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Influence of Precision Nitrogen Management through Crop Sensors on Growth and Yield of Maize (*Zea mays* L.)

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Abstract

Field experiment was conducted at Zonal Agricultural Research Station, UAS, GKVK, Bengaluru to assess the influence of precision nitrogen management through crop sensors on growth and yield of maize with twelve treatments and replicated thrice using RCBD during *kharif*2016. The results revealed that,growth parameters, like plant height (225.0 cm), number of leaves (15.37), leaf area and leaf area index (9839cm^2 plant^{-1} and 5.47) and dry matter production (440.43 g plant^{-1}) were significantly higher when NPK fertilizers were applied through STCR method for target yield of 11 t ha^{-1} as compared to absolute control and other treatments. However, it was on par with NPK application through SSNM, GreenSeeker and SPAD sufficiency index 96-100 per cent. The treatment which receives STCR based NPK management for target yield of 11 t ha^{-1}recorded significantly higher number of cobs per plant (2.08), cob length and girth (21.10 cm and 7.06 cm),number of rows cob^{-1} (17.13), kernels row^{-1} (42.30), kernels cob^{-1} (729), higher grain yield (110.81qha^{-1}) and straw yield (137.20 q ha^{-1}) compared to absolute control but it was on par with SSNM, GreenSeeker and SPAD sufficiency index 96-100 per cent. Higher gross returns and net returns (` 1,91,650 ha$^{-1}$ and ` 1,38,100 ha^{-1}, respectively) were noticed in application of NPK fertilizers through STCR method for target yield of 11 t ha^{-1} but higher B: C ratio (3.60) was registered in nitrogen management through GreenSeeker as compared to recommended dose of nitrogen as per package of practices and absolute control.

Keywords: Precision nitrogen management, crop sensors, maize, growth and yield

Maize (*Zea mays* L.) is one of the important cereal crops next to wheat and rice in the world. It is called as Queen of Cereals because of its productive potential compared to any other cereal crop and King of Fodder due to its great importance in animal diet. Globally, it is grown over an area of 185.90 m. ha with an annual production of 1,075.49 m. t with a productivity of 5790 kg ha^{-1} (Anon., 2016). In India, it stands third in area and production after rice and wheat. Currently it is cultivated in an area of 9.89 m. ha with a production of 25.90 m. t. and it contributes to nearly 9 per cent of the national food basket (Dass *et al*., 2012). However, the productivity in India is much lower (2620 kg ha^{-1}) than world average (Anon., 2016). The states that contributes, more than 80 per cent of total maize production are Andhra Pradesh (20.9%), Karnataka (16.5%), Rajasthan (9.9%), Madhya Pradesh (5.7%) and Himachal Pradesh (4.4%). In India, about 35 per cent of the maize produced is used for human consumption, 25 per cent each in poultry and cattle feed and 15 per cent in food processing industries for preparation of corn flakes, popcorn, starch, dextrose, corn syrup and corn oil etc. Apart from bulk production, Karnataka is also a major seed producing state. In the state, maize is grown over an area of 1.18 m. ha with a production and productivity of 3.28 m. t and 2773 kg ha^{-1}, respectively (Anon., 2015). During the last ten years, the area under maize in Karnataka has increased by 41 per cent.

Nitrogen is one of the most important factors for growth and development of plants and most limiting nutrient in the crop production particularly in cereals. The absorption of N by crops is variable among and between seasons, as well as between locations in the same field, even when the N supplies are high. The N supply from soil to crop varies spatially. Consequently, the demand for N by the crop also varies. As a result, the crop's nutritional status is a good indicator of the necessary N rate application. The current approaches to detect soil and plant N levels are soil-testing, visual diagnosis and foliar analysis. However, these conventional approaches are time consuming, expensive; require considerable effort for soil collection or plant sampling, processing and results are not immediately available. Therefore, to provide appropriate recommendations of spatial N applications, it is necessary to use several tools simultaneously, such as crop and soil sensors, to achieve reliable measurements of N availability from soil and crops need. The evaluation of nitrogen use efficiency (NUE) in agriculture is an important way to evaluate the density of N applied and its role on yield. Because crop responses to N application depend on the organic matter in the soil, strategies of N management in cereal crops that include reliable predictions of the response index in each season could increase NUE. In this scenario, sensors are becoming more prevalent in agricultural lands. Using variable rate equipment or application, it is possible to detect variability in crops and make rapid decisions in the field. Some sensors allow real time changes in agricultural practices by detecting variability and responding to that variability.

Maize has got wider adoptability under different agro-climatic condition. Precision agriculture technologies are becoming part of many farming operations and can play a key role in sustainable N fertilizer management. Addressing spatially variable fertilizer N requirements with variable rate management strategies can increase profitability.

The purpose of the study was to develop precision nitrogen management technologies and to improve growers' knowledge for effective nitrogen (N) management. The overall goal is to improve the nitrogen use efficiency and increase crop productivity in a sustained manner. Keeping these above facts, the present study was conducted to standardize the precision nitrogen management practices using crop sensors and to know their effects on growth and yield of maize.

Material and Methods

A field experiment was conducted at ZARS, UAS, Bengaluru during *Kharif* 2016. The site is located at 13^0 05' 2'' N latitude and 77^0 34' 02'' E longitudes with an altitude of 930 m above mean sea level. The soil of the experimental site was sandy loam. The initial pH was 5.97 and electrical conductivity was 0.26 dS m^{-1}. The available nitrogen, phosphorus and potassium were 215.33, 18.26 and 260.33 kg NPKha^{-1}, respectively. The experiment was laid out in Randomized Complete Block Design (RCBD) with twelve treatments and replicated thrice. Treatments included, T_1: Nitrogen management through SPAD sufficiency index 85-89 per cent, T_2: Nitrogen management through SPAD sufficiency index 90-95 per cent, T_3: Nitrogen management through SPAD sufficiency index 96-100 per cent, T_4: Nitrogen management through SPAD-30, N 25, T_5: Nitrogen management through SPAD-35, N 25, T_6: Nitrogen management through SPAD-40, N 25, T_7: GreenSeeker based nitrogen management, T_8: Nitrogen management through SSNM for target of 11 t ha^{-1}, T_9: STCR based N management for target of 11 t ha^{-1}, T_{10}: STCR based NPK management for target of 11 t ha^{-1}, T_{11}: Recommended dose of N as per package of practices and T_{12}: Absolute control.

The land was brought to fine tilth before sowing by ploughing twice with tractor drawn disc plough and passing cultivator and two harrowing. Drip system including pump, filter units, main line and sub lines were installed. In line laterals of 16 mm size within lines spaced at 45 cm apart with 4 lph capacities were laid out at a distance of 60 cm apart and thereby lateral spacing of 60 cm was fixed. There were 14 maize rows at a distance of 60 cm apart in each treatment extending to 8.4 meter length.Seeds of Hema (NAH-1137) maize hybrids (two seeds per hole) were dibbled at 30 cm interval in the furrows spaced at 60 cm apart. The required fertilizer were calculated and applied as per the treatments. Based on the soil test results in case of SPAD and GreenSeeker based nitrogen management, 25 per cent of the recommended dose of nitrogen was applied as basal along with full dose of P_2O_5 and K_2O. Remaining nitrogen was supplied as per the treatments. In case of SSNM and STCR 50 per cent of the nitrogen was applied as basal and the balance 50 per cent N was applied at 30 and 45 DAS along with recommended P_2O_5 and K_2O were applied at the time of sowing. In case of recommended practices, nitrogen (150 kg ha^{-1}) was applied as per package of practices. Recommended dose of FYM (10 t ha^{-1})was applied to all the treatments except in case of absolute control and mixed into the soil 15 days prior to sowing. Irrigation was scheduled at weekly interval through drip based on the rainfall, soil and crop appearance during the crop periods. Irrigation was with held 10 days before the crop attained maturity. Atrazine @ 1000 g *a.i.* ha^{-1} was applied as pre-emergence spray at one day after sowing of maize followed by one hand weeding was attended at 30 days after sowing to control the weeds. During the season earthing up was carried out at 30 days after sowing. Plant population was maintained in all the treatments by thinning out of excess seedlings at 15 DAS and leaving one seedlings per spot. Healthy crop stand was ensured by adopting need based crop protection and recommended packages of practices. Five plants were selected at random and tagged. These plants were used for recording plant height (cm), number of leaves, leaf area and leaf area index and dry matter production. Leaf area was measured using leaf area meter and LAI was calculated as ratio of leaf area per plant to area occupied by the plant. Yield attributes like, number of rows per cob, kernels per row, kernels per cob, test weight, grain yield and straw yield were recorded. The data was statistically analyzed by following standard procedure developed by Gomez and Gomez, 1984.

Results and Discussion

Growth parameters of maize were significantly influenced by precision nitrogen management through crop sensors (Table I). Significantly higher plant height (225.0 cm), maximum number of leaves (15.37) leaf area (9839 cm^2 plant^{-1}), LAI (5.47) and total dry matter production (440.43g plant^{-1}) at harvest were recorded in treatment receiving STCR based NPK management for target yield of 11 t ha^{-1} and it was found on par with nitrogen management through SSNM for target of 11 t ha^{-1}. Similar trend was observed with plant height, number of leaves, leaf area, LAI and total dry matter production. SPAD reading recorded significantly higher in GreenSeeker based nitrogen management (42.42) and it was on par with nitrogen management through SPAD-40, N_{25} (41.65) at 75 DAS compared to other treatments. Significantly lower growth parameters were recorded in absolute control.

Table I

Growth parameters of maize at harvest as influenced by precision nutrient management practices through crop sensors

Treatments	Plant height (cm)	Number of leaves	Leaf area (cm^2 plant^{-1})	LAI	Dry matter production (g plant^{-1})	SPAD readings
T_1	175.0	10.70	6953	3.86	301.10	37.25
T_2	181.7	11.70	8072	4.48	311.30	37.44
T_3	210.2	14.50	9257	5.14	404.67	40.42
T_4	180.3	11.10	7792	4.33	304.33	38.48
T_5	185.6	12.87	8460	4.70	331.10	38.61
T_6	192.5	13.73	8758	4.87	393.40	41.65
T_7	216.0	14.77	9432	5.24	413.33	42.42
T_8	220.9	15.03	9583	5.32	430.65	39.83
T_9	198.9	14.33	8909	4.95	400.88	37.06
T_{10}	225.0	15.37	9839	5.47	440.43	40.92
T_{11}	188.9	13.17	8645	4.80	372.43	41.00
T_{12}	167.9	9.97	6450	3.58	292.40	31.93
S.Em$\pm$	1.91	0.19	192	0.11	4.47	0.45
CD at 5%	5.59	0.56	563	0.31	13.10	1.31

An optimum plant height is claimed to be positively correlated with productivity of plant. The plant height helps to increase the dry matter production and was increased with successive increase in nutrient levels required to achieve the higher target yields. The increased plant height was due to increased nutrient availability which contributed for prolonged greenness and larger leaf surface. Similar observations were made by Santosh Pagad (2014) and Nagarjun (2015). Leaf area increased due to synchronization of applied nitrogen between crop demand and supply leads to development of more and more chlorophyll pigments. This in turn increases specific leaf weight and resulted in higher light interception, root development, leaves development and plant height resulting in better dry matter production and distribution in the plant parts especially in cobs and better yield and yield components. These results are in conformity with the findings of El-habbal *et al.* (2010) in wheat. Increased SPAD readings was due to application of nutrients synchronizing with crop demand enhanced growth, leaf turgidity as well as chlorophyll content and improved the efficiencies of fertilizers. The results are in accordance with the findings of Suryavanshi *et al.*, (2008). The chlorophyll content regulates the photosynthetic efficiency. Precise application of fertilizer N through target yield approach increased the SPAD chlorophyll meter readings and NDVI values. Increase in SPAD chlorophyll meter readings indicates production of appreciable amount of chlorophyll in the leaves. The higher SPAD chlorophyll meter readings with higher target yield levels were due to better schedule of top dressing with nitrogenous fertilizers. These results were also in conformity with Sarnaik (2010).

This increase in total dry matter was due to development of more photosynthetic area in terms of increased leaf area and number of leaves per plant. This is achieved due to synchronization of applied nitrogen between crop demand and supply which resulted in production of chlorophyll pigments since N is the major nutrient in chlorophyll. Similar findings were also reported by Biradar *et al.* (2013).

Yield attributes, yield and economics of maize

Yield attributes like, number of cob per plant, cob length and girth, number of rows per cob, kernels per row, kernels per cob, as well as grain yield, stoveryield and economics of maize were favorably influenced by precision nitrogen management through crop sensors (Table II and III).

The data (Table II) showed that, application of NPK fertilizers through STCR based method for target yield of 11 t ha^{-1} recorded significantly higher number of cobs per plant (2.08), higher cob length and girth (21.10 cm and 7.06 cm), number of rows per cob (17.13), kernels per row (42.30) and kernels per cob (729) as compared to rest of the treatments and it was on par with nitrogen management through SSNM for target yield of 11 t ha^{-1} (1.92, 20.97 and 7.03 cm, 17.08, 41.10 and 700, respectively) and GreenSeeker based nitrogen management (1.92, 20.75 and 6.97 cm, 17.04, 40.50 and 698, respectively). Absolute control recorded significantly lower number of cobs per plant (0.91), shorter cob length and girth (13.30 cm and 4.37 cm), lower number of rows per cob (14.67), kernels per row (27.67) and kernels per cob (399). The results are in conformity with the findings of Trinh *et al.* (2008) Jemal (2010) and Daikho (2013). The enhanced values of yield attributing characters could be ascribed to the tendency of nitrogen in accelerating growth, photosynthetic activity and translocation efficiency for photosynthates with increasing NPK rates. This higher yield attributes under precision nutrient management practices were further due to improved growth attributes *viz.*, plant height, number of leaves, leaf area, SPAD values which reflected in significantly higher total dry matter production.

Test weight of maize showed non-significant due to nitrogen management through crop sensors and other management practices. However, higher values found in STCR based NPK management for target of 11 t ha^{-1} (38.13 g) and nitrogen management through SSNM for target of 11 t ha^{-1} (37.86 g) as compared to absolute control treatment (35.73 g).

The data on grain yield and stover (Table III) revealed that, significantly higher maize grain yield and stover yield (110.10q ha^{-1} and 137.20 q ha^{-1}) was recorded with the application of nutrients through STCR based NPK management for target of 11 t ha^{-1} and it was noticed on par with nitrogen management through SSNM for target of 11 t ha^{-1} (109.24q ha^{-1}and

TABLE II

Yield attributes of maize as influenced by precision nutrient management practices through crop sensors

Treatments	Number of cobs plant^{-1}	Cob length (cm)	Cob girth (cm)	Number of rows cob^{-1}	Number of kernal row^{-1}	Number of kernal cob^{-1}	100 kernel weight (g)
T_1	1.04	15.28	4.93	15.83	31.30	503	37.29
T_2	1.14	16.40	5.97	16.39	35.97	580	35.72
T_3	2.02	19.55	6.92	16.43	40.13	658	37.44
T_4	1.06	15.99	5.53	15.93	35.37	569	34.70
T_5	1.24	17.37	6.01	16.50	36.43	598	36.30
T_6	1.58	18.27	6.43	16.56	38.50	649	36.70
T_7	1.92	20.75	6.97	17.04	40.50	698	37.67
T_8	1.92	20.97	7.03	17.08	41.10	700	37.86
T_9	1.76	19.17	6.82	16.25	39.57	640	37.27
T_{10}	2.08	21.10	7.06	17.13	42.30	729	38.13
T_{11}	1.43	18.24	6.30	15.92	37.10	592	36.23
T_{12}	0.91	13.30	4.37	14.67	27.67	399	35.73
S.Em$\pm$	0.07	0.89	0.29	0.28	0.72	11	0.69
CD at 5%	0.22	2.60	0.86	0.53	2.10	31	NS

TABLE III

Yieldand economics of maize as influenced by precision nutrient management practices through crop sensors

Treatments	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	HI	Gross returns (` ha^{-1})	Net returns (` ha^{-1})	B:C ratio
T_1	80.60	115.41	0.41	123450	78130	2.72
T_2	84.37	117.31	0.42	124565	80315	2.82
T_3	107.21	134.73	0.44	165430	119200	3.58
T_4	82.44	119.41	0.41	127230	82720	2.86
T_5	85.19	117.30	0.42	127890	82910	2.84
T_6	92.36	122.26	0.43	129800	84570	2.87
T_7	107.58	134.78	0.44	175490	126700	3.60
T_8	109.24	137.16	0.44	190560	137210	3.57
T_9	101.38	130.26	0.44	147850	99600	3.06
T_{10}	110.81	137.20	0.45	191650	138100	3.57
T_{11}	86.96	121.38	0.42	145320	95780	2.93
T_{12}	45.57	70.93	0.39	71230	37780	2.13
S.Em$\pm$	1.24	0.85	-	-	-	-
CD at 5%	3.65	2.50	-	-	-	-

137.16 q ha^{-1}), GreenSeeker based nitrogen management (107.58 q ha^{-1}and 134.78 q ha^{-1}) and nitrogen management through SPAD sufficiency index 96-100 per cent (107.21 q ha^{-1} and 134.73 q ha^{-1}). Significantly lower grain yield and stover yield (45.57 q ha^{-1}and 70.93 q ha^{-1}) was recorded with absolute control treatment.

Significantly higher grain yield of maize in precision nutrient management practices was mainly due to higher number of cobs (2.08), higher cob length and girth (21.10 cm and 7.06 cm), more number of rows cob^{-1} (17.13), number of kernel row^{-1} (42.30) and higher test weight (38.13 g) (Table II). The results are in conformity with the findings of Arunkumar *et al*. (2017), Chandrakanth *et al*. (2017) and Dapake *et al.* (2017). The enhanced values of yield attributing characters could be ascribed to the tendency of nitrogen in accelerating growth, photosynthetic activity and translocation efficiency for photosynthates in presence of increasing NPK rates. Further, higher grain and stover yield of maize was mainly due to better translocation of photosynthates from source to sink and higher growth attributing characters like higher number of leaves, leaf area and higher dry matter production and its accumulation into different parts of plant and yield attributing characters like, number of kernel rows cob^{-1}, number of kernels row^{-1}, number of kernels cob^{-1}, test weight and kernel weight cob^{-1}. These results are in accordance with the findings of Sreelatha *et al*. (2012) and Biradar *et al*. (2013) who indicated that application of nutrients based on the principles of SSNM enhanced the productivity of maize. Mohanty *et al.* (2015), Ramanjit *et al*. (2015) and Mallikarjuna *et al*. (2016) who reported that, GreenSeeker based nitrogen management practices recorded significantly higher yield and yield attributes in rice, cotton, sweet corn and maize, respectively.

The higher values of above mentioned yield components were due to better growth parameters particularly total dry matter production which was significantly higher at harvest stage (440.43 and 430.65 g plant^{-1}, respectively) in STCR and SSNM based NPK management for target yield of 11 t ha^{-1}. The results are in conformity with Chandrakanth *et al*. (2017), Arunkumar *et al*. (2017), Dapake *et al.* (2017), Sinha (2016) and Biradar *et al*. (2013) who observed that increase in NPK levels increased the dry matter production. Increase in dry matter production per unit area is a first step in achieving higher yield. Dry matter production during various growth stages of any crop is an important pre-requisite for higher yields as it signifies photosynthetic ability of the crop and also indicates other synthetic processes during developmental sequences.

In the present investigation harvest index did not significantly differ due to nitrogen management through crop sensors and other management practices (Table III). However, higher values of harvest index (0.45) was observed in STCR based NPK management for target of 11 t ha^{-1}, nitrogen management through SSNM for target of 11 t ha^{-1} (0.44) and GreenSeeker based nitrogen management (0.44) as compared to absolute control (0.39).

Due to higher grain yield and better market price, the gross returns (` 1,91,650 ha$^{-1}$) was higher with the application of NPK fertilizers based on STCR method for target yield of 11 t ha$^{-1}$ followed by application of nitrogen fertilizer through SSNM method for target yield of 11 t ha$^{-1}$and GreenSeeker based nitrogen management ( ` 1,90,560 ha^{-1} and ` 1,75,490 ha$^{-1}$, respectively). Higher net returns was obtained in application of NPK fertilizers based on STCR method for target yield of 11 t ha$^{-1}$ ( ` 1,38,100 ha^{-1}) followed by application of nitrogen through SSNM for target of 11 t ha^{-1} and GreenSeeker based nitrogen management (` 1,37,210 ha$^{-1}$ and ` 1,26,700 ha^{-1}, respectively) but higher B: C ratio was registered in GreenSeeker based nitrogen management (3.60) followed by nitrogen management through SPAD sufficiency index 96-100 per cent STCR based NPK management for target of 11 t ha^{-1} and nitrogen management through SSNM for target of 11 t ha^{-1} (3.58, 3.57 and 3.57, respectively) (Table III). Despite increase in the cost of cultivation with higher targets, the large increase in yield of maize has resulted in higher returns and B: C ratio under SSNM and STCR methods but numerically higher B: C ratio was obtained in GreenSeeker sensors due to reduced cost on nitrogen as compared to SSNM and STCR methods.

The lower gross return, net return and B: C ratio was obtained in absolute control (` 71,230 ha$^{-1}$, ` 37,780 ha^{-1} 2.13, respectively). This was mainly due to lower fertilizer usage and decreased yield. These results were in close proximity with the findings of Anilkumar *et al*. (2005) and Biradar *et al*. (2012).

From the study, it can be concluded that application of NPK fertilizer through STCR and SSNM method for target yield of 11 t ha^{-1}, nitrogen management through GreenSeeker and SPAD sufficiency index are thebest precision nitrogen management practices in maize for realizing higher grain yield and higher nitrogen use efficiency with higher monetary advantage.

References

Anil Kumar, Thakur, K. S. and Sanjay Sharma, 2005, Integrated nutrient management in maize (*Zea mays* L.) – gobhisarson (*Brassica napus*) cropping system under rainfed condition. *Indian J. Agron*., **50**(4): 274-277.

Anonymous, 2015, Area, production and productivity of major cereals in India. http//www.indiastat.com.

Anonymous, 2016, Area, production and productivity of major cereals in India. http//www.indiastat.com.

Arunkumar, B. R., Srinivasa, N., Prakash, S. S. and Krishna Murthy, R., 2017, Economics and productivity of hybrid maize as influenced by combination of gypsum and borax under different nutrient management practices. *Int. J. Curr. Microbiol. App. Sci.*, **6** (9) : 1112 - 1119.

Biradar, D. P., Aladakatti, Y. R. and Basavanneppa, M. A., 2012, Enhancing the productivity and economic returns of field crops with balanced nutrient application through site specific nutrient management approach. Proc. *Agro-Informatics and Precision Agric.*, 1-3 August, Hydrabad, India: pp. 146-151.

Biradar, A., Jayadeva, H. M., Shankarlingappa, B. C. and Vishwanath, A. P., 2013, Effect of target yield approach on growth, yield and nutrient uptake at flowering of maize. *Mysore J. Agric. Sci*., **47** (4) : 707 - 712.

Chandrakant, Basavaraja, P. K. and Mudalagiriyappa, 2017, Influence of different approaches and forms of fertilizers on hybrid maize yield, uptake and nutrient balance in *Alfisols* of eastern dry zone of Karnataka. *Asian J. Soil Sci.*, **12** (1) : 18 - 24.

Daikho, A., 2013, Performance of maize hybrids to varying fertilizer levels in the northern transitional zone of Karnataka. *M. Sc. (Agri.) Thesis*, submitted to Univ. Agric. Sci., Dharwad (India).

Dapake, P. P., Chaudhari, P. M., Ghodke, S. K. and Patil, M. R., 2017, Effect of sowing time and nutrient management on growth, yield and quality of pearl millet cv. dhanashakti under rainfed condition. *Contempor. Res. India*, **7** (3) : 471 - 478.

Dass, S., Jat, S. L., Chikkappa, G. K., Kumar, B., Kaul, Jyothi, Parihar, C. M., Kumar, A., Kumar, R., Kamboj, M. C., Singh, V., Yatish, K. R., Jat, M. L. And Singh, A. K., 2012, Genetic enhancement and crop management lead maize revolution in India. *Maize J*., **1** (1) : 7 - 12.

El-Habbal, M. S. F., Ashmawy, H. S. Saoudi and Iman, K. H. Abbas, 2010, Effect of nitrogen fertilizer rates on yield, yield components and grain quality measurements of wheat cultivars using SPAD meter. *Egypt J. Agric. Res*., **88** (1) : 14 - 18.

Gomez, K. A. and Gomez, A. A., 1984, Statistical procedure for agricultural research - an international rice research institute book, a wiley inter science, John Wiley and Sons Inc., New York, USA.

Jemal Abdulai, 2010, Response of maize (*Zea mays* L.) and chickpea (*Cicer arietinum* L.) to site specific nutrient management (SSNM) through targeted yield a proach, *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).

Mallikarjuna, S., Umesh, M. R., Ananda, N., Shanwad, U. K., Amaregouda, A. and Manjunath, N., 2016, Precision nitrogen management for rabi sweet corn (*Zea mays saccharata* L.) through decision support tools. *J. Farm Sci.*, **29** (1) : 14 - 18.

Mohanty, S. K., Singh, A. K., Jat, S. L., Parihar, C.M., Pooniya, V., Sharma, S., Sandhya, V., Chaudhary and Bahadur Singh, 2015, Precision nitrogen-management practices influences growth and yield of wheat (*Triticum aestivum*) under conservation agriculture. *Indian J. Agron.,* **60** (4) : 617 - 621.

NAGARJUN, P., 2015, Studies on precision nitrogen management in drip irrigated maize (*Zea mays* L.). *M. Sc. (Agri.) Thesis*. Univ. Agric. Sci., Bengaluru.

RAMANJIT, K., ANCHAL, D. AND VERMA, V. P., 2015, Nitrogen management schedule for Bt cotton under different planting geometries in semi-arid north-western plains of India. *Ann. Agric. Res*., **36** (4) : 384 - 389.

SANTHOSH PAGAD, S., 2014, Precision nutrient management in maize. *M. Sc. (Agri.) Thesis,* Univ. Agric. Sci., Dharwad, Karnataka (India).

SARNAIK, P. H., 2010, Nitrogen manage ment in hybrid maize (*Zea mays* L.) through leaf colour chart. *M. Sc. (Agri.) Thesis*, submitted to Univ. Agric. Sci., Dharwad (India).

SINHA, A. K., 2016, Effect of site specific nutrient management on production and productivity of maize (*Zea mays* L.) under mid hill condition of Chhatisgarh. *Int. J. Plant Sci.,* **11** (2) : 167 - 170.

SREELATHA, D., SIVALAKSHMI, Y., ANURADHA, M. AND RANGAREDDY, R., 2012, Productivity and profitability of rice-maize cropping system as influenced by site-specific nutrient management. *Maize J.*, **1** (1) : 58 - 60.

SURYAVANSHI, V. P., CHAVAN, B.N., JADHAV, V. T. AND BAIG, M. I. A., 2008, Response of maize to nitrogen and phosphorus application in *Vertisols. Int. J. Trop. Agric.* **26** (3&4) : 293 - 296.

TRINH, Q. K., PHAM, S. AND CHRISTIAN, W., 2008, Improving of maize yield and profitability through site-specific nutrient management (SSNM) and planting density. *Oman rice*, **16** : 88 - 92.

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