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A Review on Impact of Tillage and Nutrient Management on Maize Production in Indian Scenario

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A B S T R A C T

Intensive tillage increases soil compaction, reduces soil aggregates stability, disrupts soil productivity, decreases retention and transportation of water and solutes and exacerbates losses due to run-off erosion. In contrast conservation agriculture like zero-till and minimum tillage (reduced tillable) increased porosity, organic carbon, water holding capacity and decreases bulk density. The FIRBS and ridge bed planting system improves soil environment for better plant and growth development with minimum requirement of irrigation water. Sub-soiling again a newly introduced intervention to break down the hard pan for improving field drainage and provides better soil tilth. The farmers often apply very high dose of nitrogen in form of urea and very little phosphorous and potassium and almost nil secondary and micronutrients leading to imbalance, toxicity as well as inadequate use of nutrients with reduce nutrient use efficiency and profitability. The intervention on plant nutrition's like site-specific nutrient management and recommended dose of fertilizer based on proper field experimentations and crop response, covering special variability in indigenous nutrient supplying capacity of are urgently required.

Introduction

Maize (*Zea mays* L.) is an important cereal crop for food, feed and fodder. It is not only an important food crop for human but also a basic element of animal feed, fodder and raw material for manufacturing of many industrial products. The industrial products include mainly corn starch, malto-dextrins, corn oil, corn syrup and products of fermentation and distilleries. It is also being recently used in the production of biofuel. Therefore, owing to its various uses, maize is known as a 'Queen of Cereals'. In term of area, maize is the third most important staple food crop in the world after wheat and rice but in term of productivity, it ranks first followed by rice, wheat and other millets. In India, maize is cultivated on 8.69 million hectare area with production and productivity of 21.81 million tonnes and 2509 kg/ha, respectively (Agriculture Research Data Book, ICAR, 2017).

Food security is major concerned of India. Maize may survive better and produce more than other crops under deficient soil moisture conditions. At present, it is difficult to increase acreage as well as irrigation because of stiff competition among different sectors; therefore to enhance the crop productivity is the only option to increase food and nutritional security of the country. Therefore different interventions like production of hybrids and genetically modified crops, development of climate resilient crops and varieties, adoption of different tillage systems, improving site specific plant nutrition, integrated pest and diseases management, post-harvest technologies, protective agriculture, application of organized remote-sensing and GIS, nanotechnology, micro-biology, biotechnology etc. are to be looked into the increase the crop productivity.

Tillage has been an integrated component of all crops mainly because it provides good soil tilth, improves water holding capacity, increase aeration and also moderates soil hydraulic conditions (Karami *et al.,* 2012). The increasing demand of agricultural production including food, feed and fodder has changed our traditional agriculture to intensive agriculture that includes intensive tillage, heavy application of chemicals, water, labor, reduced the soil fertility and productivity. The research findings also confirmed that intensive tillage increases soil compaction, reduces soil aggregates stability, disrupts soil productivity, decreases retention and transportation of water and solutes and exacerbates losses due to run-off erosion (Goddard *et al.,* 2008). In contrast many beneficial effects of no-till/zero-till and minimum tillage have also been reported like increased porosity, organic carbon, water holding capacity and decreases bulk density. Similarly, the FIRBS and ridge bed planting system have also been reported very beneficial for improving soil environment for better plant and growth development with minimum requirement of irrigation water. Sub-soiling is again a newly introduced intervention to break down the hard pan for improving field drainage and provides better soil tilth. The paradigm shift in tillage options like minimum tillage, zero tillage, FIRBS, raised bed planting has been observed world over. Due to the availability of herbicides, insecticides and fungicides and also more mechanization, the farmers prefer new tillage options compared to conventional tillage that is required mainly for seedbed preparation and weed control (Mohanty *et al.,* 2006). The research findings have confirmed that minimum tillage increases aggregate stability Rusu (2005), zero tillage also promotes high aggregate stability, decreases soil temperature and maintains high carbon and nitrogen (Irizar *et al.,* 2013). Zero tillage also reduces weed population in wheat (Sen *et al.,* 2002). The cost of cultivation, irrigation and nutrient requirement in *rice-wheat* system are reduced under FIRBS and raised bed planting systems (Naresh *et al.,* 2009) and increased soil quality (Goverts *et al.,* 1999). The sub soiling is an urgent need to break the hard pan and also improve the soil porosity and percolation. Therefore, some of the research findings have already indicated that the sub soiling may be beneficial to improve the productivity and profitability of the system compared to adopting conventional tillage system.

It is a general practice in our country to provide blanket fertilizer recommendation for production of different crops. Different field surveys have also revealed that the farmers of Indo-Gangetic plains of India often apply very high dose of nitrogen in form of urea and very little phosphorous and potassium and almost nil secondary and micronutrients (Sing *et al.,* 2014) leading to imbalance, toxicity as well as inadequate use of nutrients with reduce nutrient use efficiency and profitability. In addition, it increases environment risk associated with loss of unutilized nutrient through emission or leaching (Pampolino *et al.,* 2012). Therefore, the intervention on plant nutritions like site-specific nutrient management and recommended dose of fertilizer based on proper field experimentations and crop response, covering special variability in indigenous nutrient supplying capacity of soil (Majumdar *et al.*, 2013) are urgently required.

Growth attributes of maize crops under different tillage system

Memon *et al.,* (2013) reported that deep tillage produced highest seedling emergence percentage while Khan *et al.,* (2008) reported that minimum tillage and conventional tillage had higher seedling emergence percentage. Memon *et al.,* (2013) observed that deep tillage produced tallest plant while Khan *et al.,* (2008) found taller plants under minimum tillage and conventional tillage and also reported that maximum number of leaves observed under conventional tillage as compared to deep tillage and zero tillage. Memon *et al.,* (2013) reported that deep tillage produced highest dry matter than the conventional tillage whereas Singh *et al.,* (2012) revealed that dry matter and leaf area index were minimum in sub soiling, while Khan *et al.,* (2008) observed that minimum tillage and conventional tillage had higher biomass and leaf area index. Hakim *et al.,* (2011) reported that both maize and cotton crops produced higher leaf area index under permanent bed planting than conventional bed planting. Akbarnia *et al.,* (2010) reported that reduced tillage achieved highest dry mass compared to conventional and no-till.

Yield and yield attributes of maize crops under different tillage system

Memon *et al.,* (2013) reported that deep tillage produced highest grain yield than conventional tillage. Singh *et al.,* (2012) reported that cob length was reduced by 13-16 per cent due to subsoil compaction in conventional tillage. Khan *et al.,* (2008) reported that minimum tillage and conventional tillage had higher grains per cob, 1000-grain weight, biological yield as compared to deep tillage whereas, ridge planting produced maximum no. of cobs per plant, no. of grain and biological yield (Bakht *et al.,* 2006). Singh *et al.,* (2012) reported that grain yield was reduced by 10-17 per cent due to subsoil compaction while, Shah *et al.,* (2014) reported that deep tillage observed higher grain yield (7.24 ton/ha) than conventional tillage and minimum tillage. Khan *et al.,* (2008) reported that minimum tillage and conventional tillage had higher grain yield compared to deep tillage. Hakim *et al.,* (2011) also noticed that maize and cotton crops produced 8 and 24% higher yield under permanent bed planting (PB) than conventional bed planting (CB), respectively and it was also supported by Bakht *et al.,* (2006).

Nutrient uptake of maize crops under different tillage system

Tolessa *et al.,* (2000) reported that N uptake was consistently superior with MTRR (minimum tillage with residue retention) compared to MTRV (minimum tillage with residue removal) and CT (Conventional tillage).

Physico-biological properties of maize crops under different tillage system

Mathew *et al.,* (2013) reported that the long-term no-tillage corn resulted in higher soil carbon and in higher phosphatase activities at the 0–5cm depth than the conventional tillage. Senjobi *et al.,* (2013) reported that traditional tillage system observed lower bulk density followed by conventional and no-tillage while, Ji1 *et al.,* (2013) observed that deep tillage had lower soil bulk density but higher soil water content than conventional tillage and they also reported that deep tillage had lower penetration resistance but higher soil water content than conventional tillage. Hakim *et al.,* (2011) reported that soil organic matter (SOM) was significantly higher in permanent bed system due to higher SOM in the 0–0.05 m layer, particularly in the furrows. Moraru *et al.,* (2010) revealed that soil moisture was higher in no tillage and minimum tillage. Garcia *et al.,* (2006) reported that no-tillage decreased cation exchange capacity (CEC) and soil pH as compared with MB, CH, and CT in the 0- to 50-mm soil layer.

Growth attributes of maize crops under different nutrients management

Singh *et al.,* (2012) reported that each successive increase in nitrogen level from 0 to 120 kg/ha significantly improved plant height but remained at par with 150 kg N/ha. Meena *et al.,* (2012) reported that treatment receiving $N_{90}P_{20}K_{25}$+ Bio-Compost equivalent to 30 kg N/ha being at par to $N_{120}P_{26}K_{33}$ recorded maximum plant height (151.8 cm). Singh *et al.,* (2010) concluded that application of 125% recommended dose of fertilizers (RDF) gave significantly higher plant height of baby corn. Nadeem *et al.,* (2009) reported that 150 kg N/ha produced significantly more number of leaves per plant than the other nitrogen levels (0, 50 and 100 kg N/ha). Meena *et al.,* (2012) reported that treatment receiving $N_{90}P_{20}K_{25}$+ Bio-Compost equivalent to 30 kg N/ha being at par to $N_{120}P_{26}K_{33}$ recorded maximum LAI while Amanullah *et al.,* (2009) reported that higher leaf area of maize with application of 50% higher N rate (180 kg/ha) than the recommended rate (120 kg/ha) in four to five splits. Kumar *et al.,* (2014) reported that maize genotypes 'CMH 08-292' recorded significantly highest dry-matter accumulation at various stages as compared to 'PMH 1' due to SSNM over RDF. Singh *et al.,* (2012) concluded that each successive increase in nitrogen level from 0 to 120 kg/ha significantly improved dry weight/plant, however application of 150 kg N/ha was at par with 120 kg N/ha. Meena *et al.,* (2012) reported that treatment receiving $N_{90}P_{20}K_{25}$+ Bio-Compost equivalent to 30 kg N/ha being at par to $N_{120}P_{26}K_{33}$ recorded maximum dry matter accumulation (67.7g/plant). Abbas *et al.,* (2005) noticed increasing rate of nitrogen application up to 300 kg N/ha increased crop growth rate in maize. Haq and Hamid (1998) also reported increased crop growth rate (CGR) with increase in nitrogen rate up to 150 kg N/ha in maize.

Yield and yield attributes under nutrients management

Yadav *et al.,* (2016) evaluated the effect of integrated nutrient management on productivity of maize with inter cropped mungbean. The result of experiment showed yield attributes and maize equivalent yield were higher at 5 t/ ha vermicompost +75% recommended dose of N.P.K. It gave higher maize equivalent yield over other treatments. In case of cropping systems, maize + mungbean recorded significantly higher grain yield over sole maize. Nsanzabaganwa *et al.,* (2014) evaluated the impact of N and P independently and interactively on winter maize. Maize yield was highest at 240 kg N/ ha. Phosphorus application increased yield up to 26.4 kg/ ha and combination of 240 kg N/ ha and 26.4 kg P/ ha, providing highest gross returns, net returns and net benefit: cost. Application of PSB biofertilizer @ 2 kg ha-1 + humic acid @ 10 kg /ha increased the biological yield, grain yield, stover yield and harvest index by 28, 50, 18 and 22% respectively as compared to control (Baloach *et al.,* 2014). Nagavani and Subbian (2014) reported that grain and stover yield of hybrid maize were recorded higher with the application of 50 per cent RDF through poultry manure + 50 per cent RDF through inorganic fertilizers followed by 50 per cent

RDF through vermicompost + 50 per cent RDF through inorganic fertilizers. Islam and Munda (2012) reported that application of FYM 2.5 t/ ha + *Alnus* 2.5 t/ ha recorded maximum grain yield of maize and system productivity as compared to FYM 2.5 t/ ha + *Eupatorium* 2.5 t/ ha. Gupta *et al.,* (2014) reported the highest yield and yield components of maize crop with 100% recommended fertilizer dose + $ZnSO_4$ @ 20 kg/ha and the grain yield was about 101% higher over the control. Kumar *et al.,* (2013) reported that maize–genotypes 'CMH 08-292' recorded significantly highest cob yield with site-specific nutrient management (SSNM) over the recommended dose of fertilizer RDF as compare to PMH. Gupta *et al.,* (2014) evaluated residual effect of organic and inorganic fertilizers in maize crop under maize-gobhisarson cropping sequence. The experiment was conducted with 10 treatments of N, P, K and FYM, crop residue and zinc sulphate nutrients and they reported that the highest growth and yield of maize was recorded under 100% recommended dose of fertilizers + $ZnSO_4$@ 20 kg/ha. Kannan *et al.,* (2013) studied the effect of integrated nutrient management on soil fertility and productivity on maize and took six different treatments and reported that INM practice including vermicompost and recommended dose of NPK showed its best results with respect to leaf area and plant height as compared to other treatments. Choudharya and Kumar (2013) reported better growth parameters at application of vermicompost compared to other treatments. The Grain yield was increased under SSNM over RDF and FFP was about 17% and 28.6%, respectively in maize, 12% and 24% in rice, 17.7% and 32.8% in wheat and 22.4% and 35.7% in *rabi* Jowar. In commercial crops, SSNM enhanced the seed cotton yield to the extent of 15.2% and 27% over RDF and FFP respectively, while the dry chilli yield increased by 12.8% and 23.6% as against the RDF and FFP. The grain yield of sunflower and chickpea under SSNM were higher by 20.9% and 34.8% and 19.6% and 26.4% respectively over RDF and FFP (Biradar *et al.,* 2012). Hammad *et al.,* (2011) recorded maximum grain yield of maize under 250 kg N/ha, while the highest biological yield was recorded at application of 300 kg N/ha. Mahesh *et al.,* (2010) reported that combined application of recommended dose of NPK (150:75:40 kg/ha) + FYM 10 t/ha recorded higher grain yield (65.9 q/ha) followed by 75 % recommended through nitrogen fertilizers and 25 % nitrogen through poultry manure being at par with each other. The lowest grain yield was noticed in the treatment receiving 100 per cent recommended dose of NPK through chemical fertilizer (150:75:40 kg/ha. Increase N rates enhanced crop productivity as maximum grain yield was recorded from plots fertilized with 300 kg N/ha (Abbas *et al.,* 2005). Similarly, the maximum grain yield (11.6 t/ha) was reported from the plot fertilized with 268 kg N/ha in site-specific management zone (Inman *et al.,* 2005). Arif *et al.,* (2010) observed that grains/ear increased with increase in N level from 80 to 160 kg/ha but the N level of 120 and 160 kg/ha were statistically at par with each other so that they reported that better ear characters were obtained with N application of 120 kg/ha and also supported by (Onasanya *et al.,* 2009). Wasaya *et al.,* (2011) observed the highest grain weight per cob at 200 kg/ha.The highest improvement in yield attributes and baby corn yield were recorded with the application of 120kg N/ha in two equal splits at sowing and knee high stages (Das *et al.,* 2009, Bindhani *et al.,* 2007 and Pandey *et al.,* 2000). Kannan *et al.,* (2013) studied the effect of integrated nutrient management on soil fertility and productivity on maize and they took six different treatments. INM practice including vermicompost and recommended dose of NPK showed its best results with respect to yield parameters like number of grains per cob, 100 seed weight and yield but the cob weight was recorded maximum under INM practice including FYM and recommended dose of NPK. Shah and Kumar (2014) evaluated the direct and residual effect of integrated nutrient management practices on hybrid rice and succeeding wheat. Integrated nutrient management showed significant influence on productivity on wheat. Residual effect of NPK 50% RDF +FYM @5 tonnes/ ha + *Azotobacter* + Neem cake @2.5 tonnes/ ha + PSB@ 5 kg/ ha, recorded the highest grain yield of maize. Randhawa *et al.,* (2012) reported that the crop applied with six irrigations and fertilized with integrated application of chemical fertilizers (250-120-125 kg N-P_2O_5--K_2O/ ha) and farmyard manure (15 t/ ha) produced the highest grain yield, number of cobs/ plant, number of grain rows/cob, number of grains/ cob, 1000-grain weight, grain weight /cob, stover yield and biological yield.

Physico-biochemical properties of soil under nutrients management

Janwal (2006) reported that application of farmyard manure (FYM) increased significantly the available N, P and K status of the soil after maize harvest. The available P status of the soil also increased significantly due to the residual effect of FYM and fertility levels. Kannan *et al.,* (2013) reported that bulk density and pore space were recorded maximum in INM practice including vermicompost and recommended dose of NPK and also particle density but organic carbon was recorded maximum in FYM application. Choudharya and Kumar (2013) conducted an experiment with six treatments *viz.,* vermicompost, poultry manure, swine manure, cow dung manure, farm yard manure and control to study the effect of applied organic nutrients on growth and yield attributes of maize and reported that the physical parameters like porosity, maximum water holding capacity (MWHC), field capacity (FC), permanent wilting point (PWP), bulk density (BD) and moisture releasing pattern were recorded higher when the crop was supplied with FYM followed by cow dung manure. Similarly chemical parameters like pH, soil organic carbon (SOC), available nitrogen (N), phosphorus (P) and potassium (K) were recorded better under vermicompost followed poultry manure over control. The poultry droppings mixed with burnt rice husk dust (PBRHD), cow dung mixed with unburnt rice husk dust (CURHD), goat dung mixed with sawdust (GSD) and NPK 20:10:10 fertilizer had significantly higher effect on total porosity, hydraulic conductivity, gravimetric moisture content (GMC) relative to control (Nwite *et al.,* 2014). Application of 25% recommended dose of fertilizers (RDF) +biofertilizers (*Azotobacter chroococcum* + phosphate solubilizing bacteria)+ green manuring (with sunhemp) + compost @10 t/ha improved soil physico- chemical properties (viz. decrease in alkaline pH by 0.4, bulk density by 0.04 g/cm^3 and increased infiltration rate by 0.65 cm/hr) and also improved the organic carbon, available N and available P_2O_5 which were increased by 0.14%, 4.4 kg/ha and 11.7 kg/ha, respectively over the initial nutrient status of soil Kalhapure *et al.,* 2013). Shilpashree *et al.,* (2012) reported that the available nitrogen was recorded lower under chemical fertilizers than the organic matter application.

Nutrient uptake under nutrients management

Shah and Kumar (2014) found that integrated nutrient management had significant influence on nutrient uptake in wheat. The residual effect of NPK 50% RDF +FYM @5 tonnes/ ha + *Azotobacter* + Neem cake @2.5 tonnes/ ha + PSB@ 5 kg/ ha, recorded the highest for N, P and K uptake by succeeding wheat crop. Choudharya and Kumar (2013) reported that the uptake of nitrogen, phosphorus and potassium was higher at application of vermicompost followed by poultry manure, whereas least nutrients were taken up at control. Parmasivan *et al.,* (2012) reported that the highest total N and Zn uptake were observed from the application of 250-76-88-7.4 kg N-P-K-Zn / ha). Rehman *et al.,* (2011) studied various doses of nitrogen and reported the highest nitrogen uptake efficiency with 250 kg N/ha fertilizer dose and proved to be a good indicator of grain yield, however, the higher dose decreased NUE (300 kg N/ha) whereas Oktem *et al.,* (2010) observed highest nitrogen use efficiency at 320 kg N/ha and decrease was seen at 360 kg N/ha dosage.

Mahesh *et al.,* (2010) reported that combined application of recommended dose of NPK (150:75:40 kg/ha) + FYM 10 t/ha recorded higher nitrogen, phosphorus and potassium uptake (160.8, 41.9 and 77.8 kg/ha, respectively) followed by 75 % recommended through nitrogen fertilizers and 25 % nitrogen through poultry manure both were at par with each other. Higher nitrogen, phosphorus and potassium uptake respectively were also noticed under receiving 100 per cent recommended dose of NPK through chemical fertilizer (150:75:40 kg/ha). Inman *et al.,* (2005) reported that nitrogen uptake and grain yield response to applied nitrogen was found to be statistically significant at 250 kg N/ha. Tolessa *et al.,* (2000) reported that higher grain N content was recorded with MTRR than with MTRV and CT. The grain, stover and total biomass N uptake were consistently superior with MTRR compared to MTRV and CT. The agronomic (NAE), recovery (NRE) and physiological (NPE) efficient use of applied N by maize for the same tillage system were consistently higher at the lower N level range of 69 - 92 kg/ ha than higher N level range of 92 - 115 kg/ ha. The maximum Zn uptake, viz., 250.7 g/ha was observed with 75% N+ 25 % CF + FYM) and 4 kg Zn/ha application. The study also revealed that substitution of 25 or 50% N with FYM + 4 kg Zn/ha performed better than 100% N fertilizer alone, and had better leaf area index, grain and straw yield, soil organic matter content and nutrient uptake (Sarwar *et al.,* 2012). Islam and Munda (2012) studied the effect of organic and inorganic on growth, productivity and nutrient uptake performance of maize-toria cropping system.

Economics under nutrients management

Yadav *et al.,* (2016) found that maize equivalent yield, net return and B: C ratio was significantly higher at 5 t/ ha vermicompost +75% recommended dose of N.P.K. The maize + mungbean cropping system gave higher maize equivalent yield, net return and B: C ratio followed by sole maize, respectively. Nsanzabaganwa *et al.,* (2014) studied the impact of N and P independently and interactively on winter maize. Maize yield was highest at 240 kg N/ ha, but was significantly at par with 160 kg N. Every kg N applied produced 44.34 kg grain, and the N-use efficiency was reduced with increased N dose. Phosphorus application increased yield up to 26.4 kg/ ha. A combination of 240 kg/ N ha and 26.4 kg/ P ha, providing highest gross returns, net returns and net benefit: cost. The economic optimum dose for N and P was 196 kg N/ ha and 23.4 kg P/ ha, respectively. Shah and Kumar (2014) reported that maximum mean net returns (Rs 87297.5/ha) and B: C ratio (1.6) under NPK 50% RDF + FYM @ 15 tonnes/ha. Kalhapure *et al.,* (2013) reported that application of 25% recommended dose of fertilizers (RDF) in combination with biofertilizers (*Azotobacter chroococcum* + phosphate solubilizing bacteria), green manuring with sunhemp and incorporation of compost @10 t/ha gave the highest gross return and net return. The B: C ratio was higher at 25% RDF+ compost+

biofertilizers + green manuring followed by application of 100% RDF which was responsible for deterioration of nutrient status of soil. Choudharya and Kumar (2013) reported that the gross and net return was higher at application of vermicompost followed by poultry manure whereas B: C ratio was recorded higher at poultry manure followed by cow dung manure. However, the lowest economic returns were recorded under control.

The agronomic efficiency was recorded higher at vermicompost followed by poultry manure. Islam and Munda (2012) reported that maize – toria system had higher economics at application of FYM 2.5 t/ ha+ *Alnus* 2.5 t/ha as compared to FYM 2.5 t/ ha + *Eupatorium* 2.5 t ha. Mahesh *et al.,* (2010) reported that combined application of recommended dose of NPK (150:75:40 kg/ha) + FYM 10 t/ha gave higher gross returns and B: C ratio, respectively followed by 75 % recommended through nitrogen fertilizers and 25 % nitrogen through poultry manure but the lowest gross returns and B: C ratio were noticed at 100 per cent recommended dose of NPK through chemical fertilizer (150:75:40 kg/ha). Parmasivan *et al.,* (2006) reported that maize (COHM 5), fertilized with (250-76-88-7.4 kg N-P-K-Zn / ha) and (200-95-88-7.4 and 200-76-110-7.4 kg N-P-K-Zn / ha. The highest net returns and net B: C were obtained in treatment applied with 250-76-88. Somasundaram *et al.,* (2007) reported that biogas slurry with *Panchagavya* had the highest net returns and benefit cost ratio than recommended dose of fertilizers and foliar sprays.

Site-specific nutrient management, recommended dose of fertilizer, FIRBS and ridge bed planting may enhance better productivity as well profitability of farmers against conventional planting in Indian scenario.

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