

Effect of Spatial and Temporal Variability in Cropping Seasons and Tillage Practices on Maize Yield Responses in Eastern India

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On-farm trials with spring and winter maize in eastern India showed that maize yields under zero-till (ZT) were higher than those under conventional till (CT) for both seasons, but the opposite was true for variability observed in N, P, and K responses of maize. Omission of N, P, and K from the ample NPK treatment reduced maize yields by varying levels across different sites.

Maize is rapidly emerging as a favourable option for farmers in South Asia as a non-traditional component crop of rice and wheat-based systems. Drivers of this change are higher productivity and profitability, lesser water requirement, and better resilience of maize to biotic and abiotic stresses than rice or wheat. However, high-yielding maize also extracts higher amounts of mineral nutrients from the soil than is extracted by rice or wheat. Therefore, balanced nutrient management in maize should aim to (a) supply fertiliser nutrients according to the demand of the crop and (b) apply nutrients in ways that minimise their loss and maximise their efficiency of use. Also, since maize is grown in eastern India under different cropping seasons, cropping systems, and tillage practices, there is lack of information on how such contrasting practices influence the nutrient supplying capacity of soils. This information is important to optimise nutrient management practices for the maize crop.

Nutrient omission trials (18) were set-up in farmers' fields by IPNI and CIMMYT (International Maize and Wheat Improvement Centre) during spring 2010 and winter 2010-11 (9 trials in each season) under the Cereal Systems Initiative for South Asia (CSISA) project in eastern India. The states of Bihar and West Bengal in eastern India offer variable soil and growing environments, where high-yielding maize is grown in rice-mustard-spring maize and rice-winter maize sequences. On-farm trials were conducted in the districts of Vaishali, Samastipur, Purnea, Kathihar, Begusarai, Patna, and Jamui in Bihar and Uttar Dinajpur and Nadia in West Bengal. These districts fall under the agro-climatic zones of northwest, northeast, and south Bihar alluvial plains and the old and new alluvial zones of West Bengal. The annual precipitation ranges between 1,100 and 1,400 mm in Bihar and between 1,300 and 1,500 mm in West Bengal, while soil textures varied from sandy loam to silty clay loam. The maize crop was planted under CT and ZT practices. Conventional tillage practice involved four preparatory tillage operations with a tractor, while ZT practice involved glyphosate spraying and planting maize two days after the spray without any ploughing. All trials included four treatments including: ample NPK, omission of N with full P and K, omission of P with full N and K, and omission of K with full N and P. Ample NPK rates were 150 to 180 kg N, 70 to 115 kg P₂O₅, and 120 to 160 kg K₂O per ha for maize yield targets between 6 to 8 t/ha. Nutrients were applied in all treatments in excess of the actual requirement of the maize crop to ensure no limitation of nutrients except the omitted

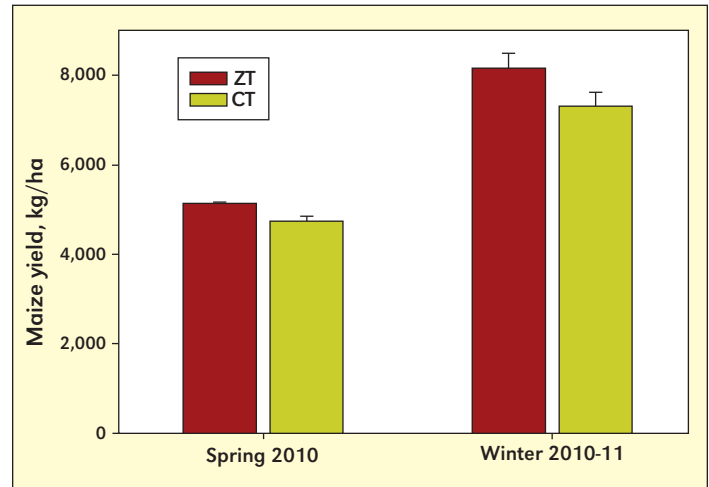


Figure 1. Effect of season and tillage practice (ZT = zero-till; CT = conventional till) on average maize yields in the ample NPK plot in eastern India. The bars represent the standard error.

one. Deficient secondary and micronutrients, determined using soil tests, were applied at the state recommended application rates. The plant density was kept at 83,333 plants/ha (60 x 20 cm spacing). At maturity, grain yields and total biomass (grain + straw) were determined and adjusted to 13% moisture content. The N, P, and K responses in each farmer's field were estimated using the following equation:

$$\text{N, P, or K response (kg/ha)} = \text{Grain yield in ample NPK plot} - \text{Grain yield in N, P, or K omission plot}$$

Results

The average spring maize yield in the ample NPK plot was 4,936 kg/ha with a range of 4,020 to 5,300 kg/ha across all sites and tillage practices (**Figure 1**). In contrast, the range of winter maize yields in the ample NPK plots across sites and tillage practices was 5,630 to 9,420 kg/ha, with a mean yield of 7,749 kg/ha. Favourable climate with a longer grain-filling period (Timsina et al., 2010) and better utilisation of water and fertiliser (Triplett and Van Doren, 1969; Moschler et al., 1972; Moschler and Martens, 1975; Wells, 1984) during the winter season usually results in higher maize yields in the region than spring or rainy seasons. Trials conducted under the All-India Coordinated Maize Improvement Project also revealed that the yield potential of winter maize was about two times that of the summer (monsoon) maize (Dayanand and Jain, 1994).

Omission of nutrients from the ample NPK treatment caused variable yield loss in both spring and winter maize. Data from the omission plot studies in winter maize under ZT showed that omission of N, P, and K from the ample NPK

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; CV = coefficient of variation; IPNI = International Plant Nutrition Institute.

treatment caused an average yield loss of 38, 15, and 12%, respectively (**Figure 2**). Similarly, maize yields and responses to applied nutrients varied considerably across farmer fields, mainly because of small and marginal landholdings that result in high variability in soil characteristics over small distances (Sen et al., 2008). This result was more pronounced in the winter season than in the spring season (**Table 1**). The high CV of N, P, and K responses highlight the high variability in soil nutrient supplying capacity across sites.

Spring maize yield responses were higher in ZT than in CT plots, but no such differences were apparent in winter maize (**Table 1**). This suggests that nutrient omission might cause higher yield loss in ZT spring maize, although higher maize yield levels were attained with ZT than with CT (**Figure 1**). In general, tillage causes short-term and immediate release of indigenous nutrients from inorganic and organic fractions of the soil. Comparatively higher release of indigenous nutrients in tilled N, P, and K omission plots may have attributed to lesser yield loss in the CT plot than in the ZT plot.

Higher CVs for nutrient responses in CT plots as compared to ZT plots (**Table 1**) might be due to variation in farmer fields due to the number of tillage operations, depth of tillage, and the extent of residues incorporated during tillage. These factors also compound the inherent variability, due to historical management differences mentioned earlier, in CT fields. For ZT plots, the spatial differences between farm fields are influenced only by historical management differences, thus showing lesser variability than CT fields. However, the very high variability in nutrient responses across fields and establishment practices suggests that such spatial and temporal variability needs to be accounted for while formulating nutrient management strategies in maize. In other words, site-specific nutrient management, based on realistic estimates of indigenous nutrient supply and nutrient requirements for a targeted yield for an individual farmer's field will be required to improve yield and nutrient use efficiencies for higher maize yield and farm profit.

Yield reduction in spring maize N omission plots was

Table 1. Descriptive statistics of maize yield response (kg/ha) under zero-till (ZT) and conventional till (CT) in spring 2010 and winter 2010-11.

| Treatment | Minimum | Maximum | Mean | Standard deviation | Standard error, ± | CV, % |
|--------------------------|---------|---------|-------|--------------------|-------------------|-------|
| ----- Spring Maize ----- | | | | | | |
| N response ZT | 1,450 | 2,120 | 1,839 | 224 | 75 | 12 |
| P response ZT | 400 | 840 | 631 | 137 | 46 | 22 |
| K response ZT | 340 | 860 | 610 | 193 | 64 | 32 |
| N response CT | 400 | 1,450 | 959 | 344 | 115 | 36 |
| P response CT | 90 | 1,010 | 462 | 251 | 84 | 54 |
| K response CT | 140 | 940 | 492 | 242 | 81 | 49 |
| ----- Winter Maize ----- | | | | | | |
| N response ZT | 1,900 | 5,160 | 3,074 | 1,174 | 391 | 38 |
| P response ZT | 940 | 1,520 | 1,213 | 221 | 74 | 18 |
| K response ZT | 570 | 1,320 | 941 | 263 | 88 | 28 |
| N response CT | 1,550 | 4,560 | 2,744 | 1,057 | 352 | 39 |
| P response CT | 630 | 1,760 | 1,106 | 345 | 115 | 31 |
| K response CT | 340 | 1,170 | 752 | 222 | 74 | 30 |

found to be higher in ZT plots as compared to CT spring maize (**Figure 3**). Lower yield in N omission plots under ZT probably resulted from either greater immobilisation of available N, losses of N through leaching and denitrification, lower mineralisation of soil organic N, or some combination of these factors (Moschler and Martens, 1975) that reduced the availability of N to maize, particularly in the initial growing phase of the crop. The same trend was not seen in winter maize, where N omission plot yield was higher in ZT than CT plots (**Figure 2**). This is probably related to the difference in duration of spring and winter maize as well as early growth stage temperature. Spring maize was planted in February and had shorter duration (approx. 125 days) than winter maize planted in November (approx. 165 days). Omission of N is expected to cause lesser availability of N to ZT maize in both seasons as compared to CT maize due to the reasons mentioned above. However, due to longer duration of winter maize, any restriction in N availability in the early stages of crop growth in ZT

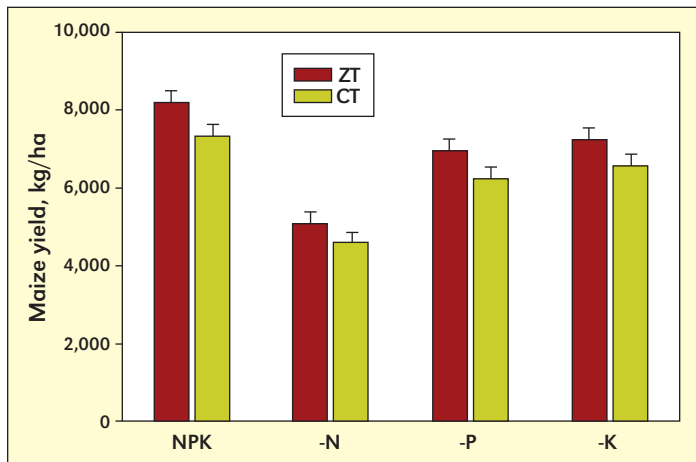


Figure 2. Average yields of winter maize in omission plot trials under zero-till (ZT) and conventional till (CT) systems. The bars represent the standard error.

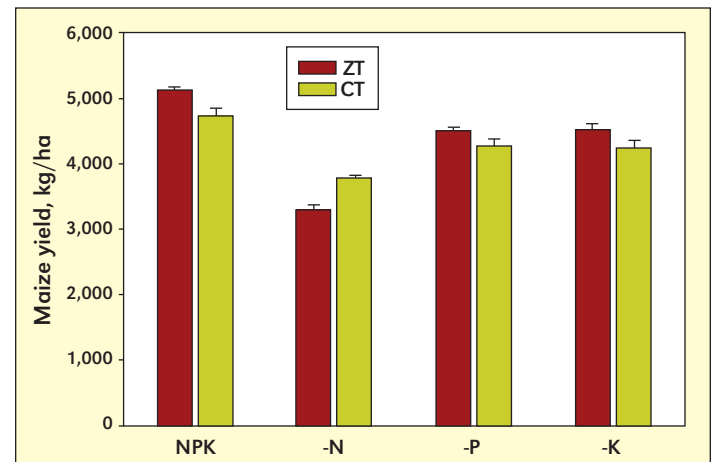


Figure 3. Average yields of spring maize in omission plot trials under zero-till (ZT) and conventional till (CT) systems. The bars represent the standard error.



Effect of contrasting tillage at early growth stage of maize.

plots is expected to cause more yield penalty in the spring crop because of shorter recovery time compared to winter maize. Due to longer duration of winter maize, the mineralisation of the immobilised N might have helped the crop as the physiological stages of N requirement (days after planting for V3 to Vt) occur later than the spring crop. Besides, the average early growth time temperature was higher for spring maize than winter maize. The major phase of N uptake in maize starts at the V3 stage of the crop. Comparatively higher ambient temperature during V3 stage of the crop in spring maize might have caused higher microbial immobilisation of indigenous N and therefore, decreased N availability to the spring crop as compared to the winter crop—leading to more yield penalty.

Maize yields in P or K omission plots were higher in ZT systems as compared to CT plots. In general, tillage was expected to cause greater mineralization, and release of P and K from soil minerals as well as organic phases, leading to higher plant availability of these nutrients in the CT plots.

However, release of P and K due to tillage may not be very significant under the prevalent aerobic conditions during maize establishment to override more efficient utilisation of these nutrients under the ZT condition (Timsina et al., 2010). In K omission plots, the contribution of K from crop residues in the ZT system probably helped to increase yield as compared to CT plots. The increased yield in P-omitted ZT plots might be related to higher mineralisation and more efficient utilisation of the indigenous P in presence of higher N and K, but more studies are needed to confirm this effect.

Summary

Results from the farmer field trials in different maize-growing environments of eastern India showed high variability in nutrient supplying capacity of soils. Both spring and winter maize showed higher yield in ZT than the conventionally grown crop. Omission of nutrients in contrasting tillage systems in spring maize suggest greater availability of P and K, but lower availability of N in ZT plots as compared to CT. Lower availability of N in ZT was not apparent in winter maize, which is probably related to growth duration and ambient temperature during the early growth stage of the crop. **ICSA**

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Crop Nutrient Deficiency Photo Contest Entries Due by December 11



December 11, 2012, is the deadline for entries in the annual IPNI contest for photos showing nutrient deficiencies in crops. An individual can submit an entry for each of the four nutrient deficiencies categories: nitrogen (N), phosphorus (P), potassium (K), and other (i.e. secondary nutrients and micronutrients).

Preference is given to original photos with as much supporting/verification data as possible. Cash prizes are offered to First Place (USD 150) and Second Place (USD 75) in each of the four categories, plus a Grand Prize of USD 200 will be awarded to the photo selected as best over all categories. Entries can only be submitted electronically to the contest website: www.ipni.net/photocontest. **ICSA**

