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Growth and Yield Response of Maize Hybrids to Varying Nutrient Management Practices

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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 through nutrient expert and farmer fertilizer practice) in subplot replicated thrice. The morpho-physiological analysis of growth and yield of maize revealed that site specific nutrient management manifested significantly higher plant height, leaf area index, dry matter accumulation, crop growth rate, relative growth rate, net assimilation rate, cob length, cob girth, number of grains/row, number of grains row/cob, 1000 grain weight and days to maturity resulting in significantly higher grain and stover yield over recommended dose of fertilizer and farmers fertilizer practice. The site specific nutrient management brought significant reduction in anthesis-silking interval and bareness percentage over recommended dose of fertilizer and farmer fertilizer practice. Among maize hybrids, CMH 08-350 being comparable to CMH 08-292 produced significantly higher leaf area index, dry matter accumulation, crop growth rate, relative growth rate, net assimilation rate, cob length, cob girth, number of grains/row and number of grains row/cob resulting in significantly higher grain and stover yield over other maize hybrids while, maize hybrid CMH 08-350 exhibited the lowest anthesis-silking interval. The plant height was found highest with maize hybrid CMH 08-292 while, the bareness percentage was found lowest with maize hybrid PMH-1. The maize hybrid HQPM-1 exhibited maximum days to maturity which was significantly superior over other hybrids.

Keywords: Crop growth rate, Leaf area index, Net assimilation rate, Nutrient expert, Relative growth rate, Site specific nutrient management

Introduction
Since the inception of Green Revolution there has been a race for increasing food grain (mainly cereals) production using chemical fertilizers in India. However, cereal production in the country increased only five fold, while fertilizer consumption increased 322 times during the 1950–51 to 2007–08 periods, implying very low fertilizer use efficiency. The use of external inputs has driven the crop productivity gains in India but the general fertilizer recommendation and current farmers' fertilizer practice are not based on the nutrient requirements of the maize crop and the nutrients available in the soil. Saharawat *et al.* (2010) [11] 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. 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 general principles underlying site-specific management are transferable from place to place, but the fine-tuning of production systems is necessarily region-specific, because soils, climate and economic conditions vary. 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 that enables researchers, extension experts and industry agronomist to quickly develop field specific fertilizer recommendation for hybrid maize (Witt *et al.*, 2009) [13]. 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 for enhancing productivity and profitability 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), site specific nutrient management based on nutrient expert (170: 67: 86 kg N:P:K/ha) and farmer fertilizer practice (100: 50: 0 kg N:P:K/ha) 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 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.

Plants sampling was done at 30, 60, 90 days after sowing and at harvest to record the growth parameters such as leaf area index, dry matter accumulation/m^2, crop growth rate, relative growth rate and net assimilation rate while the plant height, yield attributes, grain yield and straw yield were recorded at harvest. The crop growth rate, relative growth rate and net assimilation rate were calculated by using the formula given by Radford (1967) [10].

$$\text{Crop growth rate (g/day)} = \frac{W_2 - W_1}{t_2 - t_1} \text{ X } \frac{1}{G}$$

$$\text{Relative growth rate (g/g/day)} = \frac{\log_e W_2 - \log_e W_1}{(t_2 - t_1)}$$

$$\text{Net assimilation rate (mg/cm}^2\text{/day)} = \frac{(W_2 - W_1)(\log A_2 - \log A_1)}{(t_2 - t_1)(A_2 - A_1)}$$

Where W_1 and W_2 represent the dry weights of the plant at the beginning and end of the time interval t_1 and t_2 respectively and A_1 and A_2 represent the leaf area at the beginning and end of the time interval t_1 and t_2 respectively. The G represents the ground area.

Results and Discussion

Plant height

Maximum plant height of maize was recorded with site specific nutrient management, being comparable to recommended dose of fertilizer but, significantly taller plant than farmer fertilizer practice (Table 1) as balanced application of nutrients as per crop need under SSNM enhances the nutrient use efficiency (Biradar, 2012) [2]. Increase input efficiency improved N, P, K supplying capacity of soil resulting in higher plant height because nitrogen is needed for the formation of chlorophyll, phosphorus for the synthesis of nucleic acids and similarly potassium is important for the growth and elongation probably due to its function as an osmoticum and may react synergistically with indole acetic acid which is responsible for growth and development. Plant height is the genetic character of the cultivar as such the maize hybrid CMH 08-292 had the tallest plant which was significantly superior over PMH 1, PMH 3 and HQPM 1 but, failed to cause significant variation in plant height with CMH 08-287 and CMH 08-350. The variation in plant height among the maize cultivar was also reported by Kumar *et.al.* (2014) [5].

Leaf area index

The leaf area index (Table 1) increased successively as the growth progressed upto 90 DAS. Site specific nutrient management had significantly higher leaf area index as compared torecommended dose of fertilizer and farmers fertilizer practice at 60 and 90 DAS. While, at early stage i.e. 30 DAS the leaf area index of maize under site specific nutrient management and recommended dose of fertilizer were comparable between themselves but, both of the nutrient management practice recorded significantly higher leaf area index than farmers fertilizer practice (Table 1). Higher leaf area under site specific nutrient management has also been reported by Mashego (2013) [6]. When the resources are suboptimal, the leaf growth rate and thus the leaf area index can be limited by low rate of net photosynthesis or insufficient cell expansion resulting in lower leaf area index under farmer's fertilizer practice. As site specific nutrient management had better nutrient supplying capacity as per crop need which in turn resulted in higher leaf growth rate and thereby higher leaf area index. Among the maize hybrids, the maximum leaf area index was recorded with CMH-08-350 being comparable with CMH-08-292 but the former showed its significant superiority over rest of the maize hybrids at 90 DAS. While, at 60 days after sowing CMH-08-350 recorded significantly higher leaf area index than CMH-08-287, PMH-1 and HQPM-1 but, remained to par to PMH-3 and CMH-08-292. At early stage i.e 30 days after sowing the maize hybrid CMH-08-350 showed its distinct superiority over PMH-1 and HQPM-1 but failed to cause significant variation in leaf area index with other maize hybrid. The difference in leaf area index within maize hybrid was due to more leaf area which is totally varietal characteristic. This was in conformity with the finding of Kumar *et.al.* (2014) [5].

Dry matter accumulation

The dry matter production/m^2 increased (Table 1) as the growth progressed being, maximum at harvest. Among the nutrient management practices, site specific nutrient management recorded significantly higher dry weight/m^2 over recommended dose of fertilizer and farmer fertilizer practice at 90 days after sowing and at maturity. At 30 and 60 days after sowing site specific nutrient management being comparable to recommended dose of fertilizers. However, both of the nutrient management practices proved its distinct superiority over farmer fertilizer practices in respect of dry matter accumulation (Table 1). The dry matter production is the sum total effect of overall growth. Site specific nutrient management had higher leaf area index indicating higher chlorophilic area thus improving photosynthetic efficiency of plant which in turn resulted in higher dry matter accumulation. Among maize hybrids, CMH-08-350 recorded the highest dry matter production at all the growth stages which was significantly superior to rest of the maize hybrids at maturity. At 90 DAS, CMH-08-350 proved its distinct superiority over PMH-3, CMH-08-287, PMH-1 and HQPM-1 in respect of dry matter accumulation but failed to cause any significant difference with the maize hybrid CMH-08-292. Similarly, at 60 DAS, CMH-08-350 recorded significantly higher dry matter accumulation over CMH-08-287, PMH-1 and HQPM-1. While, at 30 days after sowing the former proved its superiority over PMH-1 and HQPM-1 but remained comparable to other hybrids in respect of dry matter accumulation. The higher dry matter accumulation with CMH-08-350 might be due higher leaf area index resulting in higher photosynthetic efficiency and ultimately higher photosynthate accumulation. Ashok. (2013) [1] also reported significant variation in dry matter accumulation among the different maize hybrid tested.

Crop growth parameters.

Pronounced improvement in crop growth rate (CGR) of maize was (Table 2) observed between 60-90 DAS and thereafter declined till harvest. Whereas, relative growth rate (RGR) and net assimilation rate (NAR) of maize showed the declining trend from the beginning till maturity of the crop. Site specific nutrient management recorded maximum crop growth rate which was significantly superior over recommended dose of fertilizer and farmer fertilizer practice at all the crop growth stages, except at 30-60 DAS, where site specific nutrient management failed to show significant superiority over recommended dose of fertilizer. recorded significantly The relative growth rate was recorded highest with site specific nutrient management which was significantly higher than recommended dose of fertilizer and farmer fertilizer practice at 90 DAS to maturity stage of crop growth. However, the SSNM failed to cause significant variation in relative growth rate and remained at par with recommended dose of fertilizer but, both of the nutrient management practices exhibited significantly higher relative growth rate than farmer fertilizer practice at 60-90 DAS. The net assimilation rate recorded with site specific nutrient management being at par with recommended dose of fertilizer which was significantly higher than farmer fertilizer practice (Table 2). This might be due to better vegetative growth under site specific nutrient management thus improving the crop growth rate, relative growth rate and net assimilation rate. The maximum crop growth rate was observed with CMH-08-350 being at par with CMH-08-292. However, the CMH-08-350 showed their distinct superiority over PMH-1, PMH-3, CMH-08-287 and HQPM-1 at all the crop growth stages except at 30-60 DAS where CMH-08-350 was significantly superior to PMH-1, CMH-08-287 and HQPM-1 but remained at par to PMH-3 and CMH-08-292 in respect of crop growth rate. The different maize hybrids failed to caused significant effect on relative growth rate at all growth stages except at 90 DAS to maturity where CMH-08-350 recorded the highest relative growth rate which remained at par toCMH-08-292. However, both of the maize hybrid proved its significant superiority over rest of the hybrids in respect of relative growth rate. The different maize hybrids did not cause significant variation in net assimilation rate during early growth stage i.e. 30-60 DAS while, at later stage i.e. 60-90 DAS, the maximum net assimilation rate was recorded with CMH-08-350 which was significantly superior to HQPM-1 but remained at par to rest of the hybrids as a result of better vegetative growth at all the stages.

Anthesis-silking interval

Among the nutrient management practices, site specific nutrient management recorded significantly lower anthesis-silking interval (Table 1) over recommended dose of fertilizer and farmer fertilizer practice. This might be due to better and balanced nutrient supply under site specific nutrient management. Among maize hybrids, CMH 08-350 recorded the minimum anthesis-silking interval which was comparable with CMH 08-292 but, the former showed its distinct superiority over rest of the maize hybrids.

Yield attributes

The nutrient management practices significantly influence the yield attributing characters i.e. cob length, cob girth, number of grain per row, number of grains row per cob, 1000 grain weight and days to maturity and the highest value were observed (Table 3) with site specific nutrient management which remained at par with recommended dose of fertilizer but both of the nutrient management practices exhibited its significant superiority over farmer fertilizer practice. The enhanced nutrient availability under site specific nutrient management led to an increase in leaf area, photosynthesis etc. which in turn resulted in the formation of healthy cobs. Increase in yield attributing characters of maize under site specific nutrient management was also reported by Biradar *et al.* (2012) [2], Murni *et al.* (2010) [8] and Pasuquin *et al.* (2010) [9]. The bareness percentage was significantly lower with site specific nutrient management than recommended dose of fertilizer and farmer fertilizer practice. Yielding ability is one of the most important quantitative characters in a crop and it depends upon the development of other plant characters, *viz* leaf area, chlorophyll content, photosynthesis and dry matter accumulation, which in turn resulted into higher growth parameters, *viz* LAI, RGR and CGR etc. (Sahoo and Guru 1998) [12] and yield attributes. Among maize hybrids, the maximum cob length, cob girth, number of grains/row and grains row/cob was recorded with CMH-08-350 which proved their significant superiority over PMH 1, CMH-08-287, and HQPM-1 but, failed to cause significant variationwith maize hybrids PMH-3 and CMH-08-292. However, the maximum thousand grain weight was recorded with CMH-08-287 which remained at par with CMH-08-350 and CMH-08-292 but the former showed its significant superiority over PMH-1, PMH-3 and HQPM-1. The maize hybrid, CMH-08-292 recorded the maximum bareness per cent which was significantly superior over PMH-1 but failed to cause significant variation with other maize hybrids. The maize hybrid HQPM-1 exhibited maximum days to maturity which was significantly superior over other hybrids.

Grain & stover yield

Site specific nutrient management produced significantly higher grain and stover yield than recommended dose of fertilizer and farmer fertilizer practice. Similarly, application of recommended dose of fertilizer also brought significant improvement in grain yield over farmer fertilizer practice (Table 3). Significant increase in growth and yield-attributing characters under site specific nutrient management were mainly responsible for improvement in grain yield and stover yield of maize. The higher yield 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. Significant increase in total grain and stover yield in site specific nutrient management was also reported by Mehta *et al.* (2011) [7]. Among maize hybrids, the maximum grain and stover yield was recorded with CMH-08-350 which remained at par with CMH-08-292 but significantly superior to rest of the hybrids. Better vegetative and reproductive growth of maize hybrids contributed towards higher dry matter accumulation resulting in significantly higher grain and stover yield with maize hybrid CMH-08-350.

Table 1: Effect of nutrient management practices on growth attributes of maize hybrids

Treatment	Plant height (cm)	Plant Population /ha	Leaf area index			Dry matter accumulation (g/m^2)				Anthesis-silking interval
			30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90DAS	At Maturity	
Maize hybrids										
PMH 1	228.61	62741	1.49	3.23	3.89	133.03	646.82	1365.39	1816.43	4.00
PMH 3	224.94	62963	1.55	3.63	4.01	142.34	706.25	1503.77	2023.47	3.67
CMH 08-350	237.11	63704	1.63	3.95	4.30	155.34	797.16	1756.56	2440.00	3.33
CMH 08-287	244.17	63556	1.52	3.37	3.96	137.45	670.94	1427.86	1929.87	3.78
CMH 08-292	248.06	63407	1.60	3.87	4.17	151.18	765.42	1648.14	2282.32	3.56
HQPM 1	212.36	62593	1.43	3.01	3.59	124.78	595.61	1246.45	1682.08	4.22
SEm±	4.07	1040	0.04	0.13	0.09	6.46	29.28	41.60	47.66	0.08
CD (P=0.05%)	12.81	NS	0.13	0.40	0.29	20.35	92.20	131.03	150.09	0.26
Nutrient management										
RDF	236.14	63000	1.56	3.52	4.12	145.54	722.66	1548.23	2111.23	3.67
SSNM	240.63	63000	1.62	3.71	4.29	151.98	757.63	1664.54	2358.28	3.33
FFP	229.86	63481	1.43	3.30	3.67	124.54	610.81	1261.32	1617.57	4.28
SEm±	3.39	576	0.03	0.07	0.09	2.60	15.13	31.91	43.96	0.07
CD (P=0.05%)	9.91	NS	0.08	0.19	0.25	7.59	44.16	93.13	128.33	0.20
CV (%)	6.19	3.87	7.91	8.02	9.26	7.84	9.21	9.08	9.19	7.68

Table 2: Effect of nutrient management practices on crop growth parameters of maize hybrids

Treatment	Crop growth rate ($g/m^2/day$)			Relative growth rate (mg/g/day)			Net assimilation rate ($g/m^2/day$)	
	30-60 DAS	60-90 DAS	90 DAS-at maturity	30-60 DAS	60-90 DAS	90 DAS-at maturity	30-60 DAS	60-90 DAS
Maize hybrids								
PMH 1	17.13	23.95	15.03	22.8	10.7	4.2	7.69	6.76
PMH 3	18.80	26.58	17.32	23.2	10.9	4.2	7.76	7.00
CMH 08-350	21.39	31.98	22.78	23.6	11.2	4.8	8.17	7.56
CMH 08-287	17.78	25.23	16.73	22.9	10.7	4.2	7.71	6.82
CMH 08-292	20.47	29.42	21.14	23.5	11.2	4.6	8.02	7.40
HQPM 1	15.69	21.69	14.52	22.7	10.7	4.0	7.47	6.65
SEm±	1.00	0.84	0.45	0.9	0.4	0.1	0.37	0.29
CD (P=0.05%)	3.14	2.65	1.42	NS	NS	0.4	NS	0.90
Nutrient management								
RDF	19.24	27.52	18.77	23.2	10.9	4.5	8.05	7.27
SSNM	20.19	30.23	23.12	23.2	11.3	5.1	8.08	7.55
FFP	16.21	21.68	11.88	23.0	10.4	3.4	7.28	6.27
SEm±	0.49	0.68	0.52	0.4	0.2	0.1	0.19	0.20
CD (P=0.05%)	1.43	1.97	1.52	1.1	0.5	0.3	0.56	0.59
CV (%)	11.22	10.84	12.35	NS	6.28	10.37	10.48	12.15

Table 3: Effect of nutrient management practices on yield attributes and yield of maize hybrids.

Treatment	Yield attributes					Bareness percentage	Days to maturity	Yield (t/ha)	
	Cob length (cm)	Cob girth (cm)	Number of grain /row	Number of grains row /cob	1000 grain weight (gm)			Grain	Stover
Maize hybrids									
PMH 1	18.10	13.94	37.02	13.56	325.33	2.61	103.22	5.89	10.44
PMH 3	19.34	14.71	39.40	14.34	310.57	2.82	104.89	6.51	10.97
CMH 08-350	19.62	14.89	39.93	14.44	340.40	2.79	105.67	7.14	11.73
CMH 08-287	18.20	13.68	37.16	13.30	350.71	3.15	104.22	6.27	10.89
CMH 08-292	18.86	14.79	38.62	14.38	335.56	3.16	105.11	6.80	11.34
HQPM 1	17.92	13.94	36.73	13.52	316.02	2.96	108.67	5.58	10.03
SEm±	0.18	0.10	0.52	0.23	5.84	0.14	0.67	1.54	0.24
CD (P=0.05%)	0.58	0.31	1.62	0.71	18.40	0.43	2.11	0.49	0.76
Nutrient management									
RDF	19.46	14.76	39.63	14.32	333.93	2.77	105.94	6.90	11.68
SSNM	19.93	15.02	40.94	14.63	346.68	2.42	106.61	7.75	12.56
FFP	16.63	13.19	33.86	12.83	308.69	3.56	103.33	4.44	8.46
SEm±	0.25	0.18	0.47	0.17	3.97	0.06	0.35	0.13	0.24
CD (P=0.05%)	0.72	0.52	1.36	0.51	11.57	0.18	1.02	0.39	0.70
CV (%)	5.60	5.32	5.20	5.28	5.10	8.79	1.40	9.00	9.38

Conclusion
Cultivation of maize hybrid CMH-08-350 grown with site specific nutrient management through nutrient expert (170:67:86 kg NPK/ha) is found to be most suitable technique for enhancing maize productivity at Kanke, Ranchi region of Jharkhand.

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