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RESEARCH PAPER

Precision nutrient management in maize (*Zea mays* L.) under northern transition zone of Karnataka

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Abstract: A field experiment was conducted during *kharif* 2016 at Main Agriculture Research Station, Dharwad, which is located in Northern Transition Zone of Karnataka. The experiment consists of two maize hybrids (NK-6240 and S-6668) were sown in main plots. Eight sub plot treatments *viz.,* three precision nutrient techniques (PNM); site specific nutrient management (SSNM), soil test crop response (STCR) and nutrient expert (NE), recommended dose of fertilizer (RDF) and absolute control are tested in split plot design . The maize hybrid S-6668 recorded significantly higher leaf area index (3.71 and 1.51) and leaf area duration (129 and 118 days) at 90 DAS and at harvest stage, higher grain and stover yield (8.18 and 10.11 t ha^{-1}), gross and net returns (₹ 1,20,569 and ₹ 54,109), respectively than NK-6240. Among the sub plots, nutrient applied as per SSNM (T_2) showed taller plants, higher leaf area Index (LAI), leaf area duration (LAD), SPAD and Normalized differential vegetation Index (NDVI) values, grain and stover yield, harvest index and gross returns as compared to all other precision nutrient techniques, RDF and absolute control. However, SPAD and NDVI values were higher over only RDF and control. Similarly, Harvest Index of T_2 was on par with STCR and NE 10 t ha^{-1}. Whereas, the net return (₹ 65,069 ha^{-1}) and B: C ratio (2.00) was higher with NE than all other treatments. However, SSNM was on par with NE. Interactions showed that, application of fertilizer based on SSNM to achieve target yield of 10 t ha^{-1} with maize hybrid S-6668 recorded higher plant height (218.26 and 219.04 cm), LAI (4.54 and 1.84), LAD (157 and 98 days) at 90 DAS and at harvest, respectively. Further, grain and stover yield (9.49 11.5 t ha^{-1}) as well as gross returns (₹ 1,45,211) were higher than all other treatment combinations, in this treatment.

Key words: Economics, Maize, Nutrient expert, Target yield

Introduction

Maize (*Zea mays*) is one of the major cereal crops with wide adaptability to diverse agro-climatic conditions in the world and stands first with respect to production in the world. In India, it ranks third after rice and wheat. The maize is being called "Queen of cereals" due to its higher production potential and wider adoptability. Maize is an exhaustive crop and requires a balanced supply of the entire 3 major nutrient (N, P and K). The hybrids of maize are very responsive to external supply of nutrients. Application rate of nutrient depends on soil nutrient status.

Precision agriculture is the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality. Several approaches used for fertilizer recommendation in maize, like precision nutrient management through spatial variability assessment and variable rate technologies, site specific nutrient management (SSNM), soil test crop response (STCR), nutrient expert (NE) and recommended dose of fertilizer etc. Among several soil test based fertilizer application techniques, site specific nutrient management (SSNM) and soil test crop response (STCR) are plant need based approaches with specific yield target. The SSNM and STCR approaches not only aim to reduce or increase fertilizer use and also cost effective tools for supplying crop nutrient as and when needed to achieve higher yield, besides this they also aims to increase system nutrient use efficiency, leading to more returns per unit of fertilizer invested (Shankar and Umesh, 2008). Nutrient Expert is a decision support tool for nutrient management in hybrid maize based on SSNM principle and easy to use. It is developed by IPNI (International Plant Nutrition Institute) and CIMMYT, Mexico. It provides nutrient recommendation for an individual farmer field both in presence or absence of soil testing data and current INM practices, plant density, SSNM rates, source, splitting and profit analysis. It also works on the 4R principle right method, right amount, right dose, and right time. This will help to increase yield and profit by target enabled fertilizer management strategy (Pompolino *et al.,* 2012).

Material and methods

A field experiment was conducted during *kharif* 2016 at Main Agriculture Research Station, Dharwad, University of Agricultural Sciences, Dharwad, situated at 15° 262 N latitude and 75° 072 East longitude and at an altitude of 678 m MSL. The rainfall during cropping period was (568.22 mm) and mean maximum and minimum temperature were 30.84 and 14.53 p C, respectively. The experiment was laid out in split plot design with two main plot and eight sub plot treatments. Main plot consists of two maize hybrids (NK-6240 and S-6668) and sub plot consists of eight precision nutrient management techniques *i.e.,* site specific nutrient management (SSNM), soil test crop response (STCR), nutrient expert (NE) to achieve target yield of 8 and 10 t ha^{-1}, recommended dose of fertilizer and absolute control. The soil of experimental site was black soil, neutral in pH (7.1), low in electrical conductivity (0.28 dS/m), medium in organic carbon (0.51 %), low in available nitrogen (126 kg ha^{-1}), medium in phosphorus (44.50 kg ha^{-1}) and high in potassium (335.4 kg ha^{-1}). SPAD chlorophyll meter readings were recorded with the help of SPAD meter at middle lamella of youngest fully opened leaf at different stages (Rostami *et al.,* 2008). The Normalized difference vegetation index (NDVI) was measured using hand- held green seeker sensors (Raun *et al.,* 2005). The quantity of nutrients required to achieve target yield was calculated by using the formulae for different techniques and is given (Table 1).

The nutrients required to achieve target yield through site specific nutrient management (SSNM) was calculated by using the formulae as given by Biradar and Aladakatti, (2007).

NR = Nutrient uptake per quintal × T × ± per cent EFR

Where,

NR = Nutrient required to achieve target yield in kg ha^{-1}

Uptake = Nutrient uptake by the crop per quintal of grain yield in the respective crop and location

T = Target yield (t ha^{-1})

EFR = Effective fertilizer rate (if the soil nutrient supply status is low, medium and high applied 20 per cent higher, same and 20 per cent lower than the estimated required quantity of nutrients, respectively).

Nutrient uptake by maize (3.06 kg N, 1.43 kg P_2O_5 and 2.82 kg K_2O) to produce a quintal of grain was worked out by referring previous 3 years data of International Plant Nutrition Institute (IPNI) project work on rainfed condition at Dharwad and 2 years data of Jnanesh (2012) on maize at the same location as suggested by IPNI was used to calculate the nutrient requirement to achieve target yields.

The STCR equation developed by All India Coordinated Research Project (AICRP) on Soil Test Crop Response (STCR), Bengaluru (Anon., 2007) was used in the study and are as follows

FN = 3.45 T - 0.093 SN ($KMnO_4$ - N)

FP_2O_5 = 2.00 T - 0.31 S P_2O_5 (Olsen's - P_2O_5)

FK_2O = 1.04 T - 0.046 S K_2O (NH_4OAC - K_2O)

Table 1. Amount of nutrients calculated and applied to achieve target yield in different treatments

Treatments		Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1 -	Target yield of 8 t ha^{-1} through SSNM	294	114	181
T_2 -	Target yield of 10 t ha^{-1} through SSNM	367	143	226
T_3 -	Target yield of 8 t ha^{-1} through STCR	264	146	68
T_4 -	Target yield of 10 t ha^{-1} through STCR	333	186	335
T_5 -	Target yield of 8 t ha^{-1} through NE	140	47	56
T_6 -	Target yield of 10 t ha^{-1} through NE	150	64	98
T_7 -	RDF	100	50	25
T_8 -	Absolute control	0.00	0.00	0.00

Where,

FN= Nitrogen supplied through fertilizer in kg ha^{-1}

FP_2O_5 = Phosphorus supplied through fertilizer in kg ha^{-1}

FK_2O = Potassium supplied through fertilizer in kg ha^{-1}

T= Target yield

S N, S P_2O_5, S K_2O = Initial soil test value for available N, P_2O_5 and K_2O (kg ha^{-1}), respectively.

For nutrient expert based fertilizer recommendation ready reckoner software developed by International Plant Nutrition Institute (IPNI), 2014 was used

The fertilizers were applied as per recommendations, at basal half of nitrogen, entire dose of phosphorus and potassium in the form of 10:26:26, Urea, Muriate of potash (MOP) and Single Super Phospherate (SSP) were applied as per the treatments. Remaining half of recommended nitrogen was top dressed at 30 DAS. Vermicompost was applied to the soil prior to sowing of crop to all the treatments including control plot at the rate 1.25 t ha^{-1}. Experimental plot was kept free from weeds throughout the crop growing period. Atrazine was applied as a pre-emergence herbicide at the rate of 1 kg a.i. ha^{-1} immediately after sowing. Two inter-cultivations were carried out at 30 DAS and 60 DAS. One hand weeding was carried out at 30 DAS. For stem borer management, Carbofuron granules were applied to the leaf whorls' at the rate of 7.5 kg ha^{-1} after 20 days of sowing. All growth and yield components were recorded at different growth stages of the crop. Agronomic data collected included plant height, leaf area index (LAI) and leaf area duration (LAD) at different growth stages of the crop. Grain and stover yield from net plot area was converted into per hectare basis. Economic returns were worked out based on the prevailing market prices of inputs, cost of fertilizers and outputs. Returns per rupee invested were worked out by considering net returns and cost of cultivation. The experimental data were analyzed statistically as per the procedures given by Gomez and Gomez (1984).

Results and discussion

Response of maize hybrids

The maize hybrid S-6668 produced significantly higher grain and stover yield (8.18 and 10.11 t ha^{-1}) which was significantly superior to NK-6240 (7.73 and 9.76 t ha^{-1},). The increase in grain yield in S-6668 was to the extent of 5.8 per cent over NK-6240 (Table 3). The higher grain yield of S-6668 could be mainly attributed to higher grain weight per cob over NK-6240. This may be due to genetic potential of S-6668 to utilize the resources properly, translocate photosynthates from source to sink and adaptability to agro-climatic conditions (Sampath *et al.,* 2013).

These photosynthetic parameters were higher with S-6668 as compared to NK-6240 as depicted through higher leaf area index, leaf area duration (LAD) at 90 DAS and at harvest stages as compared to NK-6240 (Table 2). Plant canopies intercept light with varying degrees of efficiency associated majorly with leaf area index. The efficiency of intercepting of incident light, combined with efficiency of photochemical reaction of the leaves

Table 2. Growth parameters of maize hybrids at 90 DAS and at harvest (AH) as influenced by different precision nutrient management

Treatments	Plant height (cm)		Leaf Area Index		Leaf Area Duration		SPAD chlorophyll values		NDVI values	
	90 DAS	AH	90 DAS	AH	60-90 DAS	90-AH	60DAS	90DAS	60DAS	90DAS
Hybrids (H)										
H_1-NK-6240	200.18	200.49	3.47	1.29	118	71	49.50	47.86	0.81	0.82
H_2-S6668	204.08	204.76	3.71	1.51	129	78	50.26	48.28	0.86	0.83
S. Em. ±	0.67	1.12	0.04	0.01	1.54	0.51	0.72	0.66	0.01	0.01
LSD (0.05)	NS	NS	0.21	0.05	9.35	3.09	NS	NS	NS	NS
PNM techniques										
T_1-SSNM target yield 8 t ha^{-1}	210.88	211.11	3.82	1.48	132	80	51.44	49.84	0.87	0.84
T_2-SSNM target yield 10 t ha^{-1}	215.45	216.14	4.31	1.83	150	92	52.42	50.99	0.89	0.86
T_3-STCR target yield 8 t ha^{-1}	209.10	209.39	3.72	1.41	128	77	50.58	49.30	0.86	0.83
T_4-STCR target yield 10 t ha^{-1}	213.90	214.28	4.15	1.72	142	88	51.82	49.90	0.87	0.85
T_5-NE target yield 8 t ha^{-1}	207.66	208.09	3.69	1.32	127	75	50.12	48.09	0.84	0.83
T_6-NE target yield 10 t ha^{-1}	212.45	213.02	3.91	1.53	137	82	50.38	49.05	0.86	0.84
T_7 RDF	185.42	186.35	2.83	1.04	97	58	47.97	45.55	0.82	0.80
T_8 Absolute control	162.19	162.62	2.29	0.90	79	48	47.97	41.87	0.81	0.78
S. Em. ±	0.47	0.56	0.06	0.04	1.18	1.02	1.06	1.09	0.02	0.02
LSD (0.05)	1.35	1.62	0.18	0.10	3.41	2.94	3.07	3.16	0.05	0.05
Interaction (H× PNM)										
H_1T_1	208.69	208.81	3.78	1.36	126	77	51.16	49.61	0.86	0.84
H_1T_2	212.65	213.25	4.08	1.69	143	87	52.07	50.98	0.88	0.85
H_1T_3	207.66	207.76	3.63	1.26	121	73	49.77	49.30	0.86	0.83
H_1T_4	211.81	211.89	3.99	1.60	135	84	51.49	49.50	0.87	0.84
H_1T_5	205.78	205.91	3.59	1.14	120	71	49.37	48.34	0.84	0.82
H_1T_6	211.17	211.72	3.91	1.42	133	80	49.63	48.87	0.86	0.83
H_1T_7	182.17	182.81	2.56	0.98	92	53	48.27	45.06	0.78	0.80
H_1T_8	161.53	161.79	2.23	0.89	77	47	44.23	41.24	0.76	0.77
H_2T_1	213.08	213.41	3.86	1.60	137	82	51.71	50.06	0.88	0.85
H_2T_2	218.26	219.04	4.54	1.97	157	98	52.77	51.00	0.90	0.87
H_2T_3	210.55	211.01	3.81	1.55	134	80	51.39	49.30	0.86	0.84
H_2T_4	216.00	216.67	4.31	1.84	150	92	52.15	50.30	0.87	0.85
H_2T_5	209.53	210.27	3.79	1.51	133	79	50.88	47.83	0.84	0.83
H_2T_6	213.73	214.32	3.91	1.64	141	83	51.13	49.23	0.87	0.85
H_2T_7	188.67	189.89	3.10	1.09	101	63	47.67	46.04	0.82	0.80
H_2T_8	162.85	163.45	2.34	0.91	81	49	44.42	42.50	0.81	0.78
S. Em. ±	0.91	1.33	0.09	0.05	2.19	1.44	1.58	1.59	0.03	0.03
LSD (0.05)	2.63	3.85	0.26	0.13	6.34	4.16	NS	NS	NS	NS

NS – Non significant PNM: Precision Nutrient Management

T_1: 294:114:181 kg N, P_2O_5 and K_2O ha^{-1} T_2: 367:143:226 kg N, P_2O_5 and K_2O kg ha^{-1}

T_3: 264:146:68 kg N, P_2O_5 and K_2O ha^{-1} T_4: 333:186:89 kg N, P_2O_5 and K_2O ha^{-1}

T_5: 140:47:56 kg N, P_2O_5 and K_2O ha^{-1} T_6: 150:64:98 kg N, P_2O_5 and K_2O ha^{-1}

T_7: 100:50:25 kg N, P_2O_5 and K_2O ha^{-1} T_8: 0:0:0 kg N, P_2O_5 and K_2O ha^{-1}

determine the efficiency of the canopy in utilizing radiation energy per unit of land area.

The SPAD Chlorophyll meter values are indirect indicator of relative content of chlorophyll and leaf nitrogen. Precise application of fertilizer N through target yield approach increased the SPAD (soil plant analysis development) values. SPAD and NDVI values recorded at 60 and 90 DAS with S-6668 were numerically superior as compared to NK-6240 (Table 2). Normalized Difference Vegetative Index (NDVI) and chlorophyll (SPAD) measurements are commonly used spectral indices in field practices due to their effectiveness and ease of use. Plant NDVI relates the reflectance in the red (Red) and Near Infra Red (NIR) spectral light bands. The absorption in the red band estimates the chlorophyll content and NIR band is sensitive to canopy cover (Shanahan *et al.,* 2001). Many researchers have reported a good relationship between plant NDVI and photosynthetic efficiency (Freeman *et al.,* 2007)

Economical returns are an important factor to assess feasibility of the practices in crop production. Among the two maize hybrids S-6668 recorded higher gross returns (₹ 1,20,569), net returns (₹ 54,109) than NK-6240 (₹ 1,14,038 and 48,139). However, B: C ratio was on par in both the hybrids. This was due to higher grain and stover yield associated with S-6668 hybrid than NK-6240 (Table 4).

Table 3. Grain yield, stover yield and harvest index of maize hybrids as influenced by different precision nutrient management (PNM)

Treatments	Grain weight cob^{-1} (g)	Grain yield (t ha^{-1})	Stover Yield (t ha^{-1})	Harvest index
Hybrids (H)				
H_1- NK6240	178.93	7.73	9.76	43.86
H_2- S6668	197.73	8.18	10.11	44.47
S. Em±	1.47	0.07	0.05	0.30
LSD (0.05)	8.95	0.43	0.29	NS
PNM techniques				
T_1 - SSNM target yield 8 t ha^{-1}	210.65	8.41	10.46	44.52
T_2 - SSNM target yield 10 t ha^{-1}	234.40	9.49	11.30	45.63
T_3 - STCR target yield 8 t ha^{-1}	204.17	8.18	10.26	44.13
T_4 - STCR target yield 10 t ha^{-1}	227.61	9.19	11.04	45.41
T_5 - NE target yield 8 t ha^{-1}	196.25	7.95	10.14	43.77
T_6 - NE target yield 10 t q ha^{-1}	224.57	8.83	10.75	45.11
T_7 - RDF	129.67	7.02	9.07	43.64
T_8 - Absolute control	79.33	4.56	6.53	41.16
S. Em±	2.01	0.09	0.06	
LSD (0.05)	5.83	0.27	0.17	0.361.03
Interaction(H x T)				
H_1T_1	197.67	7.98	10.15	43.98
H_1T_2	223.40	9.10	11.01	45.24
H_1T_3	193.02	7.97	10.10	43.60
H_1T_4	218.06	8.85	10.81	45.00
H_1T_5	182.96	7.83	9.98	43.57
H_1T_6	216.20	8.63	10.65	44.76
H_1T_7	121.83	6.97	8.96	43.77
H_1T_8	78.33	4.49	6.49	40.92
H_2T_1	223.63	8.83	10.77	45.06
H_2T_2	245.40	9.88	11.59	46.02
H_2T_3	215.32	8.40	10.41	44.66
H_2T_4	237.17	9.53	11.27	45.81
H_2T_5	209.53	8.08	10.30	43.96
H_2T_6	232.95	9.03	10.84	45.46
H_2T_7	137.50	7.06	9.17	43.50
H_2T_8	80.33	4.63	6.57	41.29
S. Em±	3.04	0.14	0.09	0.56
LSD (0.05)	8.82	0.41	0.27	NS

NS – Non significant

T_1: 294:114:181 kg N, P_2O_5 and K_2O ha^{-1}
T_2: 367:143:226 kg N, P_2O_5 and K_2O kg ha^{-1}
T_3: 264:146:68 kg N, P_2O_5 and K_2O ha^{-1}
T_4: 333:186:89 kg N, P_2O_5 and K_2O ha^{-1}
T_5: 140:47:56 kg N, P_2O_5 and K_2O ha^{-1}
T_6: 150:64:98 kg N, P_2O_5 and K_2O ha^{-1}
T_7: 100:50:25 kg N, P_2O_5 and K_2O ha^{-1}
T_8: 0:0:0 kg N, P_2O_5 and K_2O ha^{-1}

Effect of different yield target based precision nutrient management techniques

Application of 367 kg of N, 143 kg of P_2O_5 and 226 kg K_2O ha^{-1} through SSNM for target yield of 10 t ha^{-1} recorded higher grain yield as compare to other treatments. It was also significantly superior to other techniques (STCR and NE). The increase in grain yield was 108 per cent over absolute control and 3.24, 7.43 and 35.13 per cent as compared to STCR, NE and RDF, respectively. The higher grain and stover yield of maize was mainly due to better translocation of photosynthates from source to sink and higher growth attributing characters. All the growth and yield components like plant height (215.45 and 216.14 cm), LAI (4.31 and 1.83), LAD (50 and 92), SPAD (52.42 and 50.99) and NDVI (0.89 and 0.86) values, at 90 DAS and AH and grain weight cob^{-1} were higher with the nutrients supplied to achieve target yield of 10 t ha^{-1} through SSNM technique than other techniques. The quantity of nutrients available to maize crop through this treatment was better than other treatments. This trend clearly indicates the importance of application of nutrients through precision nutrient management to achieve the target yield of maize. The increase in grain yield of maize was due to the application of higher level of inorganic fertilizes. These results are in accordance with those obtained by Chetan (2015).

Nutrient level significantly influenced SPAD chlorophyll meter and NDVI values. The NDVI and SPAD values showed direct correlation with plant growth. Precise application of fertilizer N through SSNM 10 t ha^{-1} increased the SPAD and NDVI values at different phenological stages. Significantly higher value of NDVI and SPAD was recorded in SSNM 10 t ha^{-1}. The higher

Table 4. Economics of maize hybrids as influenced by different precision nutrient management (PNM)

Treatments	Gross returns (₹ ha^{-1})	Cost of cultivation (₹ha^{-1})	Net returns (₹ha^{-1})	B: C ratio
Hybrids (H)				
H_1- NK6240	1,14,038	65,899	48,139	1.72
H_2- S6668	1,20,569	66,460	54,109	1.80
S. Em±	958	-	958	0.01
LSD (0.05)	5831	-	5831	NS
PNM techniques with target yield (T)				
T_1 - SSNM target yield 8 t ha^{-1}	1,23,946	72,150	51,796	1.72
T_2 - SSNM target yield 10 t ha^{-1}	1,39,574	77,683	61,891	1.80
T_3 - STCR target yield 8 t ha^{-1}	1,20,734	69,760	50,974	1.73
T_4 - STCR target yield 10 t ha^{-1}	1,35,244	75,032	60,213	1.80
T_5 - NE target yield 8 t ha^{-1}	1,17,413	61,409	56,004	1.91
T_6 - NE target yield 10 t ha^{-1}	1,30,055	64,986	65,069	2.00
T_7 - RDF	1,03,706	58,873	44,833	1.76
T_8 - Absolute control	67,754	49,544	18,211	1.37
S. Em±	1319	-	1319	0.02
LSD (0.05)	3820	-	3820	0.06
Interaction(H x T)				
H_1T_1	1,17,810	71,622	46,188	1.64
H_1T_2	1,33,936	77,198	56,738	1.73
H_1T_3	1,17,621	69,492	48,129	1.69
H_1T_4	1,30,367	74,611	55,756	1.75
H_1T_5	1,15,550	61,252	54,298	1.89
H_1T_6	1,27,214	64,739	62,475	1.97
H_1T_7	1,03,012	58,817	44,195	1.75
H_1T_8	66,791	49,460	17,331	1.35
H_2T_1	1,30,082	72,678	57,404	1.79
H_2T_2	1,45,211	78,168	67,043	1.86
H_2T_3	1,23,846	70,028	53,818	1.77
H_2T_4	1,40,121	75,453	64,669	1.86
H_2T_5	1,19,277	61,566	57,711	1.94
H_2T_6	1,32,896	65,233	67,663	2.04
H_2T_7	1,04,400	58,928	45,472	1.77
H_2T_8	68,717	49,627	19,091	1.38
S. Em±	1990	-	1990	0.03
LSD (0.05)	5765	-	NS	NS

NS – Non significant

T_1: 294:114:181 kg N, P_2O_5 and K_2O ha^{-1}
T_2: 367:143:226 kg N, P_2O_5 and K_2O kg ha^{-1}
T_3: 264:146:68 kg N, P_2O_5 and K_2O ha^{-1}
T_4: 333:186:89 kg N, P_2O_5 and K_2O ha^{-1}
T_5: 140:47:56 kg N, P_2O_5 and K_2O ha^{-1}
T_6: 150:64:98 kg N, P_2O_5 and K_2O ha^{-1}
T_7: 100:50:25 kg N, P_2O_5 and K_2O ha^{-1}
T_8: 0:0:0 kg N, P_2O_5 and K_2O ha^{-1}

Price of grain: ₹1400 q^{-1}, stover: ₹ 60 q^{-1}
Note: cost of cultivation not analyzed statistically

SPAD and NDVI values were due to balance nutrient prescription in the SSNM, leading to more chlorophyll development in crop plant which resulted in higher NDVI and SPAD values. The yield parameters differed significantly due to application of nutrient applied based on precision nutrient management with target yield (Table 3). Application of nutrient with SSNM 10 t ha^{-1} recorded significantly higher gross returns (1,39,574), but net returns (65,069) and B: C (2.00) ratios were higher in nutrient expert with target yield of 10 t ha^{-1} as compared to other precision nutrient management treatments. This was due to lesser and precise quantity of nutrients applied through nutrient expert, as the software calculates required quantity of nutrient based on previous history, target yield and soil and climatic conditions.

Interaction effect of maize hybrids and precision nutrient management techniques

Significantly higher grain yield (9.87 t ha^{-1}) was obtained in S-6668 with SSNM 10 t ha^{-1} than other treatment combinations and it was on par with STCR 10 t ha^{-1}. Lower grain yield (4.49 t ha^{-1}) was recorded with treatment combination of NK-6240 with absolute control (Table 3). The increase in grain and stover yield was to the extent of 39.80 and 26.31 per cent higher in S-6668 with SSNM 10 t ha^{-1} over RDF. The superiority of economical yield in treatment combination of S-6668 with SSNM 10 t ha^{-1} than other treatment combinations might be due to better translocation of photosynthates from source to sink and higher growth attributing characters like plant height, LAI , LAD and yield attributing characters like grain yield per plant (Table 2 and 3). Higher grain yield in SSNM with target yield of 10 t ha^{-1} was ascribed to higher rate of fertilizer and also balanced nutrient application.

The maize hybrid S-6668 with application of nutrient (367:143:226 kg N, P_2O_5 and K_2O ha^{-1}) to achieve target yield of 10 t ha^{-1} through SSNM recorded significantly higher gross returns (₹ 1,39,574) than all other treatment combinations due to higher economical yield (Table 4). The same result was also observed by Vikram *et al.* (2015). Even though, net returns and B: C ratios were non significant among treatment combinations, but both net returns and B: C ratios (67663 and 2.04, resp.,) were higher in S-6668 with nutrient expert 10 t ha^{-1} than other treatments. This was due to lower doses of fertilizer applied to achieve target yield of 10 t ha^{-1} through nutrient expert (150:64:98 kg N, P_2O_5 and K_2O ha^{-1}) than SSNM (367:143:226 kg N, P_2O_5 and K_2O ha^{-1}). This leads to lesser cost of cultivation in nutrient expert technique (₹ 58,928) as compared to SSNM (₹ 78,168).

Conclusion

It could be concluded that the performance of maize hybrid S-6668 was better than NK-6240. The target yield of 10 t ha^{-1} in maize could be achieved (9.87 t ha^{-1}) through site specific nutrient management with S-6668 other than PNM treatments. Higher productivity was achieved with SSNM with yield target of 10 t ha^{-1} but, higher profitability was in terms of net return was observed with NE with target yield of 10 t ha^{-1}. Higher economic returns *viz.,* net returns and B: C ratios were obtained by application of nutrient to achieve target yield of 10 t ha^{-1} (150:64:98 kg N, P_2O_5 and K_2O ha^{-1}) through nutrient expert than other precision nutrient management treatments.

References

Anonymous, 2007, STCR an approach for fertilizer recommendations based on targeted yield concept. *Tech. Bul.,* AICRP on STCR. Univ. Agric. Sci., Bangalore.

Biradar, D. P. and Aladakatti, Y. R., 2007, Site- specific nutrient management (SSNM) - another green revolution in Northern Karnataka. *Better Crops,* 90(3): 33-35.

Chetan, H. T., 2015, Site specific nutrient management for target yield in maize hybrids under irrigated situation. *M.Sc. (Agri.) Thesis,* Univ. Agric. Sci., Dharwad, Karnataka (India).

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, United State of America, pp.130-150.

Freeman, K. W. D. B., Arnall, R. W., Mullen, K. G., Garima, K. L., Martin, R. K, Teal and Raun, W. R., 2007, By- plant prediction of corn forage biomass and nitrogen uptake at various growth stages using remote sensing and plant height measures. *Agron J.,* 99: 530-536.

Jnanesha, A. C., 2012, Integrated nutrient management practices in maize- chickpea cropping under broad bed and furrow in model watershed Dharwad. *Ph.D. Thesis,* Univ. Agric. Sci., Dharwad, Karnataka (India).

Pampolino, M.F., Witt, C., Pasuquin, J.M., Johnston, A. and Fisher, M. J., 2012, Development approach and evaluation of the nutrient expert software for nutrient management in cereal crops. *Comp. and Elecl. in Agric.,* 88:103-110.

Raun, W. R., Solie, J. B., Johnson, G. V., Stone, M. L., Mullen, R. W., Freeman, K. W., Thomson, W. E. and Lukina, E, V., 2005. Improving nitrogen use efficiency in cereal grain production with optical sensing and variable rate application. *Agron. J.,* 94: 815-820.

Rostami, M., Koocheki, A. R., Mahallati, M. N. and Kafi, M., 2008, Evaluation of chlorophyll meter (SPAD) data for prediction of nitrogen status in corn (*Zea mays* L.). *Am- Euras. J. Agric. Environ.* Sci.,3(1): 79-85.

Shanahan, J. F., Schepers, J. S., Francis, D. D. Varvel, G. E., Wilhelm, W. W., Tringe, J. M., Schemmer, M. R and Major, D. J., 2001, Use of remote-sensing imagery to estimate corn grain yield. *Agron. J*., 93: 583-589.

Shankar, M. A. and Umesh, M. R., 2008. Site specific nutrient management (SSNM): An approach and methodology for achieving sustainable crop productivity in dryland *Alfisols* of Karnataka. *In: Tec. Bult. Univ. Agric. Sci.,* Bangalore.

Sampath, O., Madhavi, M. and Chandrashekar, R. P., 2013, Evaluation of genotypes and nitrogen levels for yield maximization in rabi maize (*Zea mays* L.). *Intl. J. Innov. Res. Dev.,* 2 (9) : 314-318.

Vikram, A. P., Biradar, D. P., Umesh, M. R., Basavaneppa, M. A. and Rao, K.N., 2015, Effect of nutrient management techniques on growth, yield and economics of hybrid maize in vertisols. *Karnataka J. Agric. Sci.,* 28(4):477-481.