6.05	8.46	78.3	18.9	28.7	26.9	10.6	147.7	104.9	32.6	175.4
SEm±	0.30	0.27	0.27	1.74	0.42	0.70	1.26	0.75	6.73	1.18	0.83	6.35
CD (P=0.05)	0.61	0.55	0.55	3.6	0.87	1.44	2.61	1.54	13.89	2.44	1.72	13.11

RDF, Recommended dose of fertilizers; SSNM, site specific nutrient management; FFP, farmer's fertilizer practice

for nutrient utilization in maize cultivars.

Economics

The variation in the gross returns, net returns and benefit: cost ratios were recorded due to different nutrient management practices, whereas, cost of cultivation was not varied much with different practices (Table 5). Significantly the highest gross returns (₹91,797/ha), net returns (₹66,350/ha) and benefit: cost ratio (2.60) recorded in

SSNM over RDF and FFP. Among the hybrids, 'CMH-08-292', recorded significantly higher gross returns, net returns and benefit: cost ratio, followed by 'CMH-08-292' and significantly superior over rest hybrids. The gross returns, net returns and benefit: cost ratio has direct correlation with economical yield under different nutrient management practices and yield potential of hybrids. Thus, the higher yield resulted into better economics in such treatments.

Table 3. Effect of nutrient management practices and hybrids on nutrient harvest index, apparent recovery, partial factor productivity, and economics of hybrids (mean data of 2 years)

Treatment	Nutrient harvest index			Apparent recovery (%)			Partial factor productivity (kg grain/kg nutrient applied)			Cost of cultivation ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
	N	P	K	N	P	K	N	P	K			
	<i>Nutrient management practice</i>											
RDF	73.0	55.2	15.0	30.3	21.2	167.9	44.1	88.1	132.2	25.8	48.3	1.87
SSNM	73.5	60.3	19.1	42.1	41.2	169.9	44.7	159.2	138.9	25.4	66.4	2.60
FFP	76.4	57.6	16.3	-	-	-	40.9	154.6	-	22.0	26.7	1.21
SEm \pm	0.54	0.62	0.38	1.26	0.82	7.45	0.80	2.76	1.75	0.00	1.03	0.04
CD (P=0.05)	1.49	1.72	1.05	3.50	2.28	20.68	2.22	7.65	4.87		2.86	0.12
<i>Hybrid</i>												
'PHM 1'	72.4	55.1	15.4	33.9	29.3	160.4	38.6	118.5	121.5	25.3	38.9	1.57
'PMH 3'	75.5	59.6	18.6	36.5	31.3	168.3	45.7	140.8	142.5	25.3	48.9	1.96
'HQPM 1'	75.8	59.4	17.2	31.8	29.2	153.1	37.3	114.8	120.7	24.9	35.1	1.42
'CMH-08-350'	72.8	56.5	16.4	38.6	31.6	180.1	45.2	140.9	140.6	25.9	53.0	2.12
'CMH-08-292'	75.1	57.8	16.5	40.2	34.6	182.6	49.4	154.8	152.3	25.9	60.1	2.41
SEm \pm	0.93	1.12	0.65	2.68	1.74	15.84	1.39	4.79	3.73	0.00	3.75	0.15
CD (P=0.05)	1.92	2.31	1.35	5.53	3.59	32.69	2.87	9.88	7.69	-	7.73	0.31

RDF, Recommended dose of fertilizers; SSNM, site specific nutrient management; FFP, farmer's fertilizer practice

Table 4. Interaction effect of nutrient management practices and hybrids on yield, net returns and benefit: cost ratio (mean data of 2 years)

Nutrient management practice	Hybrid	Grain yield (t/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
RDF	'PHM 1'	4.76	40.8	1.58
	'PMH 3'	5.53	51.6	2.00
	'HQPM 1'	4.56	38.1	1.48
	'CMH-08-350'	5.61	52.8	2.05
	'CMH-08-292'	5.99	58.1	2.26
SSNM	'PHM 1'	5.73	55.0	2.17
	'PMH 3'	6.75	69.3	2.74
	'HQPM 1'	5.23	48.3	1.94
	'CMH-08-350'	7.19	74.8	2.89
	'CMH-08-292'	7.90	84.7	3.27
FFP	'PHM 1'	3.07	20.9	0.95
	'PMH 3'	3.35	24.9	1.13
	'HQPM 1'	2.92	18.9	0.86
	'CMH-08-350'	3.82	31.4	1.42
	'CMH-08-292'	4.26	37.5	1.70
SEm \pm		0.42	5.81	0.23
CD (P=0.05)		0.96	13.40	0.54

RDF, Recommended dose of fertilizers; SSNM, site specific nutrient management; FFP, farmer's fertilizer practice

Interaction effect of nutrient management practices and hybrids

The interaction effect of nutrient management practices and hybrids was observed on yield, net returns and benefit: cost ratio (Table 6) indicated that maximum grain yield (7.90 t/ha), net returns (₹84,723/ha) and benefit: cost ratio (3.27) recorded with 'CMH-08-292' with SSNM, which found at par with 'CMH-08-350' with SSNM and significantly superior over rest interactions. The lowest value of yield and net returns were recorded under the farmer's fertilizer practice for all hybrids, which might be due to lower/imbalance doses of nutrients under farmer's fertilizer practice in comparison to recommended doses and SSNM. It indicates that every hybrid needs a differential nutrient management strategy for realization of the highest yield and profit.

Based on 2 years study, it can be concluded that target yield based-site-specific nutrient management practice proved to be higher productive, viable and profitable than recommended dose of fertilizers and farmer's fertilizer practices for growing high yielding hybrids in sub-humid condition of Southern Rajasthan and similar agroecoloiges.

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