



## Nitrogen and phosphorus effects on the growth, phenology, heat and nutrients accumulation and yield of winter maize (*Zea mays*) in western Indo-Gangetic Plains

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Winter maize (*Zea mays* L.) cultivation is an innovation in the western Indo-Gangetic Plains (IGP), encompassing parts of Uttar Pradesh, Uttarakhand, Delhi, Punjab and Haryana. It has long growing period about 170-180 days. Maize is a heavy feeder cereal crop, which requires large quantities of N and P for higher yields. Nitrogen and P are two key nutrients, which affect directly or indirectly the growth and yield of a crop (Dordas 2009). Nitrogen can affect the development and maintenance of leaf area as well as photosynthetic efficiency and dry matter partitioning to reproductive organs (Prystupa *et al.* 2004). Crop experiences periods during the growth cycle when yield is limited mainly by the source strength, sink capacity or by both (Borras *et al.* 2004). The performance of most field crops in realizing expected yield depends on the performance in the sink build-up over the growth period (Miralles and Slafer 2007). High P availability shortens both periods between emergence and flowering, and between flowering and physiological maturity. Phosphorus diminishes biomass accumulation in a different fashion than N (Prystupa *et al.* 2004). The studies, encompassing the effects of N and P on winter maize growth, nutrient accumulation, phenology and yield are scant. The effect is location-specific as well. Therefore, this study was undertaken to investigate the individual as well as combined effect of N and P on the growth pattern, accumulation of dry matter, nutrients and yield of winter maize in western IGP.

A field experiment on winter maize (cv. HQPM 1) was undertaken at the Indian Agricultural Research Institute, New Delhi during winter 2010-11. Soil was sandy loam with 0.69% organic carbon, 19.4 kg/ha  $\text{NH}_4^+\text{-N}$ , 21.3 kg/ha  $\text{NO}_3^-\text{-N}$ , 269.9 kg/ha extractable K and 19.6 kg/ha available P and pH 7.2. The treatments comprising four levels of N [0 ( $\text{N}_0$ ), 80 ( $\text{N}_1$ ), 160 ( $\text{N}_2$ ) and 240 ( $\text{N}_3$ ) kg/ha] in the main plot and four levels of P [0 ( $\text{P}_0$ ), 13.2 ( $\text{P}_1$ ), 26.4 ( $\text{P}_2$ ) and

39.6 ( $\text{P}_3$ ) kg/ha] in the sub-plot were laid out in a split plot design with three replications. Nitrogen was applied in three splits - at sowing, knee high and tasseling, while P was applied as basal. Potassium at 50 kg/ha, Zn and S (as zinc sulfate 25 kg/ha) were applied uniformly. For biometric measurements, maize plant samples were collected every 30 days to analyze the pattern of dry matter production and N and P accumulation. The crop growth rate (CGR) and the relative growth rate (RGR) of maize were calculated from dry weight. Leaf area index (LAI) was calculated from the leaf area taken non-destructively by taking the length and breadth of the leaves multiplied by 0.7338.

It was observed that N levels did not influence maize plant height up to 30 days after sowing (DAS) (Table 1), dry weight (Fig 1) and crop growth rate (CGR; Table 2) up to 90 DAS and relative growth rate (data not shown) up to 121 DAS. Slow growth of maize at the early stages up to 90 DAS was due to low temperatures observed during that period. The low temperature and photoperiod marred the effect of N or P application (Sinclair and Muchow 2001), which remained insignificant. Winter maize attained the highest values for plant height (Table 1) and dry weight (Fig 1) at 240 kg N/ha. Nitrogen influences biomass production through its effect on the foliage cover, intercepting radiation and its subsequent conversion efficiency into biomass (De Grazia *et al.* 2003). The total dry weight as affected by P was highest at 26.4 kg/ha beyond which any further increase reduced its values.

A significant interaction between N and P levels was observed for plant height throughout the growing period except at tasseling and for the total plant dry weight at 90 DAS and onwards, which revealed a combination of N at 240 kg/ha and P at 26.4 kg/ha most superior all through the growing period.

The CGR (Table 2) of winter maize increased during 30-60 DAS and decreased during 60-90 DAS. A sharp increase was observed in its values between 90 DAS and anthesis, which then continued to decline up to maturity. The increase in levels of N from 0 to 240 kg/ha caused an

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Table 1 Effect of N and P levels on winter maize plant height (cm) across stages

Treatment	30 DAS	60 DAS	90 DAS	121 DAS	136 DAS	168 DAS
			(Tasseling)	(Silking)	(Maturity)	
<i>Nitrogen (kg/ha)</i>						
0	7.4	12.6	21.7	77.9	114.5	127.8
80	7.7	13.7	23.3	97.3	134.1	149.6
160	8.2	14.7	25.4	101.5	138.0	154.0
240	7.6	13.1	23.5	97.7	146.6	163.6
CD (P=0.05)	NS	0.9	1.3	9.4	11.2	12.5
<i>Phosphorus (kg/ha)</i>						
0	7.6	13.1	22.8	92.8	135.3	150.9
13.2	7.8	13.3	23.1	94.3	134.7	150.4
26.4	7.4	13.7	24.5	96.8	136.1	151.9
39.6	8.1	13.9	23.6	90.4	127.1	141.8
CD (P=0.05)	0.5	NS	0.9	4.8	NS	NS
<i>N × P interaction</i>						
CD (P=0.05)	1.1	NS	1.8	NS	15.7	1.8

increase in CGR, the highest increase was observed at 240 kg/ha. The leaf area index (LAI) of winter maize increased with advancement in growth stages, having its highest value at silking at around 136 DAS (Fig 2). Increase in the doses of N from 0 to 240 kg/ha and P from 0 to 26.4 kg/ha significantly improved LAI. Phosphorus application higher than 26.4 kg/ha caused a reduction in LAI. The interaction between N and P has shown a significant difference in all stages with N 240 kg/ha in combination with P 26.4 kg/ha always showing the highest values. Penet *et al.* (2000) reported increase in leaf area in response to P application to

Table 2 Effect of N and P levels on crop growth rate (g/m<sup>2</sup>/day) in winter maize

Treatment	0-30 DAS	30-60 DAS	60-90 DAS	90-121 DAS	121-136 DAS	136-168 DAS
				(Tasseling)	(Maturity)	(Silking)
<i>Nitrogen (kg/ha)</i>						
0	0.11	3.81	3.00	13.12	6.27	4.67
80	0.11	4.00	3.89	13.56	11.66	3.97
160	0.11	4.15	3.49	13.95	14.75	4.24
240	0.12	4.20	4.19	15.05	18.02	2.93
CD (P=0.05)	NS	NS	NS	1.29	1.12	NS
<i>Phosphorus (kg/ha)</i>						
0	0.10	4.05	3.71	13.17	11.41	3.36
13.2	0.11	3.89	3.72	13.56	13.69	3.84
26.4	0.11	4.18	3.54	14.93	12.97	3.87
39.6	0.12	4.04	3.61	14.01	12.63	4.73
CD (P=0.05)	NS	NS	NS	NS	0.87	NS
<i>N × P interaction</i>						
CD (P=0.05)	NS	NS	NS	NS	1.74	2.19

maize. Fletcher *et al.* (2008) observed that P deficiency delays leaf initiation, but Assuero *et al.* (2004) showed that the decreased leaf area of P deficient maize was due to reduced number of cells produced early in leaf development.

Winter maize recorded 50% tasseling at around 121 DAS, 50% silking at 136 DAS and physiological maturity at around 168 DAS (Table 3). Interaction between N and P did not yield eventual variation in the time to silking or maturity, but was found to be significant for days to tasseling where the combination of N and P at 240 and 39.6 kg/ha, respectively resulted in the shortest time to tasseling. Nitrogen stress prolonged the period between anthesis and silking, causing an increase in the number of days to 50% tasseling and silking, but shortened the time from silking to maturity, and, hence, hastened maturity. The early maturity in N stressed plots can be explained by increased leaf senescence in those plots, reducing the growth period. This could affect ovule fertilization, thus, the highest level of

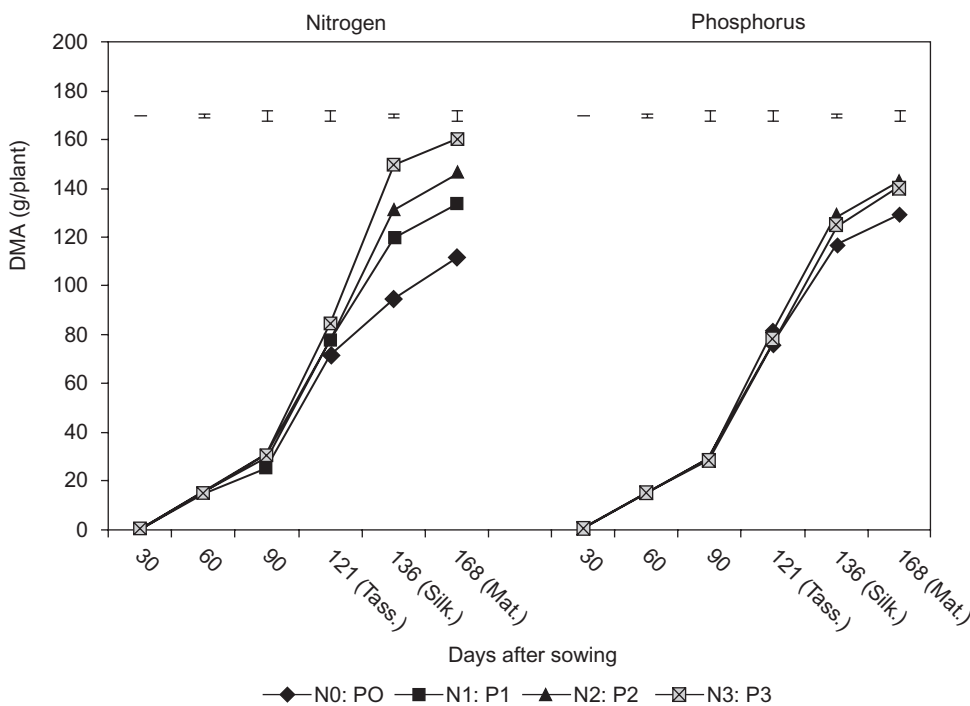


Fig 1 Dry matter accumulation (g/plant) of winter maize as influenced by N and P levels

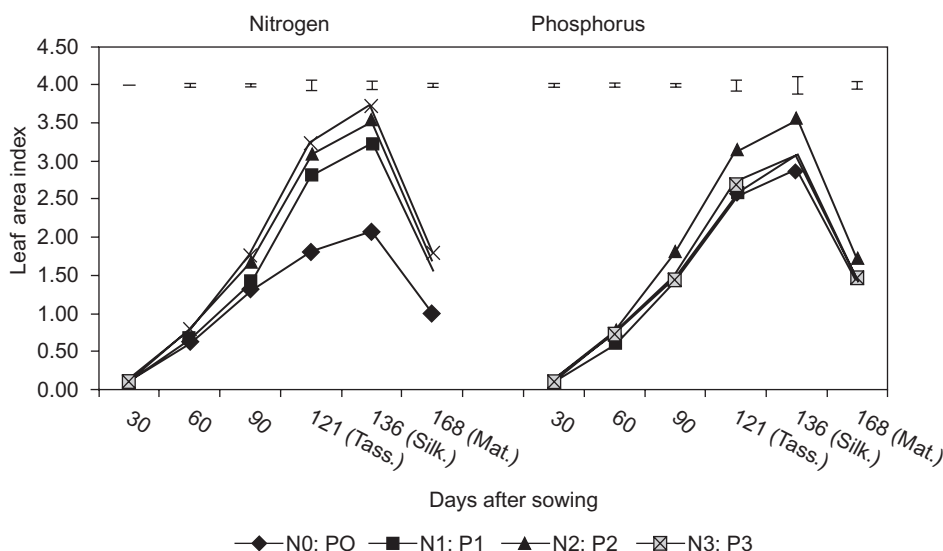


Fig 2 Effect of N and P levels on leaf area index (LAI) in winter maize

unfertilized seeds on cobs was observed in these plots. The number of days for the appearance of a particular phenophase such as tasseling, silking played a major role in the overall variation of the heat accumulation or GDD required (Table 3). Nitrogen, having a direct effect on the phenophases appearance, affected the GDD requirement of winter maize for different phenophases, while the effect of P was less manifested.

Nitrogen and P application had a significant impact on maize grain yield. Nitrogen levels at 80, 160 and 240 kg/ha resulted in 54.1, 60.0 and 62.4% increase in yield,

Table 3 Effect of N and P levels on days to anthesis and physiological maturity and growing degree days (GDD) in winter maize

Treat- ment	Tasseling		Silking		Physiological maturity		Winter maize yield (t/ha)
	Days	GDD	Days	GDD	Days	GDD	
<i>Nitrogen (kg/ha)</i>							
0	123.6	1019.8	138.3	1238.2	166.1	1695.2	2.457
80	120.7	1044.5	135.6	1198.9	168.1	1737.4	5.390
160	120.0	1042.5	133.8	1177.2	167.8	1734.9	6.144
240	119.9	1040.5	134.4	1185.1	168.4	1740.8	6.541
CD	0.9	11.1	1.2	15.0	1.2	21.9	0.696
(P=0.05)							
<i>Phosphorus (kg/ha)</i>							
0	121.6	1036.0	136.2	1208.3	166.9	1714.6	4.541
13.2	120.8	1034.7	135.2	1195.2	167.7	1730.0	5.194
26.4	121.2	1039.0	135.5	1199.7	168.0	1734.5	5.503
39.6	120.7	1037.6	135.3	1196.2	167.8	1729.2	5.294
CD	0.4	NS	0.7	8.2	0.7	13.6	0.457
(P=0.05)							
<i>N x P interaction</i>							
CD	0.9	7.5	NS	16.5	1.3	27.1	0.915
(P=0.05)							

respectively over control (Table 3). Similarly, maize yield increased by 12.6, 17.5 and 14.3% with P 13.2, 26.4 and 39.6 kg/ha, respectively. The highest yield was obtained at P 26.4 kg/ha after which further increase in P level declined the yield.

The concentration of N as influenced by N application continued to decrease as the crop grew and was significant in all physiological stages reaching its lowest at maturity. The P concentration followed the same trends across levels of N. On the other hand, the effect of P on N concentration in above ground parts was not significant in the pre-anthesis period and its effect

on P concentration was found to increase with the increase in N and P levels. Fertilizer N application up to 240 kg/ha significantly increased the concentrations of N, but P concentration increased up to 26.4 kg/ha and beyond this application level, the concentration of each of these nutrients either declined or remained unchanged.

The dilution effect (Kogbe and Adediran 2003) arising from substantial increase in biomass weight at the successive growth stages caused a reduction in the concentration of these nutrients. However, application of N and P could counteract this effect to a small extent and continued to maintain the concentration of N or P at higher levels in the plots fertilized with higher levels of these nutrients compared to that in control at the successive growth stages. Grain N concentration was increased by 6.6, 14.5 and 15.9% over control due to applications of 80, 160 and 240 kg/ha, respectively. Grain P concentration was increased by 2.5, 4.0 and 3.2% over control due to applications of 13.2, 26.4 and 39.6 kg/ha, respectively, but the increase was recorded up to 26.4 kg/ha. Similarly, increased N application caused an increase in N concentration in maize stover over control. Stover P did not increase until the highest N level (i.e. 240 kg/ha) was applied. Therefore, a significant (P<0.05) N x P interaction was observed at N 240 kg/ha and P 26.4 kg/ha, which resulted in the highest uptake of N and P by maize plants. A certain degree of synergy between N and P has been reported for many field crops (Hussaini *et al.* 2008). The addition of N influences the uptake by plant of soil and fertilizer P sources (Nelson 1956). This phenomenon can be explained by the fact that the supply of N enhances the production of small roots and root hairs, which, in turn, facilitated the high absorbing capacity per unit of dry matter.

SUMMARY

The results show that plant height, dry weight, crop growth rate (CGR) and leaf area index (LAI) of winter maize were increased with the increase in N levels, the

highest values observed at the highest dose of 240 kg/ha. Nitrogen stress delayed tasseling and silking, but hastened maturity of maize. Nitrogen application at each dose tested caused a significant increase in grain yield over control, the highest increase was at 240 kg/ha. The effect of P on grain yield was also significant, and the highest yield was obtained at 26.4 kg/ha after which further increase in P level declined the yield. Thus, N and P individually and interactively influenced growth variables, appearance of phenological stages, heat and nutrient accumulation and yield in winter maize. The interaction between N and P for LAI, nutrient content and dry matter and heat accumulation was observed across physiological stages with higher values of most of these parameters observed at N 240 kg/ha and P 26.4 kg/ha. It is, therefore, concluded that, a combination of N 240 or 160 (being comparable with 240 kg/ha) kg/ha and P 26.4 kg/ha may be recommended for a significant improvement in winter maize growth, yield and nutrient and heat accumulation over a longer growing period under the western IGP conditions.

#### REFERENCES

- Assuero S G, Mollier A and Pellerin S. 2004. The decrease in growth of phosphorus-deficient maize leaves is related to a lower cell production. *Plant Cell and Environment* **27**(7): 887–95.
- Borras L, Slafer G A and Otegui M E. 2004. Seed dry weight response to source-sink manipulations in wheat, maize and soybean: a qualitative reappraisal. *Field Crops Research* **86**: 131–46.
- De Grazia J, Tittonell P A, Germinara D and Chiesa A. 2003. Phosphorus and nitrogen fertilization in sweet corn (*Zea mays* L.) var. sacchrata baily. *Spanish Journal of Agricultural Research* **1**(2): 103–7.
- Dordas C. 2009. Dry matter, nitrogen and phosphorus accumulation, partitioning and remobilization as affected by N and P fertilization and source-sink relations. *European Journal of Agronomy* **30**: 129–39.
- Fletcher A L, Moot D J and Stone P J. 2008. Radiation use efficiency and leaf photosynthesis of sweet corn in response to phosphorus in cool temperature environment. *European Journal of Agronomy* **29**(1): 88–93.
- Hussaini M A, Ogunlela V B, Ramalan A A and Falaki A M. 2008. Mineral composition of dry season maize (*Zea mays* L.) in response to varying levels of nitrogen, phosphorus and irrigation at Kadawa, Nigeria. *World Journal of Agricultural Sciences* **4** (6): 775–80.
- Kogbe J O S and Adediran J A. 2003. Influence of nitrogen, phosphorus and potassium application on the yield of maize in the savanna zone of Nigeria. *African Journal of Biotechnology* **2**(10): 345–49.
- Miralles D J and Slafer G A. 2007. Sink limitation to yield in wheat: how could it be reduced? *Journal of Agricultural Sciences* **145**:139–49.
- Nelson L B. 1956. The mineral nutrition of corn as related to its growth and culture. *Advances in Agronomy* **8**: 321–75.
- Plenet D, Etchebest S, Mollier A and Pellerin S. 2000. Growth analysis of maize field crops grown under phosphorus deficiency. I. Leaf growth. *Plant and Soil* **223**: 117–30.
- Pyrstupa P, Savin R and Slafer G A. 2004. Grain number and its relationship with dry matter, N and P in the spikes at the heading response to N x P fertilization in barley. *Field Crops Research* **90**: 245–54.
- Sinclair T R and Muchow R C. 2001. System analysis of plant traits to increase grain yield on limited water supplies. *Agronomy Journal* **93**:263–70.