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TEMPORAL DYNAMICS OF NITROGEN ACQUISITION IN MAIZE CULTIVARS GROWN UNDER ORGANIC-N SUPPLY

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ABSTRACT

The field experiment was conducted at the Indian Institute of Soil Science, Bhopal during *kharif* 2014 to study the influence of organic N supply on nitrogen concentration, uptake and partitioning in different parts of twelve different maize cultivars at various growth stages. The twelve varieties of maize viz., Kanchan, Arawali, Sona-222, JM-8, JM-12, JM-216, Pratap-5, Pratap-6, Proagro-4412, CPBG-4202, Popcorn-1 and Sweetcorn were grown in a randomized block design (RBD) with three replications under 100 kg ha^{-1} N through cattle dung manure, vermicompost and poultry manure in equal proportion (1:1:1) on N-equivalent basis. The results revealed that, the N uptake was found lower in stalks than leaves at 45 and 75 DAS as well as at harvest. The N uptake in all the cultivars was highest in grain than in leaves and stalks. The Maize cultivar Kanchan removed maximum nitrogen from soil followed by Proagro-4412, Pratap-5 and JM-12 cultivars. The range of N uptake by cultivars was found relatively lower as it varied between 28.1 and 61.6 kg ha^{-1}. The partitioning indicated, 24 per cent, 12 per cent and 64 per cent of total N uptake was concentrated in leaves, stalk and grain, respectively. The temporal N-uptake revealed that, the maize required adequate supply of N during initial (up to 45 DAS) and final (after 75 DAS) growth stage as these stages contributed 23 per cent and 65 per cent of the total N uptake by maize cultivars. The temporal N-uptake pattern of maize followed the trend: [45-75 DAS] < [up to 45 DAS] < [75DAS-Harvest] in all the maize cultivars.

(Key words: Maize, nitrogen partitioning, nitrogen uptake, organic farming)

INTRODUCTION

Maize 'the queen of cereals' is one of the most potential cereals grown globally, and is the third after wheat and rice in total food grain production in the country (Kumar *et al.,* 2015). Maize is now widely cultivated around the world, and a greater weight of maize is produced each year than any other grain (Singh *et al.,* 2010). The maize crop is considered as a heavy feeder as it requires adequate and timely supply of nitrogen for optimum production (Skowronska and Filipek, 2010). On the other hand, the limited supply of fertilizers and related heavy expenses increasing the cost of cultivation. Similarly, the imbalanced use of chemical fertilizers threatens the sustainability of agricultural production as the long term field experiments have clearly visualized the negative impact of continuous use of chemical fertilizers on soil health (Yadav, 2003).

Researchers throughout the globe highlighted the importance of organic farming for soil health sustenance and production of healthy foods in sufficient quantities (Aher *et al.,* 2012; Aher *et al.,* 2015) through crop rotation, green manure, compost and biological pest control (Subba Rao *et al.,* 2013). However, it has not been practiced for the cultivation of high yielding varieties due to their high nutrient demand. But the recent findings emphasized that though nutrient release pattern especially of N from organic sources is slow, they still able to fulfill the nutrient demand of the plant and helps to uptake nutrient for longer time (Sharma and Mitra, 1991; Vanlauwe *et al.,* 2004; Abou el-Magd *et al.,* 2005). The nitrogen uptake, accumulation and partitioning under fertilizer N supply has widely studied (Abendroth *et al.*, 2011; Bender *et al.*, 2013; Havlin *et al.,* 2014; Ciampitti *et al.,* 2013; Tiwari *et al.,* 2018) but the scientific information with respect to the nitrogen acquisition under N supply through organic sources is lacking. The narrowing of research gap in this context has been tried by studying the nutrient acquisition pattern of twelve maize varieties under organic-N supply.

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MATERIALS AND METHODS

The present study was conducted under Network Project on Organic Farming (NPOF) at Indian Institute of Soil Science, Bhopal during *kharif* 2014. The study site located at 23° 18' N, 77° 24' E and 485 m above mean sea level having sub-humid tropical climate with a mean annual air temperature of 25°C and annual rainfall of 1208 mm. The soil of the experimental site is clayey in texture (*Typic Haplustert*), medium in organic C, slightly alkaline, and non-saline with low available N, medium P, and high K contents (Table 1).

The twelve varieties of maize viz. Kanchan, Arawali, Sona-222, JM-8, JM-12, JM-216, Pratap-5, Pratap-6, Proagro-4412, CPGB-4202, Popcorn-1 and Sweetcorn were selected for present study. The field experiment was laid in a randomized block design (RBD) with three replications under organic farming in *kharif* 2014. All the cultivars were sown in July with a spacing of 60 cm from row to row and 25 cm from plant to plant and harvested at physiological maturity in Mid-October. The cultivars were raised with similar dose of organic manures viz., cattle dung manure + vermicompost + poultry manure (1:1:1) meeting a total of 100 kg N ha^{-1} applied before sowing. The maize cultivars were grown under rainfed condition with standard package of practice of organic farming. The plant sampling was carried out at periodic intervals (at 45 DAS, 75 DAS and Harvest) and biomass accumulation in different plant parts viz., leaves, stalk and grain was computed gravimetrically. The plant parts from collected plant sample was separated and dried in an oven at 60°C till constant weight. After gravimetric determination, the samples were processed in a grinder for nitrogen analysis. The total nitrogen was estimated following the standard method of Chapman and Pratt (1982). The nitrogen uptake in different plant tissues at various growth stages was calculated by multiplying the yield with their respective nitrogen concentration. The total uptake was the summation of various tissue uptakes at a particular stage. The obtained data was subjected for statistical analysis. The mean values were grouped for comparisons and the least significant differences among them were calculated at $P < 0.05$ confidence level using ANOVA statistics as outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

N Concentration in leaf

The maximum concentration of N in leaf was recorded at 45 DAS (Table 2). It varied between 1.08 (JM-8) and 1.85 per cent (Sona-222). There was statistically different N concentration in leaves of different cultivars. Sona-222 and Popcorn-1 were statistically at par for N content in leaves. Further JM-216 and Pratap-5 had significantly lower N content in leaves compared to Popcorn-1 and Sona-222. At 75 DAS there was considerable decrease in N content of leaves. The lowest N content was again recorded for JM-8 (0.94 per cent) followed by Arawali, Sweetcorn, CPGB-4202 and Proagro-4412. All the three cultivars of maize recorded significantly different N content in leaves at 75 DAS. At harvest stage the N content further declined in all the treatments and ranged between 0.83 and 1.60 per cent. Again the highest N content was in Sona-222 followed by Popcorn-1, Pratap-5, JM-216 and Pratap-6. Different cultivars have shown significant differences in N content of leaves except between Arawali, CPGB-4202 and Sweetcorn and Pratap-5 and Popcorn-1.

N Concentration in stalk and grain

The N content in stalks at 45 DAS was relatively lower than leaves. It ranged between 0.74 per cent in sweetcorn to 1.24 per cent in Sona-222 (Table 2). The cultivars which were statistically at par with each other with respect to N content in stalks include Popcorn-1, JM-216 and Proagro-4412; Arawali, JM-216, Pratap-5 and Proagro-4412; Kanchan and Pratap-6; CPGB-4202 and sweetcorn; JM-8 and JM-12. Remaining cultivars were statistically different from one another. At 75 DAS the N content in stalks declined sharply than at 45 DAS. It was ranged between 0.28 per cent (CPGB 4208) and 0.39 per cent (Arawali). At this stage the differences among cultivars were also less prominent. CPGB-4202 recorded least N content in stalks at this stage and it was statistically lower than all other cultivars. At harvest stage the N content was further reduced in stalks and was ranged between 0.20 per cent (Sweetcorn) and 0.28 per cent (Popcorn-1 and JM-216). Out of twelve cultivars six were found statistically at par with each other with respect to N content in stalks. The N content of maize grains varied between 0.98 and 1.30 per cent (Table 2). The cultivars Popcorn-1, Sweetcorn, Kanchan, Arawali, Sona-222 and Pratap-5 were statistically at par with respect to N content in grains. Similarly, the cultivars JM-8, JM-12, JM-216 and CPGB-4202 also did not differ from one another in N content in grains.

It is known fact that maize is one of the highly exhaustive field crops and N responsive producing higher biomass per unit of external application. Nitrogen being a structural component of proteins involved in various biological functions. The N removal and accumulation in plant parts affected by degree of root proliferation and deep penetration which in turn absorb higher amount of nutrients from the rhizosphere and supply to the crop resulting in higher dry matter production and higher nitrogen content in plant parts (Skowronska and Filipek, 2010). In leaves the N varied between 0.83 and 1.80 per cent during crop growth. With time the N content decreased with increase in biomass yield. In maize stalks the content among cultivars varied between 0.20 and 1.24 per cent during 45 DAS, 75 DAS and at harvest stage that was lower than leaves. Skowronska and Filipek (2010) also reported higher concentration of N in grains (1.44-1.60 per cent) followed by leaves (0.78-0.87 per cent) and stalks (0.34-0.45 per cent) of Turini variety of maize in South-eastern part of Lubelin province. Recently, Kumar *et al.* (2015) also observed N concentration 1.26-1.39 per cent and 0.32-0.48 per cent in grain and stover of hybrid cultivars of maize.

Biomass accumulation in different parts of maize

The biomass accumulation in different parts of maize cultivars at 45 DAS, 75 DAS and harvest has been presented in Table 3. The leaves and stalks biomass and grain yield was used for calculating the nitrogen uptake in the respective plant parts.

Leaf N uptake

The N uptake by leaves at 45 DAS varied between 3.6 and 10.0 kg ha^{-1} (Table 4). The highest N uptake was recorded by Proagro-4412 followed by Pratap-6 (8.6 kg ha^{-1}) and Kanchan (6.9 kg ha^{-1}). The cultivars viz., Arawali, Sona-222, JM-8, JM-12, JM-216 and Sweetcorn, Popcorn-1 and CPGB-4202 were found statistically at par in N uptake at this stage. At 75 DAS the N removal was more than double the amount removed at 45 DAS. The N removal by leaves varied between 5.3 and 13.1 kg ha^{-1}. The highest removal was recorded for Pratap-6 and Proagro-4412 followed by Kanchan (11.2 kg ha^{-1}). Rests of cultivars were statistically at par with each other with respect to N removal except CPGB-4202 and Sweetcorn. At harvest, the N removal by leaves was varied between 6.3 and 14.1 kg ha^{-1} (Pratap-6). The N uptake by Proagro-4412 was significantly lower than Pratap-6, but at par with Pratap-5, Sona-222 and Kanchan. Significantly lower N uptake was recorded by leaves of Arawali, JM-8, CPGB-4202 and Popcorn-1 (Table 4).

Stalk and grain N uptake

Data regarding N uptake by stalks has been presented in table 4. At 45 DAS the total N uptake varied between 2.1 and 7.6 kg ha^{-1}. The highest N uptake was recorded by Proagro-4412 followed by Arawali and Kanchan (5.5 kg ha^{-1}). The cultivars viz., JM-8 and JM-12, CPGB-4202, Pratap-5 and Pratap-6 found statistically at par in content of N at 45 DAS. At 75 DAS the N removal was highest in Kanchan followed by Proagro-4412 which was statistically at par with each other. The N removal by stalks varied between 3.5 and 8.8 kg ha^{-1}. The cultivars Sona-222, CPGB-4202, Popcorn-1 and Sweetcorn and Pratap-5, Pratap-6 and JM-216 were statistically at par. At harvest, the N removal by stalk was varied between 2.8 and 6.8 kg ha^{-1} (Proagro-4412). The N uptake in grains ranged between 19.1 (Sweetcorn) and 43.5 kg ha^{-1} (Kanchan). The N uptake in grains of most of the cultivars ranged between 20-30 kg ha^{-1}. Cultivars Proagro-4412, Pratap-5, JM-8 and Arawali were statistically at par with each other with respect to N uptake in grains. Similarly, JM-12, Arawali, JM-8 and Pratap-5 were also statistically at par for N uptake in grains (Table 4).

Total N uptake

Data regarding cumulative N uptake at 45 DAS, 75 DAS and at harvest are presented in table 5. At initial stage of 45 DAS total N uptake varied between 5.7 and 17.6 kg ha^{-1} with minimum under Sweetcorn and maximum by Proagro-4412. Kanchan and Pratap-6 removed significantly lower amount of N that was next to Proagro-4412. Most of other varieties were statistically at par with each other, except CPGB-4202. At 75 DAS the magnitude of N uptake was around double than that at 45 DAS and it was varied between 9.2 and 21.1 kg ha^{-1}. The highest N uptake at this stage was again recorded by Proagro-4412 followed by Kanchan and Pratap-6. Rests of the cultivars were statistically at par with each other except CPGB-4202 and Popcorn-1 (Table 5). At harvest stage, the N uptake varied between 28.1 and 61.6 kg ha^{-1} under Kanchan and Sweetcorn, respectively. At this stage, Proagro 4212 recorded significantly lower N uptake than Kanchan. The cultivars JM-12, Pratap-5 and Pratap-6 were statistically at par with respect to N uptake. Similarly, the cultivars JM-216 and CPGB 42202 were also statistically at par with each other (Table 5).

Temporal distribution of total N uptake

The stage wise nitrogen uptake by various maize cultivars has been presented in table 6. The nitrogen uptake up to 45 DAS was ranged 18-33 per cent among different varieties. At this stage maize cultivar Proagro-4412 exhausted 33 per cent uptake while cultivar JM-8 only able to extract 18 per cent of the total uptake. On an average, up to 45 DAS maize cultivars contributed 23 per cent of total nitrogen uptake. As the time passes, 45 DAS onward the nitrogen uptake gradually reduced and from 45 DAS to 75 DAS, maize cultivars added 12 per cent of total N uptake. The data indicated the nitrogen mobilization in the plant system hence the uptake rate from soil found reduced. At 75 DAS and onwards up to the harvest stage, the plants exhausted maximum portion of the total uptake (65 per cent). During the period (75 DAS to harvest), all maize cultivars showed maximum N uptake share (61-69 per cent). Thus, the temporal uptake pattern followed the trend: 45-75 DAS< up to 45 DAS < 75DAS-Harvest in all the maize cultivars (Table 6). The maximum variation in uptake was observed during middle growth stage of maize as it depends on the genetic characteristics of the cultivar. Proagro-4412 and Popcorn-1 cultivars showed maximum N mobilization in plant system during the period.

N uptake by leaves of different maize cultivars increased with crop growth. At 45 DAS the removal by leaves and stalks was almost similar. However, at 75 DAS and at harvest more N was removed by leaves than stalks. The N distribution pattern within plant organs mainly dependent on the intensity of metabolism processes in plant (Skowronska and Filipek, 2010). Therefore, the leaves and grain were the main accumulation pool for N. Total N uptake was recorded by Kanchan followed by Proagro-4412 and Pratap-6. Many of the other cultivars were statistically at par with each other. The lowest N uptake by Sweetcorn and Popcorn-1 may be attributed to poor biomass yield recorded by these cultivars. The grains of all cultivars removed more N than in leaves and stalks due to more N concentration in them. Basavaraju (2007) also found higher nitrogen content in the seed (2.19-2.26 per cent) than stover (0.95-1.01 per cent) in hybrid maize (var. Super 900 M). Tiwari *et al.* (2018) observed 78-85 kg ha^{-1} and 48-52 kg ha^{-1} uptake of grain and stover N, respectively in two different hybrid cultivars supplied with 150 kg ha^{-1} dose of nitrogen, indicating the similar trend in allocation of N plant parts of maize. Bak *et al.* (2016) reported 60-70 per cent N accumulated in maize grain at harvest stage.

Table 1. Initial characteristics of experimental soil (0-15 cm)

pH	EC (dS m^{-1})	Organic Carbon (%)	Available nutrients (kg ha^{-1})			Particle distribution (%)		
			N	P	K	Sand	Silt	Clay
7.85	0.50	0.67	154.2	12.8	530.2	25.2	18.0	56.8

Table 2. Temporal variation in N concentration in plant parts of maize cultivars

Maize cultivar	N concentration (%)						
	45 DAS		75 DAS		Harvest		
	Leaf	stalk	Leaf	stalk	Leaf	stalk	Grain
Kanchan	1.23	0.83	0.98	0.37	0.92	0.24	1.27
Pratap-5	1.62	0.94	1.50	0.36	1.47	0.27	1.30
Arawali	1.35	0.97	1.03	0.39	0.96	0.25	1.19
Sona-222	1.85	1.24	1.68	0.34	1.60	0.27	1.23
Pratap-6	1.51	0.87	1.33	0.37	1.30	0.24	1.07
JM-216	1.58	0.98	1.43	0.35	1.32	0.28	1.09
Popcorn-1	1.80	1.04	1.58	0.34	1.49	0.28	1.22
JM-8	1.08	0.62	0.94	0.34	0.83	0.22	1.00
JM-12	1.39	0.65	1.26	0.36	1.18	0.28	1.05
Proagro-4412	1.25	1.01	1.01	0.30	0.90	0.22	0.98
Sweetcorn	1.37	0.74	1.10	0.35	1.00	0.20	1.24
CPGB-4202	1.36	0.75	1.07	0.28	0.99	0.25	1.11
SEd (±)	0.03	0.04	0.03	0.02	0.02	0.02	0.06
CD (0.05)	0.07	0.07	0.06	0.05	0.04	0.03	0.11

Table 3. Biomass accumulation in maize cultivars at various growth stages

Maize cultivar	45 DAS		75 DAS		Harvest		
	Leaves biomass	Stalk biomass	Leaves biomass	Stalk biomass	Leaves biomass	Stalk biomass	Grain yield
Kanchan	559	657	1145	2339	1269	2728	3426
Pratap-5	382	402	718	1575	863	2053	2492
Arawali	325	565	815	1817	912	2184	2509
Sona-222	239	388	521	1422	829	1922	2122
Pratap-6	568	455	980	1565	1084	2354	2494
JM-216	320	468	661	1850	827	2028	2309
Popcorn-1	308	283	490	1047	586	1324	1665
JM-8	421	552	910	1992	1052	2398	2971
JM-12	426	538	722	2006	981	2306	2777
Proagro-4412	804	756	1273	2784	1404	3101	3499
Sweetcorn	262	279	480	1119	628	1401	1538
CPGB-4202	377	345	691	1504	859	1803	2223
SEd (±)	45	24	41	79	47	48	140
CD (0.05)	92	49	85	164	98	101	290

*Values in kg ha^{-1}

Table 4. N uptake in maize cultivars at different growth stages

Maize cultivar	N uptake (kg ha^{-1})						
	45 DAS		75 DAS		Harvest		
	Leaf	stalk	Leaf	stalk	Leaf	stalk	Grain
Kanchan	6.9	5.5	11.2	8.8	11.6	6.5	43.5
Pratap-5	6.2	3.8	10.8	5.6	12.7	5.6	32.4
Arawali	4.4	5.5	8.4	7.1	8.8	5.5	29.9
Sona-222	4.4	4.8	8.7	4.9	13.2	5.1	26.1
Pratap-6	8.6	3.9	13.1	5.8	14.1	5.7	26.8
JM-216	5.1	4.6	9.5	6.5	10.9	5.7	25.1
Popcorn-1	5.5	2.9	7.7	3.5	8.7	3.8	20.4
JM-8	4.6	3.4	8.5	6.7	8.7	5.3	29.6
JM-12	5.9	3.5	9.1	7.2	11.6	6.4	29.0
Proagro-4412	10.0	7.6	12.9	8.2	12.7	6.8	34.4
Sweetcorn	3.6	2.1	5.3	3.9	6.3	2.8	19.1
CPGB-4202	5.2	2.6	7.4	4.2	8.5	4.4	24.6
SEd (±)	0.6	0.3	0.6	0.5	0.6	0.5	2.4
CD (0.05)	1.3	0.6	1.3	1.1	1.3	0.9	4.9

Table 5. Total N uptake by maize cultivars at 45 DAS, 75 DAS and at harvest

Maize cultivar	Total N Uptake (kg ha^{-1})		
	45 DAS	75 DAS	Harvest
Kanchan	12.4	19.9	61.6
Pratap-5	10.0	16.4	50.7
Arawali	9.9	15.5	44.2
Sona-222	9.2	13.6	44.5
Pratap-6	12.6	18.9	46.6
JM-216	9.6	16.0	41.8
Popcorn-1	8.5	11.3	32.9
JM-8	8.0	15.3	43.6
JM-12	9.4	16.3	47.0
Proagro-4412	17.6	21.1	53.9
Sweetcorn	5.7	9.2	28.1
CPGB-4202	7.7	11.6	37.6
SEd (±)	0.8	0.9	2.5
CD (0.05)	1.7	1.9	5.1

Table 6. Temporal distribution of total N uptake in maize cultivars

Maize cultivar	N Uptake (%)		
	0 - 45 DAS	45 - 75 DAS	75 DAS - Harvest
Kanchan	20	12	68
Pratap-5	20	13	68
Arawali	22	13	65
Sona-222	21	10	69
Pratap-6	27	14	60
JM-216	23	15	62
Popcorn-1	26	8	66
JM-8	18	17	65
JM-12	20	15	65
Proagro-4412	33	7	61
Sweetcorn	20	12	67
CPGB-4202	21	10	69
Mean	23	12	65
SD (±)	4.1	2.9	3.2

Table 7. N Partitioning in major plant parts of maize at different growth stages

Maize cultivar	N Partitioning (%)						
	45 DAS		75 DAS		Harvest		
	Leaf	stalk	Leaf	stalk	Leaf	stalk	Grain
Kanchan	56	44	56	44	19	11	71
Pratap-5	62	38	66	34	25	11	64
Arawali	44	56	54	46	20	12	68
Sona-222	48	52	64	36	30	12	59
Pratap-6	69	31	69	31	30	12	58
JM-216	52	48	59	41	26	14	60
Popcorn-1	65	35	69	31	27	11	62
JM-8	57	43	56	44	20	12	68
JM-12	63	37	56	44	25	14	62
Proagro-4412	57	43	61	39	23	13	64
Sweetcorn	63	37	57	43	22	10	68
CPGB-4202	66	34	63	37	23	12	66
Mean	59	41	61	39	24	12	64
SD (±)	7.6	7.6	5.3	5.3	3.7	1.1	4.1

N Partitioning

The nitrogen partitioning in leaves:stalk at 45 DAS and 75 DAS was 59:41 and 61:39, respectively (Table 7). The partitioning trend at 45 DAS and 75 DAS was found almost similar. The highest and lowest contribution of leaf N was found in cultivar Pratap-6 (69 per cent) and Arawali (44 per cent), respectively. Besides Arawali, Sona-222 also showed lower allocation of N as compared to stalk. However, at 75 DAS, leaf contributed higher uptake than stalk in all cultivars. At harvest stage, the average N uptake partitioning was found in the order of Grain> Leaf> Stalk (24 per cent, 12 per cent and 64 per cent, respectively). The cultivar Sona-222 and Pratap-6 showed lower allocation of grain N as compared to other varieties. The genetic characteristics of the various cultivars might be responsible for the difference in the N allocation in different plant parts (Table 7). The differences in nitrogen acquisition pattern among different maize varieties could be due to the differences in the plant uptake ability from the soil nitrogen (Ehdaie and Waines, 2001) and which is the basic genetic character of the crops and their varieties. Also the N mobility, grain composition and dilution effects responsible for variable N uptake by different parts viz., leaves, stalks and grains at various growth stages. Most genetic variation in N uptake due to morphological differences in root system, root length and diameter and plant dry matter production (Bohrani and Sarvestani, 2006). Besides varietal characters, the plant density and nitrogen stress during vegetative growth stage also alters the N-acquisition pattern (Ciampitti *et al.,* 2013).

The results of the study indicated that the N concentration in leaf and stalk was declined with crop growth due to dilution effect on account of increase in biomass yield. The N uptake was lowered in stalks than leaves at 45 DAS and 75 DAS as well as at harvest. The N uptake in all the cultivars was highest in grain than in leaves and stalks. Maize cultivar Kanchan removed maximum nitrogen from soil followed by Proagro-4412, Pratap-5 and JM-12 cultivars. The temporal N-uptake pattern of maize followed the trend: [45-75 DAS] < [up to 45 DAS] < [75DAS-Harvest] in all the maize cultivars. The average N uptake partitioning in maize cultivars was found in the order of Grain > Leaf > Stalk (24 per cent, 12 per cent and 64 per cent, respectively). The total N uptake by cultivars is relatively lower as it varied between 28.1 and 61.6 kg ha^{-1} indicating either limited supply of N from organic manure or common dose of nitrogen for all cultivar. Further investigations may be carried out with higher dose of N since, the N supply through the manure may be slow and maize is sensitive to N availability.

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