

INFLUENCE OF PLANT HEIGHT AND OF LEAF NUMBER ON MAIZE PRODUCTION AT HIGH PLANT DENSITIES¹

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ABSTRACT - This experiment was conducted in Ames, Iowa, US, with the purpose of verifying if reduction in plant height, through the use of dwarfing genes, or leaf number, by growing short season genotypes, can be a useful strategy to reduce barrenness and improve maize tolerance to drought and high plant population stresses. Five genotypes were tested: a full season hybrid, a short season hybrid, and three dwarf lines, containing the homozygous recessive genes *d3*, *br2* and *d1*. Each genotype was planted at four plant populations: 25,000, 50,000, 75,000 and 100,000 plants.ha⁻¹. There was no significant drought stress during the entire growing season of 1994. High plant population decreased number of grains per ear of dwarf lines and did not affect this variable for hybrids. Consequently, differences in yield between hybrids and dwarves were greater at the higher plant populations. Inbreeding depression, unimproved genetic background and poor plant architecture limited the response of dwarf grain yield to the increase in plant population.

Index terms: *Zea mays*, plant population, grain yield.

INFLUÊNCIA DA ESTATURA DA PLANTA E DO NÚMERO DE FOLHAS NA PRODUÇÃO DE MILHO EM ALTAS DENSIDADES POPULACIONAIS

RESUMO - Este trabalho foi conduzido em Ames, Iowa, Estados Unidos, com o objetivo de verificar se a redução na estatura, mediante a utilização de genes de nanismo, ou do número de folhas produzidas por planta, através do cultivo de materiais de ciclo superprecoce, podem contribuir para aumentar o rendimento de grãos de milho, em ambientes de alta densidade de semeadura e restrição hídrica. Cinco genótipos foram avaliados: um híbrido de ciclo normal, um híbrido superprecoce e três linhagens anãs contendo os genes *d3*, *br2* e *d1*. Cada genótipo foi semeado em quatro densidades, equivalentes a 25.000, 50.000, 75.000 e 100.000 plantas.ha⁻¹. Não houve incidência de deficiência hídrica durante o período experimental. A utilização de densidades elevadas reduziu o número de grãos por espiga das linhagens anãs e não interferiu significativamente nesta variável nos híbridos. Conseqüentemente, as diferenças em rendimento de grãos entre híbridos e linhagens anãs foram maiores nas populações mais densas. Depressão endogâmica, falta de uma melhor base genética e presença de uma arquitetura de plantas inapropriada limitaram a resposta do rendimento de grãos das linhagens anãs ao incremento na densidade populacional das plantas.

Termos para indexação: *Zea mays*, população de plantas, rendimento de grãos.

INTRODUCTION

Population density, whether operating directly on the plant or indirectly on biotic factors associated with plant density, is one of the most important fac-

tors in determining grain yield and other important agronomic attributes of a crop (Meyer, 1970). The corn plant is less capable of adjustment to a poor stand than other members of the grass family. Modern maize varieties do not tiller much, even at low plant densities, and very often produce only one ear per plant. Therefore, maize does not have the flexibility of most crop species, which can increase leaf area and number of reproductive units by branching at low crop densities (Gardner et al., 1985).

On the other hand, the use of high populations may be detrimental to final yield by stimulating api-

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cal dominance and inducing barrenness. As the number of plants in a planting pattern increases, distance between plants decreases and competition among individuals increases (Duncan, 1984). At lower than maximum yield population, adding more plants compensates for the lowered grain yield per plant due to the increased crowding. Above some population, however, the effect of rapidly increasing crowding due to the closer plant spacing can't be offset by the yield of the added plants. Consequently, grain yield per unit area beyond this point decreases as a consequence of the sharp reduction in kernel number and kernel size produced per plant (Lemcoff & Loomis, 1994).

For each production situation, there is a population that maximizes the utilization of the resources available, especially light, water and nutrients, allowing the production of maximum grain yield. Optimum corn population for maximum economic grain yield varies with cultivar, row width, soil fertility, soil water and climatic effects (Dungan et al., 1958; Larson & Hanway, 1977).

Two important factors to consider in defining optimum population for maize are plant architecture and water availability. Generally speaking, tall and leafy cultivars require low densities to maximize grain yield per area (Aldrich et al., 1986). It is also well known that increasing plant density increases leaf area index and, consequently, water consumption (Tetio-Kagho & Gardner, 1988). The use of high plant populations under limited water supply may increase plant stress and reduce grain yield dramatically, specially if the water shortage coincides with the period of 2-3 weeks bracketing silking (Classen & Shaw, 1970; Frey, 1981; Westgate, 1994). Therefore, drought stress, particularly when combined with high plant density, can cause complete loss of grain production, if severe stress occurs during the tasseling and silking stage of reproduction (Herrero & Johnson, 1981; Edmeades et al., 1993).

Theoretically, with a smaller and less leafy plant, the level of competition of each individual over the others should be lower. Thus, more individuals can be planted per unit of land area and fewer inputs per plant should be required. In a water limited environment, the lower amount of vegetative biomass

should reduce water costs per plant for vegetative growth and maintenance, resulting in greater resource availability for grain production.

Two ways to reduce plant height and leaf number are 1) dwarfing genes, and 2) selection for earliness. A number of dwarf and semi-dwarf mutants are available and the trait is simply inherited (Neuffer et al., 1968). Most of the experiments reported in the literature to evaluate dwarf maize were performed in the late 50s and early 60s by Leng (1957), Leng & Ross (1959), Pendleton & Seif (1961, 1962), and Sowell et al. (1961). The main objective at that time was to develop a plant with a better standability and that could withstand high plant populations under favorable edaphic and climatic conditions.

No report in the literature was found of an experiment with the specific purpose of evaluating the possible advantages of short stalked cultivars over normal maize at high plant population and dry environments. There is some indirect evidence derived from experiments with growth retardants that a reduction in plant height has the potential for improving resistance to drought in corn (Shanahan & Nielsen, 1987; Kasele et al., 1994). In support to this approach, Ackerson (1983) observed, in a comparison of two drought resistant hybrids, that the more resistant material was shorter and produced fewer, smaller and shorter leaves. In addition to that, Kriedemann & Barrs (1983) noticed that the ratio of potential evapotranspiration to potential photosynthesis increases with height in high insolation and windy environments. Consequently, shorter plants are better adapted than taller plants to such conditions.

This work was designed to evaluate if reductions in plant height, through the use of dwarfing genes, or leaf number, by growing short season genotypes, may be an effective way to reduce barrenness and to increase grain yield under high plant population and limited water availability.

MATERIAL AND METHODS

The experiment was performed during the growing season of 1994, in Ames, Iowa, US. The climate of the region is classified as Dfa, cold with a moist winter and a hot summer. Study site soil was a Nicollet loam (Fine-loamy, mixed, mesic Aquic Hapludoll).

The trial was designed as a factorial combination of two factors: cultivar and plant density. The experimental design was a split plot with the main plots arranged in a randomized complete block. Each treatment was replicated four times. In the main plot, five genotypes were evaluated: one full season hybrid adapted to Central Iowa (Northrup king 4525), one short season hybrid adapted to northern Minnesota (Cargill 1077) two no-tillering (156-A, 117-A) and one tillering inbred lines (302-E), containing, respectively, the homozygous recessive dwarfing genes *d3*, *br2* and *d1*.

In the split plot, four plant populations were tested: 25,000, 50,000, 75,000 and 100,000 plants.ha⁻¹. Each split plot was constituted by four 6 meter rows, spaced 0.50 cm equidistantly. The space between two adjacent plants within each row was 0.8, 0.4, 0.267 and 0.2 m for the densities of 25,000, 50,000, 75,000 and 100,000 plants.ha⁻¹, respectively.

Fertilizer was applied according to soil test recommendations from the ISU soil testing laboratory. The experiments were hand-planted on May 3, 1994. Three seeds were dropped per hill to assure the desired stand on each treatment. When plants were at stage V4 (Ritchie & Hanway, 1982), thinning was performed to adjust the population to desired levels. Plots were also hand-hoed and wheel-hoed to control weed competition.

At anthesis, five plants randomly chosen within each split plot were used to determine number of leaves produced per plant. Earlier in the season, the tips of the fourth and eighth leaf were marked with a non-washable ink, serving as a reference point to correctly determine the total number of expanded leaves. Plant height was also measured on five plants in the two central rows of the plot when they reached R3, the milk stage (Ritchie & Hanway, 1982).

Harvesting was done by hand when the leaves of each variety senesced entirely. The two central rows of each split plot were harvested, representing an area of 6 m². Ears were dehusked, dried, shelled and weighed. To determine grain yield, values were converted to an area of one hectare and adjusted to a standard moisture of 15.5%. A sub-sample of 200 grains was taken and re-weighed. The value obtained was multiplied by 5 and converted to a moisture of 15.5% to express the weight of 1,000 grains. The number of grains per ear was estimated indirectly through the relationship between weight of 200 grains, weight of total number of kernels and number of ears harvested within each split plot.

An analysis of variance was performed using the General Linear Models procedure of the Statistical Analysis System (SAS), version 6.07 for Unix Systems (SAS

Institute, 1987). F values for main treatment effects and their interactions were considered significant at the $P < 0.05$ level. Whenever a particular factor or interaction of factors significantly influenced a variable, means were separated using Fischer's LSD test at the 0.05 probability level, following methodology presented in Little & Hills (1978). To provide better understanding of the main effects and their interactions, specific orthogonal contrasts were calculated.

The following contrasts were examined:

Cultivar effect

a1: hybrids (NK 4525 + C 1077) x dwarves (156-A + 117-A + 302-E);

a2: full season hybrid (NK 4525) x short season hybrid (C 1077);

a3: tillering dwarf (302-E) x non-tillering dwarves (156-A + 117-A);

a4: non-tillering dwarf 1 (156-A) x non-tillering dwarf 2 (117-A).

Density effect

b1: linear effect;

b2: quadratic effect.

A regression analysis was performed and the linear and quadratic effects for each significant contrast were calculated. The equations that provided higher coefficients of determination, and that better explained the biological behavior of the genotypes, were chosen to summarize the information gathered for each variable. To describe the results, plant densities of 25,000, 50,000, 75,000 and 100,000 pl.ha⁻¹ are represented by the numbers 1, 2, 3 and 4, respectively. Linear and quadratic equations were also calculated with these values of x .

RESULTS AND DISCUSSION

Overall precipitation in 1994 was slightly below average. However, no significant water deficit was observed, probably due to the great soil-moisture reserve carried from the previous season (1993 was an year with a record amount of precipitation in Iowa), and also due to the cooler temperatures experienced during periods of potentially high evaporative demand.

No effect of plant density was detected on rate of growth and development of the plants. Hybrids germinated faster than dwarf inbreds (Table 1). No difference in the amount of time required for emergence was observed between the two hybrids or among the three dwarves. Plants of the early hybrid

silked in approximately 20% less time after emergence, when compared to the hybrid adapted to central Iowa conditions. Dwarves showed slower vegetative development, reaching the silking stage more than a week after the full season hybrid. Little difference among the dwarves was noticed in time required to reach silking. Despite their slow vegetative development, dwarves had quicker leaf senescence after anthesis than hybrids. This contributed to speed their grain development, decreasing the amount of time between silking and harvesting in comparison to hybrids. The full season hybrid was the cultivar with the slowest rates of leaf senescence.

Considering each cultivar individually, the theoretical population to accomplish maximum yield (optimal population) was rather different. NK 4525 reached maximum grain yield at 99,000 pl.ha⁻¹, whereas the ideal population for the short season hybrid could not be estimated because its yield increased linearly within the range of densities used (Fig. 1). The maximum potential yield of the dwarves was achieved between 70,000 and 80,000 pl.ha⁻¹, depending on the material. Little difference in grain yield within the dwarves was observed, regardless of plant density. Considering mean values of the four plant populations tested in the trial, hybrids yielded 10.12 Mg.ha⁻¹ whereas dwarves produced 3.64 Mg.ha⁻¹.

Hybrids and dwarves responded differently to the increase in plant population (Fig. 2). Within the range of plant densities evaluated, hybrids increase

grain yield by 1.9 Mg.ha⁻¹ for each increment of 25,000 pl.ha⁻¹. In contrast, dwarf grain yield went quadratically up to 82,500 pl.ha⁻¹ and then declined. Therefore, differences in yield between dwarves and

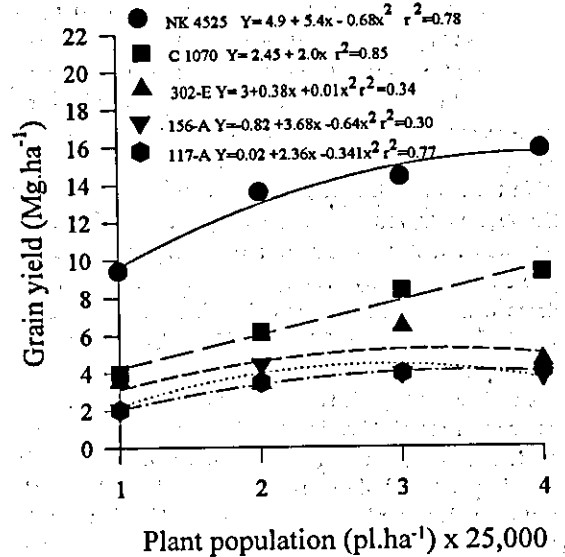


FIG. 1. Grain yield of a full season hybrid (NK 4525), a short season hybrid (C 1077), a tillering (302-E) and two no-tillering (117-A e 156-A) dwarf inbred lines, at four plant populations, Ames, Iowa, 1994.

TABLE 1. Phenological development of a full season hybrid (NK 4525), a short season hybrid (C 1077), a tillering (302-E) and two no-tillering (117-A e 156-A) dwarf inbred lines, averaged at four plant populations, Ames, Iowa, 1994.

Phenological stage ¹	NK 4525	C 1077	302-E	156-A	117-A
Duration of phenological stages (days) ²					
Pl - Em	12	12	16	16	16
Em - Sil	57	46	68	67	66
Sil - Har	77	64	54	56	62
Pl - Har	146	122	138	139	144

¹ Pl = planting; Em = emergence; Sil = silking; Har = harvesting.

² Number of days when at least 50% of the plants on each split plot reached the specific phenological stage.

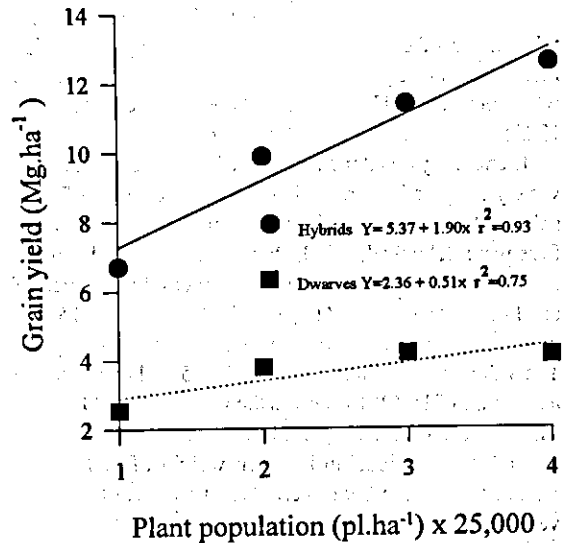


FIG. 2. Grain yield of hybrids and dwarf lines at four plant populations, Ames, Iowa, 1994.

hybrids were more accentuated at higher plant populations.

Weight of 1,000 grains was affected significantly by cultivar and by the contrast a1(hybrids x dwarves)* b2(quadratic effect of plant density). NK 4525 had grains that were 22% heavier than C 1077 (Table 2). Non-tillering dwarves 156-A and 117-A produced heavier grains than the tillering short stalked line 302-E. Regardless of plant density, weight of 1,000 grains was higher for hybrids than for dwarf lines (Fig. 3). Moreover, hybrids were able to increase grain weight with increase in population up to 60,000 pl.ha⁻¹. In contrast, plant populations above 25,000 pl.ha⁻¹ promoted a decrease in weight of 1,000 grains of dwarves.

Similarly, number of grains produced per ear was higher in the full season hybrid than in the short season hybrid, and in the non-tillering dwarves than in the tillering line (Table 2). Hybrids did not vary number of grains produced per ear significantly at the range of populations evaluated (Fig. 4). On the other hand, this yield component was reduced by 21 grains each time dwarf plant population was increased by 25,000 pl.ha⁻¹.

Number of grain bearing ears was affected differently in each genotype by the increase in plant population. The tillering dwarf-line 302-E produced

more ears per plant than the other materials, particularly at the lower plant populations (Fig. 5). This line tillered profusely at 25,000 and 50,000 pl.ha⁻¹. Some of the tillers produced were well developed and had grain bearing ears, which contributed to

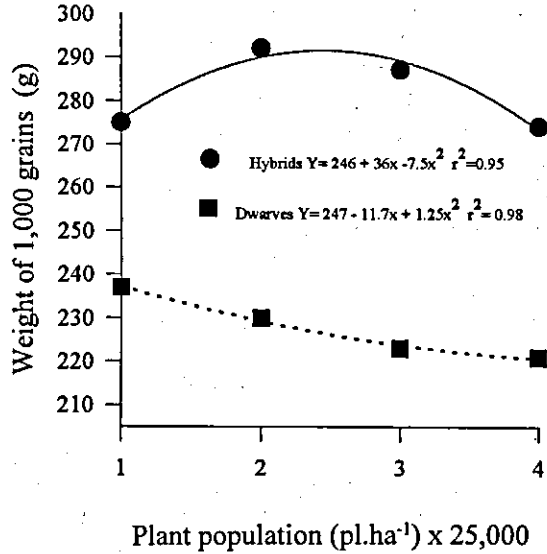


FIG. 3. Weight of 1,000 grains of hybrids and dwarf lines at four plant populations, Ames, Iowa, 1994.

TABLE 2. Yield components, plant height and number of leaves per plant of a full season hybrid (NK 4525), a short season hybrid (C 1077), a tillering (302-E) and two non-tillering (117-A e 156- A) dwarf inbred lines, averaged at four plant populations, Ames, Iowa, 1994¹.

Genotype	Grains per ear (n°)	Weight of 1,000 grains (g)	Plant height (cm)	Leaves per plant (n°)
NK 4525	592 a	310 a	241 a	18.8 b
C 1077	356 b	254 b	143 b	15.4 c
302-E	245 d	211 d	135 c	20.1 a
156-A	269 c	232 c	112 d	20.0 a
117-A	274 c	241 c	134 c	19.0 b
L S D A means	27	11	5.6	0.5
C.V. A (%)	10.1	5.5	4.7	3.8
C.V. B (%)	11.5	7.0	5.0	2.9

¹ For each variable, means followed by the same letter in the column are not significantly different by the LSD test (P=0.05).

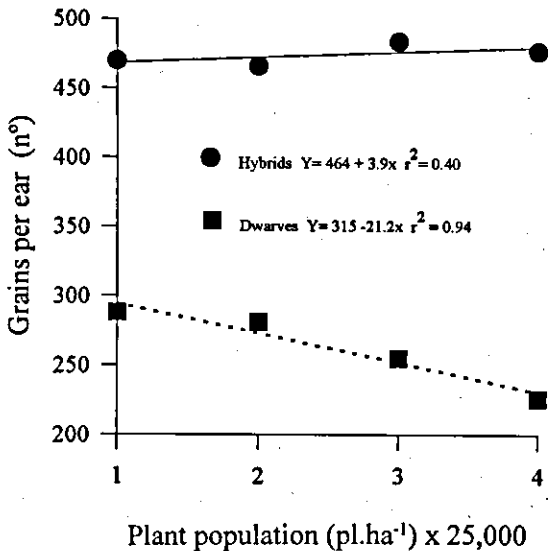


FIG. 4. Grains per ear of hybrids and dwarf lines at four plant populations, Ames, Iowa, 1994.

the high number of fruiting sites observed at low plant populations. All cultivars decreased number of ears per plant with increase in plant population. The rates of decrease were more accentuated in the tillering dwarf, intermediate in the hybrids and very small for the non-tillering dwarves (Fig.5). Consequently, there were more significant differences in the number of viable ears among materials at the lower than at the higher plant populations.

Plant height was significantly influenced by the single effects of cultivars and plant density. Averaged of all cultivars, each increase in 25,000 pl.ha⁻¹ promoted an increase of 2.7 cm in plant height. The cultivars can be classified in four categories in terms of their stature, when averaged across plant densities (Table 2). The long season hybrid had taller plants than the short season hybrid, which, in turn, was taller than the other dwarves. Among the dwarves, 156-A had smaller plants than the other two materials.

Number of leaves produced per plant was only affected significantly by cultivar. The short season hybrid had the lowest number of leaves per plant of

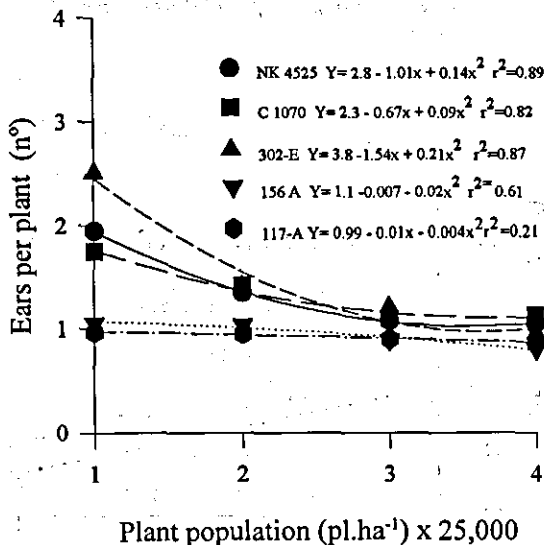


FIG. 5. Ears per plant of a full season hybrid (NK 4525), a short season hybrid (C 1077), a tillering (302-E) and two no-tillering (117-A and 156-A) dwarf inbred lines, at four plant populations, Ames, Iowa, 1994.

all materials, when averaged across plant densities (Table 2). Dwarves produced more leaves than hybrids regardless of plant density.

The response of grain yield to the increase in plant population observed in this experiment was higher than what has been reported by Stickler (1964), Andrew & Peek (1971), Olson & Sanders (1988) and Tollenaar (1992). Most published results from various states in the US have shown few instances where yield continues to increase above 70,000 pl.ha⁻¹ unless corn was irrigated. In the present study, hybrids improved grain production per area above 70,000 pl.ha⁻¹ without irrigation (Fig. 1 and 2).

One of the main causes of yield reduction at high plant densities is an increase in barrenness. High interplant competition for light, water and nutrients may decrease grain yield per plant to the extent that the addition of more plants can't compensate for the loss of production on an individual plant basis, resulting in lower grain production per area (Duncan, 1984). Usually the yield component that is affected most negatively by greater than optimum population is the number of grains per ear (Lemcoff & Loomis, 1986, 1994; Jacobs & Pearson, 1991). In contrast to what has been reported in the literature, the increase in plant population did not decrease the number of kernels set per ear for the hybrids (Fig. 4) which contributed to their positive response to plant density.

Several factors can be advanced to explain the higher than average response of grain yield to plant density. First, 1994 was a season with very favorable climatic conditions for corn growth and development in Central Iowa, registering record yields in the whole state. No significant periods of water deficit were observed during the most critical stages of the crop ontogeny. Increasing plant population increases water use and thereby generally enhances the potential for water stress (Downey, 1971). Adequate water availability undoubtedly played an important role in improved yield response to plant density. Associated with favorable weather, the fertile soil of the experimental area probably also helped support higher than average plant populations. Additionally, a narrow row spacing may have provided better distribution of plants and better utilization of solar radiation. Reducing row width to pro-

vide a more equidistant spatial pattern may shift optimum plant population to a higher value, particularly in early plantings, with high fertility levels, and good water availability (Pasziwick, 1994).

The higher yield per area of hybrid NK 4525, relative to C 1077, regardless of plant density (Fig. 1), was mainly due to higher number of grains per ear and to the production of heavier grains (Table 2). The short season hybrid reached anthesis 11 days earlier than the full season hybrid (Table 1). A positive relation between number of days to flowering and yield has been reported for Hallauer et al. (1967), Tollenaar (1977) and Olson & Sanders (1988). Short season hybrids hasten the period between ear differentiation and silking. The shorter time available for ear development and spikelet differentiation may negatively impact the number of potential spikelets available to be fertilized, decreasing kernels set per ear. On the other hand, the lower number of leaves produced by these genotypes (Table 2) may also represent a source limitation contributing to limit their ability to fill a higher number of kernels. Milborn (1977), Hunter (1980) and Salvador (1984) have pointed out that the source capacity of the plant may be the major factor limiting yield of maize cultivars grown at high latitudes.

The short season hybrid had a shorter silking-harvesting period than the full season-hybrid. Even though physiological maturity was not precisely determined in this experiment, it appears that C 1077 also had a shorter grain filling period than NK 4525, which might have contributed to decrease 1,000-grain weight and yield. A strong positive correlation between filling period duration and final yield has been reported by Crosbie & Mock (1981) and Dwyer et al. (1994). Therefore, under favorable environmental conditions, specially lack of drought stress, reduction in leaf number through earliness was not an efficient strategy to improve maize grain yield at high plant densities in relation to a full season hybrid adapted to Central Iowa.

As in earlier reports of Pendleton & Seif (1961), dwarf lines yielded significantly less per area than hybrids (Fig. 1 and 2). Contrary to the initial hypothesis, reduction in plant size through introduction of dwarfing genes did not improve the performance of the plants at higher plant populations. The

higher absolute values of grain yield presented by the hybrids over the dwarf lines was an expected result since almost always hybrids yield better than inbred lines regardless of using dwarfing genes. However, the expectation was that the relative difference in yield between hybrids and dwarf lines should be lower at the higher plant populations which did not happen. In fact, the higher the population the greater the difference in yield per area between the hybrids and the dwarf lines. The superiority in yield expressed by the hybrids was mainly due to their heavier grains and greater number of grains per ear, regardless of plant density (Table 2 and Fig. 3 and 4).

Genetic and physiological constraints probably limited a better agronomic performance of the dwarf lines used in the trial at the high plant populations. It was not possible to obtain any elite source of dwarfness that could be compared to its normal counterpart. With the early disappointing results derived from experiments carried out in the late 50s and early 60s, the whole dwarfing program was abandoned by most seed companies and today it is almost impossible to find commercial source of dwarf elite genotype. The genetic background of lines 117-A, 302-E and 156-A was a mixture of old inbreds, including W23, M13 and L 317, which are not used commercially any longer. Those inbreds were important parents of midwestern hybrids in the 60s and 70s and have been maintained by selfing and sib-crossing for many years. Therefore, inbreeding depression and unimproved genetic background are important factors explaining the poorer relative performance of the dwarves in comparison to the hybrids.

Several measured attributes of the dwarves accounted for their grain yield variation. Dwarves required more time to reach silking than hybrids (Table 2). For normal corn cultivars, there is usually a positive correlation between length of the period emergence-flowering and the size of the female inflorescence. This did not happen with the dwarves. Their large number of leaves would indicate that they take more time to differentiate reproductive structures. They might also have had lower rates of ear development after differentiation. Both things have been observed by Stephens (1948) and Stein (1955),

and may help to explain the lack of a better association between the length of emergence-silking period and the size of the dwarf ear.

The dwarves used in this experiment presented the same kind of plant architecture problems reported by Katta & Castro (1970) and Castro (1975). In spite of their small stature, their number of leaves was at least similar to the full season hybrid (Table 2). The combination of these two factors resulted in very short internodes and the emergence of leaves in a single vertical plane. The presence of short internodes and the uniform directional alignment of leaves may have prevented better penetration of solar radiation into the canopy, even at the lower plant densities. Therefore, dwarf plant architecture probably increased intraplant competition for light, which in turn may have reduced source potential for providing assimilates to the developing reproductive structures. Besides promoting heavy shading, the close superposition of leaves around the ear node may also have created a physical barrier to pollination. With the tight arrangement of leaves around the ear, pollen could not have reached silks as efficiently as it should, contributing to reduce kernel set.

The early senescence of dwarf leaves (Table 1) is evidence that the filling period was shorter for dwarves than for hybrids. The shorter filling period may have contributed to decrease 1,000 grain weight of the dwarves. Lemcoff & Loomis (1986) and Salvador & Pearce (1995) have pointed out that differences in final grain weight among corn genotypes are determined mainly by differences in effective filling period.

The shorter filling period of dwarves can be linked to limitations in source potential, sink strength, or both. Fischer (1975), Stay (1976), Tollenaar (1977) and Salvador (1984) have suggested that both sink and source limitations may occur in crop plants and the particular combination of genotype and environment determines which one predominates. One could hypothesize that limitations in photosynthesis promoted by poor canopy architecture and unimproved genetic background led to limiting ear sink capacity of the dwarves. There is evidence that maize sink strength is, to some extent, related to assimilate supply to the ear during the pre-flowering and flowering period. In addition, leaf photosynthetic rates may

be affected by grain demand (Moss, 1962; Thiagarajah et al., 1981). When fertilization of the ears is prevented totally or partially, photosynthetic rates decline continuously. This correlation between leaf assimilation and sink demand during grain filling has also been reported in other crops by Thorne & Koller (1974). So, it is possible that early senescence, shorter grain filling period and the production of lighter grains in the dwarves are all consequences of the weak sink establishment at the beginning of the filling phase.

Almost all the information reported in the literature, plus the data generated herein, indicate that reduction in plant height alone, through the use of dwarfing genes, will not improve maize tolerance to high plant population. It is also important to reduce the number of leaves and to select for optimum leaf arrangement. In addition, these features should be incorporated into an improved genetic background. The presence of drought stress and the development of isogenic elite dwarf inbred lines are important points to observe, so that a better comparison can be made between dwarves and their normal counterparts in terms of tolerance to high plant population and reduction in barrenness.

CONCLUSIONS

1. Reduction in plant height through the use of dwarfing genes does not decrease barrenness or improve relative grain yield of maize inbred lines at high plant populations, in relation to a full season hybrid adapted to Central Iowa.
2. Inbreeding depression, the lack of a better genetic background and the close superposition of numerous leaves around the ear node prevent better agronomic performance of the dwarf lines at high plant densities.

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