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Nutrient expert assisted site-specific-nutrient-management: An alternative precision fertilization technology for maize production in Chota-nagpur plateau region of Jharkhand

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Abstract
A field experiment was conducted during *kharif* season of 2014 at Birsa Agricultural University, Ranchi, Jharkhand to evaluate the performance of maize hybrids under different nutrient management practices. The experiment was laid out in split plot design with 6 maize hybrids (PMH-1, PMH-3, CMH 08-350, CMH 08-287, CMH 08-292 and HQPM-1) in main plot and 3 nutrient management practices (recommended dose of fertilizer, site specific nutrient management and farmer fertilizer practice) in subplot replicated thrice. Site specific nutrient management exhibited significantly higher cob yield, grain yield, stover yield, which led to significantly higher net return, gross energy output, net energy return over recommended dose of fertilizer and farmer fertilizer practice. The benefit: cost ratio, energy use efficiency, energy productivity with site specific nutrient management was comparable with recommended dose of fertilizer but, significantly higher than farmer fertilizer practice. Significant enhancement in nutrient uptake of nitrogen, phosphorus and potash was also recorded significantly higher under site specific nutrient management than recommended dose of fertilizer and farmer fertilizer practice. Among maize hybrids, CMH 08-350 being comparable to CMH 08-292 produced significantly higher cob yield, grain yield, stover yield, net return, benefit: cost ratio, gross energy output, net energy return, energy use efficiency and energy productivity over other maize hybrids. The maize hybrid CMH 08-350 also removes higher nitrogen, phosphorus and potassium than PMH-1, PMH-3, CMH 08-287 and HQPM-1.

Keywords: Economics, energetics, maize, net returns, nutrient uptake, productivity

Introduction
Under the current scenario of farming with changing natural resource base, food habits, industrialization, maize having adaptability across diverse soil and climatic conditions has emerged as an important crop for food and nutritional security and farm economy. Among all the cereals, the growth of maize production is highest (4.2%), which is much higher than the major crops (rice and wheat). Although there has been an increasing trend in area, production and productivity of maize, there exists wide gap between attainable and actual yields at farm level. Saharawat *et al.* (2010) [9] reported that simulated, attainable and actual maize yields in maize growing agro–ecologies in South-Asia revealed wide management yield gaps ranging from 36–77%. These yield gaps are due to poor yielding genotypes and crop establishment techniques as well as imbalanced nutrient applications as 15–45% maize area remains unfertilized (Jat *et al.* 2011) [3]. Therefore, the goal of Indian agriculture has to be increase food-grain production with the minimum and efficient use of chemical fertilizers. On a macro-scale, N:P:K ratio of 4 : 2 : 1 has come to be known as an ideal ratio, and a deviation in NPK consumption pattern, would suggest imbalanced fertilizers use. This is not entirely true as there is hardly any basis for the suggested single valued ideal N:P:K ratio. The NPK ratio is likely to vary with crops, cropping systems, conservation agriculture (CA) practices, soils and their reactions. It appears that there is need to work out new N:P:K ratios for different regions. From plant nutrition point of view, the importance of the concept of balanced fertilizer use lies in adjusting the level of fertilizer use, taking into account available soil nutrients, crops requirement for targeted production levels under specific soil-water-crop management practices.

In this context, Site-Specific Nutrient Management (SSNM) approach is one such option which focuses on balanced and crop need-based nutrient application (Johnston *et al*., 2014) [4]. It provides an opportunity for the timely application of fertilizers at optimal rates to fill the deficit between the nutrient needs of a high-yielding crop and the nutrient supply from naturally occurring indigenous sources, including soil, crop residues, manures, and irrigation water. Site-Specific Nutrient Management (SSNM) ensures for balanced precision nutrition application of nitrogen, phosphorus and potassium along with secondary and micronutrients based on the nutrient supplying capacity of the soil and nutrient requirement of a particular crop to produce a unit quantity of yield or set yield target. The Nutrient Expert for Hybrid Maize is developed by IPNI (International Plant Nutrition Institute), Penang, Malaysia. It is a new computer based decision support tool based on site specific nutrient management principle that enables researchers, extension experts and industry agronomist to quickly develop field specific fertilizer recommendation for hybrid maize (Witt *et al.,* 2009) [10]. Site-specific nutrient management combined with good crop management practices that will help farmers attain high yield and achieve high profitability both in the short and medium-term. Considering above facts, an attempt has been made to study SSNM-NE practice to reorient the nutrient management practices of maize in chotanagpur plateau region of Jharkhand.

Materials and Methods

A field experiment was conducted at the University Research Farm of Birsa Agricultural University, Kanke, Ranchi during *kharif* season of 2014. The soil was sandy loam (sand, silt and clay contents of 63.2, 22.2 and 14.6% respectively), having pH 6.13, organic carbon 4.2 g kg^{-1} of soil and available NPK were 242.7, 18.72, 164.8 kg ha^{-1}, respectively. The experiment was laid out in split plot design with six maize hybrids *i.e.* PMH-1, PMH-3, CMH 08-350, CMH 08-287, CMH 08-292 and HQPM-1 in main plot and three nutrient management practices *i.e.* recommended dose of fertilizer (100:50:25 kg N:P:K ha^{-1}), site specific nutrient management based on nutrient expert (170: 67: 86 kg N:P:K ha^{-1}) and farmer fertilizer practice (100: 50: 0 kg N:P:K ha^{-1}) in subplot replicated thrice. All agronomic cultivation practices were followed as per recommendations. The maize crop was sown on 15th July, 2014 by line sowing at 75 cm rows spacing and 20 cm plant to plant distance with seed rate of 20 kg ha^{-1}. Thinning and gap filling was done 15 days after sowing to maintain the plant population. Pre-emergence application of Atrazine @ 1.5 kg ha^{-1} along with two hand weeding at 20 and 40 days after sowing were done to control the weed population. Need-based plant protection measures were adopted. A basal dose of full P_2O_5 in the form of diammonium phosphate (DAP), K_2O through muriate of potash (MOP) and 1/3rd of the nitrogen through urea was applied as basal application as per treatment. The remaining 2/3rd of nitrogen was top dressed in two equal splits at knee-high stage and tasseling stage. The SSNM dose was calculated through nutrient expert, decision support system software developed by International Plant Nutrition Institute (IPNI) in collaboration with International Maize and Wheat Improvement Centre (CIMMYT). Nutrient expert a precision nutrient management tool developed for maize crops based on SSNM principles which is easy-to-use, highly interactive and computer friendly that rapidly provides effective fertilizer recommendations by considering yield responses, targeted agronomic efficiencies alongwith contribution of nutrients from indigenous sources as well as systematic approach of capturing site-specific information both in the presence or absence of soil-testing data. In addition to the fertilizer doses this software also appropriates maize planting density and provides stage specific fertilizer scheduling to attain the desired yield levels.

The cobs from net plot area were harvested and sun dried in open on cemented floor. After complete sun drying the cob weight of each net plot was recorded and converted to kg ha^{-1}. The grains from harvested cobs were shelled and cleaned grain yield was recorded and converted to kg ha^{-1}. The stover yield was obtained by weighing the stalk harvested from the net plot area and converted to kg ha^{-1}. The nutrient uptake was estimated by multiplying the nutrient concentration with the grain and straw yield. The data were subjected to statistical analysis as prescribed by Gomez and Gomez (1984) [2] and significant effects were presented. The economics were computed on the basis of prevailing market rates of produce and agro-inputs. The net return was calculated by subtracting total cost of cultivation from gross return. The benefit: cost ratio was calculated by dividing the net return by the cost of cultivation. Energy input of each treatment was calculated from the data for each item of operations and expressed in MJ ha^{-1} for each treatment using standard values suggested by Paneshar and Bhatnagar (1994) [8]. Similarly, grain as well as straw yield (kg ha^{-1}) of each treatment was also converted into energy unit to find out the energy output. The energetic of maize production was calculated as per method adopted by Kumar *et al.* (2005) [5]. Net energy output (MJ ha^{-1}) was calculated by subtracting energy input from the respective gross energy output.

Net energy output (MJ ha-1) = Gross energy output (MJ ha-1)- Energy input (MJ ha-1)

The energy use efficiency based on input: output energy ratio was determined to assess the efficiency of management practices. Energy use efficiency is energy produced by per unit energy consumed.

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

Specific energy is the amount of energy required to produce one tonne of grain.

$$\text{Specific energy (MJ ha}^{-1}) = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Grain yield (t ha}^{-1})}$$

Results and Discussion

Yield attributes

Existing fertilizer recommendations are made up of pre-determined rates of major nutrients which are constant over time; however, crop needs differ due to season, management and climate. SSNM-NE provides nutrient recommendations based on crop need-based nutrient-supplying capacity as per target yield. That's why, the cob yield, grain yield and stover yield of maize under conventional nutrient management *i.e.* 100% RDF and farmer's fertilizer practice are comparatively less over SSNM-NE in the current study. The higher yield (Table 1) under site specific nutrient management was due to adequate supply of nutrients which contributed towards higher dry matter accumulation and better partitioning of photosynthates resulting in higher yield traits and ultimately the yield. The harvest index and shelling percentage was also recorded maximum with site specific nutrient management being at par with recommended dose of fertilizer. However, both of the nutrient management practices were significantly superior to farmer fertilizer practice. Significant increase in total grain yield, harvest index and shelling percentage in site specific nutrient management was also reported by Mehta *et al.* (2011) [7].

In case of maize hybrids, the increase of yield was associated with the increase in yield attributing characters since grain yield is manifestation of yield traits. Maize hybrid like CMH 08-350 had faourably influenced dry matter accumulation and its partitioning towards reproductive organs which consequently produced higher yield and yield attributes. Straw yield of crop is closely related to vegetative growth and as such maize hybrid CMH 08-350 proved instrumental in improving the growth attributes and ultimately led to higher straw yield.

Economics

Economics of maize production depends on several factors such as input cost, labour requirements and above all the weather condition prevailing during the crop period. The higher input cost under site specific nutrient management was (Table 1) responsible for higher cost of cultivation under SSNM and lowest cost of cultivation under farmer's fertilizer practice was due to lower amount of input used. Net return was significantly higher with site specific nutrient management than recommended dose of fertilizer and farmer fertilizer practice while, benefit: cost ratio under site specific nutrient management and recommended dose of fertilizer were comparable between themselves but significantly higher than farmer fertilizer practice. The higher grain yield with site specific nutrient management was responsible for higher net return and benefit: cost ratio. Higher profitability under site specific nutrient management than recommended dose of fertilizer and farmer fertilizer practice was also reported by Birader *et al.* (2012) [1]. Similarly, in case of maize hybrids, higher yield of CMH 08-350 led to higher net return and benefit: cost ratio followed by CMH 08-292, PMH-3, CMH 08-287, PMH-1 and HQPM-1 in decreasing order. Inspite of similar cost of cultivation, the variation in net return and benefit: cost ratio of different maize hybrid was due to variation in grain, stover and stone yield of the maize hybrid along with their market price. The variation in the profitability of maize hybrids was also reported by Kumar *et al.* (2014) [6].

Nutrient Uptake

Site specific nutrient management recorded higher uptake of nitrogen, (Table 1) phosphorus and potassium by grain and stover as compared to recommended dose of fertilizer and farmers fertilizer practice. Sufficient quantity of nutrient applied under site specific nutrient management might have helped in higher amount of nutrient uptake by the crop in accordance with the potential of the crop and genotype whereas, imbalanced and under nutrition of the crops under farmers fertilizer practice resulted in lower nutrient uptake (Birader *et al.,* 2012) [1]. Among maize hybrid, CMH 08-350 recorded the highest NPK uptake by grain and stover followed by CMH 08-292, PMH-3, CMH 08-287, PMH-1 and HQPM-1 which could be ascribed to better vegetative and reproductive growth thereby producing higher grain and stover yield since uptake of a nutrient is a function of concentration of nutrient and yield per hectare. Significant variation in nitrogen, phosphorus and potassium uptake among different maize hybrids has also been reported by Kumar *et al.* (2014) [6].

Table 1: Yield, economics and nutrient uptake as influenced by maize hybrids and nutrient management practices.

Treatment	Cob yield (t/ha)	Grain yield (t/ha)	Stover yield (t/ha)	Net return (₹/ha)	BC ratio	Total nutrient uptake (kg/ha)		
						Nitrogen	Phosphorus	Potassium
Maize hybrids								
PMH 1	7.13	5.89	10.44	46616	1.72	139.73	25.55	135.43
PMH 3	7.85	6.51	10.97	54228	2.00	148.95	27.08	140.03
CMH 08-350	8.69	7.14	11.73	62067	2.29	159.33	28.76	146.86
CMH 08-287	7.53	6.27	10.89	51256	1.88	146.65	26.64	139.78
CMH 08-292	8.27	6.80	11.34	57902	2.13	154.76	27.98	143.82
HQPM 1	6.82	5.58	10.03	42886	1.60	134.02	23.62	129.00
SEm±	0.18	1.54	0.24	1893	0.07	3.53	0.60	3.21
CD (P=0.05%)	0.58	0.49	0.76	5960	0.22	11.13	1.89	10.11
Nutrient management								
RDF	8.25	6.90	11.68	59013	2.20	159.39	29.20	149.24
SSNM	9.15	7.75	12.56	67218	2.33	177.25	31.74	164.21
FFP	5.74	4.44	8.46	31247	1.28	105.09	18.88	104.02
SEm±	0.15	0.13	0.24	1657	0.06	2.71	0.52	2.87
CD (P=0.05%)	0.43	0.39	0.70	4835	0.18	7.91	1.52	8.38
CV (%)	8.11	9.00	9.38	13.39	13.69	7.81	8.28	8.76

Energetics

Energetics of maize revealed that maximum gross energy input, (Table 2) gross energy output, net energy return, energy use efficiency and energy productivity was obtained under site specific nutrient management than the other nutrient management practices while, specific energy was highest under farmers fertilizer practice. The higher grain production and less input energy under site specific nutrient management resulted in achieving maximum net energy return, energy use efficiency, energy productivity and minimum specific energy. Among maize hybrids CMH 08-350 led to higher energy output, net energy return, energy use efficiency and energy productivity than CMH 08-292, PMH-3, CMH 08-287, PMH-1 and HQPM-1due to higher grain yield. However, the reverse trend was obtained in case of specific energy due to lower grain yield obtained with maize hybrid HQPM-1 having highest specific energy among all maize hybrid tested.

Table 2: Energy input-output as influenced by maize hybrids and nutrient management practices.

Treatment	Energy input- output relationship in maize					
	Energy input (MJ/ha)	Energy output (MJ/ha)	Net energy return (MJ/ha)	Energy use efficiency	Energy productivity (g/MJ)	Specific energy (MJ/t)
Maize hybrids						
PMH 1	12898	86534	73636	6.64	452.00	2233.1
PMH 3	12898	95670	82772	7.31	497.58	2034.6
CMH 08-350	12898	104958	92060	8.01	544.93	1867.4
CMH 08-287	12898	92098	79201	7.02	477.36	2140.2
CMH 08-292	12898	100004	87106	7.65	520.39	1951.1
HQPM 1	12898	82070	69172	6.42	436.97	2312.4
SEm±	-	2264	2264	0.17	11.55	51.7
CD (P=0.05%)	-	7129	7129	0.53	36.37	162.8
Nutrient management						
RDF	13501	101495	87994	7.52	511.39	1983.0
SSNM	15099	113860	98761	7.54	512.98	1985.0
FFP	10092	65312	55219	6.47	440.24	2301.4
SEm±	-	1984	1984	0.16	10.95	47.0
CD (P=0.05%)	-	5791	5791	0.47	31.97	137.1
CV (%)	-	9.00	10.44	9.52	9.52	9.54

Nutrient status of soil

Available nutrient status (Table 3) of the soil under study i.e. organic carbon, pH, available nitrogen, phosphorus and potassium content of the soil did not showed significant difference in respect of nutrient management practices and maize hybrids. Since, it is the first year of experiment so change in nutrient management practices or maize hybrids will not able to make any change in available nutrient status but, of course they will affect the nutrient status in long run.

Table 3: Soil nutrient status as influenced by maize hybrids and nutrient management practices.

Treatment	Soil Nutrient status				
	Organic carbon (%)	pH	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
Maize hybrids					
PMH 1	0.417	6.11	236.39	18.15	163.06
PMH 3	0.413	6.07	234.66	17.75	160.06
CMH 08-350	0.409	6.02	231.97	17.49	156.04
CMH 08-287	0.419	6.09	235.95	17.96	161.63
CMH 08-292	0.410	6.05	233.07	17.67	157.43
HQPM 1	0.422	6.14	239.58	18.32	164.73
SEm±	0.007	0.11	3.57	0.30	3.42
CD (P=0.05%)	NS	NS	NS	NS	NS
Nutrient management					
RDF	0.415	6.08	238.45	18.23	160.70
SSNM	0.422	6.11	236.13	17.38	162.85
FFP	0.408	6.05	231.24	18.06	157.92
SEm±	0.006	0.08	3.07	0.33	1.98
CD (P=0.05%)	NS	NS	NS	NS	NS
CV (%)	5.81	5.84	5.54	7.84	NS

Conclusion

Cultivation of maize hybrid CMH-08-350 with site specific nutrient management through nutrient expert (170:67:86 kg NPK/ha) is most productive, economically feasible and energy conservative at Kanke, Ranchi region of Jharkhand.

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