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Research Paper

Evaluation of maize (*Zea mays*) genotypes under different nitrogen levels in a Trans-Gangetic Plains region

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ABSTRACT

An experiment was conducted during rainy (*kharif*) seasons of 2021 and 2022 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi to study the effects of different genotypes and nitrogen levels on growth and yield of maize (*Zea mays* L.). Six maize genotypes ('AH 4271', 'DKC 9164', 'PJMH 1', 'PMH 13', 'PC 4' and Pusa Vivek QPM 9' Improved (PV QPM 9-I) and 7 levels of nitrogen (0, 40, 80, 120, 160, 200 and 240 kg N/ha) were evaluated using factorial randomized complete block design with two replications. Results showed that among the genotypes the 'DKC 9164' produced the highest kernel yield and resulted in maximum net returns (₹ 78.0 and 82.8 × 10^3/ha) as compared to other genotypes. The growth parameters and yield increased with the increasing level of nitrogen from 0 to 240 kg/ha. Application of nitrogen @240 kg N/ha produced the maximum plant height, total number of leaves, leaf area index and stover as well as biological yield, whereas the maximum kernel yield and net returns (₹ 91.1 & 97.2 × 10^3/ha) were obtained with 200 kg N/ha which was at par with 160 kg N/ha

Key words: Genotype, Growth parameters, Maize, Nitrogen, Yield

Maize (*Zea mays* L.) is one of the most important crops in the world, occupying third place after rice and wheat in terms of cereal crop production (FAO, 2018). In India it is grown on 9.86 million ha area, contributing 31.5 million tonnes produce (DES, 2021), and employing roughly 15 million farmers (Dhillon *et al.,* 2020). It is referred to as the 'queen of cereals' since it is the most widely produced, fastest-growing, short-duration crop with the highest potential yield (Begam *et al*., 2018). It is a traditional crop that is typically used for food, feed and fodder (Govind *et al*., 2015) and plays a major role in the human nutrition, animal industry, and biofuel production.

To achieve the maximum yield, genotypes suitable for specific agro-ecological conditions, seasons, uses, and crop period must be chosen because different varieties responded differently to their genotypic characteristics, input requirements, and growth process under the dominant environment. Maize being a high nutrient mining crop needs a higher amount of nitrogen for its economic production (Adhikary *et al*., 2020). The response of maize plants to the application of nitrogen fertilizers varies from variety to variety, location to location, and also depends on the availability of the nutrients (Onasanya *et al*., 2009). Local varieties of maize are less responsive to high rates of nitrogenous fertilizers than hybrid and improved maize varieties (Shrestha *et al*., 2018) which consume fertilizers in high rates.

Nitrogen is one of the most vital and costly inputs in the production of maize. Nitrogen application timings and its suitable rate are unquestionably linked to better nitrogen management (Khan and Akma, 2021). Only 33% of applied nitrogen is converted to grain production (Bryant-Schlobohm *et al.,* 2020); superfluous nitrogen (>60%) is lost from the plant-soil system in the form of surface run-off, volatilized ammonia or nitrogen oxide emissions, or it is leached beyond the root zone as nitrate, posing major environmental risks such as global warming, water and soil pollution, and climate change (Dhital and Raun, 2016). In agricultural crops, efficient nitrogen use is increasingly becoming more significant since it has the potential to lower fertilizer input and increase nitrogen use efficiency. The significance of nitrogen is fairly obvious, but efforts must be made to identify the ideal level of nitrogen for boosting yield while taking into account the cost and availability of nitrogen fertilizers. Therefore, a study was carried

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out to determine the optimal nitrogen application levels for various maize genotypes. For this purpose, genotypes with varying maturity, morphologies and yield potentials were chosen.

MATERIALS AND METHODS

An experiment was conducted during rainy (*kharif*) seasons of 2021 and 2022 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi (28° 4'N, 77° 12'E and at 228.6 m amsl) under irrigated condition. The test soil was sandy loam, slightly alkaline (7.7) and poor in organic carbon content (0.44%). It was also low in available N (185 kg/ha) and medium in available P (12.8 kg/ha) and K (205 kg/ha). The total rainfall received during crop growing period was 1256 and 821 mm, respectively during 2021 and 2022. The experiment was conducted in the factorial randomized block design (RBD) design and replicated twice. The experiment comprises of 6 maize genotypes, viz. 'AH 4271', 'DKC 9164', 'PJMH 1', 'PMH 13', 'PC 4' and 'Pusa Vivek QPM 9' Improved (PV QPM 9-I) and 7 levels of nitrogen, viz. 0, 40, 80, 120, 160, 200 and 240 kg N/ha. Nitrogen was applied in 3 equal splits at sowing, 30 and 45 days after sowing (DAS). A recommended amounts of P (80 kg P_2O_5/ha) and K (60 kg K_2O/ha) were applied by single super phosphate (SSP), and muriate of potash (mop), respectively as basal dose. Maize was planted on 15 July 2021 and 09 July 2022 at 5 cm depth with 60 cm rows spacing and 20 cm plant-to-plant spacing using 20 kg seeds/ha. Recommended package of practices were followed to raise the crop. All the observations were taken following the standard methodology.

RESULTS AND DISCUSSION

Growth parameters

Plant height: The result shows that plant height was significantly influenced by the genotype and nitrogen levels. During both the years, genotype 'PJHM 1' recorded the maximum plant height which was statistically at par to 'DKC 9164' (Table 1). Nitrogen dose 240 kg/ha had the maximum plant height whereas minimum height was recorded with control during both the years. An increase in chlorophyll content due to nitrogen application increased the rate of photosynthesis, therefore, the plant grew faster and taller (Adhikari *et al*., 2021).

Leaf count: The results further showed that the genotype and nitrogen levels had significant effect on total leaf number/plant. Among the genotypes the minimum leaf number/plant was recorded with genotype 'PV QPM 9-I '(10.0 and 11.0), whereas, maximum was found with genotype 'PJHM 1' (13.6 and 12.2) which was at par with 'DKC 9164' (Table 1). The plants applied with 240 N kg/ha recorded the highest number of total leaves whilst, the control plants applied with 0 N kg/ha recorded the lowest number of total leaves during both the years. This might be owing to the enhanced cell division and elongation under nitrogen fertilization which supported vegetative growth, stem elongation and leaf production etc.

Table 1. Effect of genotypes and nitrogen levels on plant height, leaf count and leaf area index of maize during 2021 and 2022

Treatment	Plant height (cm)		Total leaves/plant		Leaf area index at silking	
	2021	2022	2021	2022	2021	2022
Genotype						
'PJHM 1'	177.8	182.0	12.2	13.6	3.79	3.85
'PC 4'	156.4	160.3	11.5	12.6	3.77	3.83
'DKC 9164'	170.4	174.4	12.4	13.4	3.83	3.94
'PMH 13'	160.8	164.6	11.8	12.8	3.85	3.96
'AH 4271'	167.7	173.7	12.8	12.8	3.73	3.79
'PV QPM 9-I'	152.4	156.6	10.0	11.0	2.84	2.94
SEm±	3.7	4.0	0.3	0.2	0.08	0.04
CD (P=0.05)	10.7	11.4	0.8	0.6	0.24	0.13
Nitrogen level (N) (kg/ha)						
0	114.0	120.3	9.2	10.5	2.51	2.58
40	139.1	144.5	11.0	12.0	3.06	3.14
80	166.3	171.4	11.6	12.5	3.44	3.52
120	172.8	176.8	12.1	13.0	3.89	3.97
160	181.5	184.9	12.4	13.1	4.02	4.09
200	186.1	189.1	12.8	13.6	4.19	4.26
240	190.0	193.1	13.4	14.1	4.34	4.41
SEm±	4.0	4.3	0.3	0.2	0.09	0.05
CD (P=0.05)	11.5	12.3	0.9	0.7	0.26	0.14
Interaction (G × N)	NS	NS	NS	NS	NS	*

Leaf area index: The effect of different genotypes and nitrogen levels on leaf area index was highly significant (Table 1). Leaf area index of 'PMH 13' was significantly 1.35 times greater than 'PV QPM 9-I', which had the lowest leaf area. There was 1.72 times higher leaf area index was obtained with the application of 240 kg N/ha over the control. Similar results were also reported by Adhikari *et al*., (2021).

Yield and harvest index

Kernel yield: Maize kernel yield was significantly affected by genotype, nitrogen levels and their interaction (Fig. 1). The genotype 'DKC 9164' recorded the highest kernel yield, whilst genotype 'PV QPM 9-I' recorded the least yield during both the years. Hybrid DKC 9164 recorded the highest kernel yield because it exhibited a longer grain filling period. Kernel yield increased with nitrogen fertilizer up to a certain level and declined with excess nitrogen. 'PC 4' and 'PV QPM 9-I' positively responded up to 160 kg N/ha while rest of genotypes showed increased yield up to 200 kg N/ha. Nitrogen stress induces barrenness by delaying silking and reduces kernel/cob due to non-synchronous flowering (Bello *et al*., 2014), therefore yield reduction was observed at 0 kg N/ha. Decreased maize yield with excess nitrogen fertilizer application may be associated with reduced root growth and harvest index,

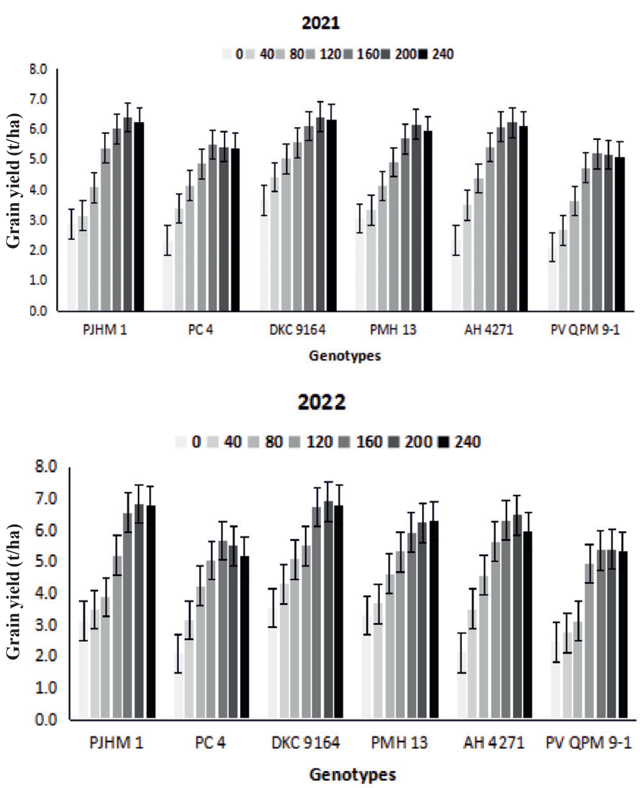

Fig. 1. Interaction effects of genotypes and nitrogen levels on kernel yield of maize during 2021 and 2022.

and higher pest infestation. Conservation agricultural practices such as crop residue retention could reduce N requirement of hybrid maize by 40 kg/ha without affecting the kernel yield (Sarangi *et al*., 2020).

Stover yield: Genotypes 'DKC 9164' produced higher stover yield than the other genotypes during both the years (Table 2). Genotypes 'DKC 9164' and 'PJHM 1' grew taller and had thicker stem with greater leaf production. The features stated led to greater stover yields in both the genotypes. Besides, 'DKC 9164' is a long duration hybrid therefore accumulated highest amount of biomass than rest other genotypes. Contrarily, 'PV QPM 9-I' had the least stover yield possibly due to its shorter maturity duration. Nitrogen level of 240 kg/ha had the highest stover yield whereas 0 kg N/ha recorded the lowest stover yield. This could be as a result of higher plant height, leaf number, stem diameter and leaf area index at 240 kg N/ha.

Biological yield: Amongst the genotypes, numerically higher values of biological yield was recorded with genotype 'DKC 9164', whilst the lowest was observed in 'PV QPM 9-I' (Table 2). Further results indicated that biological yield of maize also increased along with the level of nitrogen fertilizer. Generally, the superiority of biological yield based on nitrogen levels are as: 240>200>160>120>80>40>0 kg N/ha.

Harvest index: Different genotypes and nitrogen levels showed significant differences in harvest index (Table 2). 'AH 4271' had the greatest harvest index which indicates that the genotype partitioned greater amount of the photosynthate into grain over vegetative plant parts. 'PC 4' recorded the least value of harvest index which was due to its larger total biomass in comparison to kernel weight. Amanullah (2014) also reported lower harvest index with composite varieties over hybrid. Up to 200 kg N/ha nitrogen rate increased the harvest index and beyond that it decreased. Earlier, Amanullah (2014) also reported positive relationship between harvest index and nitrogen rates up to a certain level (150 kg N/ha).

Economics

The highest gross returns, net returns and benefit cost (B:C) ratio were recorded with 'DKC 9164' followed by 'PJHM 1', 'AH 4271', 'PMH 13' and 'PC 4' whereas the least economical profits were fetched from 'PV QPM 9-I' (Table 3). The higher gross and net returns from 'DKC 9164' is mainly attributed to higher kernel and straw yields. 'DKC 9164' had the highest cultivation costs, which were caused by its more expensive seed compared to genotypes from the public sector. Cost of cultivation increased with nitrogen levels and application of 240 kg N/ha incurred maximum production cost. Whereas, gross and net returns as well as B:C ratio were increased with nitrogen

Table 2. Effect of genotypes and nitrogen levels on stover and biological yields, and harvest index of maize during 2021 and 2022

Treatment	Yield (t/ha)				Harvest index (%)	
	Stover		Biological			
	2021	2022	2021	2022	2021	2022
Genotype						
'PJHM 1'	8.05	8.42	12.9	13.5	37.3	37.7
'PC 4'	7.61	7.54	12.0	11.9	36.8	36.3
'DKC 9164'	8.98	9.52	14.3	15.1	37.2	36.0
'PMH 13'	7.98	8.24	12.7	13.3	37.0	37.7
'AH 4271'	7.76	7.94	12.6	12.9	37.9	37.8
'PV QPM 9-I'	6.77	6.96	10.9	11.2	37.3	37.1
SEm±	0.18	0.20	0.2	0.3	0.2	0.1
CD (P=0.05)	0.52	0.57	0.7	0.8	0.6	0.3
Nitrogen level (N) (kg/ha)						
0	5.28	5.42	8.0	8.2	34.2	33.8
40	6.33	6.30	9.7	9.8	35.2	35.4
80	7.54	7.72	11.8	12.0	36.0	35.5
120	8.24	8.66	13.4	13.9	38.5	38.0
160	8.83	9.45	14.6	15.5	39.6	39.2
200	9.06	9.47	15.0	15.7	39.7	39.6
240	9.74	9.70	15.6	15.8	37.5	38.3
SEm±	0.20	0.22	0.3	0.3	0.2	0.3
CD (P=0.05)	0.56	0.62	0.8	0.9	0.6	0.9
Interaction (G × N)	NS	NS	NS	NS	*	*

Table 3. Effect of genotypes and nitrogen levels on economics of maize during 2021 and 2022

Treatment	Cost of cultivation ($\times 10^3$ /ha)		Gross returns ($\times 10^3$ /ha)		Net Returns ($\times 10^3$ /ha)		Benefit: cost	
	2021	2022	2021	2022	2021	2022	2021	2022
Genotype								
'PJHM 1'	35.7	36.7	106	112	70.6	75.6	1.95	2.04
'PC 4'	35.7	36.7	97	97	61.4	60.8	1.70	1.65
'DKC 9164'	39.1	40.1	117	123	78.0	82.8	1.98	2.06
'PMH 13'	35.7	36.7	104	111	67.9	74.2	1.88	2.01
'AH 4271'	35.7	36.7	106	108	69.7	71.6	1.93	1.94
'PV QPM 9-I'	35.7	36.7	89	92	53.3	55.6	1.47	1.50
SEm±	-	-	2	2	1.6	2.1	0.04	0.06
CD (P=0.05)	-	-	5	6	4.5	6.1	0.12	0.16
Nitrogen level (N) (kg/ha)								
0	34.0	35.0	61	63	26.4	27.0	0.75	0.76
40	34.8	35.8	76	78	40.3	41.2	1.13	1.13
80	35.2	36.2	93	95	57.4	58.0	1.59	1.58
120	35.7	36.7	112	116	75.2	78.3	2.07	2.10
160	36.2	37.2	124	133	87.4	95.1	2.37	2.52
200	36.6	37.6	129	135	91.1	97.2	2.44	2.55
240	37.1	38.1	128	133	89.8	93.9	2.37	2.43
SEm±	-	-	2	2	1.7	2.3	0.05	0.06
CD (P=0.05)	-	-	5	7	4.9	6.6	0.13	0.18

application up to 200 kg N/ha. Due to decrease in yield, excessive nitrogen fertilizer (240 kg N/ha) reduced the net return and B:C ratio.

After reviewing the aforementioned studies, it may be concluded that varietal performance may differ depending on its genetic make-up or the climatic conditions. For composite variety and short duration hybrid of maize (75–80 days), 160 kg N/ha was found most economical, while medium (90–95 days) and long duration (>95 days) hybrids of maize performed well at 200 kg N/ha.

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