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# EFFECT OF PLANT POPULATION AND NITROGEN LEVELS AND METHODS OF APPLICATION ON EAR CHARACTERS AND YIELD OF MAIZE

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**Abstract**

Field experiments were conducted at Agricultural Research Farm, NWFP Agricultural University, Peshawar, Pakistan during summer 2006 and 2007 in randomized complete block design with split plot arrangements having three replications. Four plant populations (4.5, 6, 7.5 and 9 plants $m^{-2}$), three nitrogen levels (80, 120 and 160 kg $ha^{-1}$) and three nitrogen application methods (full dose at emergence, half each at emergence and knee height, one third each at emergence, knee height and pre-tasseling stages) were included in the experiments. Plant populations (PP) were kept in the main plot, while combinations of nitrogen levels (N) and nitrogen application methods were kept in the sub-plots. Maize variety Azam was sown with the help of a planter in a plot size of 3 x 3 $m^2$ with row to row distance of 75 cm. Grain and biological yields increased with increase in PP from 4.5 plants $m^{-2}$ to 7.5 plants $m^{-2}$ but further increase in PP did not significantly enhance grain and biological yields of maize. Likewise, increase in N level significantly improved grain and biological yields of maize up to 120 kg $ha^{-1}$. Similarly, N application in three splits performed better than sole or two splits in terms of biological yield production in maize. HI consistently increased with increase in PP from 4.5 plants $m^{-2}$ to 9 plants $m^{-2}$. Ear characters were not affected by PP except grain weight which was higher at PP of 7.5 plants $m^{-2}$. In similar fashion, N level significantly affected only grains $row^{-1}$ and grain $ear^{-1}$. Both grains $row^{-1}$ and grain $ear^{-1}$ increased with increase in N level from 80 to 160 kg $ha^{-1}$ but the N level of 120 and 160 kg $ha^{-1}$ were statistically at par with each other. It is concluded that higher yield and better ear characters were obtained at PP of 7.5 plant $m^{-2}$ with N application @120 kg $ha^{-1}$.

## Introduction

More maize is produced worldwide than any other cereal grain and it is of huge importance to subsistence farmers and commercial farmers alike (Anon., 2005). In Pakistan, it is the third most important cereal grain crop after wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.) and is used as a staple food for humans, as feed for livestock and as raw material for industry (Harris *et al*., 2007). During 2006, it was planted on 1.042 million hectares in Pakistan, with total production of almost 3.109 million tonnes. In the North West Frontier Province (NWFP), maize was sown on around 0.492 million hectares with production of nearly 0.782 million tons and an average yield of only 1.59 t $ha^{-1}$ reflecting the high proportion of rainfed cropping in the province (Anon., 2005). There are two seasons of maize production; the spring season crop is sown from mid-February to the end of March and the main summer crop from June to mid-July. Both seasons' crops have durations of about 3–4 months. Mostly open-pollinated maize cultivars are sown (Chaudhry, 1994).

The importance of plant population (PP) as a factor determining growth and yield has been well established for the main maize production areas (Cox, 1996). Determining corn PP response is a recurrent area of study but it is very inconsistent across different environment and management practices. For example, Norwood & Currie (1996) reported that dryland corn performed best at PP not exceeding 44500 plants $ha^{-1}$. Contrary to that, Norwood (2001) achieved maximum grain yield of maize at PP up to 60,000 plants $ha^{-1}$. However, no yield differences were found for low corn populations of 21000, 24700 and 37100 plants $ha^{-1}$ (Havlin & Lamm, 1988). In a summary of research, results from locations across the USA and Canada, corn grain yields leveled off but did not decrease above the optimum plant population, except in those fields with yield levels below 7500 kg $ha^{-1}$ (Paszkiewicz & Butzen, 2001). Modern hybrids typically have a greater tolerance of high plant density than older hybrids (Tollenaar, 1992).

Nitrogen plays an important role in crop life. It is one of the most important nutrients needed by plants in large quantities. It is essential to know the best level of nitrogen application for getting a higher crop yield so that maximum benefits could be achieved. In cereals, adequate nitrogen increases the plumpness of grains and their proteins content. Adequate nitrogen promotes vigorous vegetative growth and deep green color. Nitrogen had been recognized as one of the most limiting nutrient. Its use and demand is continuously increasing day by day. Since it is highly mobile, it is subjected to greater loss from the soil plant system. Even under the best management practices, 30-50% of the applied N is lost (Stevenson, 1985) and hence the farmer is compelled to apply more than the actual need of the crop to meet the losses. The loss of N not only harasses the farmers but it also has hazardous impact on the environment (Gosh & Bhat, 1998). Higher inputs of chemical fertilizer for sustainable crop production cause soil degradation and environmental pollution (William, 1992). Thus it is the need of the time to search not only for the optimum N level of a crop but also to find out appropriate method for its application to reduce the losses. Different approaches may be adopted for effective and efficient utilization of nitrogenous fertilizers.

It is very difficult rather impossible to recommend a single level of N for maize without considering the variation in locations, soil types and other factors. Therefore, different researchers have found optimum corn yields at different level of N. For example, Al-Kaisi & Yin (2003) found optimum corn yield at 140 to 250 kg N $ha^{-1}$. Gehl *et al*., (2005) reported that a split application of 185 kg N $ha^{-1}$ was sufficient to achieve maximum corn yield and in most instances 125 kg N $ha^{-1}$ was sufficient. Ma *et al*., (2005) found that grain yields increased significantly with fertilizes rates up to 120 kg N $ha^{-1}$.

Timing of fertilizer N application is an important management tool in this effort (Jokela & Randall., 1989). Maximum efficiency is obtained when N is applied so it is available for uptake by the plant as needed. This suggests that plant uptake of fertilizers N is more efficient when applied just prior maximum plant need. At the six leaf stage, maize starts its most active growth and substantially increases N and water consumption (Ritchie & Hanway, 1982) and therefore, fertilization at six-leaf stage is more efficient than the application at planting (Wells *et al*., 1992). The period of rapid growth and nutrient uptake by grain crops occur about 35 days after emergence (Vanderlip, 1993) at the eight-leaf growth stage. Field studies under both irrigated and non irrigated conditions in Nebraska (Rehm & Wiese, 1975), Illinois (Welch *et al*., 1971), Wisconson (Bundy, 1992) and New York (Lathwell *et al*., 1970) have shown increased grain yields and more efficient use of fertilizer N by corn when N application was delayed until several weeks post emergence rather than applied before planting.

These experiments were conducted to study the response of PP to N levels and their methods of application and to find out an optimum N level with a proper method of application for a particular PP in maize.

## Materials and Methods

**Experimental site:** Peshawar has a warm to hot, semi-arid, sub-tropical, continental climate with mean annual rainfall of about 360 mm. Summer (May–September) has a mean maximum temperature of 40°C and mean minimum temperature of 25°C. Winter (December to the end of March) has mean minimum temperature of 4°C and a maximum of 18.4°C. The average winter rainfall is higher than that of summer. The highest winter rainfall has been recorded in March, while the highest summer rainfall is in August. Soil of the experimental site is deficient in N, P and available Zn, but has adequate K. Canal water is available for irrigation (Harris *et al*., 2007). The physio-chemical properties of the experimental site are given in Table 1.

**Experimental description:** The field experiments were conducted at Agricultural Research Farm, NWFP Agricultural University, Peshawar, Pakistan during summer 2006 and 2007. The experiments were laid out in randomized complete block design with split plot arrangements having three replications. Four plant populations (45,000, 60,000, 75,000 and 90,000 plants $ha^{-1}$), three nitrogen levels (80, 120 and 160 kg $ha^{-1}$) and three nitrogen application methods (full dose at emergence, half each at emergence and knee height, one third each at emergence, knee height and pre-tasseling stages) were included in the experiment. Plant populations were kept in the main plot, while combinations of nitrogen levels and nitrogen application methods were kept in the sub-plots. Maize variety Azam was sown with the help of a planter in a plot size of 3 x 3 $m^2$ with row to row distance of 75 cm. Plant populations were maintained by thinning after emergence. For plant populations of 45,000, 60,000, 75,000 and 90,000 plants $ha^{-1}$, plant to plant distances of 30 cm, 22 cm, 17.6 cm and 15 cm, respectively were maintained. Phosphorus was applied @100 kg $ha^{-1}$ at the time of sowing. Urea and single super phosphate (SSP) were used as sources of nitrogen and phosphorus.

**Data analysis:** The data recorded were analyzed statistically combined over years by statistical package Genstat v 8.1. Main and interaction effects were compared using LSD test at 0.05 level of probability, when the F-values were significant (Steel & Torrie, 1980).

## Results and Discussion

**Grain yield:** Grain yield varied significantly with plant population (PP) and N levels (N). The effects of year and N application methods (M) were not significant. None of the interactions was significant. Grain yield increased with increase in PP from 4.5 to 7.5 plants $m^{-2}$ but further increase in PP did not significantly enhance grain yield of maize. Higher grain yield (8490 kg $ha^{-1}$) was recorded at PP of 9 plants $m^{-2}$ followed by grain yield (8097 kg $ha^{-1}$) obtained at PP of 7.5 plants $m^{-2}$. Minimum grain yield (4823 kg $ha^{-1}$) was recorded at the lower PP of 4.5 plants $m^{-2}$. Likewise, increase in N level significantly improved grain yield up to 120 kg $ha^{-1}$. Maximum grain yield (7216 kg $ha^{-1}$) was obtained at the highest N level of 160 kg $ha^{-1}$ followed by N level of 120 kg $ha^{-1}$ where grain yield of 6943 kg $ha^{-1}$ was recorded and minimum grain yield (6715 kg $ha^{-1}$) was obtained at the lowest N rate of 80 kg $ha^{-1}$.

**Table 1. Physico-chemical properties of the experimental site.**

| | |
|---|---|
| Sand (%) | 8.7 |
| Silt (%) | 51.3 |
| Clay (%) | 40.0 |
| Textural Class | Silty clay loam |
| Organic matter (g $kg^{-1}$) | 0.845 |
| Total N (g $kg^{-1}$) | 0.04 |
| $CaCo_3$ (%) | 14.4 |
| pH 1:1 Water | 8.02 |
| Electrical Conductivity (dS $m^{-1}$) | 0.87 |
| **AB-DTPA extractible nutrients** | |
| P (mg $kg^{-1}$) | 3.80 |
| K (mg $kg^{-1}$) | 105 |
| Zn (mg $kg^{-1}$) | 0.86 |

Data from Bhatti (2002) and Tariq *et al.*, (2002) for Agricultural University Peshawar farm.

Grain yield per unit area increases with plant density until the increase in yield attributable to plants is offset by decline in mean yield per plant (Tollenaar & Wu, 1999). On the other hand, lower than optimum plant density delays canopy closure with reduced interception of seasonal incident solar radiation (Westgate *et al*., 1997), leading to greater number of grains per plant, but lower grain yield per unit area (Andrade *et al*., 1999). However, response to plant population is dependent on location, variety and season. Different researchers have obtained greater yield at different PP. For example, Shapiro & Wortmann (2006) reported that maximum grain yield and yield response to applied N can be achieved with 62000 plants $ha^{-1}$. Similarly, Nafziger (1994) found that maize hybrids were especially responsive to higher plant density under adequate rainfall but less responsive when there was insufficient precipitation. Bavec & Bavec (2002) also found an increase in grain yield with increasing PP.

Various studies indicate that optimum fertilizers and plant populations provide better crop growth and yield (Workayehu, 2000). However, response to N fertilizer is variable depending upon amount and distribution of moisture, soil fertility and variety (Workayehu, 2000). Many researchers have reported increase in grain yield and yield components due to application of high levels of N (El-Sheikh, 1998); Samira *et al*., 1998). Zeidan and Amany (2006) reported that applied N tended to improve plant growth and development of yield attributes which in turn results in increasing seed yield. Our results are supported by El-Sheikh (1998) who reported that application of 160 kg N $ha^{-1}$ significantly increased grain yield of maize. Likewise, Zeidan and Amany (2006) reported that maize grown in soil amended with 140 kg N $ha^{-1}$ gave the highest yield compared with the control. They ascribed the increase in yield to increased availability of N which causes accelerated photosynthetic rate and thus leading to the production of more carbohydrates. In similar fashion, Killorn & Zourarakis (1992) reported least yield of hybrid maize from control plots and improved yield from the higher rate of N (196 kg $ha^{-1}$). However, our results do not agree with Kayode & Agboola (1981) who reported that optimum N required for maize varies between 50 and 100 kg $ha^{-1}$. Similarly, Shapiro & Wortmann, (2006) found that grain yield regularly increased with application of 84 kg N $ha^{-1}$ but response to higher rates of N was inconsistent.

**Table 2. Grain yield, biological yield and harvest index of maize as affected by plant population and nitrogen levels and methods of application.**

| Plant population (PP) | Grain yield (kg ha$^{-1}$) | Biological yield (kg ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|
| 45,000 | 4823 c | 13243 c | 36.8 c |
| 60,000 | 6422 b | 15212 b | 42.9 b |
| 75,000 | 8097 a | 18303 a | 44.4 b |
| 90,000 | 8490 a | 18408 a | 46.6 a |
| LSD | 689.9 | 1171 | 1.871 |
| **Nitrogen levels (N)** | | | |
| 80 kg ha$^{-1}$ | 6715 a | 15203 b | 43.7 |
| 120 kg ha$^{-1}$ | 6943 ab | 16530 a | 42.3 |
| 160 kg ha$^{-1}$ | 7216 a | 17142 a | 42.4 |
| LSD | 466.2 | 1352 | NS |
| **Methods (M)** | | | |
| Sole | 6728 | 16047 b | 42.3 |
| Two splits | 6615 | 15865 b | 42.8 |
| Three splits | 6989 | 16961 a | 42.9 |
| LSD | NS | 1352 | NS |
| Year 1 | 6930 | 16552 | 41.9 |
| Year 2 | 6986 | 16031 | 43.5 |
| Significance level | NS | * | NS |
| **Interactions** | Significance | | |
| PP x N | NS | NS | NS |
| PP x M | NS | NS | NS |
| N x M | NS | NS | NS |
| PP x N x M | NS | NS | NS |

* = Significant at 5% level of probability; NS = Non-significant

Means of the same category followed by different letters are not significantly different at 5% level of probability.

**Biological yield:** Biological yield varied significantly with year, PP, N and M. However, none of the interactions was significant. Higher biological yield was recorded during first year than second year of the experiments. Biological yield increased with increase in PP from 4.5 to 7.5 plants m$^{-2}$ but further increase in PP did not significantly enhance biological yield of maize. Higher biological yield (18408 kg ha$^{-1}$) was recorded at PP of 9 plants m$^{-2}$ followed by biological yield (18303 kg ha$^{-1}$) obtained at PP of 7.5 plants m$^{-2}$ which were statistically at same level with each other. Likewise, increase in N level from 80 to 160 kg ha$^{-1}$ improved biological yield but the N levels of 120 and 160 kg ha$^{-1}$ produced statistically similar biological yield. Maximum biological yield (17142 kg ha$^{-1}$) was obtained at the highest N level of 160 kg ha$^{-1}$ followed by N level of 120 kg ha$^{-1}$ where grain yield of 16530 kg ha$^{-1}$ was recorded. N application in three splits performed better than sole or two splits in terms of biological yield production in maize. Our results agree with Gul *et al*., (2009) who reported that biological yield increased with increase in plant density. Our results are also in line with Alam *et al*., (2003) and Sikandar *et al*., (2007) who obtained higher biological yield at 80,000 and 95,000 plants ha$^{-1}$, respectively. The results regarding N levels are also in line with Shapiro and Wortmann (2006) who reported that corn biomass increased with applied N. Similarly, Ogunlela *et al*., (1988) reported that growth and yield components in field grown maize were enhanced by nitrogen fertilization ranging from 50 to 200 kg N ha$^{-1}$.

**Table 3. Ear characteristics of maize as affected by plant population and nitrogen levels and its methods of application.**

| Plant population (plant ha$^{-1}$) | Grains rows ear$^{-1}$ | Grains row$^{-1}$ | Grains ear$^{-1}$ | 100-grain weight (g) |
|---|---|---|---|---|
| 45,000 | 13.5 | 30.4 | 409 | 32.2 ab |
| 60,000 | 13.0 | 31.2 | 406 | 31.8 ab |
| 75,000 | 13.4 | 31.1 | 415 | 33.2 a |
| 90,000 | 13.2 | 29.5 | 390 | 30.4 b |
| LSD | NS | NS | NS | 2.456 |
| **Nitrogen levels (N)** | | | | |
| 80 kg ha$^{-1}$ | 13.3 | 29.4 b | 392 b | 315 |
| 120 kg ha$^{-1}$ | 13.1 | 31.0 a | 407 ab | 322 |
| 160 kg ha$^{-1}$ | 13.4 | 31.1 a | 416 a | 320 |
| LSD | NS | 1.691 | 15.75 | NS |
| **Methods (M)** | | | | |
| Sole | 13.1 | 29.3 c | 400 | 318 |
| Two splits | 13.4 | 30.1 b | 405 | 312 |
| Three splits | 13.3 | 31.9 a | 411 | 326 |
| LSD | NS | 1.691 | NS | NS |
| Year 1 | 13.1 | 31.8 | 416 | 32 |
| Year 2 | 13.5 | 29.3 | 394 | 32 |
| Significance level | NS | NS | NS | NS |
| **Interactions** | | | | |
| PP x N | NS | NS | NS | NS |
| PP x M | NS | NS | NS | NS |
| N x M | NS | NS | NS | NS |
| PP x N x M | NS | NS | NS | NS |

* = Significant at 5% level of probability; NS = Non-significant

Means of the same category followed by different letters are not significantly different at 5% level of probability.

**Harvest index:** Year as a source of variation significantly affected harvest index (HI) of maize. Similarly, HI also varied significantly with PP. The effects of N levels and methods were not significant. All the interactions were also not significant. HI was higher during second year of the experiments. Likewise, HI consistently increased with increase in PP from 4.5 to 9 plants m$^{-2}$. Higher HI was recorded at PP of 9 plants m$^{-2}$ followed by 7.5 and 6 plants m$^{-2}$ which were statistically at par with each other. Lower HI was recorded at the lowest PP of 4.5 plants m$^{-2}$.

Our results do not agree with Shapiro & Wortmann (2006) who found that HI decreased with increase in PP or HI was similar at all populations. Likewise, Workayehu (2000) reported that increasing PP from 25000 to 75000 plants ha$^{-1}$ did not affect grain stover ration. Our results regarding N levels, however agree with Shapiro & Wortmann (2006) and Workayehu (2000) who observed that nitrogen rate did not affect HI but do not agree with Ogunlela *et al*., (1988) who reported that grain stover ratio increased as N fertilization rate was increased up to 100 or 150 kg ha$^{-1}$.

**Ear characters:** Year as a source of variation did not significantly affect any of the ear traits. PP also did not significantly affect grain row ear$^{-1}$, grains row$^{-1}$, grain ear$^{-1}$ but significantly affected hundred grain weight of the maize crop. Grain weight was higher at

PP of 7.5 plants $m^{-2}$ followed by PP of 4.5 and 6 plants $m^{-2}$ and were all statistically at same level. Higher grain weight of 33.2 g was recorded for PP of 7.5 plants $m^{-2}$ while minimum grain weight of 30.4 g was recorded for the highest PP of 9 plants $m^{-2}$. In similar fashion, N level did not significantly affect any of the ear traits except grains $row^{-1}$ and grain $ear^{-1}$. Both grains $row^{-1}$ and grain $ear^{-1}$ increased with increase in N level from 80 to 160 kg $ha^{-1}$ but the N level of 120 and 160 kg $ha^{-1}$ were statistically at par with each other. Higher number of grains $row^{-1}$ (31.1) and grain $ear^{-1}$ (416) were produced by N level of 160 kg $ha^{-1}$ followed by N level of 120 kg $ha^{-1}$. Minimum number of grains $row^{-1}$ (29.4) and grain $ear^{-1}$ (392) were produced by the lowest N level of 80 kg $ha^{-1}$.

The competition between maize plants for light, soil fertility and other environmental factors usually increase with increase in PP (Ali *et al*., 1994). Likewise, Bavec & Bavec, (2002) reported that number of grain rows and number of rows $ear^{-1}$ significantly changed due to increase in PP. In similar fashion, many researchers observed that grains per ear usually decrease with increase in PP. For instance, Remission & Lucas, (1982) and Bavec and Bavec, (2002) noted that increase in PP decreased number of grains $ear^{-1}$. On the other hand, lower than optimum PP delay canopy closure with reduced interception of seasonal incident solar radiation (Westgate *et al*., 1997), leading to greater number of grains per plant and therefore Remision & Lucas, (1982) reported that increase in PP did not affect number of grains $row^{-1}$. Similarly, grain weight may not be (Tethio-kagho & Gardner, 1988) or may (Hashemi-Dezfouli & Herbert 1992) be affected by PP.

The results regarding N levels agree with Samira *et al*., (1998) who found that yield and yield components of maize were increased by increasing the rate of applied nitrogen. El-Sheikh (1998) reported that applying 160 kg N $Fed^{-1}$ while Zeidan & Amany (2006) reported that soil amended with 140 kg N $acre^{-1}$ significantly increased ear characters and grain yield of maize. Increased grain yield and yield components due to application of high N were also reported by El-Sheikh (1998); Griesh & Yakout, (2001); Samira *et al*., (1998). Maqsood *et al*., (2001) reported that nitrogenous fertilizer improves number of grain $ear^{-1}$. Likewise, Maqsood *et al*., (2001) reported that N level of 120 kg $ha^{-1}$ produced significantly higher thousand grain weight and Khan *et al*., (2005) recorded significantly higher cobs $plant^{-1}$, 1000 grain weight, number of grains $cob^{-1}$ and grain yield with 120 kg N $ha^{-1}$.

## Conclusion

Higher grain and biological yields and grain weight were obtained at PP of 7.5 plants $m^{-2}$. Likewise, grain and biological yields, grains $row^{-1}$ and grain $ear^{-1}$ increased up to 120 kg N $ha^{-1}$. Nitrogen application method did not have any noteworthy effect. Therefore it can be inferred form the results that higher yield and ear characters were obtained at PP of 7.5 plants $m^{-2}$ with N application of 120 kg $ha^{-1}$.

## References

Alam, M.M., M.M. Basher, A. Karim, M.A. Rahman and M.R. Islam. 2003. Effect of rate of nitrogen fertilizer and population density on the yield and yield attributes of maize (*Zea mays* L.). *Pakistan J. Biol. Sci*., 6(20): 1770-1773.

Al-Kaisi, M.M. and X. Yin. 2003. Effect of nitrogen rate, irrigation rate, and plant population on corn yield and water use efficiency. *Agron. J*., 95: 1475-1482.

Andrade, F.H., C. Vega, S. Uhart, A. Cirilo, M. Cantarero and O. Valentinuz. 1999. Grains number determination in maize. *Crop Sci*., 39: 453-459.

Anonymous. 2005. *Agricultural Statistics of Pakistan* 2004–2005. Ministry of Food, Agriculture and Livestock, Government of Pakistan, Islamabad, Pakistan.

Bavec, F. and M. Bavec. 2002. Effects of plant population on leaf area index, cob characteristics and grain yield of early maturing maize cultivars (FAO 100-400). *European J. Agron*., 16: 151-159.

Bhatti, A.U. 2002. *Soil Fertility Status of Malakandher Farm*. Soil Bull. 6. Dept. Soil and Env. Sci., NWFP Agricultural University, Peshawar, Pakistan.

Bundy, L.G. 1992. Urease inhibitors: NBPT use with surface-applied urea and 28% N solution. *New Horizons in Soil Science*. No. 2-92. Department of Soil Science, University of Wisconsin. 7 p.

Chaudhry, A.R. 1994. Fodder crops. In: *Crop Production*. (Eds.): S. Nazir, E. Bashir and R. Bantel. *National Book Foundation*, Islamabad, Pakistan. p. 402.

Cox, W.J. 1996. Whole plant physiological and yield responses of maize to plant density. *Agronomy J*., 88: 489-496.

Dwyer, L.M., M. Tollenaar, D.W. Stewart. 1991. Changes in plant density dependence of leaf photosynthesis of maize (*Zea mays* L.) hybrids. *Can. J. Plant Sci*., 71: 1-11.

El-Sheikh, F.T. 1998. Effect of soil application of nitrogen and foliar application with manganese on grain yield and quality of maize (*Zea mays,* L). *Proc. 8th Conf. Agron*., *Suez Canal Univ., Ismailia, Egypt*, 28-29 Nov., pp. 182-189.

Gehl, R.J., J.P. Schmidt, L.D. Maddux and W.B. Gordon. 2005. Corn yield response to nitrogen rate and timing in sandy irrigated soils. *Agron*. *J.,* 97: 1230-1238.

Gosh, B.C. and R. Bhat. 1998. Environmental hazards of nitrogen loading in wet land rice fields. *Environmental Pollution*, 102 (1st Supply): 123-126.

Gul, B., K.B. Marwat, G. Hassan, A. Khan, S. Hashim and I.A. Khan. 2009. Impact of tillage, plant population and mulches on biological yield of maize, *Pak. J. Bot*., 41(5): 2243-2249.

Harris, D., A. Rashid, G. Miraj, M. Arif and H. Shah. 2007. 'On-farm' seed priming with zinc sulphate solution—A cost-effective way to increase the maize yields of resource-poor farmers. *Field Crops Res*., 102: 119-127.

Havlin, J.L. and F.R. Lamm. 1988. Management of dryland corn for the central great plains. p.837-838. In: *Challenges in dry land Agriculture- a global perspective*. (Eds.): P.W. Unger *et al*., Proc. Int. Conf. on Dryland Farming, Amarillo, TX. 15–17 Aug. 1988. Texas Agric. Exp. Stn., College Station.

Jokela, W.E. and G.W. Randall. 1989. Corn yield and residual soil nitrate as affected by time and rate of nitrogen application. *Agron .J*., 81: 720-726.

Kayode, G.O. and A.A. Agboola. 1981. Effect of different N levels, plant population and soil nutrient status on yield and yield components of maize (*Zea mays* L.) in different ecological zones of Nigeria. *Nutrient cycling in agro-ecosystems,* 2(3): 177-191.

Khan, A., A. Jan and S. Alam. 2005. Effect of nitrogen and seed size on maize crop II: yield and yield components. *J. Agric. Soc. Sci*., 1(3): 18 23.

Killorn, R. and D. Zourarakis. 1992. Nitrogen fertilizer management effects on corn grain yield and nitrogen up take. *J. Production Agric*., 5: 142-148.

Lathwell, D.J., D.R. Bouldin and W.S. Reid. 1970. Effect of nitrogen fertilizer application in agriculture. P. 192-206. In relationship of agriculture to soil and water pollution. *Proc. Cornell Univ. Conf. on Agric. Wast Mgmt., Syrecuse, NY*. 19-21 Jan. 1970. Cornell univ., Ithaca, NY.

Ma, B.L., K.D. Subedi and C. Costa. 2005. Comparison of crop-based indicators with soil nitrate test for corn nitrogen requirement. *Agron*. *J*., 97: 462-471.

Maqsood, M., A.A. Abid, A. Iqbal and M.I Hussain. 2001. Effect of Variable Rates of Nitrogen and Phosphorus on Growth and Yield of Maize (Golden). *J. Biol. Sci*., 1(1): 19-20.

Nafziger, E.D. 1994. Corn planting date and plant population. *J. Production Agric*., 7: 59-62.

Nafziger, E.D. 1996. Effects of missing and two-plant hills on corn grain yield. *J. Prod. Agric*., 9: 238-240.

Norwood, C.A. 2001. Dry land corn in Western Kansas: Effects of hybrid maturity, planting date and plant population. *Agron. J*., 93: 540-547.

Norwood, C.A. and R.S. Currie. 1996. Tillage, planting date and plant population effects on dryland corn. *J. Prod Agric*., 9: 119-122.

Ogunlela, V.B., G.M. Amorwa and O.O. Ologunde. 1988. Growth, yield components and micronutrient nutrition of field-grown maize (*Zea mays* L.) as affected by nitrogen fertilization and plant density. *Fert. Res*., 17: 189-196.

Paszkiewicz, S. and S. Butzen. 2001. Corn hybrid response to plant population. *Crop Insights*, 11(6): 1-5. Pioneer Hi-Bred Int. Johntial ston, IA.

Rehm, G.W. and R.A. Wiese. 1975. Effect of method of N application on corn (*Zea mays* L.) grown on irrigated sandy soil. *Soil Sci. Soc. Am. Proc*., 39: 1217-1220.

Remision, S.U. and E.O. Lucas. 1982. Effects of planting density on leaf area and productivity of two maize cultivars. *Exp. Agric*., 18: 93-100.

Ritchie, S.W. and J.J. Hanway. 1982. *How a corn plant develops*. Spec. Rep. 48. Coop. Ext. Ser., Iowa State Univ., Ames.

Samira M., A. Hussein, M.A. Haikel and M.A. El-Masry. 1998. Effect of some preceding crops, hill spacing and nitrogen fertilization on yield attributes and grain yield of maize under reclaimed sandy soil conditions in East Delta. *Proc. 8th Conf. Agron., Suez Canal Univ., Ismailia, Egypt*, 28-29 Nov. pp. 174-181.

Shapiro, C.A. and C.S. Wortmann. 2006. Corn response to nitrogen rate, row spacing, and plant density in eastern Nebraska. *Agron. J.,* 98: 529-535.

Sikandar, A., M. Ali, M. Amin, S. Bibi and M. Arif. 2007. Effect of plant population on maize hybrids. *J. Agric. Biol. Sci*., 2(1): 1990-6145.

Steel, R.G.D. and J.H. Torrie. 1980. *Principles and procedures of statistics: A biometrical approach*. 2nd ed. McGraw-Hill, New York.

Stevenson, F.J. 1985. The nitrogen cycle in soil: Global and ecological aspects. P. 106-153. In: *Cycles of Soils*. A Wiley Inter. Sci. Public. New York, USA.

Tariq, M., M.A. Khan and S. Perveen. 2002. Response of maize to applied soil zinc. *Asian J. Plant Sci*., 1(4): 476-477.

Tethio-Kagho, F. and F.P. Gardner. 1988. Responses of maize to plant population density. II. Reproductive Development, yield and yield adjustments. *Agron. J*., 80: 935-940.

Tollenaar, M. and A. Aguilera. 1992. Radiation use efficiency of an old and a new maize hybrid. *Agron. J*., 84: 536-541.

Tollenaar, M. and J. Wu. 1999. Yield improvement in temperate maize is attributable to greater stress tolerance. *Crop Sci*., 39: 1597-1604.

Vanderlip, R.L. 1993. *How a sorghum plant develops*. Coop. Ext. Serv. Contrib. 1203, Kansas Agric. Exp. Stn., Manhattan, KS.

Welch, L.F., D.L. Mulvaney, M.G. Oldham, L.V. Boone and J.W. Pendleton. 1971. Corn yields with fall, spring, and side dress nitrogen. *Agron. J*., 63: 119-123.

Wells, K.L., W.O. Thoms, and H.B. Rice. 1992. Response of no-till corn to nitrogen source, rate, and time of application. *J. Prod. Agric*., 5: 607-610.

Westgate, M.E., F. Forcella, D.C. Reicosky and J. Somsen. 1997. Rapid canopy closure for maize production in the northern US Corn Belt: Radiation use efficiency and grain yield. *Field Crops Res*., 49: 249-258.

William, P.H. 1992. The role of fertilizers in environmental pollution. In: *Proc. of Inter. Symp. on nutrient management for sustainable productivity*. Deptt. Soil, Punjab Agric. Univ. Ludhiana, India. pp.195-215.

Workayehu, T. 2000. Effect of N fertilizer rates and plant density on grain yield of maize. *African Crop Sci. J*., 8(3): 273-282.

Zeidan, M.S., M.F. Amany Bahr El-Kramany. 2006. Effect of N-Fertilizer and Plant Density on Yield and Quality of Maize in Sandy Soil. *Res. J. Agric. Biol. Sci*., 2(4): 156-161.

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