Next Generation Technology for Nutrient and Water Management in Maize (*Zea mays* L.)

KRISHNA DESAI AND MUDALAGIRIYAPPA
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : krishnadesai2295@gmail.com

ABSTRACT

A field experiment on next generation technology for nutrient and water management in maize were carried out during *kharif* 2019-20 and 2020-21 at H-8 Block, GKVK, Bengaluru. Consisting of twelve treatments replicated three times, assigning three levels of irrigation as main plot treatment with four sub plots of nutrient management practices in a split plot design. The results revealed that sensor based drip irrigation at 50 per cent depletion of available soil moisture (DASM) (M_2) along with software based nutrient expert tool (N_1) recorded significantly higher plant height at 30, 60, 90 DAS and at harvest (67.3, 188.9, 206.5 and 220.9 cm, respectively), leaf area at 30, 60, 90 DAS and at harvest (2362, 9105, 12645 and 9020 cm^2 $plant^{-1}$, respectively), SPAD readings at 15, 30, 45, 60, 75 DAS (30.6, 32.3, 33.2, 40.4 and 38.5, respectively) and higher kernel yield (9725 kg ha^{-1}) and stover yield (10352 kg ha^{-1}) on pooled basis compared to sensor based drip irrigation at 75 per cent depletion of available soil moisture (DASM) (M_3) combined with site specific nutrient management (SSNM) (N_2) and also the treatment receiving surface irrigation (M_1) along with recommended dose of fertilizers (N_4) recorded significantly lower plant height (40.1, 153.9, 172.2 and 185.6 cm, respectively), leaf area (1633, 5977, 8304 and 5817 cm^2 $plant^{-1}$, respectively), SPAD values (23.2, 24.7, 25.1, 30.6 and 29.2, respectively), lower kernel weight (6916 kg ha^{-1}) and stover yield (7820 kg ha^{-1}).

Keywords : Depletion of available soil moisture, Nutrient expert, Growth parameters, Yield

MAIZE (*Zea mays* L.) is the most versatile crop among cereals with respect to its adaptability, types and uses. It is the second most widely grown crop in the world and is popularly known as 'Queen of Cereals'. It is cultivated in varying climates of tropics to temperate. Commonly known types of maize include field corn, sweet corn, pop corn and baby corn. Within field corn, it has several other types like quality protein maize (QPM), waxy maize, high-oil maize etc. Maize is an important crop for billions of people as food, feed and industrial raw material. Currently, nearly 1147.7 million MT of maize is being produced together by over 170 countries from an area of 193.7 million ha with an average productivity of 5.75 t ha^{-1} (Anonymous, 2020). In India it occupies a cropped area of 9.63 million hectares with an annual production of 25.89 million tonnes. In Karnataka, maize is grown over an area of 1.37 million hectares with an annual production of 3.31 million tonnes and the productivity being 3000 kg ha^{-1} (Anonymous, 2019).

The global consumption pattern of maize is 25 per cent as feed, 17 per cent as food and 22 per cent as industry. It has attained a position of industrial crop globally as 83 per cent of its production in the world, is used in feed, starch and bio-fuel industries. Further, using maize directly or indirectly, more than 3000 products are being made providing wide opportunity for value addition. Because of its myriad uses, it is a prime driver of the global agricultural economy. Maize has its imperative significance because it has wider adaptability and biological efficacy. Increasing the coarse cereals production is important to meet the rising food requirement in the country. It has been predicted that demand for maize will further continue to rise in a sustainable way due to increasing demand from livestock and poultry production. Further, due to urbanization there is no scope to increase area under maize. Hence, intensifying the crop in the available maize growing area is mandatory. So, maximizing the productivity per unit area, utilizing water and time is a possible solution to the larger food requirement.

Innovation is more important in modern agriculture than ever before. The industry as a whole is facing huge challenges, from rising costs of supplies, a shortage of labour and changes in consumer preferences for transparency and sustainability. Technology that promises to unleash agricultural productivity is here today. The combination punch of advanced mathematics, automation, advancements in sensor systems and next-generation technologies are setting the stage for the next Green Revolution, which is what we need to ensure a sustainable future. Next generation farms are putting science and technology to work to deliver a step change in yields.

Nutrient management is a major component in maize production system. Applying the required quantities of nutrients at all the stages of growth and understanding the soil ability to supply of those nutrients is critical in profitable crop production. Among the major nutrients, nitrogen is the key plant nutrient that determines maize yield, as it is an important component of chlorophyll, protein and nucleic acid influencing photosynthesis and making up 1-4 per cent of dry matter of plants. However, a large requirement of nitrogen for maize is a major concern to the producers because N-fertilizers are often applied in bulk quantities at one time and not as per plant demand, thus not taken up by plant (Ghosh *et al.*, 2017).

Conventionally, scheduling of irrigation is mainly based on soil moisture measurement or by using soil water balance calculation method which are tiresome and laborious. Utilizing different sensors to schedule irrigation is known to increase the yield of maize crop by saving water. The precision and accuracy of the sensors are crucial to get precision in irrigation scheduling. Sensors accompanied with drip irrigation could be an effective management practice to increase water productivity. Keeping the above facts in view, a study was carried out to know the influence of next generation technology (NGT) in water and nutrient management on growth and yield of maize.

Material and Methods

A field experiment on next generation technology for nutrient and water management in maize (*Zea mays* L.) was carried out during *kharif* 2019-20 and 2020-21 at Agro-forestry unit (H-8 block) of Zonal Agricultural Research Station, Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences (UAS), Bangalore. The site of experimentation was in Region III of Agro Climatic Zone V (Eastern Dry Zone) of Karnataka. The initial pH was 5.44 and electrical conductivity was 0.37 dS m^{-1}. The organic carbon was 0.44 per cent. The available nitrogen, phosphorus and potassium were 282.9, 55.5 and 239.9 kg NPK ha^{-1}, respectively. The experiment was laid out in split plot design. There were twelve treatments combinations consists three main plots and four sub plots. Main plots: M_1- Surface Irrigation, M_2- Drip irrigation at 50 per cent DASM, M_3- Drip irrigation at 75 per cent DASM. Sub plots: N_1- Nutrient expert based target 10 t ha^{-1} (NE_{10}), N_2- Site specific nutrient management (SSNM) @ 10 t ha^{-1}, N_3- Green seeker guided nutrient management, N_4- Recommended dose of fertilizer (RDF). Before sowing, the land was prepared to a fine tilth. The furrows were opened with a furrow opener by adjusting the width to the required row spacing of 60 cm. The calculated amounts of nutrients were applied to the respective treatments. High yielding, disease tolerant, stay green single cross maize hybrid MAH-14-5 suitable for cultivation in rained situation was used for sowing.

The amount of nutrient required to achieve target yield was calculated by using the formulae for different techniques. Nutrient expert is a software or decision support tool for nutrient management in hybrid maize developed by IPNI and CIMMYT, Mexico (Satyanarayana *et al.*, 2014) Nutrient

Expert® for hybrid maize, an MS Access - based computer application consists of five working modules. Current nutrient management practices, the first module in the software documents the history of maize yields obtained by the farmers' field. The planting density module decides whether or not the farmer is practicing an optimum plant population. An SSNM rate, the third and the most critical module of the software, initially establishes an attainable yield target considering the growing environment of the farmer's field. The sources and splitting transform the nutrient rates into fertilizer sources available at farmers' doorstep and provide a final 4R compliant (*i.e.*, Right source, Right rate, Right time and Right place). The profit analysis module compares the cost economics associated with both the SSNM and farmer's practice.

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

$$NR = \text{Uptake per quintal} \times T$$

Where,

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

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

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

EFR = Effective fertilizer rate

Green seeker is an optical sensor that emits and measures reflected light at two different wave lengths *viz.,* one in the visible spectrum (660 nm) and another one in the near-infrared spectrum (770 nm). Measured spectral reflectance is expressed as spectral vegetation indices such as NDVI. NDVI is an indicator of soil nitrogen and also nitrogen status of the crop canopy. NDVI values range from 0 to 1. If NDVI values are below 0.3 (15-30 DAS) applied 25 kg ha^{-1} nitrogen, if values are in between 0.3 to 0.5 (45- 60 DAS) applied 25 kg ha^{-1} nitrogen, if it is not in the range no nitrogen was applied and values are more than 0.7 no need to apply additional nitrogen. Application of nitrogen was discontinued after the initiation of silking (Pune et al, 2011).

Using moisture probe meter and time domain reflectometry (TDR) probe soil moisture content at panicle initiation and grain filling stage was measured. Surface irrigation applies more water at the head of the field than at the bottom because of the longer soaking time. Sensors should be placed in both locations to improve the uniformity of surface irrigation. As for sensor depth and distance from the crop row, these are dependent on the soaking pattern which varies by soil type and length of time irrigation is turned on. One sensor should be placed in the middle of the root zone (depth-wise) and should be within the wetted pattern of the furrow. Soil moisture content is measured on a volumetric basis per cent.

To ensure enough water for crop growth, one sensor should be put between the drip tapes and the edge of the wetting zone in drip irrigation. The last sensor should be placed along the crop row on the outside edge of the wetting zone to measure horizontal soaking from drip irrigation as well as water stored in the soil outside of the drip irrigation recharge zone.

Results and Discussion

The data pertaining to plant height of hybrid maize at different growth stages as influenced by next generation technologies in irrigation and nutrient management practices are presented in Table 1.

Sensor based drip irrigation at 50 per cent DASM recorded significantly higher plant height at 30, 60, 90 DAS and at harvest (55.0, 172.8, 190.9 and 204.7 cm, respectively) as compared to surface irrigation (45.8, 163.4, 181.7 and 195.2 cm, respectively) and it was found to be on par with application of irrigation at 75 per cent DASM (50.1, 166.3, 184.5 and 198.1 cm, respectively). Significantly higher plant height at 30, 60, 90 DAS and at harvest was observed with application of fertilizer using nutrient expert (58.0, 179.3, 197.2 and 211.2 cm, respectively) as compared to application of recommended dose

TABLE 1

Plant height (cm) at different growth stages in maize as influenced by next generation technologies

Treatments	30 DAS			60 DAS			90 DAS			At harvest		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Main plot												
M_1 : Surface irrigation	45.3	46.2	45.8	162.1	164.8	163.4	179.9	183.5	181.7	193.3	197.1	195.2
M_2 : 50% DASM	54.5	55.6	55.0	171.4	174.2	172.8	189.1	192.6	190.9	202.7	206.7	204.7
M_3 : 75% DASM	49.6	50.6	50.1	164.9	167.7	166.3	182.7	186.3	184.5	196.2	200.1	198.1
F test	*	*	*	*	*	*	*	*	*	*	*	*
SEm±	1.18	1.23	1.20	1.20	1.20	1.20	1.18	1.26	1.22	1.20	1.20	1.20
CD at 5 %	4.62	4.83	4.72	4.70	4.73	4.71	4.64	4.94	4.77	4.70	4.73	4.72
Sub plot												
N_1 : Nutrient expert	57.4	58.6	58.0	177.8	180.8	179.3	195.4	199.0	197.2	209.2	213.3	211.2
N_2 : SSNM	54.2	55.3	54.7	174.6	177.5	176.0	192.2	196.1	194.1	205.9	210.0	207.9
N_3 : Green Seeker	46.1	47.1	46.6	158.2	160.8	159.5	176.0	179.5	177.8	189.4	193.2	191.3
N_4 : RDF	41.5	42.3	41.9	154.0	156.5	155.2	171.8	175.3	173.6	185.1	188.8	187.0
F test	*	*	*	*	*	*	*	*	*	*	*	*
SEm±	1.07	1.07	1.05	1.11	1.12	1.11	1.09	1.03	1.05	1.12	1.13	1.12
CD at 5 %	3.19	3.17	3.12	3.29	3.33	3.31	3.25	3.05	3.13	3.32	3.35	3.33
Interaction												
M_1N_1	50.0	51.0	50.5	170.5	173.3	171.9	188.2	191.9	190.0	201.7	205.8	203.8
M_1N_2	48.7	49.7	49.2	169.3	172.1	170.7	187.0	190.7	188.8	200.5	204.5	202.5
M_1N_3	42.8	43.7	43.3	155.9	158.5	157.2	173.8	177.3	175.5	187.1	190.8	189.0
M_1N_4	39.7	40.4	40.1	152.6	155.2	153.9	170.5	173.9	172.2	183.8	187.5	185.6
M_2N_1	66.5	68.1	67.3	187.3	190.4	188.9	204.8	208.1	206.5	218.8	223.1	220.9
M_2N_2	60.5	61.8	61.1	180.7	183.7	182.2	198.3	202.2	200.3	212.0	216.3	214.2
M_2N_3	48.2	49.2	48.7	161.9	164.6	163.2	179.7	183.3	181.5	193.1	196.9	195.0
M_2N_4	42.6	43.5	43.0	155.7	158.3	157.0	173.5	177.0	175.3	186.8	190.6	188.7
M_3N_1	55.6	56.8	56.2	175.7	178.6	177.1	193.3	197.1	195.2	207.0	211.1	209.0
M_3N_2	53.4	54.4	53.9	173.7	176.6	175.2	191.4	195.2	193.3	205.0	209.1	207.1
M_3N_3	47.3	48.3	47.8	156.7	159.4	158.0	174.6	178.1	176.3	187.9	191.7	189.8
M_3N_4	42.1	43.0	42.6	153.6	156.2	154.9	171.5	174.9	173.2	184.8	188.5	186.6
F test	*	*	*	*	*	*	*	*	*	*	*	*
SEm±	1.86	1.85	1.82	1.92	1.94	1.93	1.89	1.78	1.83	1.94	1.95	1.94
CD at 5%	5.52	5.49	5.41	5.70	5.77	5.73	5.63	5.28	5.42	5.75	5.80	5.78

fertilizers (41.9, 155.2, 173.6 and 187.0 cm, respectively) and it was statistically at par with application of fertilizers using SSNM approach (54.7, 176.0 194.1 and 207.9 cm, respectively).

Sensor based drip irrigation at 50 per cent DASM along with application of fertilizer using nutrient expert recorded significantly higher plant height at 30, 60, 90 DAS and at harvest (67.3, 188.9, 206.5 and 220.9 cm, respectively) which was followed by 50 per cent DASM along with application of fertilizers using SSNM approach (61.2, 182.2, 200.3 and 214.2 cm, respectively) and 75 per cent DASM along with nutrient expert (56.2, 177.1, 195.2 and 209.0 cm). However, significantly lower recorded in surface irrigation with RDF (40.1, 153.9, 172.2 and 185.6 cm, respectively). The increased plant height which is mainly influenced by next generation technologies in irrigation and nutrient management practices was due to continuous availability of nutrients at right time, right place and these NGT's was able to manage the variability in growing environments and can therefore be a reliable tool for site-speciuc fertilizer application (Banerjee *et al.*, 2014).

Adequate supply of moisture close to the crop root region during the cropping period, could have contributed to longer greenness and larger leaf surface area. Similar observations were made by Singh *et al.* (2003) and Arvind Verma *et al*. (2006). Growth analysis studies are helpful in elucidating an adverse effect of irrigation levels on plant height. Higher plant height was observed under sensor based irrigation at 50 per cent DASM was mainly due to irrigating the crop at required time which results in continuous availability of required moisture near the root zone which in turn might have helped in higher nutrient uptake resulting in greater cell division and elongation. In surface irrigation, maximum moisture availability will be at the time of irrigation followed by intermittent dryness which might have affected cell division and elongation. On the other hand, severe stress imposed at surface irrigation has reduced plant height at harvest to an extent of 9.2 per cent. Similar findings were reported by Chigign Adamu (2011). Scheduling drip irrigation in maize at 3 days interval resulted significantly higher plant height, total dry matter, leaf area as compared to scheduling of irrigation at 4, 5, 6 days interval on a sandy loam soil (Hokam *et al.,* 2011).

The data on leaf area per plant as influenced by next generation technologies in irrigation and nutrient management in maize are presented in Table 2.

Significantly higher leaf area was observed at 30, 60, 90 DAS and at harvest (2032, 7690, 10681, and 7571 cm^2 $plant^{-1}$, respectively) with the sensor based drip irrigation at 50 per cent DASM, as compared to surface irrigation (1837, 6854, 9517 and 6711 cm^2 $plant^{-1}$, respectively) and it was found to be statistically on par with application of irrigation at 75 per cent DASM (1922, 7217, 10025 and 7087 cm^2 $plant^{-1}$, respectively). Application of fertilizer using software based nutrient expert tool recorded significantly higher leaf area at 30, 60, 90 DAS and at harvest (2154, 8211, 11405 and 8105 cm^2 $plant^{-1}$, respectively) as compared to application of recommended dose of fertilizers (1653, 6064, 8424 and 5906 cm^2 $plant^{-1}$, respectively) and it was found to be on par with application of fertilizers using SSNM approach (2091, 7943, 11029 and 7826 cm^2 $plant^{-1}$, respectively).

Among different irrigation and nutrient management practices, sensor based drip irrigation at 50 per cent DASM along with application of fertilizer using nutrient expert, recorded significantly higher leaf area at 30, 60, 90 DAS and at harvest (2362, 9105, 12645 and 9020 cm^2 $plant^{-1}$, respectively) followed by sensor based drip irrigation at 50 per cent DASM using SSNM approach (2219, 8491, 11795 and 8391 cm^2 $plant^{-1}$, respectively) and sensor based drip irrigation at 75 per cent DASM along with nutrient expert (2117, 8053, 11185 and 7944 cm^2 $plant^{-1}$). Significantly lower was recorded in surface irrigation with RDF (1633, 5977, 8304 and 5817 cm^2 $plant^{-1}$, respectively). Leaf area of maize was significantly higher due to application of balanced nutrients led to better utilization of nutrients that linked with nutrients supplied to the crop as per the crop demand. Uptake and utilization of nutrients is witness for better response in terms of more leaves when compared to low and unfertilized plot. Results were in line with the findings of Kolawole

TABLE 2

Leaf area (cm^2 plant^{-1}) at different growth stages in maize as influenced by next generation technologies

Treatments	30 DAS			60 DAS			90 DAS			At harvest		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Main plot												
M_1 : Surface irrigation	1810	1864	1837	6787	6921	6854	9419	9615	9517	6635	6787	6711
M_2 : 50 % DASM	2002	2062	2032	7613	7766	7690	10572	10790	10681	7483	7658	7571
M_3 : 75 % DASM	1893	1950	1922	7145	7288	7217	9922	10128	10025	7005	7169	7087
F test	*	*	*	*	*	*	*	*	*	*	*	*
SEm±	27.1	28.1	27.6	115.3	119.3	117.3	160	161.2	160.6	117.7	122.2	119.9
CD at 5 %	106.3	110.3	108.3	452.8	468.6	460.7	628	633.0	630.7	462.3	479.7	470.9
Sub plot												
N_1 : Nutrient expert	2122	2185	2154	8129	8292	8211	11288	11521	11405	8011	8198	8105
N_2 : SSNM	2060	2122	2091	7865	8022	7943	10915	11142	11029	7736	7916	7826
N_3 : Green Seeker	1797	1850	1823	6728	6862	6795	9343	9536	9440	6579	6731	6655
N_4 : RDF	1629	1677	1653	6004	6124	6064	8338	8511	8424	5839	5974	5906
F test	*	*	*	*	*	*	*	*	*	*	*	*
SEm±	21.3	22.0	21.6	91.1	93.2	92.1	127	129.0	127.7	93.1	96.1	94.6
CD at 5 %	63.2	65.4	64.3	270.7	276.9	273.8	376	383.3	379.5	276.6	285.7	281.0
Interaction												
M_1N_1	1953	2011	1982	7401	7548	7474	10277	10490	10384	7266	7434	7350
M_1N_2	1943	2001	1972	7358	7505	7432	10198	10409	10303	7208	7375	7291
M_1N_3	1736	1788	1762	6469	6596	6532	8983	9172	9078	6314	6457	6385
M_1N_4	1609	1657	1633	5918	6035	5977	8218	8389	8304	5750	5884	5817
M_2N_1	2327	2397	2362	9014	9196	9105	12517	12773	12645	8915	9124	9020
M_2N_2	2186	2251	2219	8407	8574	8491	11674	11917	11795	8295	8487	8391
M_2N_3	1840	1896	1868	6916	7055	6986	9604	9801	9702	6770	6931	6851
M_2N_4	1655	1704	1679	6116	6239	6178	8493	8667	8580	5953	6089	6021
M_3N_1	2085	2148	2117	7973	8133	8053	11071	11300	11185	7851	8036	7944
M_3N_2	2052	2114	2083	7831	7986	7908	10874	11101	10988	7706	7886	7796
M_3N_3	1813	1867	1840	6799	6936	6868	9442	9636	9539	6651	6806	6729
M_3N_4	1623	1672	1647	5979	6097	6038	8302	8475	8389	5812	5948	5880
F test	*	*	*	*	*	*	*	*	*	*	*	*
SEm±	36.9	38.1	37.5	157.8	161.4	159.6	219	223.4	221.2	161.3	166.5	163.8
CD at 5%	109.5	113.2	111.4	468.9	479.6	474.2	651.0	663.8	657.3	479.1	494.8	486.8

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TABLE 3

SPAD readings at different growth stages in maize as influenced by next generation technologies

Treatments	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Main plot															
M_1 : Surface irrigation	26.2	26.8	26.5	27.7	28.3	28.0	28.5	29.0	28.7	34.6	35.3	35.0	33.0	33.7	33.4
M_2 : 50 % DASM	30.3	30.9	30.6	32.0	32.6	32.3	32.9	33.5	33.2	40.0	40.8	40.4	38.2	38.9	38.5
M_3 : 75 % DASM	28.1	28.6	28.4	29.7	30.3	30.0	30.4	31.1	30.8	37.1	37.8	37.4	35.4	36.1	35.7
F test	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
SEm ±	0.52	0.54	0.53	0.55	0.56	0.55	0.56	0.56	0.56	0.69	0.71	0.70	0.65	0.68	0.67
CD at 5 %	2.04	2.12	2.08	2.15	2.19	2.17	2.21	2.22	2.21	2.69	2.79	2.74	2.57	2.68	2.62
Sub plot															
N_1 : Nutrient expert	32.5	33.2	32.8	34.3	35.0	34.7	35.2	35.9	35.6	42.9	43.8	43.3	40.9	41.8	41.3
N_2 : SSNM	30.9	31.5	31.2	32.6	33.3	33.0	33.5	34.2	33.8	40.8	41.6	41.2	38.9	39.7	39.3
N_3 : GreenSeeker	25.8	26.3	26.0	27.2	27.8	27.5	27.9	28.5	28.2	34.0	34.7	34.3	32.4	33.1	32.8
N_4 : RDF	23.7	24.1	23.9	25.0	25.5	25.3	25.7	26.2	25.9	31.2	31.9	31.6	29.8	30.4	30.1
F test	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
SEm ±	0.57	0.59	0.58	0.60	0.61	0.60	0.62	0.63	0.62	0.75	0.77	0.76	0.72	0.74	0.73
CD at 5 %	1.69	1.75	1.72	1.78	1.80	1.79	1.83	1.86	1.84	2.23	2.29	2.26	2.13	2.20	2.16
Interaction															
M_1N_1	29.1	29.7	29.4	30.8	31.4	31.1	31.6	32.2	31.9	38.4	39.2	38.8	36.7	37.4	37.0
M_1N_2	27.7	28.3	28.0	29.3	29.9	29.6	30.1	30.7	30.4	36.6	37.4	37.0	34.9	35.6	35.3
M_1N_3	25.2	25.7	25.4	26.6	27.1	26.9	27.3	27.9	27.6	33.3	33.9	33.6	31.7	32.4	32.0
M_1N_4	22.9	23.4	23.2	24.2	24.7	24.5	24.9	25.4	25.1	30.3	30.9	30.6	28.9	29.4	29.2
M_2N_1	36.7	37.5	37.1	38.8	39.6	39.2	39.8	40.6	40.2	48.5	49.5	49.0	46.3	47.2	46.7
M_2N_2	33.7	34.4	34.1	35.7	36.4	36.0	36.6	37.3	36.9	44.6	45.5	45.0	42.5	43.4	42.9
M_2N_3	26.4	27.0	26.7	27.9	28.5	28.2	28.7	29.3	29.0	34.9	35.6	35.3	33.3	34.0	33.6
M_2N_4	24.3	24.7	24.5	25.6	26.2	25.9	26.3	26.8	26.6	32.0	32.7	32.4	30.6	31.2	30.9
M_3N_1	31.7	32.3	32.0	33.4	34.1	33.8	34.3	35.0	34.7	41.8	42.6	42.2	39.9	40.7	40.3
M_3N_2	31.2	31.8	31.5	33.0	33.7	33.3	33.9	34.6	34.2	41.2	42.0	41.6	39.3	40.1	39.7
M_3N_3	25.6	26.1	25.9	27.1	27.6	27.3	27.8	28.3	28.1	33.8	34.5	34.2	32.3	32.9	32.6
M_3N_4	23.8	24.3	24.0	25.1	25.6	25.4	25.8	26.3	26.1	31.4	32.0	31.7	30.0	30.6	30.3
F test	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
SEm ±	0.98	1.02	1.00	1.04	1.05	1.05	1.07	1.08	1.07	1.30	1.33	1.32	1.24	1.28	1.26
CD at 5 %	2.92	3.02	2.97	3.09	3.12	3.11	3.17	3.22	3.19	3.86	3.96	3.91	3.68	3.81	3.75

and Joyce (2009); Santosh Pagad (2014) and Nagarjun (2015).

In the present investigation, sensor based drip irrigation at 50 per cent DASM has recorded higher leaf area, which clearly depicts the superiority of sensor based drip irrigation over other treatments in maize and in turn adequate amount of soil moisture and nutrient are available for crop growth throughout growth period due to the availability of required quantity of water and nutrients during the crop period matching with the crop demand. In turn, it helped the photosynthetic area to develop and active for longer period and was responsible for total growth of plant. The lesser moisture availability or moisture stress in between two successive irrigations in surface irrigation was hindered the leaf area production and development resulting in lower yield.

The data on SPAD values recorded at 30, 60 and 90 DAS of maize as influenced by next generation technologies with target yield are presented in Table 3.

At 15, 30, 45, 60, 75 DAS (30.6, 32.3, 33.2, 40.4 and 38.5, respectively) recorded significantly higher SPAD values were recorded with sensor based drip irrigation at 50 per cent DASM as compared to surface irrigation (26.5, 28.0, 28.7, 35.0 and 33.4, at 15, 30, 45, 60, 75 DAS, respectively) and showed statistically on par to sensor based drip irrigation at 75 per cent DASM (28.4, 30.0, 30.8, 37.4 and 35.7, respectively). Out of different nutrient management practices application of fertilizer using nutrient expert recorded significantly higher SPAD reading at 15, 30, 45, 60, 75 DAS (32.8, 34.7, 35.6, 43.3 and 41.3, respectively) as compared to application of recommended dose fertilizers (23.9, 25.3, 25.9, 31.6 and 30.1, respectively) and found to be on par with application of fertilizers using SSNM approach (31.2, 33.0, 33.8, 41.3 and 39.3, respectively).

Sensor based drip irrigation at 50 per cent DASM along with application of fertilizer using nutrient expert, recorded significantly higher SPAD values at 15, 30, 45, 60, 75 DAS (37.1, 39.2, 40.2, 49.0 and 46.7, respectively) followed by sensor based drip irrigation at 50 per cent DASM along with SSNM approach (34.0, 36.0, 37.0, 45.01 and 42.9, respectively) and sensor based drip irrigation at 75 per cent DASM with nutrient expert (32.0, 33.8, 34.7, 42.2 and 40.3, respectively). However, surface irrigation with RDF recorded lower SPAD values (23.2, 24.5, 25.1, 30.6 and 29.2, respectively).

The chlorophyll content regulates the photosynthetic efficiency. Precise application of fertilizer through target yield approach and crop sensors increased the SPAD chlorophyll meter readings. Balanced amount of nitrogen to achieve higher target yield had the higher chlorophyll readings. Uptake and utilization of applied nitrogenous fertilizer was witnessed for better responses in terms of SPAD chlorophyll meter readings when compared to low and unfertilized plants with kernel and stover yield. Further, the application of nutrients synchronizing with crop demand will enhanced the growth, the leaf turgidity as well as chlorophyll content. The results are in accordance with the findings of Suryavanshi *et al.* (2008); (Prakasha and Mudalagiriyappa, 2018). The higher SPAD chlorophyll meter readings with higher yield levels might be due to better schedule of top dressing with nitrogenous fertilizers. These results were also in conformity with Varvel *et al.* (1997) and Sarnaik (2010). In the present study, nutrient level significantly influenced SPAD chlorophyll meter. SPAD values showed direct correlation with plant growth. Precise application of fertilizer N through nutrient expert 10 t ha^{-1} increases the SPAD values at different phenological stages. Significantly higher value of SPAD was recorded in NE 10 t ha^{-1}. These results are line with Ashok (2013) and Kumar *et al.* (2014). The higher SPAD values were due to balance nutrient prescription in the nutrient expert, leading to more chlorophyll development in crop plant which probably resulted in higher SPAD values.

The data on maize kernel yield was significantly affected due to various next generation technologies, on pooled basis. Kernel yield differed significantly among the treatments. Sensor based drip irrigation at 50 per cent DASM recorded significantly higher kernel yield (8554 kg ha^{-1}) as compared to surface irrigation (7825 kg ha^{-1}) and found on par with sensor based

TABLE 4

Kernel yield, stover yield, and harvest index in maize as influenced by next generation technologies

Treatments	Kernel yield (kg ha^{-1})			Stover yield (kg ha^{-1})			Harvest index (%)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Main plot									
M_1 : Surface irrigation	7685	7965	7825	8298	8514	8406	0.48	0.48	0.48
M_2 : 50 % DASM	8401	8706	8554	9028	9260	9144	0.48	0.48	0.48
M_3 : 75 % DASM	7998	8286	8142	8544	8765	8654	0.48	0.49	0.48
F test	*	*	*	*	*	*	NS	NS	NS
SEm±	97.8	99.3	98.5	73.4	76.6	75.0	0.01	0.01	0.01
CD at 5 %	384.0	390.0	386.9	288.0	300.7	294.4	NS	NS	NS
Sub plot									
N_1 : Nutrient expert	8908	9232	9070	9404	9643	9523	0.49	0.49	0.49
N_2 : SSNM	8704	9021	8863	9021	9253	9137	0.48	0.49	0.49
N_3 : GreenSeeker	7627	7902	7764	8256	8472	8364	0.48	0.48	0.48
N_4 : RDF	6874	7121	6998	7813	8019	7916	0.46	0.47	0.47
F test	*	*	*	*	*	*	NS	NS	NS
SEm±	69.7	72.8	71.2	129.2	132.0	130.6	0.01	0.01	0.01
CD at 5 %	206.9	216.3	211.4	383.7	392.3	388.0	0.02	0.02	0.02
Interaction									
M_1N_1	8345	8649	8497	8856	9085	8971	0.49	0.49	0.49
M_1N_2	8295	8596	8445	8626	8851	8738	0.49	0.49	0.49
M_1N_3	7307	7576	7442	7991	8199	8095	0.48	0.48	0.48
M_1N_4	6794	7038	6916	7719	7921	7820	0.46	0.47	0.46
M_2N_1	9550	9899	9725	10225	10479	10352	0.48	0.49	0.48
M_2N_2	9124	9457	9290	9446	9687	9567	0.47	0.48	0.48
M_2N_3	7953	8238	8096	8571	8795	8683	0.48	0.48	0.48
M_2N_4	6978	7230	7104	7872	8080	7976	0.47	0.47	0.47
M_3N_1	8828	9147	8987	9130	9363	9246	0.49	0.49	0.49
M_3N_2	8695	9009	8852	8990	9220	9105	0.49	0.49	0.49
M_3N_3	7619	7893	7756	8207	8421	8314	0.48	0.48	0.48
M_3N_4	6852	7095	6973	7849	8056	7952	0.47	0.47	0.47
F test	*	*	*	NS	NS	NS	NS	NS	NS
SEm±	120.6	126.1	123.2	223.7	228.7	226.2	0.01	0.01	0.01
CD at 5 %	358.4	374.6	366.2	NS	NS	NS	NS	NS	NS

drip irrigation at 75 per cent DASM (8142 kg ha^{-1}). Significantly higher kernel yield was observed with application of fertilizer using nutrient expert (9070 kg ha^{-1}) as compared to application of recommended dose fertilizers (6998 kg ha^{-1}) and it was found to be statistically on par with application of fertilizers using SSNM approach (8863 kg ha^{-1}).

With respect to, interaction sensor based drip irrigation at 50 per cent DASM along with application of fertilizer using nutrient expert, recorded significantly higher kernel yield (9725 kg ha^{-1}) followed by sensor based drip irrigation at 50 per cent with SSNM approach (9290 kg ha^{-1}) and sensor based drip irrigation 75 per cent DASM along with application of fertilizers using nutrient expert software based tool (8987 kg ha^{-1}) However, surface irrigation with RDF recorded significantly lower kernel yield (6916 kg ha^{-1}). The increment in the kernel yield of maize was due to higher yield attributing characteristics and it is governed by the factors which have direct or indirect impact. The factors which have direct influence on the kernel yield are the yield components and its accumulation into various plant parts have an indirect influence on kernel yield through the yield components, which in turn depends on different growth components *viz*., plant height leaf area and chlorophyll content in leaf. All these growth components could have been promoted by more quantity of nutrients made available by the treatments to maize crop. Adjustments in scheduling of fertilizer N applications were the key to achieving greater yield. This was due to higher uptake of nutrients; Similar result was observed by Doberman *et al*. (2002a); Heckman *et al*., 2001 b, Trinh *et al*., 2008 and Biradar *et al.* (2013).

Growth and yield of maize are drastically affected by moisture stress. In the present study also kernel yield was influenced by different levels of irrigation scheduling. In other words, irrigation played an imperative role in deciding the potential ability of maize to produce economic yield. The higher kernel yield observed in sensor based drip irrigation at 50 per cent DASM maintained adequate availability of moisture throughout the crop growth period in turn it might have helped in good uptake of nutrients and favoured on yield contributing factors.

Sensor based drip irrigation at 50 per cent DASM recorded significantly higher stover yield (9144 kg ha^{-1}) as compared to surface irrigation (8406 kg ha^{-1}) and showed on par with application of irrigation at 75 per cent DASM (8654 kg ha^{-1}). Significantly higher stover yield was observed with application of fertilizer using nutrient expert (9523 kg ha^{-1}) as compared to application of recommended dose fertilizers (7916 kg ha^{-1}) and found to be statistically on par with application of fertilizers using SSNM approach (9137 kg ha^{-1}).

The data on overall interaction in stover yield found to be non significant between irrigation combined with nutrients. Significantly higher stover yield was attributed due to better nutrient availability during the crop growth stages. Increased kernel and stover yield with SSNM approach was ascribed to the higher rate and balanced level of nutrient application. This was evidenced through findings of Jayaprakash *et al*. (2006), Doberman *et al.* (2002b), Heckman *et al.* (2001a), Arun Kumar *et al*. (2007) and Umesh (2008). Harvest Index indicates the percentage of dry matter partitioned and accumulated in the economic portion. In the present investigation, harvest index did not showed any significant difference due to nutrient management practices and targeted yield levels. From the study it was concluded that, sensor based drip irrigation 50 per cent DASM combined with nutrient expert software based tool for the application of NPK fertilizer enhanced maize kernel yield.

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(*Received :* November 2021 *Accepted :* December 2021)