Advances in Crop Science and Technology

Sher et al., Adv Crop Sci Tech 2017, 5:3
DOI: 10.4172/2329-8863.1000275

Review Article

OMICS International

# Response of Maize Grown Under High Plant Density; Performance, Issues and Management - A Critical Review

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## Abstract

Modern cropping is based on relatively high plant density. The improved grain yield per unit area of modern maize (*Zea mays* L.) hybrids is due to the increased optimum plant population rather than the improved grain yield per plant. High plant density has been widely used to enhance grain yield in maize. Subsequently we review the effect of planting density on physiology, phenology, morphology, nitrogen use efficiency, water use efficiency grain yield information in maize crop. At higher plant populations reduced grain yield also results from the increased pollen-to-silking interval and the following barrenness. However, it may lead to higher risk lodging hence causing significant yield loss of the crop. Future insights are morphological and physiological basis controlling barren and stalk lodging resistance. How root traits, and anatomy of sheath and stem of maize plants correspond to high plant population and a further study on the physiological and biological basis of organ development that may govern the mechanisms of high plant density would be essential for future research.

**Keywords:** Maize; High plant density; Phenology; Canopy morphology; Nitrogen use efficiency; WUE; Grain yield

## Introduction

In 94 developing countries of the world, Maize crop provides at least 30 percent food calories to more than 4.5 billion people which highlights the importance of maize to ensure global food security [1]. Maize crop is grown mainly in temperate, tropical and subtropical regions on marginal lands and face biotic and abiotic stresses under various extreme climatic conditions [2-4]. Maize yields generally higher in temperate region than in tropical zone the main reason is temperature and solar radiation conjunctions [5]. For 4500 years, maize has had a important role in the lives and the development of the cultural history of the peoples of world [6]. High plant density is a good strategy to obtain high yield [7,8] to meet the current and future food necessities of high population and their rising dietary needs [9]. Improvement in corn yield is dependent on its genetic characteristics, morph-physiological behaviour and its interaction with the environment [10]. Increasing the population density of plants is an agronomical practice that has continuously been studied for maize crops (Table 1). This crop technique has evolved and will continue to evolve over the years and it is the agronomic management factor that has changed the most over the past six decades [11]. After the introduction of the first hybrids, farmers started to steadily increase the plant density, at an average rate of 0.3 plants $m^{-1}$. In the US Corn Belt of the 1930s, the mean population density was 3 plants $m^{-2}$, while it was 4 plants $m^{-2}$ in the 1960s and 6 plants $m^{-2}$ in the 1980s [12]. Nowadays, the average density in the USA, where maize cultivation is intense, is around 8 plants $m^{-2}$ [13], whereas in the EU, where the pedoclimatic conditions are more heterogeneous across countries, it can vary from 6 to 8 plants $m^{-2}$ for medium-late maturing hybrids infertile growing areas (Table 2).

| | |
|---|---|
| **ASI** | Anthesis to silking interval |
| **NHI** | N harvest index |
| **HI** | Harvest index |
| **NUE** | Nitrogen use efficiency |
| **PPFD** | Photosynthetic photon flux densities |
| **DM** | Dry matter |
| **EDAH** | Diethyl Aminoethyl Hexanote |
| **GxEXM** | Genetics, Environment, Management |
| **GY** | Grain yield |
| **LAI** | Leaf area index |
| **NC** | Nitrogen content |
| **NR** | Nitrogen ratio |
| **RUE** | Radiation use efficiency |
| **NUE** | Nitrogen use efficiency |

**Table 1:** Abbreviations.

### Plant density effect on phenology of maize crop

Phenological events governs crop development which is sensitive to abiotic stresses, so the precise prediction of phenology is critical according to plant density. Modern corn hybrids are characterised by high production per unit area under high plant population, owing to morphological and phenological adaptations such as early silking, short anthesis to silking interval (ASI), few barren stalks, and prolificacy [14]. All the phenological characteristics (vegetative stage, days to tasseling, silking, and maturity), were significantly affected by plant density, rate and timing of nitrogen application [15,16]. During the vegetation period, the percent of plants decaying after emergence increased up to 27% [17]. This delay in emergence increased lengthening of the time interval between anthesis and silking which reduced kernel number per ear and enhanced number of barren plants and caused kernel abortion [18,19]. Moreover in modern cropping pattern corn seeds must be planted under optimum density, in order to reserve the resources like moisture, nutrients and solar radiation [20,21], but high plant population imposed a variety of stresses on corn plants, including

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**Received** April 04, 2017; **Accepted** May 01, 2017; **Published** May 08, 2017

**Citation:** Sher A, Khan A, Cai LJ, Ahmad MI, Asharf U, et al. (2017) Response of Maize Grown Under High Plant Density; Performance, Issues and Management - A Critical Review. Adv Crop Sci Tech 5: 275. doi: 10.4172/2329-8863.1000275

| No | Country | Author | Design | Year | Plant density (m²) | No of genotypes | Main features |
|---|---|---|---|---|---|---|---|
| 1 | USA | Williams II [11] | Split plot | 2005/2006/2007 | 4.3,8.6 | 6 | Agronomics and economics of plant population on sweet corn. |
| 2 | Pakistan | Ahmed et al. [111] | Split plot | 2006/2007 | 5.9, 7.4,9.8 | 3 | Allometery and productivity of autumn planted maize |
| 3 | Turkey | Turgut et al. [12] | Splitsplit plot | 2002/2003 | 6.5,8.5, 10.5,12.5 | 3 | Plant Density Effects on Forage and Dry Matter yield of corn |
| 4 | USA | Grant and Hesketh [39] |  | 1988 | 1.5, 4.3, 5.7, 8.6, 10.3 | 1 | SIMULATION OF MAIZE GROWTH under high plant density. |
| 5 | China | Ma et al. [89] | Split plot | 2009/2010/2011 | 3.7, 5.2, 6.7, 8.2 | 8 | Changes in Morphological traits of maize |
| 6 | USA | Armstrong and Albrecht [93] | RCBD factorial | 2005 | 2, 4, 6,8 | 1 | Plant Density effect on Forage yield and Quality. |
| 7 | USA | Shapiro and Wortmann [91] | Split Split Plot | 1996/1997/1998 | 6, 7,8 | 1 | Plant Density,nitrogen Rate, row Spacing |
| 8 | USA | Lauer and Rankin [90] | RCBD factorial | 1999/2000/2001 | 3.7, 7.4 | 3 | Plant Spacing Variation under high planting density |
| 9 | China | Liu et al. [96] | RCBD factorial | 2011/2012 | 4.50,8.25,12 | 2 | Effect of Planting Density on Root lodging Resistance in Maize. |
| 10 | Argentina | Ferreira et al. [85] | RCBD | 2012 | 6, 7, 8,9 | 2 | Effect of planting densityon nutritional quality of corn |
| 11 | Iran | Sharifi et al. [86] | RCBD factorial | 2007 | 8,10,12 | 3 | Effect of plant density on yield related traits in maize |
| 12 | Greece | Gerakis and Tasopoulou [17] | Split plot | 1970-1971 | 5,5, 10 | 5 | Effects of Dense Planting on Maize Hybrids |
| 13 | USA | Uribelarrea etal. [82] | RCBD | 2001/2002/2003 | 6.5 | 4 | Divergent selection for grain protein, contrasting maize genotypes |
| 14 | India | Jadva et al. [56] | Split plot | 1987/1988 | 5.3 | 1 | Effect of irrigation and mulching on maize nutrient uptake. |
| 15 | Argentine | Rossini et al. [23] | split plot | 2006/2007/2008 | 6,9,12 | 2 | Inter-plant competition for resources in maize crop under high plant density. |
| 16 | Argentine | Maddonie and otegui [18] | Split plot | 1999/2000/2001/2002 | 6,9,12 | 2 | Intra specific competition in maize; contribution of extreme plant hierarchs of grain and yield, yield components and kernel composition. |
| 17 | Argentine | Pagano et al. [10] | RCBD factorial | 2004/2005/2006 | 6,12,12 | 2 | Plant density in maize: Ear development, Flowering and kernel set |
| 18 | Argentine | Maddonie and otegui [5] | split- plot | 1999/2000/2001/2002 | 6,9,12 | 2 | Intra-specific competition in maize: early establishment of hierarchies among plants affects final kernel set. |
| 19 | Argentine | Echarte et al. [13] | Split plot | 1998/1999/2000 | 2,4,8,16,30 | 4 | Kernel Number Determination in Argentinean Maize Hybrids Released between 1965 and 1993 |
| 20 | Argentine | Maddonni and Otegui [16] | Split plot | 1993/1994 | 7 | 3 | Leaf area, light interception, and crop development in maize under planting density |
| 21 | Argentine | Borass et al. [22] | Split split plot | 1997/1998/1999/2000 | 3,9,12 | 3 | Leaf senescence in maize hybrid: plant population, row spacing and kernel set. |
| 22 | Austerlia | Massignam et al. [29] | RCBD | 1999/2000/2001 | 3.5,6.7,6.9 | 1 | Maize and Sunflower. Physiological measurements under plant density and N. |
| 23 | Egypt | Mehdat et al. [61] | Split split plot | 2011/2012/2013 | 4.7,7.1,9.5 | 6 | Maize response to elevated plant density combined with lowered fertilizer rate. |
| 24 | USA | Jorge et al. [32] | split plot | 1994/1996 | 4.4,5.9, 7.4,8.9, 10.4 | 2 | Plant Density Influence on Maize Forage yield and Quality |
| 25 | Kenya | Najoka et al. [28] | RCBD factorial | 2001/2002 | 4.4,8.8,17.7,35.5 | 1 | Plant density and thinning effect on maize grain and forage yield. |
| 26 | USA/SE Asia | Setiyaono et al. [30] | Different USA/ Asia | 2004/2005/2006/2007 | 2.7,9.6 | Diverse hybrids | N, P, K Accumulation under high plant density |
| 27 | USA | Widdicomb [41] | split plot | 1998/1999 | 5.6, 6.5,7.3,8.1,9.0 | 4 | Row Width and plant Density Effects on corn Grain Production in the Northern corn Belt |
| 28 | USA | Bruns and Abbas [54] | Split plot | 2001/2002 | 4.3,4.8,5.4,6.4,7.6 | 6 | Effect of plant population on maize hybrid in the subtropical mid-south USA |
| 29 | USA | Sarlangue et al. [46] | Split plot | 2000/2001 | 4, 6, 8, 10, 12,14 | 3 | Why corn Hybrids Respond Differently to Variations in plant Density. |
| 30 | USA | Pan et al. [29] | Split split Plot | 1983/1984 | 3.4–4.5 | 5 | Altering source-sink. Prolific maize under plant density |

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|---|---|---|---|---|---|---|---|
| 31 | Argentina | Dandrea et al. [24] | Splitplot | 2002/2003/2004 | 7 | 12 | Inbreds and hybrids evaluated at contrasting N levels and plant population. |
| 32 | China | Mi et al. [49] | Splitplot | 1996/1997 | 6.0 | 3 | Genotypes differing in leaf Senescence |
| 33 | USA | Ciampitti andVyn [63] | Split split plot | 2009 | 5.4, 7.9,10.4 | 2 | Plant density and N rate levels, grain HI, NHI |
| 34 | USA | Camberato [71] | Split-split plot | 1982/1983 | 3.4, 4.5 6.8 | 4 | Plant density and nitrogen rates Prolific and one-eared hybrids |
| 35 | Germany | Presterl et al. [4] | 7 × 7-lattice square | 1992 | 8,9,11 | 2 | European maize hybrids under different plant density and N. |
| 36 | Argentina | Cirilo et al. [1] | Split plot | 2003 | 8.2 (± 0.6) | 8 | Morpho-physiological traits under contrasting N environments. |
| 37 | USA | Ciampitti And Vyn [3] | Split split plot | 2010 | 5.4, 7.9, 10.4 | 2 | Plant density and nitrogen rates using two different genotypes. |
| 38 | USA | Inman et al. [6] | Management zones (nested) | 2001/2002/2003 | 7.5 | 2 | Site-specific management zones in irrigated maize production. |
| 39 | USA | LemcoffandLoomis [9] | Split plot | 1981 | 3.7, 7.3 | 1 | Contrasting plant densities and N rates on physiological determinants |
| 40 | Slovenia | Bavec and Bavec [15] | Split plot | 1989/1990/1991 | 4.5,6.0,7.5,9.0,10.5,12,13.5 | 4 | Effects of plant population on leaf area index, cob characteristics and grain yield |
| 41 | Slovenia | Bavec and Bavec [19] | split plot | 1994/1995/1996/1997/1998 | 7, 9, 11, 13 | 10 | Effects of plant population on leaf area index, cob characteristics and grain yield of early maturing maize |
| 42 | India | Shivey and Singh [25] | Split plot | 1992/1993 | 6.0 | 1 | Different cropping systems, plant density and N rate levels. |
| 43 | France | Coque and Gallis [27] | RCBD | 2002/2003 | 9.0, 11.0 | 23 | Genetic variation in European varieties under high plant density and N levels. |
| 44 | Argentine | Maddonni et al. [36] | RCBD factorial | 1997/1998/1999 | 3,9,12 | 2 | Row Width and Maize Grain yield under high plant population. |
| 45 | India | Parmer and Sharma [38] | RCBD | 1997/1998/1999 | 8.3 | 1 | Maize and wheat Cropping system under rainfed conditions. |
| 46 | USA | Maskine et al. [44] | Split plot | 1986/1987/1988 | 3.7, 4.2 | 1 | Residue and no tillage effect under plant density. |
| 47 | USA | Reed et al. [47] | RCBD | 1978 | 4.5 | 4 | Grain protein accumulation during reproductive stage |
| 48 | Italy | Testa et al. [59] | split plot | 2013/2014 | 7.5,9,10.5,12 | 2 | Maize grain yield enhancement through high plant density cultivation with different inter and intra row spacings. |
| 49 | China | Zhang et al. [50] | Split plot | 2012/2013 | 4.5,6,7.5,9 | 2 | Maize yield and quality in response to plant density and novel growth applicator |

**Table 2:** About previous experiments of Maize under high Plant density.

competition for light, water, and nutrients [22], as well as enhanced incidence and severity of ear rots and caused leaf diseases [23]. Light is very important component to measure day length and phenology for example competition for light and water delayed silk emergence and caused in problematic ASI [24,25], finally resulted poor pollination and lower yield.

## Plant density effect on canopy morphology of maize crop

Maize yield can also be related to increased plant density effect on plant morphology and physiology. Improved morphology was the key for promoting light use efficiency per plant [26-28] which influenced canopy morphology, light interception and ultimately yield [29,30]. The effects of high plant density on corn morphological development have been studied extensively at the canopy level [31-33]. Whole plant canopy level effects indicated that through local responses that may vary with positions in different types of organs [28,34,35]. For example, the effect of plant density on leaf area expansion through two parts i.e., lamina length and lamina width, the first being consistently decreased in both lower and upper phytomers [36] whereas the second being increased in lower phytomers and decreased in upper phytomers [37]. Increasing panting density accelerated leaf senescence [38], increased the shading of leaves [18], and reduced the net assimilation of individual plants.

In a crop canopy, factors such as plant shape, plant populations, and row width affected leaf distributions, PAR interception and yield [29]. Leaf area, leaf sheath and internode mass decreased with higher planting density, with greater decrease was at higher nodes [39,40]. As an example of a tillering Gramineae species wheat crop morphological leaf components were influences by plant population [36]. It was observed that the most significant effect of higher plant population on leaf area per plant was the absence of later formed tillers. The lack of tiller formation was related to low local assimilate availability, induced by low photosynthetic photon flux densities or low red/far red ratios at the site of the incipient tiller. When a species does not form tillers, plant density can only affect the growth of leaves on the main stem. A study into the effects of environmental factors on the morphological development of such a plant type could lead to a better understanding of mechanisms involved in the effects of plant density on leaf area development. Moreover, at higher plant densities, leaf area per plant is decreased in later phases of growth, 40% increased in LAI at high plant density from mid-vegetative to early grain fill even though per plant biomass decreased 40 to 60% at high plant density [41-43]. This decreased in per plant biomass reduces in photosynthetic rate per plant which increased plant barrenness [44] as plant population increased [43,45]. According to morphology plant height is very important factor which is affected by plant density. Plant height is not correlated with root lodging but it is was significantly correlated with grain yield [46,47].

## Plant density effect on nitrogen use efficiency

To fulfil the requirement of food it is necessary to improve NUE in cereal crops at low input of fertilizer. Most of the cereal crops require large amount of nitrogen to produce maximum yield and for which NUE is estimated to be far less than 50% [48,49]. Nitrogen fertilization and soil management practices are very important to enhance the crop yield [49,50]. Nitrogen demand may also increase as plant density increases dissection of the complex interactions among years, planting populations and N rates began with division of treatment mean data into two time periods defined by year(s) of the original research: (i) studies from 1940 to 1990 (“Old Era”) and, (ii) studies from 1991 to 2011 (“New Era”). For the Old Era, corn GY averaged 7.2 mg ha$^{-1}$ at a mean plant density of 5.6 pl m$^{-2}$ with a total plant N uptake of 152 kg N ha$^{-1}$, N harvest index (NHI) of 63% and a grain harvest index (HI) of 48%. For the New Era, maize GY averaged 9.0 Mg ha$^{-1}$ at a mean plant density of 7.1 pl m$^{-2}$, total plant N uptake of 170 kg N ha$^{-1}$, NHI of 64% and a grain HI of 50% [51]. Nitrogen has a major effect on growth of maize plant among the major nutrients needed by plants (especially the three elements of N, P, K) [52]. Corn crop response to nitrogen is different due to weather conditions, soil type and maize rotation [53,54]. Various stresses, including nitrogen deprivation and inter-plant competition by high plant density decreased ear size and kernel row number, as well as kernel set in maize and reduced yield [55]. Increased N supply, increased accumulation of dry matter and N by aboveground plant parts of corn during grain filling and ultimately increased yields [56,57] whereas low-yielding maize hybrids responded poorly to added N [58]. Nitrogen fertilization affected corn dry matter (DM) production by influencing leaf area development, leaf area maintenance and photosynthetic efficiency of the leaf area [59] and maximum economic DM for corn occurred at an N rate of about 150 kgha$^{-1}$ [60]. Efficiency of applied nitrogen to corn crop increased under higher plant populations [61]. Higher plant populations enhanced pre-silking N uptake, but had relatively minor impact on post-silking N uptake for hybrids [45].

**Calculation of nitrogen use efficiency:** NUE can be calculated by different methods. In plot- or field scale experiments, plots with and without applying N or with 15N labelled fertilizer is used to calculate NUE [62,63]. According to the methodology NUE was also calculated by using an output/input ratio by using this formula [49]. NUE=(Ng-Nr/ (NC)).100 where **NC** is the application of N fertilizer (in tone) for crop production which is 53% of all nitrogen fertilizers [64]. NG is determined by multiplying N concentration in cereals by its yield, for different crops the values of N concentration (in g kg$^{-1}$) are as follows: rice (12.3 g kg$^{-1}$), oat (19.3 g kg$^{-1}$), rye (22.1 g kg$^{-1}$), barley (20.2 g kg$^{-1}$), maize (12.6 g kg$^{-1}$), sorghum (19.2 g kg$^{-1}$), and wheat (21.3 g kg$^{-1}$). NR is the N released by cereals coming from the soil natural fertilization or deposited by rainfall [65,66]. NR can vary from 40 to 60% in cereals [67,68] have reported mineralized N and atmospheric deposition are the source of 50% of the N taken up in plant. Abundant part of the N taken up in plants comes from the soil [69].

## Plant density effect on water use efficiency

Management of irrigation water is crucial in order to improve corn productivity with reduced pollution risks [70] and can reduces yield loss if applied in an inappropriate way [71]. Direct evaporation of water from the soil surface is influenced by a number of factors. One is increase of transpiration (T) from a canopy, which can reduces moisture lost daily (Esc) by humidifying the crop canopy [72,73]. Soil evaporation is also affected by the shading of the soil surface by a crop canopy [74]. Higher water use efficiencies of maize reduced (Esc) and a concurrent increase in transpiration (T), due to nitrogen application which was associated with a larger crop leaf canopy [75]. Thus, potentially, early in the season Esc may be reduced by the presence of a dense crop canopy. High plant density is one way of achieving a dense crop canopy soon after sowing. Use of groundcover by high density to affect Esc and T, by changing plant spacing, therefore provide a low input means of adjusting the evaporation from a cropped field, and increases a efficient use of water. An increase in planting density increased water use efficiency by 24% under irrigation but reduced by 17% under rainfed conditions. Moisture lost daily (Esc) was 4% less, and transpiration (T) was 9% greater at the highest plant population density owing to a larger crop leaf canopy. Irrigation increased the amount of Esc and T by 41%.

Neither Esc nor T were affected by the interaction between population density and water regime. The increase in leaf area index due to a higher population density was greater under irrigation (78%), than under rainfed conditions (21%) [76]. Despite the significant increasing in biological yield at the rates of 5.9% and 10.9% grain yield significantly decreased at the rate of 1.8% and 10.7% by increasing plant population from 7 to 8 and 9 plant $m^2$, respectively. The irrigation and plant density interactions were statistically significant for plant height and yield. There is also one opinion that the super optimal plant population used water more efficiently (25% less than other populations). Therefore, the water use efficiency of maize was changed through the manipulation of plant population density. For the plant population 66,000 plants $ha^{-1}$ treatment used more water (442.37 mm) and the 38,000 plants $ha^{-1}$ is next (441.22 mm), while the 53,000 plants $ha^{-1}$ treatment used the less water (426.87 mm) [76].

## Plant density effect on grain yield information

Maize yield was significantly affected by plant density [77]. Only in proper plant density, plants can achieve highest yield [78]. In order to determine proper density of plants, hybrid type is more effective. The higher plant density decreased cob length (-10.8%) ear weight (-6%), kernel weight (-7.1%), the number of kernels per row (-10%) thousand kernels weight by (-18%) and stalk area (-20%) [79]. There is contrary opinion that kernel number and kernel weight are affected by plant density. Kernel number may not be affected by planting density. High plant population affected yield components by reducing the number of ears $plant^{-1}$, kernels per ear and kernel weight. As plant population increased kernel weight is more stable than other yield components [80-82]. Source-sink relationships during grain filling effected the kernel weight [83]. Various stresses, including nitrogen deprivation and inter-plant competition by increasing plant population decreased ear size and kernel row number, as well as kernel set in maize and reduced yield. High plant population declined above ground biomass and HI, increased barrenness, delayed reproductive processes, reduced kernel weight and number and affected plant grain yield. At high plant densities, many kernels may not develop an event that occurs in some hybrids following poor pollination resulting from a silking period that is delayed relative to tassel emergence [84] and/or owing to a limitation in assimilate supply that caused grain and cob abortion in corn [85]. Moreover, some researchers and Scientists have opinion that corn grain yield typically exhibited a quadratic response to plant density, a gradually decreased rate of yield increase relative to density increase, and finally a yield plateau at some relatively high plant density [86,87]. Increased plant density increased grain yield quadratically [88-90]. Some researchers indicated responses other than quadratic [91-93]. Some scientists concluded that most current hybrids may actually exhibit quadratic-plateau models [92]. Plant to plant variability reduced grain yield and reduced resource use efficiency [94]. Corn yield differed significantly at varying plant density levels, owing to differences in genetic potential [95]. Higher plant population increased plant sterility and the interval between male and female blooms, and decreased the number of grains per ear [96,97].

## Strategies to improve maize performance under high plant density

**"Genotype (G) x external environment (E) x management (GxExM) interaction":** Maize yield potential is defined as the maximum yield obtained by a genotype (G) developed in an adapted environment (E), with non-limiting water and nutrients resources, under no pressureof pests and diseases, using the best management (M) practices (e.g., planting time, plant density, N fertilizer rate, tillage practices, crop rotation, etc.) for the specific hybrid, weather and soil conditions [98,99]. Substantial studies have been conducted to identify high yielding and consistent performing maize genotypes (also known as stable genotypes). However, most of the high stable genotypes are less predictable across different crop management practices since plant breeders often perform analysis of two-way data (genotype x site or GxE) for several consecutive years to detect stable genotypes without taking crop management practices into account. Previous studies on crop management practices suggest that optimization of management practice alter the external environment that a maize plant live in, which result in scale or rank shift in its performance [100,101]. This relative shift of genotype performance from one environment to another across management practices is known as genotype x environment x management interaction (GxExM) [102,103]. The impenetrable interaction of a crop bio-system with the external environment introduces challenges when making breeding decisions because it may result in low correlation between phenotypic and genotypic values, thereby reducing progress from selection. This reduction leads to bias in the estimation of heritability and in the prediction of genetic advance [104-106]. Plant population density depends on both genotypic [107] and climatic factors [108]. Improving hybrid and management practices are very important to increase corn yield [109-111]. On an average 50% yield enhance was due to management and 50% was due to breeding strategies [112]. Recently developed hybrids are more prone to withstand higher planting density than older hybrids. Planting density-tolerant genotypes have ability to decrease production of grain per unit of leaf area is necessary to obtain high yield. Genetically modified brittle stalk mutants and growth regulators like EDAH are good source for controlling stalk lodging in maize crop. Brittle stalk mutants are good indicator of the mechanism of cell wall formation, and a number of brittle stalk mutants had been identified in plants including barley [113,114], *Arabidopsis* [115], maize [116] and rice [117-119]. At recently, most efforts have been done on the phenotypic observation, genetic analysis, gene mapping, and several genes related traits of brittle have been discovered and characterised [120-122]. A new brittle stalk mutant in corn, designated as Bk-x, was screened from a library of mutants constructed by a cross between a maize inbred Zong 31 and a Mutator active line W22::Mu. The anatomical, morphological, and biochemical difference between Bk-x and normal plants was analysed and genetic behaviour of this trait was investigated using several genetic segregation populations. The other agronomical traits, such as plant height, flowering time, stem diameter, and kernel size in brittle stalk mutants are same with that in the normal plants.

Selection procedures used to improve corn performance in a wide range of climatic conditions brought a series of morphologicall modifications and adaptation to high plant densities like plant canopy morphology and phenology development. Modifications in plant canopy morphology also in a corn permit new hybrids to withstand higher leaf photosynthetic rates than pervious hybrids at high planting densities. This also promote to increase RUE during grain filling, which further increased to the production of more kernels perplant and higher grain yield. Moreover, plant architecture and morphology at high plant densities has alsobeen important in enhancing maize stand ability by reducing problems like stalk and root lodging. Agronomic factors affecting plant population are i. Cultivar ii. length of the growing season. iii. Time of planting, vi. water availability. v. Row spacing.

Some factors affecting NUE, so these factors are very important to improve NUE under high plant density. 20 to 50% losses nitrogen fertilizer in cereal production are reproted in 15N recovery experiments.

These losses are due to denitrification, volatilization, and/or leaching. Loss of fertilizer N results from: i. Soil nitrification/denitrification: 9.5% N losses in winter wheat are due to denitrification from applied fertilizer, 10% in lowland rice, and 10% to 22% (no-till) in corn. Zero till plots can double denitrification losses due to use of straw or application of straw on the surface of soil. ii. NO3--leaching: All applied nitrogen fertilizer sources are converted to the form. In textured soil profile with excessive rains this nitrate N form is not held tightly by soil particles and can be leached. Nitrate leaching can be significant in cereal crops when fertilizer N is applied at rates in excess of that needed for maximum yield. In cooler temperate climates, under conventional tillage corn when only 115 kg N $ha^{-1}$ was applied nitrate losses was 26 kg N $ha^{-1}$ $yr^{-1}$ iii. Volatilization of urea based products: Volatilization losses are due to urea based fertilizers products are susceptible to of N. In the soil and plant residues Urease enzyme in the soil converts the urea component to ammonia gas. 15-20% of the urea based nitrogen may volatilize within a week, if this conversion occurs at the soil surface in a warm sunny days iv. Inherent ability of genotypes. V. Presence of soil microflora. Vi. Major factor which affects NUE is nitrogen metabolism.

## Conclusion and Future Inspective

High density planting, while important to increased yields, can also lead to greater competition for resources and morphological changes in the plant and caused lodging. Plant's translocation and photosynthetic activity is severely affected by lodging and decreased yield. Plant population recognized as a important factor determining the degree of competition between plants. The development of earlier hybrids, with shorter plant height, lower leaf number, upright leaves, smaller tassels and more synchronized floral development improved maize ability to withstand high plant densities without presenting a higher percentage of barren plants. The use of higher plant populations enabled corn to intercept virtually all the available solar radiation earlier in the season, transforming this energy into storage carbohydrates and other foods in more grains per area. Plant population recognized as a important factor determining the degree of competition between plants. The taller plant heights, smaller shoot dry weights and stem diameter of plants in high planting density make them more susceptible to lodging than the shorter plant heights, bigger shoot dry weights and stem diameters of plants in less planting density. Moreover, response of sheath and stem anatomy due to high plant population is future prospect to reduce the lodging risk in maize crop.

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