RESPONSE OF HYBRID MAIZE TO PLANT DENSITY AND FERTILIZER LEVELS – A REVIEW

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ABSTRACT

Maize is one of the most important cereal crops grown in tropical and temperate regions of the world. Despite its high yield potential, it is giving low yields because of lack of appropriate information on plant geometry and fertilizer management. Nitrogen, phosphorus and potassium are the major plant nutrients, which limit normal plant growth. Increasing productivity per unit area through agronomic management is one of the important strategies to increase the production of maize grain. Keeping this in view, an attempt was carried out to review the work done on the effect of spacing and fertilizer levels on yield and economics of maize hybrids. In maize, the effect of plant density and fertilizer levels is well documented. From the review, it is understood that the response of hybrid maize to plant density and fertilizer requirement varies widely. Summarizing the review undertaken, it can be concluded that the potential productivity of hybrid maize could be achieved when it is grown under optimum spacing of 75 x 20 cm and high fertilizer levels of 200:100:100 NPK Kg ha⁻¹ under irrigated condition.

Maize hybrids generate high yield. The plants are bigger, stronger and more vigorous and hence it resists pests and diseases and are highly responsive to application of fertilizers. Hybrid maize is well known for its high demand for plant nutrients. Modern hybrids, respond more favourably to plant densities because of a higher Leaf Area Index (LAI) at silking, which results in more interception of photosynthetically active radiation and have higher radiation use efficiency during grain filling (Azam et al., 2007). Hence, standardization of plant density and fertilizer levels assumes greater importance to achieve more economic returns. The yield potential of maize hybrids is realized only if it is grown with adequate fertilization and optimum plant population (Singh and Singh, 2006). The impact of plant density on maize yield has been studied extensively, as it varies substantially with genotype, management practices and location. The importance of density and geometry of planting as factors in deciding growth and yield of maize varieties is well established. However, no specific recommendations are available on plant density and fertilizer dosage for higher productivity in hybrid maize.

Effect of plant density on growth parameters of maize: The results of the study conducted at Bangalore, during kharif season on maize hybrid PBRH-2 revealed that the growth parameters such as plant height, number of leaves, leaf area and stem girth increased linearly with increase in spacing from 60 x 10 cm to 60 x 30 cm (Munisamy et al., 2007). Siva (2007) reported that the growth attributes viz., plant height, LAI and drymatter production were higher in maize sown under 60 x 20 cm spacing. Kunjir et al. (2007) reported that in sweet corn, plant height increased significantly with subsequent increase in the plant density and hence, closer spacing (45 x 20 cm) recorded significantly taller plants than the wider spacing of 60 x 20 cm to 75 x 20 cm.

Gozubenli et al. (2003) conducted an experiment on hybrid maize during kharif season on clay loam soil and found that the plant characteristics of maize were significantly affected by plant population. High plant densities produced taller plants with lower stem diameter. Collar and Patil (2000) reported that the increase in plant density from 55, 555 to 1, 11, 111 plants ha⁻¹ increased the Leaf Area Index (LAI) of hybrid maize from 3.46 to 5.84.

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but the number of leaves were higher in lower densities compared to high density planting. Similar results were also reported by Verma and Joshi (1999), Begna et al. (1999) and Singh et al. (1997).

A study conducted in USA with six level of plant densities varying from 61,750 to 1,23,500 plants ha\(^{-1}\) revealed that all the growth attributes such as plant height, number of leaves, stem girth were significant at 1,04,500 and 98,800 plants ha\(^{-1}\) for Bt and Non-Bt hybrid maize respectively (Stanger and Laner, 2006). Bruns and Abbas (2005) reported that increased plant densities in most of the cereal crops resulted in taller plants with smaller stem diameter. Similar finding of decreasing the stem diameter with increasing plant densities was also reported by Turgut et al. (2005) and Cox (1997). In Shillong, Govil and Pandey (1999) conducted an experiment on hybrid maize, Deccan 101 with different plant densities. The leaf area index, crop growth rate and biological yield were higher with 1,35,000 plants ha\(^{-1}\). However, relative growth rate, net assimilation rate and harvest index were higher with 90,000 plants ha\(^{-1}\).

### Effect of plant density on maize yield attributes:
Siva (2007) stated that the yield attributes viz., cob length, cob girth, cob weight, number of grains cob\(^{-1}\), grain weight cob\(^{-1}\) and test weight of maize were higher when sown at wider spacing of 60 x 30 cm. Azam et al. (2007) reported enhancement in yield attributes of maize viz., number of grains cob\(^{-1}\) (399), cob length (34 cm), cob weight (324 g), and 1000 grain weight (262 g) at 70 x 25 cm. An experiment conducted in maize at Turkey revealed that ear length, ear diameter and grain weight per ear decreased with increasing plant densities. The highest ear length, ear diameter and grain weight per ear were obtained at lower (50,000 plants ha\(^{-1}\)) plant density (Gozubenli et al., 2003).

### Effect of fertilizer level on maize:

#### Effect of Nitrogen on maize:
Several studies have shown that maize responded well to nitrogen under various edapho-climatic conditions. Response of added fertilizer N depends upon the variety or hybrid, initial fertility status of the soil and climatic conditions. With
the advent of new high yielding hybrids and pressing demand to increase the productivity, adequate N fertilizer application is becoming increasingly important.

**Effect of N on growth parameters of maize:**
Parasuraman (2005) observed taller plants at 170 kg N ha\(^{-1}\) compared to 135 kg N ha\(^{-1}\) in hybrid maize. Higher dose of N recorded taller plants, more number of leaves and leaf area when compared to 80 kg N ha\(^{-1}\) (Munisamy et al., 2007). The growth parameters viz. plant height, number of leaves and dry matter accumulation per plant increased significantly with the subsequent increase in nitrogen level up to 225 kg ha\(^{-1}\). Further 225 and 150 kg N ha\(^{-1}\) were at par with each other in respect of the above referred growth parameters (Kunjir et al., 2007). Similar findings were also reported by Shivay et al. (1999).

Ali et al. (1999) conducted an experiment on the response of maize genotypes to graded levels of nitrogen and observed maximum plant height at 230 kg N ha\(^{-1}\) which was, however, statistically at par with the height obtained at 180 kg N ha\(^{-1}\). Maize responds well to N fertilization (Stone et al., 1999; Tyagi et al., 1998). Parthipan and Premsekhar (2002) reported that increase in N levels from 0 to 200 kg ha\(^{-1}\) increased the plant height, LAI and drymatter production of irrigated maize in sandy clay loam soil of Coimbatore under irrigated condition. In a field trial conducted at Hisar on spring maize cv. Ageti 76 with different N levels (Singh et al., 2003).

**Influence of N on yield attributes of maize:**
Varughese and Iruthayaraj (1996) reported that application of 187.5 kg N ha\(^{-1}\) recorded higher cob length, cob girth, number of grains cob\(^{-1}\) and test weight in maize at Coimbatore. Parasuraman (2005) reported that application of 170 kg N ha\(^{-1}\) registered the highest values of cob length, cob girth, cob weight and 100 grain weight at 225 kg N ha\(^{-1}\) in maize. Kunjir et al. (2007) reported that in sweet corn, cob length, cob girth and cob weight were significantly higher at increased N level (225 kg N ha\(^{-1}\)).

Magsood et al. (2000) observed that number of grains cob\(^{-1}\) were found to be higher at 250 kg ha\(^{-1}\) of N application but this treatment did not differ significantly from the treatment with 200 kg N ha\(^{-1}\). The results of experiment conducted at Faisalabad during autumn season on maize cv. Golden revealed that the 1000 grain weight and number of grains cob\(^{-1}\) were higher under nitrogen level of 300 kg N ha\(^{-1}\) but was statistically on par with nitrogen level of 200 kg.
N ha\(^{-1}\) (Mahmood et al., 1998). An experiment conducted at Uttar Pradesh during winter season on PG 2320 hybrid maize revealed that increasing N levels from 120 to 180 kg ha\(^{-1}\) resulted in significant increase in length of cob, girth of cob, number of grains cob\(^{-1}\), grain weight cob\(^{-1}\) and test weight of maize in clay loam soil under irrigated condition (Singh et al., 2003). Misra et al. (1994) also noted significant increase in number of rows cob\(^{-1}\), number of cobs ha\(^{-1}\) and test weight with increase in N levels from 100 to 200 kg ha\(^{-1}\) during winter season in Deccan 103 hybrid maize in a sandy loam soil under irrigated condition.

Yield attributes of spring maize variety, Ageti 76 increased with higher N application of 225 kg ha\(^{-1}\) over 150 and 75 kg N ha\(^{-1}\) in sandy loam soils of Hissar under irrigated condition (Tyagi et al., 1998). A study conducted in Madhya Pradesh during winter season on five improved maize varieties revealed that increased N levels from 80 to 240 kg ha\(^{-1}\) resulted in significant increase in number of cobs, cob length and number of grains (Paradkar and Sharma, 1993). Maximum grains cob\(^{-1}\) and 100 grain weight were recorded by application of 230 kg N ha\(^{-1}\); the response was comparable with 180 kg N ha\(^{-1}\) (Ali et al., 1999).

Effect of N on grain yield of maize: Maize crop in general is responsive to the applied N fertilizer (Haque et al., 2002; Inman et al., 2005; Scharf et al., 2005). Parthipan and Premsekhar (2002) found that increased rates of N from 0 to 200 kg ha\(^{-1}\) increased the grain yield of hybrid maize COH 3, from 3.10 to 5.31 t ha\(^{-1}\) under irrigated condition at Coimbatore and also noticed that the response of grain yield to applied N was positive and linear. Ali et al. (1999) reported that the higher grain yield was obtained by application of 230 kg N ha\(^{-1}\). Mahmood et al. (1998) concluded that maximum grain yield (7.11 t ha\(^{-1}\)) was recorded in the maize crop fertilized with 300 kg N ha\(^{-1}\), that was, however, statistically on par with nitrogen level of 200 kg N ha\(^{-1}\) with a yield of (6.97 t ha\(^{-1}\)).

Masood et al. (2000) observed that maximum grain yield was recorded with 250 kg N ha\(^{-1}\) which did not statistically differ from treatment with 200 kg N ha\(^{-1}\). Paolo and Rinaldi (2008) observed that application of nitrogen from 0 to 300 kg N ha\(^{-1}\) significantly increased the grain yield. Kunjir et al. (2007) reported that in sweet corn, green cob yield and green biomass yield were significantly higher under the highest level of nitrogen (225 kg N ha\(^{-1}\)). Under irrigated conditions, a spacing of 60 x 20 cm (83,333 plants ha\(^{-1}\)) with 225 kg N ha\(^{-1}\) recorded maximum maize yield (Siva, 2007).

Luchsinger and Guzman (1999) obtained higher grain yield at enhanced N rates up to 260 kg N ha\(^{-1}\) in six early maturing maize hybrids. In a trial conducted at Lakhoti of Uttar Pradesh, maize crop responded to N application up to 200 kg ha\(^{-1}\) and recorded a yield of 4.73 t ha\(^{-1}\) (Singh et al., 2000). Singh and Sarkar (2001) reported that in maize cv. Swan, higher application of N increased the yield from 30 q to 40 q ha\(^{-1}\) with an additional yield increase of 33 percent over the State recommended dose of N (100 kg) in Jharkhand region. Tyagi et al. (1998) conducted an experiment on maize cv. Ageti 76 during spring season in sandy loam soil of Hissar and found that application of N at 225 kg ha\(^{-1}\) registered 137 percent increased grain yield over control. In an experiment conducted at Vazansai, higher rate of N application (210 kg ha\(^{-1}\) over recommended level (120 kg ha\(^{-1}\) increased the maize grain yield from 6.15 to 7.12 t ha\(^{-1}\) (Singh et al., 2003). Scharf et al. (2005) reported that the grain yield of maize increased with increasing N levels up to 280 kg ha\(^{-1}\).

Effect of N on stover yield of maize: Green and dry fodder yields of maize increased with each successive increment of N level (Thakur and Sharma, 1999; Parthipan and Premsekhar,
Linear response of stover yield with an increase in N levels was also observed by Varughese and Iruthayaraj (1996). Parasuraman (2005) reported that in maize, stover yield varied significantly with varying nitrogen levels and recorded higher stover yield at 170 kg N ha⁻¹. Several workers have reported that maximum stover yield in maize was obtained with an application of 175 to 180 kg N ha⁻¹ (Reddy et al., 1994; Singh et al., 2000 and Pandey et al., 2000). Nanjundappa and Manure (2002) reported that application of 150 kg N ha⁻¹ recorded the highest dry fodder yield of maize (34 t ha⁻¹) in comparison with absolute control (3.6 t ha⁻¹). Singh et al. (2003) reported that application of 210 kg N ha⁻¹ recorded the highest stover yield of 11.4 t ha⁻¹ in maize.

**Effect of N levels on nutrient uptake in maize:**

**Nitrogen:** Nitrogen uptake significantly increased with successive increment of N in maize (Al-Kaisi and Yin, 2003; Gehl et al., 2005). Nitrogen application significantly increased the N uptake of leaves, leaf sheath, stem, husk and maize cob upto 90 DAS, but uptake in the grain increased upto maturity (Imran et al., 2005). Maximum N uptake in maize was observed with applications of N ranging from 120 to 150 kg ha⁻¹ as reported by several workers (Adaiikkappan, 1996; Singh and Vyas, 1998; Shivay et al., 1999). Parasuraman (2005) reported that N uptake increased both in grain (37.1 to 52.4 kg ha⁻¹) and stover (47.2 to 74.7) when N levels were increased from 130 to 170 kg N ha⁻¹.

Application of 200 kg N ha⁻¹ recorded higher N uptake in hybrid maize COH 3 in a sandy loam soil at Coimbatore (Parthipan and Premsekhar, 2002). The results of the experiment conducted on sandy loam soil of Uttar Pradesh indicated that N uptake increased from 66.5 kg ha⁻¹ to 95.2 kg ha⁻¹ with increase in N application from 100 to 200 kg ha⁻¹, respectively, in Decoan 103 hybrid maize (Misra et al., 1994). Increase in N levels from 75 to 175 kg ha⁻¹ in clay loam soil of Coimbatore during kharif season increased the N uptake from 98.0 to 207.1 kg ha⁻¹ in CO 1 maize under irrigated condition (Selvaraju and Iruthayaraj, 1995).

**Phosphorus:** Several studies have shown that N application at higher rates increased the P uptake (Vadivel et al., 1999; Singh and Sarkar, 2001). Phosphorus uptake increased from 25 to 27 kg ha⁻¹ with increasing levels of N application from 75 to 175 kg ha⁻¹ on clay loam soil of Coimbatore under irrigated condition (Selvaraju and Iruthayaraj, 1995). Ramakrishnan (1992) reported that increased doses of N application from 135.0 to 202.5 kg ha⁻¹ increased the P uptake from 29 to 33 kg ha⁻¹ in CO 1 maize under Coimbatore conditions. Similarly, Adaiikkappan (1996) also found that P uptake significantly increased with 125 kg N ha⁻¹ (28 kg P ha⁻¹) as compared to 62.5 kg N ha⁻¹ (16 kg P ha⁻¹) in irrigated CO 1 maize on sandy clay loam soil of Coimbatore.

Parthipan and Premsekhar (2002) reported that P uptake increased from 25.3 to 32.0 kg ha⁻¹ when N level was increased from 100 to 200 kg ha⁻¹ on maize hybrid COH 3 in clay loam soil of Coimbatore. Increased N level from 0 to 150 kg ha⁻¹ increased the P uptake of grain (4.12 to 9.79) and stover (4.62 to 17.15), respectively (Manojkumar and Singh, 2003). Similarly, Adaiikkappan (1996) found that P uptake significantly increased with 125 kg N ha⁻¹ (28 kg P ha⁻¹) as compared to 62.5 kg N ha⁻¹ (16 kg P ha⁻¹) in irrigated CO 1 maize on sandy clay loam soil of Coimbatore.

**Potassium:** Potassium uptake increased with increasing levels of nitrogen (Manojkumar and Singh, 2003). In maize hybrid COH 3, K uptake increased from 165.5 to 191.0 kg ha⁻¹ with increasing levels of N application from 100 to 200 kg ha⁻¹ on clay loam soil of Coimbatore (Parthipan and Premsekhar, 2002). Selvaraju and Iruthayaraj (1995) observed that K uptake increased from 201 to 211 kg ha⁻¹ when the N level was increased from 75 to 175 kg ha⁻¹ on clay loam soil of Coimbatore under irrigated condition. Increase in N and K level increased the uptake of both the nutrients because of
synergistic effect between them (Nanjundappa et al., 1994).

**Effect of Phosphorus on maize**: Phosphorus, one of the major nutrients, plays an important role in plant nutrition. It is necessary for growth promotion, as it promotes cell division and nucleus formation.

**Effect of P on growth parameters of maize**: In plants, phosphorus is a common component of organic compounds. Phosphorus deficiency, however, significantly reduces plant growth (Marschner, 1997). Khan et al., (1999) reported that application of phosphorus at 120 kg P₂O₅ - ha⁻¹ increased the plant height over control. Alias (1997) reported that application of phosphorus at the rate of 125 kg P₂O₅ - ha⁻¹ to maize cv. Composite - 17 significantly increased the total leaf area and plant height. Saeed et al. (2001) observed that application of phosphorus at 90 kg P₂O₅ ha⁻¹ increased the plant height, number of leaves and leaf area over absolute control. Akhtar et al. (1999) found that growth parameters of hybrid maize varied significantly with increased levels of P (125 kg P₂O₅ - ha⁻¹).

**Effect of P on yield attributes of maize**: Yogananda et al. (1999) reported that in pop corn the yield components such as cob length, cob girth, rows cob⁻¹, grains row⁻¹ and test weight were higher under 75 kg P₂O₅ - ha⁻¹ than absolute control. Khan et al. (1999) reported that yield attributes of hybrid maize were favourably influenced at 120 kg P₂O₅ ha⁻¹ over control. Alias (1997) reported that application of phosphorus at the rate of 125 kg P₂O₅ - ha⁻¹ to maize cv. Composite - 17 markedly influenced the cob length, number of grain rows cob⁻¹, number of grains row⁻¹, 1000 grain weight and harvest index.

**Effect of P on grain yield of maize**: Muthusamy et al. (1990) reported that grain and stover yields of maize were the highest with optimum dose of P fertilizers in conjunction with FYM. Yogananda et al. (1999) reported that in pop corn there was a significant increase in grain yield when phosphorus was applied at 75 kg P₂O₅ - ha⁻¹. He also reported that increase in grain yield may be attributed to higher grain yield per plant. Khan et al. (1999) reported that in hybrid maize, yield level was significantly higher at higher phosphorus level of 120 kg P₂O₅ - ha⁻¹.

Saeed et al. (2001) reported that maize grain yield was higher at 90 kg P₂O₅ - ha⁻¹. Alias (1997) reported that application of phosphorus at the rate of 125 kg P₂O₅ - ha⁻¹ to maize cv. Composite - 17 significantly increased the grain yield (5.71 t ha⁻¹). Cabrerera et al. (1986) studied the effect of P fertilizer and found that application of P increased the grain yield of maize crop. Saleem et al. (2003) reported that grain yield increased with increase in dose of P fertilizer (70 kg P₂O₅ - ha⁻¹). Macbool and Silva (1998) and Gaitum et al. (2002) also reported the same findings. Ali et al. (2002) reported that yield of maize hybrid was significantly higher at 120 kg P₂O₅ - ha⁻¹ than at 60 kg P₂O₅ - ha⁻¹.

**Effect of P on stover yield of maize**: Ayub et al. (2002) noticed that phosphorus application increased the green fodder yield of maize. Yogananda et al. (1999) reported that in pop corn there was significant increase in stover yield when phosphorus was applied at 75 kg P₂O₅ - ha⁻¹. Saeed et al. (2001) reported that the highest fodder yield of 17.22 t ha⁻¹ was recorded in the plots fertilized with 90 kg P₂O₅ - ha⁻¹ against the lowest of 8.32 t ha⁻¹ in the control treatment. This value showed that more than 50% increase in fresh fodder yield.

**Effect of P levels on nutrient uptake in maize**: Ali et al. (2002) reported that in hybrid maize, nitrogen uptake increased with increasing levels of P and the highest uptake (76.17 kg N ha⁻¹) at maturity was observed at P level of 120 kg ha⁻¹, while plots that received no phosphorus had the least nitrogen uptake. Increasing levels of Phosphorus increased the uptake of N by grain and the maximum uptake
Effect of Potassium on maize: Maize has high yield potential and responds favorably to application of potassium fertilizer. Therefore, proper management of potassium nutrient is essential to realize maximum potential of the crop because it plays an important role in activating various enzymes. Potassium affects plant metabolism, although the amount needed for this purpose is very small. Large amount of potassium is also needed for regulation of different physico-chemical processes in plants including water utilization by the plants.

The intensive cropping activities at present have deprived the soil of essential plant nutrients such as nitrogen, phosphorus and potassium. This had resulted in lowering the yield of crops especially fast growing crops like maize. Until now, the use of chemical fertilizer has been mainly confined to the application of nitrogen and phosphorus, but no attention has been paid to potassium (Chaudhry and Malik, 2000).

Effect of K on growth parameters of maize: Akhtar et al. (1999) observed that maize recorded maximum plant height and leaf area when fertilized with 125 kg K₂O ha⁻¹ over control. Sadiq (2001) reported that potassium applied at 180 kg K₂O ha⁻¹ significantly increased the plant height and leaf area over other levels of potash.

Effect of K on yield attributes of maize: Yogananda et al. (1999) reported that in pop corn, there was significant increase in yield components such as cob length, cob girth, rows cob⁻¹, grains row⁻¹ and test weight when potassium was applied at 100 kg K₂O ha⁻¹. The significant difference in the number of grain row⁻¹ of 30.83 was recorded from treatment of 100 kg K₂O ha⁻¹. On the contrary, the lower number of grains row⁻¹ was recorded for control (Akhtar et al., 1999).

Ali et al. (2004) observed that potassium levels @ 150 kg K₂O ha⁻¹ produced significantly higher 1000 grain weight in hybrid maize. Maize responded positively to increase in K dose up to 150 kg K₂O ha⁻¹ in K deficient soils (Kovacevic et al., 2006).

Effect of K on grain yield of maize: The increment in K levels from 100 to 150 per cent increased the maize grain yield by 14.8 per cent (Sankaran et al., 2005). Yogananda et al. (1999) reported that pop corn yield increased significantly with increase in potassium levels. Higher potassium level (100 kg K₂O ha⁻¹) gave a higher grain yield (3097 kg ha⁻¹), whereas lower grain yield (2502 kg ha⁻¹) was obtained in plots which received no potassium.

Ali et al. (2004) observed that potassium levels at 150 kg K₂O ha⁻¹ resulted in higher grain yield in hybrid maize than other levels. These results are in line with Shahzad et al. (1996) who reported that the grain yield of maize increased with the increasing K doses. Differences in grain yield were significant and maximum grain yield of 6.02 t ha⁻¹ was recorded at 100 kg K₂O ha⁻¹ followed by 5.83 t ha⁻¹ at 75 kg K₂O ha⁻¹. Yield increased significantly with the increasing levels of K (Akhtar et al., 1999).

Mahmood et al. (2000) reported that application of K significantly increased grain yield over control. Maize crop fertilized with 200 kg K₂O ha⁻¹ produced higher grain yield (8.39 t ha⁻¹) followed by 150 and 100 kg K₂O ha⁻¹ which produced 8.06 and 7.39 t ha⁻¹, respectively and significantly differed from each other.

Effect of K on stover yield of maize: Yogananda et al. (1999) reported that in pop corn stover yield increased significantly with increase in potassium levels from 50 to 100 kg K₂O ha⁻¹. Chaudhry and Malik (2000) observed that potassium @ 150 kg K₂O ha⁻¹ significantly increased the stover yield up to 15.94 t ha⁻¹ and remained on par with yield obtained by application of potassium dose of 200 kg K₂O ha⁻¹. These results are in agreement with
Chaudhry and Roy (1992) Nanjundappa et al. (1994) conducted a field experiment in Bangalore to study the influence of potassium applications on the yield and quality attributes of fodder maize. Based on the study he concluded that application of K @ 75 kg K₂O ha⁻¹ increased the dry fodder yield of maize. Ali et al. (2004) observed that potassium levels @ 150 kg K₂O ha⁻¹ produced more stover yield in hybrid maize over other levels. The findings of Sadiq (2001) and Abid (2002) were also the same.

Effect of K levels on nutrient uptake in maize: Naidu et al. (2005) reported that increased dose of NPK fertilizers resulted in higher growth and productivity of fodder maize with better nutrient uptake. Yogananda et al. (1999) reported that in pop corn nutrient uptake were found to increase with potassium levels from 50 to 100 kg K₂O ha⁻¹. The results are in accordance with the findings of Roy and Kumar (1990).

Effect of N, P, and K levels on quality of maize grain: Nanjundappa and Manure (2002) observed that the crude protein content in fodder maize increased significantly by nitrogen application, since maize crop needs large amount of dry matter which augmented protein synthesis. Protein content generally increased with N fertilizer rate and the response can be linear or quadratic and the protein content increased from 65 g kg⁻¹ to 89 g kg⁻¹ when nitrogen is increased from 0 to 350 kg ha⁻¹ (Miao et al., 2006).

Increasing levels of N up to 200 kg ha⁻¹ resulted in significant increase in protein content of hybrid maize Decoan 103 on sandy loam soils of Uttar Pradesh under irrigated condition (Misra et al., 1994). Shannugusundaram and Govindaswamy (1984) reported that application of 90 and 120 kg N ha⁻¹ were on par and recorded significantly higher crude protein. In general, protein content of maize grain could be increased with application of N as reported by Muthukrishnan and Subramaniyan (1984) and Ippersiel et al. (1989). Ali et al. (1999) reported that all nitrogen levels significantly increased grain protein content with maximum (10.07 %) at 230 kg N ha⁻¹. Mahmood et al. (1998) recorded the highest; grain protein content (10.53 %) was recorded by the maize crop at 300 kg ha⁻¹ of applied nitrogen, which was however statistically equal to 200 kg N ha⁻¹ (9.75 %).

Rai et al. (1984) reported an increase in the leaves protein content of maize in response to phosphorus application. Mahmood et al. (2000) reported that in maize, 200 kg K₂O ha⁻¹ produced maximum grain starch content, oil content, and crude protein content but was statistically equal to 150 kg K₂O ha⁻¹. Chaudhry and Malik (2000) observed that potassium @ 150 kg K₂O ha⁻¹ resulted in enhanced grain protein content over the other levels. Miao et al. (2006) stated that both starch and extractable starch content were decreased by increase in N fertilization and they found that starch content decreased from 745 g kg⁻¹ to 725 g kg⁻¹ when N was increased from 0 to 350 kg ha⁻¹. Duraisami et al. (2002) concluded that starch content exhibited a reverse trend with increase in levels of N in maize. Anukumar et al. (2007) reported that in sweet corn, the per cent non reducing sugar varied widely among the treatments from a lowest content of 17.01 percent (75% RDF) to 24.38 per cent (125% RDF).

Spacing and Nitrogen Interaction on maize:

Interaction on growth parameters: Increased growth was dependent on the effect and interaction of both plant densities and N rate; the best results were obtained at 50,000 plants ha⁻¹ and 180 kg N ha⁻¹ in the maize hybrid, Knezha 530 (Andreinski et al., 2000). An experiment conducted at Hissar with maize variety, Ageti 76 with varying plant population and N levels revealed that successive increase in plant population from 95, 555 to 88, 888 and N levels from 0 to 225 kg ha⁻¹, increased plant height, number of leaves, LAI and drymatter
production (Singh et al., 1997). Mazaheri and Akbarzadeh (1999) reported that application of N at 100 kg ha\(^{-1}\) with 85,000 plants ha\(^{-1}\) recorded significantly higher plant height, LAI and dry matter production. An experiment conducted in Yuma, USA showed that N levels from 140 to 250 kg ha\(^{-1}\) and plant populations of 57,000 to 69,000 plants ha\(^{-1}\) were the best combinations for maize in irrigated condition (Mahdi et al., 2003). In a study at IARI, Delhi, uptake of nutrients increased significantly with increase in N application upto 200 kg ha\(^{-1}\) along with doubling the plant population to 1,11,000 plants ha\(^{-1}\) in sandy loam soil (Reddy and Khera, 2000).

**Interaction of N and plant density on yield and yield attributes:** In a study at New Zealand with sweet corn cv. Challenger, increased N (250 kg ha\(^{-1}\)) at 90,000 plants ha\(^{-1}\) recorded higher yield (Stone et al., 1999). Increased maize grain yield with doubled plant density of 1,11,111 plants ha\(^{-1}\) was recorded in sandy loam soil at New Delhi (Reddy and Khera, 2000). During kharif, application of 150 per cent of recommended N (202.5 kg ha\(^{-1}\)) with 130 per cent of recommended population recorded higher maize yield (5210 kg ha\(^{-1}\)) than the recommended level under irrigated condition of Coimbatore (Sankaran et al., 2005). In a study at Rahuri of Maharashtra on African tall maize, plant spacings and N level significantly affected the yield and yield attributes. The yield attributes were higher in wider spacing (75 x 30 cm) with 200 kg N ha\(^{-1}\) (Khot et al., 1993).

Irrespective of N levels (100-200 kg ha\(^{-1}\)), grain yield markedly increased with crop geometry upto 95,000 plants ha\(^{-1}\). Crop geometries of 53,000 to 98,000 plants ha\(^{-1}\) significantly increased the grain yield with N level upto 200 kg ha\(^{-1}\) in Deccan 103 hybrid maize (Misra et al., 1994). An experiment conducted at China, showed that the plant population of 82,500 plants ha\(^{-1}\) and N at 450 kg ha\(^{-1}\) were optimum for Tangdan 82 hybrid maize (Biqiu et al., 1999). Yield was significantly enhanced by increasing the plant density from 40,000 to 90,000 ha\(^{-1}\) and N levels from 0 to 180 kg ha\(^{-1}\). Maximum grain yield of 7270 kg ha\(^{-1}\) was obtained at 180 kg N with 90,000 plants ha\(^{-1}\) in Partab 1 maize under irrigated condition in sandy loam soil at Hisar.

**Economics:** In sweet corn, the maximum net profit (Rs. 15,200 ha\(^{-1}\)) was obtained with a spacing of 60 x 25 cm at Orissa (Sahoo and Mahapatra, 2004). Chandenkar et al. (2005) observed that cultivating maize at 60 x 20 cm spacing resulted in higher net return and B:C ratio (Rs. 19, 268 ha\(^{-1}\) and 2.62). Higher net return (Rs. 44,751 ha\(^{-1}\)) and B:C ratio (2.83) was obtained with baby corn at 30 x 30 cm spacing (Kumar, 2007). Siva (2007) reported that the highest gross return (Rs. 41,216 ha\(^{-1}\)) and net return (Rs. 26,662 ha\(^{-1}\)) and B:C ratio (2.77) was recorded at 60 x 20 cm spacing. In Dharwad the two maize genotypes, Deccan 103 and G 25 under increased plant density from 55,555 to 1,11,111 plants ha\(^{-1}\) recorded higher net income (Rs. 16,221) and B:C ratio of 3.1 (Gollar and Patil, 2000). The highest net profit of Rs. 4916 was obtained with a plant population of 90,000 plants ha\(^{-1}\) with 180 kg N ha\(^{-1}\) (Bangarwa et al., 1989). Radhavathi and Gopalswamy (1995) reported that the gross return ha\(^{-1}\) (Rs. 10,274), net return ha\(^{-1}\) (Rs. 6,334) and net return per rupee invested (Rs.1.61) were higher with the application of 120 kg N ha\(^{-1}\) in irrigated maize, CO 1.

Application of 200 kg N ha\(^{-1}\) recorded the highest net return (Rs. 48,481) in baby corn (Thakur and Sharma, 1999). Similarly application of 200 kg N ha\(^{-1}\) could be more economical and recorded higher gross (Rs.34,377) and net return ha\(^{-1}\) (Rs.22,227) in hybrid maize, COH 3 under irrigated condition at Coimbatore (Parthipan and Premasekhar., 2002). Sankaran et al. (2005) opined that the enhancement in fertilizer application to the tune of 25-50 percent above the recommended level increased the gross, net return and B:C ratio. Application of 150 per
cent recommended dose of fertilizer with recommended maize population (83,333 plants ha\(^{-1}\)) is suggested for obtaining maximum productivity and B:C ratio under irrigated condition.

Baby corn sown at 40 x 20 cm spacing gave maximum net return (Rs. 50,843 ha\(^{-1}\)) as reported by Thakur and Sharma (1999). Sahoo and Panda (1997) also opined that among the different crop geometry, 40 x 20 cm recorded the highest net return. Ameta and Dakur (2000) reported that higher monetary return and B:C ratio of maize were obtained with narrow row spacing (60 cm) when compared to wider (75 cm) row spacing. Saeed et al. (2001) observed that application of Phosphorus at 90 kg P\(_{2}O_{5}\) ha\(^{-1}\) increased the net income of maize crop (Rs.45,931 ha\(^{-1}\)) over control (Rs.15,096 ha\(^{-1}\)). Mahmood et al. (2000) concluded that application of K significantly increased the net income ha\(^{-1}\) over control. Application of 200 kg K\(_{2}O\) ha\(^{-1}\) gave maximum net income of Rs. 32,694 ha\(^{-1}\) and was statistically equal to 150 kg K\(_{2}O\) ha\(^{-1}\) but significantly differed from 100 kg K\(_{2}O\) ha\(^{-1}\). From the foregoing review, information pertaining to plant density and fertilizer requirement of hybrid maize varies widely. In maize, the effect of plant density and fertilizer levels is well documented. Summarizing the review undertaken, it is understood that the potential productivity of hybrid maize could be achieved when it is grown under optimum spacing and high fertilizer levels. In this context, the present review would pave way to improve the productivity of maize in order to get higher profit under irrigated condition.

REFERENCES