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Review Article

PERFORMANCE OF MAIZE UNDER CONSERVATION TILLAGE

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Abstract- Tillage is one of the basic agro-technical operations in agriculture because of its influence on soil properties, environment and crop growth. Since, continuous soil tillage strongly influences the soil physico-chemical and biological environment, hence, it is important to follow appropriate tillage practices that avoid the degradation of soil structure, maintain crop yield as well as ecosystem stability. Conventional mode of tillage associated with soil compaction, reduced soil organic matter and soil microbial diversity. Repeated tillage leads to sub-soil compaction, which is associated with the reduced beneficial use of water and nutrient recovery by crop plants. Recently, conservation agriculture (CA) based crop management practices involving lesser soil disturbance, soil cover and cost-effective cropping sequences found to be useful in lowering the production cost besides providing environmental services in terms of lower carbon emission and improved soil health. So, there is a need for adoption of the conservation agriculture in India for harnessing crop production profitability and making soil more productive with more environmental and social benefits. The literature about the performance of maize (*Zea mays* L.) under conservation tillage practices *viz*. zero tillage, permanent bed planting and reduced tillage are reviewed in this paper.

Keywords- Bed Planting, Conservation tillage, Maize and Zero tillage.

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Introduction

Maize (*Zea mays* L.), popularly known as the queen of the cereals, is considered third most important cereal crop after wheat and rice in the world. India ranks fourth in terms of the maize growing country in the world with 9.4 million ha area, 24.26 million tonnes of production and average productivity of 2.57 t/ha [15]. It contributes to more than half of the coarse cereal production of the country and widely used as a dual purpose crop for animal feed as well as industrial raw material in the developed countries, whereas, in the developing countries it is used as a general feed for human being. In concern to the Indian agricultural scenario, the growth in maize area and production was steady since 1950 but the growth rate in both area and production of maize was unprecedented in the country during the last ten years due to adoption of improved production technologies, varieties/hybrids as well as expansion in non-traditional areas/states like Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu, etc. [64]. With the development of high yielding varieties and hybrids in maize, which are competitive to rice with respect to farm profitability and the resource-use efficiency under diverse soils and climatic conditions, maize-wheat cropping system is gaining importance in indo-gangetic plains. Maize-wheat cropping system has emerged as a potential system, covering an area of 1.13 million hectares and contributes about 2.25% to national the food grain production [63].

The fundamental principal for all agro-technologies is to maximize the yield by utilizing the soil and other natural resources without making a negative impact on the environment. In this aspect, Conservation Agriculture (CA) focuses on achieving a proper equilibrium of agricultural, economic and environmental benefits [5]. Introduction of CA was a concept to achieve sustainable and profitable farming and consequently aiming to enhanced livelihoods of farmers through integrated management of soil, water and biological resources along with externally applied inputs [13].

Effect of Conservation Tillage on

Growth parameters and yield attributes

The growth and yield attributes of any crop are influenced by many above and below ground factors and a combination of good condition results in better yield. Results of various on-farm participatory trials suggested little or no difference in growth and yield attributes of zero-till (ZT) planted maize compared to conventional tillage (CT) planted maize [19]. Likewise, [1, 49] reported that all the growth parameters (plant height, dry matter and leaf area index (LAI) and yield attributes (cobs/plant, grains/cob and test weight) of maize were not significantly influenced by long-term effect of tillage practices, which means these attributes are more genetically governed and needs other practices like genetic/breeding approaches, etc for their manipulation.

Beside above disused negative or no effect of conservation tillage practices, several studies also reported positive impact of these practices on the maize growth and phonological parameters. Permanent Bed planting helped in increased aeration of the root zone and assured plant stand by the increasing emergence, particularly in crusting type soils, which resulted in higher growth, and yield attributes of maize as compared to CT [37, 45].

Long term application of conservation tillage practices resulted into higher values of plant height, dry matter accumulation, LAI, crop growth rate (CGR) and relative growth rate (RGR) under permanent bed with legume residue than no-residue and this might be due to better soil health and micro-environment created by the continuous adoption of these resources conserving practice [36,48, 58].

Crop yield

Considering, the physical soil environment is very important to understand the yield variation due to its variable effect plant growth. The physical environment is the output of the collective effects of soil structure, texture and consistence. Tillage is aimed at producing good soil tilth. The impacts of CA on crop yield can be uneven [11]. In a long term field trial 16% yield reduction was found in crop yield from no tillage (NT) planted against deep CT maize crop [27, 43]. Similarly, lower grain and stover yield of maize under ZT maize compare to CT planted maize were reported at New Delhi [53]. The yield reduction in ZT had been explained by more weed infestation under ZT maize environment. Further, in another study author reported that under ZT mean decrease in grain and stover yield was 6.8-20% 12.1% and 5.9-17.1% as compared to CT [54, 60].

Contrast to the above studies, conservation tillage practices residue had 14-19% higher grain yield of maize under maize-wheat cropping system as compared to conventional tillage [52]. In another study author reported that farmers of the Yaqui Valley obtained 8% higher yields of maize at 15% less operational costs from permanent bed planting as compared to conventionally flat systems of crop growing [3]. Likewise, the author reported that ZT planting maize better performed over to CT in sandy loam soil in terms of yield and productivity [56]. After a long term tillage based study author suggested that the corn yield in Texas responded positively to planting a corn row either on permanent bed or a conservational tillage system [59]. Similarly, from a field experiment conducted at Ludhiana (India), found about 25% higher grain yield with a permanent bed planting of maize than flat sowing [28]. The highest, yield in bed planting with the bed was due to increased number of cobs per plant and more grains per cob than flat sowing.

Nutrient uptake

Tillage practices affect the nutrient uptake maize through changes in soil basic physical properties i.e. aeration, hydraulic conductivity, bulk density and total pore space as well as by its effect on root growth and its configuration. In most cases, nutrient uptake is reduced by soil compaction [33]. Results of a tillage and nutrient management based experiment showed that the nutrient concentration of maize under ZT were significantly lower than CT [52]. Further author found that there was no significant difference of macronutrient concentration in wheat-maize cropping system across different tillage management practices however, the concentration of these nutrients were found slightly higher in ZT compared to CT [32].

Contrast to the above studies, [20] found that no tillage resulted in a redistribution and concentration of soil nutrients at the soil surface, compared with CT which resulted in higher uptake of the nutrient former tillage system. Likewise, [40] found that nitrogen and P uptake were significantly higher in the permanent bed planted maize than CT but there was no significant difference for K uptake across the tillage practices. In another study author also observed that the total N uptake was 73.68% higher in ZT planted than the CT planted maize [2]. No significant change recorded in N concentration of maize stover and grain, however, both zero tillage and permanent bed planting had a significant effect on P concentration in stover [4].

Grain quality

Protein content

Chemical composition and grain quality of crops is influenced by various tillage systems and management practices and mineral elements in grain also depend on the type and composition of soil as well as on crop location [6]. Various tillage practices did not significantly influence the protein and starch content in maize grains, but higher protein content was observed in CT as compared to ZT [5, 34, 21].

In contrast, some researchers reported that under a long term tillage experiment in maize significantly higher protein content in ZT compared to CT which might be due to decomposition of the residue in the later stage of maize growth period [39, 50]. An increase in nitrogen content in the grain significantly increases the grain protein content of maize when it was planted in ZT over CT [46].

Zn and Fe content

Tillage system did not significantly affect the micronutrient content of maize, but higher content was found in ZT compared to CT plots [14]. Similar results of no difference between zero and traditional cultivation in terms of the micronutrient concentration in grain of corn were observed by [35]. The probable cause of these differences under CA practices might be due to better root development, increased forage area for nutrient extraction and higher content of Fe and Zn in the soil of the ZT than on those with the CT [8, 47] under ZT. ZT system increased contents of total ash, Zn and Fe in maize and wheat over CT planting [62].

Contrast to above [34] also reported higher amount of Zn and Fe under CT compared to ZT planted maize in maize –wheat-cropping system. The CT system increased Zn and Fe content of grain compared to RT and ZT, which resulted from higher concentration of both of the nutrient in the soil under CT due to residue incorporation, which in turn positively correlated with the concentration of these two elements in wheat grain.

Input use efficiency

Energy relation

Agriculture productivity is closely linked and positively correlated with the energy inputs. Sustainable energy management is one of the key components for maintaining the soil productivity and these can be achieved via., efficient use of commercial energies, and secondly harnessing substituting commercial energy sources with renewable energy sources [61]. The direct energy inputs for agriculture production generated from various operations performed by human, animals, electricity, fuel engines, and farm machineries *etc*. as well as indirect energy inputs (seeds, fertilizers, manures, pesticides and growth regulators, *etc*).

[24, 42] reported that system productivity in term of maize equivalent yield was influenced significantly due to different tillage practices and the permanent bed planting resulted into maximum system productivity during both of year of investigation compare to ZT and CT. Establishment of maize through ZT resulted in maximum energy output, energy productivity and net energy over CT in diversified maize based cropping systems [41]. The ZT practices reduce the energy requirement due to the saving of energy in tillage practices as well as in weeding operations than CT practices [23]. Establishment of maize through conservation tillage based ZT reported significantly more energy-use efficiency and energy productivity than CT [18]. However, [49] found minimum input energy and energy output/input ratio (13.82) in PB treatment, while energy output (3, 92,035 MJ/ha/year) was highest in NT + straw in maize–wheat cropping system.

Primary tillage before planting which required about one-third (936 MJ/ha) of the total operational energy (2795 MJ/ha) could omit without compromising the yield with ZT (4.85 t/ha) compared to CT (4.94 t/ha) [55]. The important significance of CA was to reduce the greenhouse gas emissions, which mainly associated with tillage operations [16]. Author conducted an experiment on rice–wheat systems in the Indo-Gangetic Plains and reported the farmer saved 15–60 l/ha diesel for land preparation with the adoption of ZT [10]. Adoption of conservation tillage in soybean and cotton crops has reduced energy consumption and has led to reduced soil and water erosion [25].

Water productivity

Conservation tillage universally recognized for improving water storage capacity as well as water use productivity. It has significant role not only in arid and semi-arid zones [30] but also heavy rainfall areas positively influenced. [7], the crop residues had prime importance to optimum growth environment for plant development and enhancing water productivity. Growing maize-wheat in sequence under rainfed condition and field should be ploughed immediately after harvesting of maize and covered with maize straw mulch @ 5 t/ha up to wheat sowing to reduce the evaporation losses and soil water storage for the succeeding wheat crop [51]. This practice improves the soil moisture conservation, efficiency about 3 times higher than control treatments (maize harvesting at 30 cm height and tillage at the time of wheat showing). It has been estimated that an additional 23 kg/ha wheat grain yield can be achieved per mm of conserved moisture. In semi- arid region of China reported that straw incorporation significantly increased water productivity of maize [60].

Establishment of maize through ZT resulted in maximum water productivity over CT in diversified maize based cropping systems in the Indo-Gangetic plain (IGP) [41]. In rice-wheat systems practiced with ZT is saved the irrigation water up to 20-35% in the wheat crop compared CT, and reducing water usage by approximately one million liter/ha [19, 22]. The savings arise because ZT wheat can be sown just after the rice harvest, making use of the residual moisture for wheat germination, potentially saving a pre-sowing irrigation, and because irrigation water advances faster in untilled soil than in tilled soil [10]. Similarly, higher WUE was also reported in the NT and with bed planting [28, 49]. Pre-planting, tillage was unnecessary in addition; high residue rates under NT were not converted into higher water use by wheat [38]. The ZT combined with crop residue retention on the soil surface greatly reduces erosion and enhances water-use efficiency compared to CT [26].

Economics

Tillage practices contribute greatly to the labour cost in any crop production system resulting in lower economic returns and economic outcomes of CA are likely to be specific to particular people, places and situations [17]. This is due to heterogeneity between regions and between farms in a region and heterogeneity in institutional factors such as farm sizes, risk attitudes, interest rates, access to markets (for inputs and outputs), farming systems, resource endowments and farm management skills, driving differences in benefits and costs of CA [12, 57]. Low labour, animal or equipment requirements are major advantages of conservation tillage because it allows elimination of several operations. The use of ZT significantly reduces energy costs, mainly by reducing tractor operational costs associated with conventional methods [9, 31].

From a tillage based experiment author reported that highest maize yield were noticed in PB planting compared to ZT and CT similar trend were also observed in wheat when it is sown followed by maize in maize-wheat-mung bean cropping system which in turn resulted into the highest net return as well as benefit cost ratio [41]. Likewise, [29] from Nepal reported that tillage and residue had no significant effect on B: C ratio. However, higher B:C ratio was obtained from ZT (2.42) as compared to CT (2.20) which indicates that ZT is more profitable. The higher B C ratio from ZT was due to the lower cost of production and higher gross return. Further, higher net returns obtained in ZT than CT and at the same time intercropping of maize and soybean in 2:2 ratio recorded maximum benefit and maize grain yield equivalent as well as the land equivalent ratio than sole and intercropping treatments [44]. Author reviewed a several studies of the economics of zero tillage in the Indo-Gangetic Plains. They found that due to site specificity and methodological differences the profitability of the various studies is sometimes complicated [10]. Nevertheless, the results consistently showed benefits-both cost savings and increased yields. On average, slightly more than half of the benefits were due to cost savings and slightly less than half were due to yield increases

The CA-based tillage and establishment options have significant advantages in terms of reduced production cost and labour use, and increased net returns for maize in rice-maize cropping system. The ZT technology proved to be a wise choice as it was reported to be economical as well as ecologically viable as compared with CT due to saving in labour, fuel, repair and machinery overhead charges and less emission of greenhouse gases [54]. Net return from maize and wheat crops and system as a whole was more under NT compared to furrow irrigated raised bed (FIRB) and CT [24]. The extent of net return from maize-wheat cropping system under NT was 30 and 322 US$/ha more over FIRB and CT, respectively. This indicates that maize-wheat cultivation under NT has been more economical.

Conclusions

Maize crop is an integral part of cereal based cropping systems. The productivity of the system as a whole and maize crop in particular, along with improvement in ecology of a system, conservation agriculture practices will help a lot. From the present review, it can be concluded that the maize crop under conservation agriculture based ZT and permanent bed planting of maize under diversified cropping sequences practices showed positive impact on crop growth, yield attributes, yields, profitability, efficient nutrient use and quality and in the long term, however, some researcher stated that the short term impact of conservation agriculture practices may not be always positive.

Conflict of Interest: None declared

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