Effect of planting date, population density, genotype and seed quality on growth, grain yield and yield components of corn (*Zea mays* L.)

by

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DEDICATION

This thesis is dedicated to my beloved wife Modesta, our sons Chikuta and Kaswana and those to come.

To my mother and father (who is not with us today) I say thank you for the everlasting support, encouragement and love given to me during the course of my upbringing and education.

"It is indeed true that life could be better."

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BACKGROUND INFORMATION

It is generally assumed that about 10% of the corn seeds (*Zea mays* L.) planted will not survive to produce harvestable plants (Johnson et al., 1986). Farmers usually take that into consideration when selecting their seeding rates. However, corn stands are frequently less than the farmers intended (Hicks, 1979). Some of the factors responsible for reduced stand are: low seed germination (or vigor), improper planting depth, unfavorable soil conditions during or following corn planting, pests, pesticide or fertilizer injury, mechanical damage, late frost, hail or a combination of the above (Johnson and Mulvaney, 1980; Benson, 1990; Hicks, 1979). Stand reductions can occur at different dates and often result in uneven plant distribution (Johnson and Mulvaney, 1980). When the final stand of corn achieved from the initial planting dates is lower than optimum, the corn producer must decide whether the original stand or a stand replanted at a later date would be the most profitable (Benson, 1990).

Before replant decisions can be made, a knowledge of what is optimum relative to planting date and stand level for the location in question is essential. Unfortunately, many replant decisions are based on emotion rather than the best possible agronomic facts available (Benson, 1990). Factors such as stand and stand uniformity, calendar date, potential replant date, health of existing plants, pest problems, hybrid characteristics and maturity, seed availability, replant costs, stand risks for a replant and crop choice must be considered (Johnson and Mulvaney, 1980; Benson, 1984; Johnson et al., 1986).

The objectives of this study were to ascertain how certain genotypic characters (fixed or flex ear type) and seed quality (low and high) influence growth and grain yield and yield components of corn relative to planting date and plant population and, in turn, how they may influence corn replant decisions.

REVIEW OF LITERATURE

Date of Planting

Early corn planting can contribute significantly to higher corn yields. Research results have shown that yields begin to decline when planting occurs later than the optimum corn planting date for an area (Hicks and Wright, 1987). Crookston et al. (1976) and Bretzlaff and Boon (1970) have reported that grain yields are generally reduced when planting is delayed until late May or early June. On average, the best time to plant corn in most of Iowa is from April 20 to May 10. The optimum planting date will vary from year to year; however, to finish planting by May 10 is a goal most Iowa farmers should work toward. Benson (1984), Johnson and Mulvaney (1980), have reported that adapted hybrids tend to yield more than early season hybrids when planted before May 20. With delayed planting, full season hybrids often lose yield potential more rapidly than early season hybrids (Johnson, 1978). Carter (1984) has reported that early planting produces shorter plants that allow increased light penetration and tend to lodge less at high populations.

In a study of planting date and fertilizer using an adapted variety, Walker and Mulvaney (1980) found that as planting date was delayed (May 22 to June 15) the grain yield response to nitrogen fertilizer decreased. At the early and moderately early dates (end April to May 22) however, yields did respond to the highest nitrogen rates (154 kg per hectare). Results from this study showed that early planted corn responds better to higher nitrogen rates than does late planted corn.

Various studies have indicated significant yield reductions occur with late planting regardless of the maturity of the hybrid (Alessi and Power, 1975; Free et al., 1966). These reductions in early and late hybrids generally have been similar, on a percentage basis, but on an actual yield basis, the later hybrids have suffered the largest losses. This had led some researchers to suggest that early hybrids can be planted relatively late and still yield satisfactorily but that later hybrids can not. Alessi and Power, (1975) investigated the extent to which seeding an early maturing corn can be delayed without greatly reducing forage and grain yields. They found significant effects of planting date and population on forage and grain yields. Delaying planting until after June 7 affected grain more than dry matter yields. However, planting prior to June 7 reduced dry matter and grain production only slightly. Late planting shortened the period of vegetative growth and ears from late planting were physiologically immature as evidenced by high water content in ears when harvested. Both the number of barren stalks and water content of ears increased as population increased. Planting date slightly affected ear- to stalk ratio. Knapp and Reid (1981) studied the effects of planting dates, plant population, N-levels and hybrids. They found that planting corn before May 15 maximized yields for all hybrids regardless of maturity. Depending on the hybrid, each day that planting was delayed past May 15 caused a yield reduction of 28 to 253 kg/ha per day. Longer season hybrids suffered the greatest actual yield losses when planted late although percentages of loss were about the same for all hybrids. Corn planted in late April had a lower plant population than later planting date in 1976, therefore early planting required a somewhat higher seeding rate than later planting if the greater plant mortality was to be offset. Yield trends show that the full season hybrids are most productive for plantings made through the third week of May. After that time, however, they fail to mature and yields drop rapidly. The failure of late-planted full-season hybrids to mature lowers their yield, but it also produces grain that is too wet for timely handling at harvest. Several days after a killing frost are required before the moisture drops low enough to be suitable for harvest (Knapp and Reid, 1981). Thus it is necessary to switch to earlier maturity hybrids to maximize yields and harvesting efficiency with late planting.

Other studies have shown increased yields from early planting similar to those observed by Knapp and Reid (1981); Alessi and Power (1975); Lang et al. (1956); and Giesbrecht (1969). Increased yields from early planting has been attributed to several variables including; more efficient use of sunlight, less injury from summer heat and moisture stress, reduced frost damage in the fall and decreased lodging. Knapp and Reid (1981) also found that late planting averaged 10-15% more lodged plants than earlier planting dates. He concluded part of this increase likely occurred because the late planting produced plants that were taller and more slender than earlier planted corn. Ear height on the late plants was also higher. These two factors made the late corn more susceptible to lodging. Corn borer damage to the stalks was observed to be more severe for late planting and this also increased lodging susceptibility. Although the lodged plants were harvested in the experimental plots, yields were probably lowered because grain filling was interferred with. Under machine harvesting where lodging would have increased harvest loss, the yield decreases measured with late planting would likely have been even greater.

Zuber (1968) reported that the most optimum planting date and response of hybrids representing different maturities in central Missouri to be April 20 and May 10, with a decrease in yield for planting dates after May 10. The relative yield response for all the maturity groups was about the same for the four planting dates (April 20, May 10, June 1 and June 20). The 125 day maturity group hybrids gave the highest yields at the earlier planting dates, while the earlier maturity groups yielded relatively better at the later planting dates. Stalk lodging was lowest for the first three planting dates and increased two fold for the last date. The 125-day maturity hybrid had the highest stalk lodging for all the four dates of planting and in general, the later maturing hybrids had more stalk lodging than the earlier maturing hybrids.

Number of days from planting to tasseling was longest for the April 20 planting date and decreased for each subsequent planting date. Number of days from planting to silking followed the same trend as the number of days from planting to tasseling. Very small differences were noted between the number of days from planting to tasseling and planting to silking. The largest differences between number of days from planting to tasseling and planting to silking were noted for those years in which stress conditions were experienced during the growing season. Only small differences in test weights were found for the first three planting dates but test weight decreased substancially for the June 20 date. Test weights were lowest for the 90- and 140-day maturity groups regardless of planting dates. Benson et al. (1978) conducted studies at two locations in Iowa (North Central Iowa and South Central Iowa) and results showed very early maturity hybrid (20 days earlier than adapted) yielded much less than the longer maturity adapted hybrids at the earlier dates of planting (May 10 and June 1). When planted by mid-June, the very early hybrid produced essentially equal yields with lower grain moisture content when compared with the longer maturity hybrids. Studies indicated that later maturing hybrids benefit proportionally more from early planting (mid-April to early May) than do early hybrids. In a planting date trial under limited moisture, Giskin and Efron

(1986) found the earlier planting dates corresponded to a longer interval from seeding to silking. Earlier planting date affected yields negatively because of exposure of plants to insufficient water at silking.

Agricultural Experimental Stations throughout north central states have generally reported yield advantages from planting corn early (late April or early May) Pendleton and Egli (1969). Such studies aroused interest in the question of what the yield potential might be if corn could be planted even earlier. Perhaps cold tolerant varieties may be developed or chemical or mechanical methods of protecting the young plants against late frost may become viable. Pendleton and Egli (1969) stated that early planted corn generally yields better because grain formation period occurs when the days are longer and the sun is at a steeper angle of incidence and thereby more radiant energy is available for photosynthesis as compared with late planted corn which matures during shorter day lengths. In a field experiment conducted at Urbana, Illinois to determine the grain yield potential of corn plants developing during the period of maximum day length as compared to plants developing later in the season, Pendleton and Egli (1969) found that plants started in the green house, transplanted to the field April 19 when approximately 15 cm tall and pollinated June 15, yielded no more grain than plants started as seed in late April and pollinated July 8. One explanation for the transplants yielding no more than early seedings may lie in their shorter plant height and less leaf surface. Results showed seedings made on May 14 and May 31 gave yield reductions of 103 kg/ha per day compared to the yield of the April 30 seeding. Stalk strength, as measured by resistance to crushing, decreased with date of planting from April 19 to May 31.

Interaction between time of planting and tillage methods has been investigated by several researchers. Free et al. (1966) investigated the interaction between planting date and plow-plant (plow-plant means plowing and planting simultaneously in a once-over operation) and conventional methods of seed bed preparation for corn reported a tendency for relative grain yields to be slightly higher for plow-plant than for conventional with early planting and slightly lower with late planting. The interaction was not significantly different. For late planting however, there is more likelihood of below optimum soil moisture with plow-plant than with the conventional method. This is associated with the longer period for moisture removal by the sod or cover crop preceding corn, and the likelihood of critically low moisture should be less where sod or cover crops are not involved. Final grain yields and percentages of dry matter in ears at harvest were significantly correlated with plant heights in mid July. Herbeck et al. (1986) in Kentucky on a poorly drained soils reported that yields from conventional plantings decreased with each planting date after early May while no-till plantings showed a trend for a yield increase as the planting dates progressed from late April to mid-May. They suggested that an optimum planting date under no-till should be 2 weeks later than that for conventional tillage. They also concluded that soils with internal drainage such as the Tilsit-Johnsburg soil on which tillage and/or planting operations are commonly delayed due to excess soil moisture can be planted at later dates using no-tillage without loss of yield.

Imholte and Carter (1987) studied the influence of planting date on; emergence (determined as the number of seedlings emerged as a percentage of kernels planted), growth (plant height to the flag-leaf collar), and development (days to 75% silk) of two corn hybrids of different maturity (95 and 100-day relative maturity), found that hybrid responses (i.e., yield components) to planting date were mostly non-significant. Emergence was generally lower under no-till compared to conventional tillage at early and medium planting dates (April 26 to May 5 and May 14-19 respectively), but not with late planting (May 27 to June 3). Planting date had little influence on emergence under conventional tillage; however, with no-till emergence increased markedly when planting was delayed. These results are similar to those of Mock and Erback (1977). Averaged over years, the greatest grain yields for both tillage systems occurred at the early date. Plant dry weight at silk stage and final height generally increased as planting was delayed for both tillage systems.

Plant Population

When subsoil moisture reserves are average or above, a suggested corn plant population would be in the range of 54,000 - 60,000 plants per hectare (Benson, 1984). Optimum population depends on such factors as moisture stress, type of hybrid, soil fertility and yield potential. When weather conditions are ideal, and all production inputs are at a very high level, maximum yields will occur when the population is from 64,000 -

74,000 plants per hectare. To optimize production at a given plant density, several researchers have shown that plant spacings approaching a more uniform distribution result in a greater yield than uneven spacings (Duncan, 1958; Hoff and Mederski, 1960; and Krall et al., 1977). As corn is planted at increasing populations, the average yield of the individual plant decreases (Duncan, 1956). This is no doubt caused by a decrease in the supply of those environmental requirements for yield that each plant is forced to share with its competing neighbors. It was postulated therefore that the average yields of plants subjected to increasing population pressure might behave like the yields of plants grown at constant population at decreasing nutrient levels (Duncan, 1956). Some researchers have investigated the effect of population on grain and silage yields. Results from these studies have shown that as the number of plants per land area increased, yields increased, reached a maximum and then declined. In general, silage yields are maximized at a higher population than grain yields. Knapp and Reid (1981) reported that grain yields were highest when the lowest population per hectare was between 48,000 and 62,000 plants. Some hybrids performed poorly at a population of 75,000 but other hybrids were tolerant of but did not benefit from this high population. Planting date did not affect population response, so they concluded it was possible to relate the combined effects of planting date and population on grain yield. Later planting, lower populations or both result in reduced yields. At a certain point however, late planting is more detrimental than a lower population. Curves showing the relationship between plant population and planting date can be used to help determine if replanting a field would be profitable. The potential of the initial planting of the lower population can be compared with the potential of a later planting at a higher population.

Lucus and Remison (1984) investigated the effect of population density on yield and dry-matter partitioning of two maize varieties in Nigeria. They reported an optimum total dry-matter yield per unit area at 80,000 plants/ha and an optimum grain yield at 53,000 plants/ha. The reproductive:vegetative ratio, shelling percentage, and harvest index were not significantly affected in the range of density (37,000 - 80,000 plants/ha). Lucas and Remison (1984) also reported that with proper management, the new, improved open-pollinated varieties used in the study were able to respond more to higher plant population than the old varieties. This was presumed to be due to their ability to withstand lodging and their superior flowering and morphological traits such as ear height, top height and interval from tassel to silk. Sharma and Adamu (1984) working with sweet corn in Nigeria found that grain yields were not significantly affected by populations of 25,000, 35,000 and 45,000 plants per hectare. In general, the values obtained for various yield components (number of ears per plant, weight of ears/plant, mean ear weight, kernel weight/ear, and 100 grain weight at 25,000 plants/ha were found to be significantly higher than for all other population levels. Wang et al. (1987) showed that, with decreasing population density (125,000 - 62,5000 - 31,250 plants/ha), total dry weight per plant, kernel number and total ear length increased. However the ratio of unfilled to total ear length decreased. Grain yield decreased significantly due to insufficient plant number at lower population densities. Wang et al. (1987) postulated therefore that maize yield was limited by sink capacity and low dry matter utilization efficiency under widely spaced conditions (80 x 40 cm). Thinning treatments showed positive effect on assimilate supply and yield performance; (i.e., total and filled ear length, kernel numbers, shelling rate, 100 - kernel weight and grain yield per plant). These, along with the high partition efficiency were the main reasons for increased grain yield.

Douglas et al. (1981), in New Zealand studied the effect of changing plant population on the grain yield of maize under high yielding conditions. Grain yields for a full season hybrid were maximized at 14 t/ha in the range of 80 - 90,000 plants/ha. The response curves gave no indication of any marked changes over the range of 70 - 100,000 plants/ha.

Sotomayor et al. (1980) using corn hybrids and selections at two population densities under tropical conditions found no yield advantage when densities were increased above 45,000 plants per hectare. Significant differences among entries were observed in time to mid silk, ear height, plant height (soil surface to the tip of the tassel) test weight of 1000 kernels and yield. No population-density X entry interaction for these characters was observed. Baenziger and Glover (1980) studied the effect of plant population on yield and kernel characteristics of sugary-2 and normal maize. Grain weight increased as population density decreased (74,775 - 49,850 - 24,925 plants/ha). Sugary - 2 had significantly less grain weight per ear, plot yield, kernels per ear, kernel volume, and kernel weight and significantly higher kernel density than the normal counterpart. The highest population had lower grain weight per ear, greater plot yields and fewer kernels per ear than did the low populations. The highest population had the highest plot yield despite having decreased grain weight per ear indicating that the decreased grain weight per ear was more than compensated for by the increased number of plants per row.

In addition to plant population; the distribution of plants over the soil area has been suggested as a means for influencing yield. Studies conducted by Parks et al. (1965) to determine the effect of spacing between rows and spacing within the row on yield of corn showed that row spacing had little influence on yield at locations where moisture was limiting. Under optimum moisture conditions, narrower row spacing may result in small increases in yield (Parks et al., 1965). Plant population had a much greater effect on yield. Sizable increases in yield were obtained by increasing the plant population from 22,222 to 37,037 plants per hectare and only a small increase above 37,037 to 44,444 plants per hectare. Ear weights and prolificacy were affected very little by row width; however increasing plant population resulted in lower ear weights and fewer ears per stalk. In a similar study Giesbrecht (1969) found that row spacings (50, 65, 80 and 95 cm) did not affect grain yield. However each increase in population (30, 45, 60 and 75 thousand plants per hectare) produced a substantial increase in grain yield. Varieties of different maturities differed significantly in their yield response to increased plant population. The later maturing, taller hybrids were better adapted to high populations than were the earlier hybrids. In a study with inbred lines and single cross hybrids at various population levels and within row spacing patterns Woolley et al. (1962) reported similar results. He found that population treatments had greater influence on various yield attributes than spacing treatments. Differences in days between pollen shedding and silking were strongly influenced by plant population. Plant barrenness had a marked influence on yield at high populations (39,506-49,383 plants per hectare) 100 seed weight decreased as the number of plants per acre increased. In the varietal trials involving planting rates and spacing for corn under Southern conditions in various parts of Tennessee, Mooers (1920) concluded that different varieties require appreciably different rates of planting. In general, the small and short season varieties required thicker planting than the large long season varieties. The results also indicated a close relationship between the best rate of planting for grain production and yield of grain per plant. It seemed safer to have higher than optimal population levels than to have less than optimal population. Population for silage corn was little different from that which gave the highest yield of grain. In practice, the best results would probably be obtained with a width of row spacing which permits the satisfactory use of tillage implements but allows the determined number of stalks to be as widely spaced as possible. Lutz et al. (1971) found that grain yields increased as the width between rows decreased (40, 60, 80 and 100 cm). Grain yields were usually higher with a late maturing variety planted at a medium or high population (54,000 - 64,200 plants per hectare). Percent moisture of the grain at harvest was not affected by row spacing or plant populations but was affected by the hybrid used. Ear weight increased with decrease in row spacing and plant population and with increased time required for maturity. Other studies by Hunter et al. (1970) showed that all short season hybrids in the test increased in grain yield with each increase in population (48,000 - 62,000 - and 72,000 plants/ha) and gave small but significant yield increases to narrowing row width (46 and 91 cm).

There are indications that planting precision or within-row variability may affect yield (Krall et al., 1977). The authors reported results which indicated that planting precision (little within-row variability) could increase yields 200 to 1200 kg/ha without changing planting rates. Hoff and Mederski (1960) reported an increase in the yield of corn with equidistant plant spacing. The yield difference between conventional 105 cm row spacing and equidistant planting was minimal at the low population level but increased with increased population (19,753 to 59,260 plants per hectare). Planting pattern did not have a marked effect on either the percent ears per plot or ear weight although both tended to be higher for the equidistant pattern. In a study to investigate the effect of a wide range of plant population densities in a constant spatial arrangement on grain yield and yield adjustments in maize Tetio-Kagho and Gardner (1988) found that ear proliferation varied between one to three ears per plant and depended on plant population density and growing season. Kernel number per ear and per row, ear number per plant in the order given were the most important yield component adjustments in response to plant population density. Total and vegetative dry matter yield response to increasing plant population density was asymptotic (non-linear) whereas ear and kernel yield responses were parabolic (Tetio-Kagho and Gardner, 1988a).

Bryant and Blaser (1968) compared plant constituents of whole plants of an early and late corn hybrid as affected by row spacing and plant-population. They reported that the stalks, leaves and husks comprised a larger proportion and the ears a smaller proportion of the total dry weight of the late than early hybrid. The proportion of stalks to total dry weight of both hybrids was the smallest from rows 53 cm apart. The weight of the total corn plant averaged for both hybrids at all population levels (39,500 to 98,800 plants/ha) decreased slightly with each increase in distance between rows (36, 53, 71 and 89 cm). As plant population increased, the weight of the individual plant constituents averaged for both hybrids at all row spacings decreased proportionally. The average yield of silage was larger but the average yield of grain was smaller from the late than early hybrid. Planting at 98,000 compared with

39,500 plants/ha gave larger silage yields with either hybrid. Lutz and Jones (1969) reported lower silage yields from the alternated 25 and 125 cm spacings than from uniform spacings (40, 60, 80 and 100 cm), and yields did not increase with increased population in 1966 (44 - 64,200 plants/ha). At 3 out of 4 locations in 1967 and 1968 tests, yields were higher with 40 cm than with 100 cm spacings.

The responses of maize to varying plant population and soil fertility levels depends on climatic conditions, spacing, and genetic factors (Kayode and Agboola, 1981). The literature seems to indicate increased yields of corn resulting from increased plant populations at high fertility levels (Thomas, 1956). Kayode and Agboola (1981) investigated the effect of nitrogen levels, plant population and soil nutrient status on maize grain yield and yield components at 8 sites representing six different ecological maize growing zones of Nigeria. They reported a significant influence of nitrogen at six of the eight sites. Optimum N required for maize varies between 50 and 100 kg N/ha in the different zones. There was a response to spacing treatments at only three out of eight sites and no significant interaction between nitrogen and spacing at any location. Nitrogen application significantly influenced ear weight at five sites, had a significant effect on the number of cobs at only 3 sites, while spacing significantly influenced number of cobs at all except one location. Nitrogen application significantly influenced lodging at 3 sites while there was a significant effect of spacing at 2 sites. Both N application and spacing had no significant effect on shelling percentage at any location. Thomas (1956) in a similar study, reported a decrease in average ear weight for the plant population of 14,815, 29,630 and 44,444 plants per hectare. The addition of nitrogen significantly increased the yield of corn but there was little or no increase for rates above 45 kg/ha with any plant population. Similarly Lang et al. (1956) reported highest yields from populations of 49,383 or 39,506 plants/ha. Hybrids showed differental yield responses to both nitrogen levels and plant population. Examination of yield components revealed that ears per 100 plants was influenced most by varying populations and fertility levels. Ears per plant and barrenness were affected more by plant population than by hybrid or nitrogen level. Hybrids which showed a tendency to be multiple eared at low population rates, had the lowest percentage of barren stalks at the high plant populations. Knapp and Reid

(1981) reported the average maximum economic yield response from 134 kg/ha of side dress N. More N was needed for maximum yields from 75,000 plant population but the high N rate was questionable economically.

In other studies associated with plant population, Row width and Nitrogen response on growth and yield of corn, Nunez and Kamprath (1969) found that Leaf Area Index (LAI) increased linearly as the plant population of corn was increased from 34,500 to 69,000 plants per hectare. The leaf area per plant however decreased as the plant population increased. Nitrogen rates of 112 to 280 kg per hectare and row width (53 cm and 106 cm) had no effect on leaf area per plant or LAI. The yield of grain per plant of the long season hybrid was not influenced by row width except under drought conditions where 53 cm rows gave higher yields than 106 cm wide rows. Highest grain yields were obtained at 280 kg of N per hectare and 51,750 plants per hectare. In similar studies, Kruger (1978) reported a slight effect of N-fertilization on stalk rot and stalk breakage. Stalk rot increased somewhat with increasing nitrogen (120, -180-240 kg/ha N). There was generally no effect of higher N-applications on yield. Under unfavorable climatic conditions, the yield even decreased. They also found a pronounced increase of stalk rot and stalk breakage at higher plant population densities (5.2, 6.9, 10.2 plants/m^2). When comparing the effect of plant populations at the same rate of N-fertilization, stalk rot and stalk breakage increased similary at all N-rates with increasing plants/m^2. As a result of stalk breakage in denser maize populations, a yield reduction took place. Yield depression took place most in cultivars susceptible to lodging and especially at higher plant population densities.

If soil fertility, soil moisture, insects, diseases and other management factors are not limiting, corn yields can be significantly increased by increasing plant population (Stevenson, 1984). Not all hybrids respond to increased plant population under intensive management. However, the importance of identifying these genotypes for maximum yield research and for future use in farm management cannot be overstated. Stevenson (1984) also stated that since increased yields and profits produced from higher plant populations are a low cost input, it has paramount importance in determining "maximum economic yields" for farmers. In some of the earlier Ohio experiments comparing corn hybrids with open pollinated varieties, Stringfield and Thatcher (1947) reported results which support the findings of other workers in indicating that as growing conditions become more favorable, the optimum stands are higher. The results also indicated that adapted hybrids, as a group, have higher optimum stands than do open-pollinated varieties probably because of the greater vigor of the hybrids. The effect of stand on grain yields is much greater at higher than at low productivity levels (Stringfield and Thatcher, 1947). Tillering decreased rapidly as stands approached the optimum. The test weight of grain did not appear to be affected by differences in stand. The silking period for a stand of five plants per 105 cm of row space was roughly 2 days later than for a stand of three plants in the same space. This would probably delay maturity by 4 or 5 days. The most serious effect of the heavier stands is in the higher incidence of stalk breakage (Stringfield and Thatcher, 1947).

Termude et al. (1963) reported highly significant differences for grain yields among hybrids representing a range in maturity from early (78 to 80 days) to late (120 to 125 days), when grown in South Dakota. Plant population effects (9,877 to 79,012 plants per hectare) were also highly significant. Grain yields reached a maximum at 29,630 to 39,506 plants per hectare and fell off drastically if population exceeded this optimum. Under conditions of drought, maximum yields may be associated with very low population levels. High plant populations in most cases increased the stalk lodging. This was expected with some hybrids as a steady decrease in stalk diameter was associated with increasing plant population. Increased planting rates caused a decrease in ear size and uniformity. At extremely high planting rates, especially when accompanied by drought, the differences in ear size among individual hybrids were completely obliterated where as under favorable conditions the decrease was proportional for each genotype. Parks et al. (1981) at the University of Tennessee reported results which showed a wide range in corn yields among varieties, row spacings and plant populations evaluated. They found corn varieties differ in their capacity to with stand stress relative to moisture, plant population, fertility and temperature during the growing season. The capacity of the farmer to control these production factors eventually determines the maximum yields possible under any given situation. The highest corn yields are obtained in planting patterns that permit the greatest plant interception of incoming radiation as long as moisture does not become limited.

They also pointed out that high corn yields are typical with irrigation or a crop year during which adequate rainfall and sunlight are well distributed over the pollination and ear development stages of growth. Years with excessive cloudy weather and higher rainfall may not always produce the highest possible corn yield because dense cloud cover reduces the amount of incoming radiation necessary for maximum corn yield. Vanderlip (1968) reported that, under low yield conditions, neither hybrid nor population used (19,753 - 69,136 plants per hectare) had much effect on grain yield. Hybrid differences are, in general, greater and more consistent under higher yield levels. Vanderlip (1968) also noted that number of ears per plant appears to be more closely related to yield than do ear weights when hybrid differences are considered. Ear weights for the hybrids studied responded similarly to changes in plant population in the population range of maximum yields. Lodging increased with increasing plant population, however, only under severe lodging conditions was the increase large enough to be of major importance. No consistent hybrid differences in lodging were found. Maturity as measured by days to 50% silking differed among hybrids but was not affected by either population or location.

Studies to investigate effect of plant population and planting pattern of corn on water use and yield have been conducted by a number of researchers. Yao and Shaw (1964) reported less water use from a 52.5 cm row spacing than for 80 or 105 cm spacings. A higher rate of water use occurred with higher stands but the increase in water use was much smaller than the stand increase. The efficiency of water use was highest on the 52.5 cm row spacing and lowest on the 105 cm spacing. Stickler (1964) reported that 50 cm rows exceeded 100 cm rows in yield by 6% under irrigation and by 5% without irrigation. The yield superiority was associated mainly with more 2-eared and fewer barren plants. Brown et al. (1961) reported a decrease in yield with increasing plant population from 50,000 to 100,000 plants/ha. Estimated optimum population appeared to be related to plant size with smaller plants requiring a higher population for maximum grain yield. Karlen and Camp (1985) reported that a plant density of approximately seven to nine plants m^{-2} appeared sufficient for irrigated production using either soil-water potential or a water balance to schedule water applications. For non-irrigated plants, plant density should not exceed seven plants m^{-2}. Irrigation increased grain yield by increasing kernel weight and number of kernels per ear.

Genotype

It is known that some hybrids differ in their response to management practices. Most corn belt researchers have found that delayed planting causes a greater yield reduction in full season than in early hybrids (Johnson and Mulvaney, 1980). Identification of maize hybrids that have the genetic potential to produce more grain in response to improved field practices has been an important contribution to greater yields. Prolific hybrids have received favorable attention in recent years because at high plant densities, they resist barrenness more than do the non prolific hybrids (Prior and Russel, 1975; Duvick, 1974; Russell, 1968; Hallauer and Troyer, 1972). With corn, prolific is a term reserved for cultivars which regularly produce more than one ear per plant. Modern corn hybrids typically bear only one ear and are the result of at least 100 years of selection for plants that were easy to harvest, ears which could win shows (Collins et al., 1965). Changes in ideas of ear size and type and wide scale use of mechanical harvesters have eliminated some of the reasons for growing one-ear-type hybrids.

A study conducted at Ames and Ankeny, Iowa in 1961 and 1962 by Collins et al. (1965) revealed that 2-ear type corn yielded more consistently than the 1-ear types when population levels were increased (19,800 to 49,400 plants per hectare). The relatively consistent performance of the 2-X 2-ear cross type was related to the capability of this type to adjust to environmental fluctuations by changing the number of ears produced. At the lowest population (19,753 plants per hectare) the 2-X 2-ear type crosses produced more grain than the single-ear types demonstrating the flexibility of the 2-ear types. Estimates of maximum planting rates for optimum yields indicated that 1-X 2-ear and 2-X 2-ear crosses may perform better in higher populations than 1 X 1 ear type crosses. Similary, Brotslaw et al. (1988) investigated the effect of prolificacy on grain yields and root and stalk strength in maize using a plant density of 55,614 plants per hectare and found that two eared plants had significantly higher mean grain yields, closer synchrony between anthesis and silking and greater ear heights than one eared plants. No significant differences were found between one- and two-eared plants for vertical root pulling resistance or stalk crushing strength. Similar results were obtained by Prior and Russel (1975). They also investigated grain yield response of non-prolific and prolific corn Belt maize single cross hybrids to plant densities from 20,500 to 72,000 plants per hectare. Four types of hybrids, each type including seven hybrids were grown at six plant densities in eight environments. The hybrid types were: 1) elite, non prolific 2) first-cycle prolific 3) second cycle or elite prolific and 4) crosses between elite, nonprolific and first-cycle prolific parental lines. Types 1 and 3 had the highest average yields over all densities and environments and were not significantly different. Type 2 and 4 yielded significantly less than types 1 and 3. Elite, prolific hybrids (type 3) yielded more uniformly over the range of densities than did the elite, nonprolific hybrids (type 1). Types 2 and 4 were intermediate in response. The extent of prolificacy at the various densities probably was the most important factor in explaining responses of the hybrid types. However, Gardner et al. (1987) found that highest yields were obtained from the non prolific hybrid but at higher plant populations than presently recommended. The prolific hybrid was lower yielding but maintained stable yields over a wide range of plant populations.

A better understanding of the prolific character may aid in determining its value in hybrids now being developed. The primary advantage of prolific hybrids is their flexibility in adapting their production with a minimum plant population to the wide range of yield levels. It is doubtful whether prolific types are physiologically more efficient than non prolific types (Bauman, 1960). In a study to investigate relative yields of first (apical) and second ears of semi prolific southern corn hybrids, Bauman (1960) reported that most of the yield variations resulted from differences in second-ear yield when a significant number of second ears were produced. First ear yield was relatively unaffected by environment unless the crop was so poor that few second ears developed. Variations in second-ear yields resulted primarily from differences in number rather than size. The plants tended to develop a full sized first ear and any additional yield came largely from second ears. In an evaluation of several early maize ideotypes to determine if maturity or prolificacy differences were important determinants of responses to variable plant densities, Cross et al. (1987) reported no significant maturity X plant density or prolificacy X plant density interactions although trends were for early hybrids to yield relatively better at higher planting densities (24,000, 48,000 and 72,000 plants per hectare). In the four environments, early hybrids out yielded late hybrids and prolific hybrids out yielded non prolific hybrids. The overall yield advantage of the early hybrids was largely as a result of moisture stress which was more severe in 1982 than 1981. Early hybrids had higher test weights, more stalk lodging, heavier kernels and more ears per plant than late hybrids. Prolific hybrids had higher yields, lower test weights, lighter kernels, more ears per plant, and more root lodging than non prolific hybrids. The highest density produced the highest average yield in all the environments. The data supported the use of early, prolific hybrids at medium to high densities. However, early prolific hybrids grown at high plant densities had increased root lodging, and stalk lodging. In a similar study Knapp and Reid (1981) reported that longer season hybrids generally produced the highest yields, regardless of planting date. In a cool year, however, later plantings of long season hybrids failed to mature satisfactorily and low yields resulted. This indicates that for best yields the longest season hybrid that can be expected to mature should be selected but too long a maturity should be avoided.

Seed Quality

Seed germination in a laboratory test is the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether or not it is able to develop further into a satisfactory plant under favorable conditions. This description defines the standard germination test as well as its limitations. Since field conditions are seldom absent of stress, significant research effort has been expended to develop an assessment of the ability of seedlings to emerge under field conditions. Such an ability is usually referred to as seed vigor. Seed vigor (Association of Official Seeds Analysts, 1983; McDonald Jr., 1980) comprises those seed properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions. The definition provides specific quantifiable parameters (rapid, uniform emergence and development of normal seedlings) against which the performance of vigor tests can be evaluated. Further the definition emphasizes seed performance in the field under a wide range of conditions to include stress conditions which distinguishes the concept of vigor from germination. However, the definition fails to include yield which is often promoted as a direct benefit of seed vigor. In the laboratory, seedling vigor is measured by cold test or seedling dry weight (Burris, 1975; Burris and Navratil, 1979). Both tests are able to detect vigor differences among seed lots. A low cold test germination in corn indicates low seed vigor and the potential for reduced seedling establishment under adverse seed bed conditions (Association of Official Seed Analysts, 1976; Burris and Navratil, 1979).

The standard germination test remains as the primary accepted measure of seed quality (Delouche and Cadwell, 1960). Results of the standard germination test generally correlate well with field emergence (Leudders and Burris, 1979) when soil conditions are favorable for rapid emergence. However, when soil and environmental conditions impose stress on the germinating seeds as may occur with early planting, the standard germination results are unable to predict field performance (Tekrony and Egli, 1989). It has been shown that regardless of crop plant studied, differences in vigor can be demonstrated in the laboratory (Burris, 1976). Many techniques can be used to quantify the morphological expression of high vigor versus low vigor, but the effects of vigor as measured in the laboratory on field performance are much less demonstratable. Vigor may have a positive influence on emergence in the field. The magnitude of the influence is however modified by the soil environment into which the crop is planted. The nearer the soil environment resembles the conditions used to demonstrate the vigor response in the laboratory, the better is the correlation between vigor and emergence (Burris, 1976). One effect of laboratory vigor that seems reasonably consistent across crops are the differences evident in initial growth rate in the field. Beyond the differences in initial growth rate, very few consistent responses to vigor can be shown in field performance. Unless very large differences in vigor exist in the seed lots under study, differences in yield (either grain or forage mass) usually are not significant (Burris, 1976).

Numerous factors associated with reduced germination, emergence and subsequent stand have been discussed (Navratil and Burris, 1980). Obendorf (1972) has grouped these factors into 1) genetic potential, 2) biochemical potential, 3) seed environment, 4) mechanical damage and 5) seed moisture. According to Obendorf (1972) genetic potential merely reflects the possession of heritable components that permit rapid germination and vigorous growth under cool conditions, but requires interaction with other factors to express this potential. Cold temperatures are known to affect biochemical processes. Likewise, environmental and mechanical stresses coupled with cold stress may have an additive or synergistic effect on germination, emergence and subsequent stand. Burris (1975) stated that anything that affects the seed during development, maturation processing and storage can affect seedling vigor. Genetic variability and heterosis play a significant role in subsequent seedling vigor. Seed deterioration due to age is also one of the causes of decline in seed vigor.

Many workers have evaluated the effect of seed quality on the performance of subsequent crops. However, literature indicates no consesus regarding the relation between seed vigor and crop performance. Evidence of positive associations of seed vigor with early plant growth has been reported in corn (Burris, 1975). In a study concerning seedling vigor and its effects on field production of corn Burris (1975) reported that vigor can have significant effects on initial plant performance in the field. A consistent relationship between laboratory seedling vigor and initial vegetative performance exists. These effects of seedling vigor usually dissipate as the plant approaches tasseling. Shifts in tassel and silking date have often been associated with vigor. The analysis across entries indicated that a one day delay in both tasseling and silking was associated with seedling vigor. Barrenness increased as seedling vigor decreased. Possibly this was due to unequal plant competition. Yields were significantly different at 10% level of probability. Across all six entries however the yield difference was less than 5%. In general, genotypes which exhibit a positive correlation between vegetative development and yield will respond positively to increased seedling vigor. Conversely, those genotypes that do not respond positively to increased vegetative development will not respond positively to vigor and may in fact respond negatively. Burris (1975) concluded that in many genotypes, reductions in seedling vigor result in reduced yield even though stand density is held constant. In another study to determine crop characters through which corn seed vigor is expressed in both uniform and reduced populations due to seed vigor, Adegbuyi and

Burris (1989) found that early vegetative growth was influenced by seed vigor, but as the plant aged, the influence of seed vigor decreased. Increased early plant height up to 6 weeks old, small stem diameter, low shoot dry-matter content, delay in days from sowing to 50% silking, and reduction in the number of ears and tiller production were observed in the uniform population. The difference in population density due to seed vigor did not have a significant effect on final grain in as much as plants in the reduced populations were able to compensate completely for missing stands.

In a study conducted to investigate relative yields from broken and entire kernels of seed corn, Brown (1920) reported lower field emergence from broken seed than from entire seed and the seedlings were weaker. The general height of plants at maturity did not materially differ. Apparently, the mutilation of the seed was not a limiting factor in the height of the plant. The broken seed exceeded the entire seed in the general average of number of ears per plant. The increase in number of ears was associated with the increased space per plant resulting from poorer stands from broken seed. The broken seed yielded less than the entire seed. In practical corn growing, the losses in yield probably would be much less, frequently negligible, but the tendency would be the same (Brown, 1920). Satisfactory results may commonly be expected from well matured seed corn up to four years old provided it has been kept free from external moisture and insect or rodent injury (Kiesselbach, 1937). This conclusion was based on a five year study in which seed ranging from one to four years of age was tested annually for yield on the experiment station in Lincoln. The comparative yields from seed of various ages were as follows: one year old, 5060.7 kg/ha; two years 5171.4 kg/ha; three years 4936.3 kg/ha; and four years 4853.3 kg/ha. These differences are so small that they would seem to have little significance. There were no effects of age upon the vegetative development of the crop. It was found that when corn seed aged up to four years gives a good germination test, satisfactory field stands may be expected. It is not uncommon for well preserved four year old seed to germinate as high as 90 percent. Thereafter its viability is apt to deteriorate rather rapidly. The maximum delay in emergence of the seedlings after planting sound old seed in the field has been one day (Kiesselbach, 1937). This delay may perhaps be accounted for by the thorough drying out of the seed and its reduced viability (Kiesselbach, 1937). Taking all things into consideration, new seed is to be preferred if its adaptation and viability are equal to the old seed. Dungan et al. (1944) in another study to investigate age of seed corn in relation to seed infection and yielding capacity, reported that plants from old seed lacked the vigor of plants from new seed. Three year old seed averaged 4.8% lower in yield than one year old seed when both lots had a perfect stand. When the number of kernels planted was uniform and no adjustment was made in stand, three year old seed yielded 7.8% less than one year old seed. At the end of seven years, reductions in yields were 10.1% and 31.7% respectively for the perfect stand and thin stand of old corn. Funk et al. (1962) also reported significant differences in field performance including yield between seed lots of the same hybrid due to seed source and seed age even when thinned to essentially identical stands. These yield differences appeared to be partially associated with the physical quality of the seed lot as measured by cold test performance and other measurements of physical-vigor. Similar results were reported by Fleming (1966).

Studies to evaluate the effect of seed vigor on plant growth and yield of corn under different tillage systems have been conducted using both conventional and no-tillage cultural systems. Tekrony et al. (1989a) found that the low and medium vigor seed lots had consistently lower emergence than high vigor seed lots in all tillage systems and planting dates. Emergence following conventional tillage was consistently greater than emergence following all no-tillage treatments; however, this difference was significant only at the early planting date. Under the stress conditions that occurred in the early planting date of 1982 and 1983 following no-tillage, the high vigor seedlots had significantly greater emergence than low-vigor seed lots. Thus seeding seedlots with high germination and vigor would be beneficial during early plantings in no-tillage systems. In another study under no-till, Tekrony et al. (1989b) reported that plants from low vigor seed lots were consitently shorter, weighed less and produced less leaf area at the four collar stage under no till. Similar trends were seen at silking; however the differences were much smaller and usually not significant. In most cases, seed vigor had no effect on grain yield. The few treatment combinations with reduced yields for the low vigor seedlots also had reduced seedling emergence. Thus, there was no direct effect of seed vigor on yield; however, seed vigor can affect yield if less than optimum plant populations are obtained.

Seed quality and herbicide injury are factors that might interact to affect corn yields. Johnson and Wax (1981) using seedlots with standard warm germinations above 90% but cold test germinations ranging from 50 to 96% conducted field studies to see if corn grown from low quality seed was more susceptible to herbicide injury, than corn grown from high quality seed. Results showed that seed quality, hybrid and seed bed environment all interacted to affect emergence, herbicide injury, stand density at harvest and final grain yield. Seedlings from lower vigor seed expressed greater herbicide injury in two of the five seed bed environments but this interaction was not significant for percent seedling emergence, plant density at maturity or grain yield. Grain yield reductions of up to 32% occurred from seed low in cold test germination. Yield reductions from low quality seed did not occur with all hybrids or in all seed beds, but when yield reductions did occur, they were associated with decreases in plant density. They concluded that any interaction of corn seed quality with herbicides applied at recommended rates is minor compared with effects of poor seed quality per se, unwarranted high herbicide rates, hybrid differences or limited soil moisture.

MATERIALS AND METHODS

Field studies were conducted for two years at two locations. In 1990, the experiments were conducted at ISU, Curtis Farm (Ames, Iowa) and Clarion-Webster Research Center (Kanawha, Iowa) which is 70 miles north of Ames. In 1991, the experiment was conducted at ISU, Agronomy Farm (Ames) and Kanawha as in the previous season. In each season, four seedlots, two different genotypes and two different seed quality levels for each genotype were provided by the Northrup King Seed Company for the purpose of this study. The seed was treated with captan (a fungicide) and methoxychlor (an insecticide). Hybrid A had a fixed ear type characteristic and hybrid B had a flex ear type. In 1990, the high quality seedlot of hybrid A had a warm germination of 96% and 96% cold test and the low quality seed lot a 91% warm and 85% cold test. The high quality seed lot of hybrid B had a 95% warm and 95% cold test germination and the low quality seed lot, 89% warm and 83% cold test.

In 1991 growing season, new seed supplies of the same genotypes were again obtained from Northrup King Seed Company. The high quality seed lot of hybrid A had a warm germination of 98% and 93% cold test and the low quality a 90% warm and 80% cold test. The high quality seed lot of hybrid B had a warm germination of 97% and 93% cold test and the low quality seed lot a 92% warm and 81% cold test.

Each genotype was planted at two planting dates at each location. In the first year of study, the planting dates were May 3 and May 29 at Ames and May 1 and May 24 at Kanawha. Seedling emergence and distribution for the second planting date and one replication of the first planting date was so poor that only data from 3 replications of the first planting was collected and reported for Ames. In the second year of study, planting dates were May 9 and May 29 at Ames and May 24 at Kanawha. We were able to plant only one date (late) at Kanawha due to unfavorable weather conditions during the early part of May. A summary of dates of planting, plant populations and replications used at both locations and years are presented in Table 1. Dates are indexed as early and late.

Three plant population densities were used for each genotype. The target populations were 74,000, 60,000 and 45,000 plants per hectare (7.4, 6.0, 4.5 plants per m^2). Even though these rates were over seeded by 20%, the stressful emergence conditions in the spring of 1990 required us to thin the plots to 60,000 45,000 and 30,000

Table 1. Summary of dates of planting, plant populations and replications used at each location and year

		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	May 3	May 9	May 1	--
	Late	--	May 29	May 24	May 24
Plant population (plants/ha)		30,000	45,000	30,000	45,000
		45,000	60,000	45,000	60,000
		60,000	74,000	60,000	74,000
Number of replications		3	4	4	4

plants per hectare (6.0, 4.5 and 3.0 plants per m^2). In 1991, plots were over seeded by more than 50% to ensure obtaining the target populations. More than adequate stands were obtained and we were able to thin to the target plant populations. Seeds were planted using a two-row planter in 4 row plots 5.5 m long X 3.0 m wide with 0.75 m row spacing. The experiment was organized as a 2 X 3 X 2 X 2 factorial design arranged as a split-split plot. Planting date was the main plot, plant population subplot and genotype and seed quality were randomized within the sub-sub plots. Four replications of each treatment were used. Each year, site combination was statistically analyzed separately.

Field Management Practices

At both locations and years, the experiment was conducted on sites where soybean had previously been grown. Conventional tillage practices were used.

Ames 1990 (Curtis Farm)

Soil tests indicated a pH of 6.7, 40 ppm P, and 190 ppm K. 0 - 67.2 - 67.2 kg/ha of N - P_2O_5 - K_2O was applied in the fall of 1989 and 168-0-0 kg/ha of N in the form of urea was applied just before the first planting.

Dual 8E at 2.9 l/ha was incorporated as a preemergent herbicide.

<u>Ames 1991 (Agronomy Farm)</u>

Soil tests indicated a pH of 7.4, 112.0 ppm P, and 230.7 ppm K. 0- 44.8- 134.4 kg/ha of N- P_2O_5 - K_2O was applied in the fall of 1990 and 168 - 0 - 0 kg/ha of N in the form of urea was broadcast just before the first planting. Bladex 4 L (cyanazine) and Lasso 4E (alachlor) were incorporated at 2.9 l/ha as preemergent herbicides.

<u>Kanawha 1990</u>

Soil tests indicated a pH of 6.5, 21 pm P, and 143 ppm K. 0 - 0 - 67.2 kg/ha of N - P_2O_5 - K_2O was applied in the fall of 1989 and 51.5 - 0 - 0 kg/ha of N in the form of urea was broadcast just before the first planting. Lasso 4E (alachlor) at 2.9 l/ha plus Bladex 4 L at 2.3 l/ha were sprayed as preemergent herbicides.

<u>Kanawha 1991</u>

Soil tests indicated a pH of 6.7, 30 ppm P, and 172 ppm K. 0 - 50.4 - 67.2 kg/ha of N - P_2O_5 - K_2O was applied in the fall of 1990 and 55.5 - 0 - 0 kg/ha in the form of urea was broadcast just before the first planting. Lasso 4E (alachlor) at 2.3 l/ha plus Bladex 4 L at 2.3 l/ha were sprayed as preemergent herbicides.

Data Collection

Percent seedling emergence was determined following complete emergence as the number of seedlings emerged as a percentage of kernels planted. This was followed by thinning the plants to the desired population densities in each plot. Plant height measurements were taken at various stages of vegetative development (for example 5/6, 10/12 leaf stages), silking and final height at physiological maturity or black layer formation. Plant height measurements were: height from the soil surface to the visible collar and height from the soil surface to the whorl. Final plant height was determined by measuring plant height after silking from the soil surface to the flag leaf. The stage of development at which plant height measurements were taken was noted including the number of days from planting. Plant height measurements were taken on 8 plants chosen at random from the 2 middle rows of a 4-row plot. The other 2 rows, one on either side of the sampling area served as borders. Number of days after planting to 50% silk and black layer formation were recorded for each treatment and replication.

Harvesting was done by hand when grain moisture content had dropped to 20-25%. Only the two middle rows were harvested. All plants in the harvest rows were harvested. During harvesting, number of lodged, barren and plants with double ears (prolific) were recorded in each plot. Main (first) ears were bagged separately from second ears and brought to the laboratory where ear measurements were done. In the laboratory, all measurements done were based on 8 main ears picked at random from each sample, and a mean taken. Ear measurements included effective ear length, number of rows per ear and number of kernels per row. After all the measurements on the ears were taken, ears were shelled using an electric sheller. Main (first) and second ears were shelled separately. Shelled samples were weighed individually and a small sample was drawn from the main ear kernels for moisture content determination and 200 kernel weight. Percent moisture was determined on a 250 g sample using a Steinlite moisture meter. 200 kernels were counted using a 100 seed tray counter and weighed on a Mettler PE 3600 electronic balance. Grain moisture contents were adjusted to 15.5% and grain yields per 8.25 m^2 plot converted to a kilogram per hectare basis before data were analyzed. Analysis of variance was performed on the data using SAS (SAS Institute).

RESULTS

Field Emergence

At both locations and years, high seed quality gave a higher percent emergence than low seed quality (Table 2). Date of planting, plant population, genotype and their interactions did not have a significant effect on percent emergence at both locations in 1990. However, in 1991, there was a genotype effect and genotype X seed quality interaction at Ames with hybrid A having a higher percent emergence than hybrid B (88 Vs 82). Seed quality differences on percent emergence were more pronounced on hybrid B than hybrid A at Ames in 1991.

Final Plant Height

<u>1990</u>

Genotype was the only factor that had a significant effect on final plant height at Ames. Hybrid B was taller than hybrid A (Table 3). Plant population, and seed quality had no significant effect and there were no interactions among the factors. At Kanawha, date of planting, population, and genotype all had significant effects on final height. Plants from the late planting date were taller than those from the early planting date. Reducing plant population resulted in shorter plants

Table 2. Influence of genotype and seed quality on field seedling emergence

Year	Location	Genotype (Hybrid)	Seed Quality	Warm Germination (%)	Cold Test (%)	Field Emergence (%)
1990	Ames	Hybrid A	High	96	96	62
		Hybrid A	Low	91	85	57
		Hybrid B	High	95	95	64
		Hybrid B	Low	89	83	55
	Kanawha	Hybrid A	High	96	96	81
		Hybrid A	Low	91	85	72
		Hybrid B	High	95	95	79
		Hybrid B	Low	89	83	71
1991	Ames	Hybrid A	High	98	93	92
		Hybrid A	Low	90	80	83
		Hybrid B	High	97	93	89
		Hybrid B	Low	92	81	75
	Kanawha	Hybrid A	High	98	93	83
		Hybrid A	Low	90	80	80
		Hybrid B	High	97	93	88
		Hybrid B	Low	92	81	74

Note: Within hybrid, location, and year, the field emergence of high versus low seed quality lots is significantly different ($P \leq 0.05$)

Table 3. Influence of date of planting, plant population, genotype and seed quality on final plant height

		Final plant height (cm)*			
		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	177.7	173.8a	184.7b	--
	Late	--	164.6b	188.7a	160.4
Plant population (plants/ha)	30,000	179.3a	--	181.9b	--
	45,000	176.8a	167.7b	187.8a	159.8a
	60,000	176.9a	167.8b	190.5a	159.4a
	74,000	--	172.1a	--	162.2a
LSD (0.05)		(9.84)	(3.09)	(4.00)	(7.78)
Genotype	Hybrid A	160.3b	154.9b	172.6b	146.4b
	Hybrid B	195.0a	183.5a	200.8a	174.5a
Seed quality	High	177.8a	168.6a	186.4a	161.0a
	Low	177.4a	169.9a	187.0a	159.9a
CV (%)		3.8	2.9	2.4	2.6

* Any two means within a column followed by the same letter are not signficantly different at the 5% level according to least significant difference.

except at Ames in 1990 where no significant differences were observed among populations. Hybrid B was taller than hybrid A in both years at both locations. There was planting date X variety interaction effect at Kanawha. Plant height differences between the hybrids were more pronounced at early than late planting (Figure 1). Seed quality had no influence on final height.

1991

Date of planting, plant population and genotype all had significant effects on final height at Ames. There were no seed quality and no interaction effects. At Kanawha, only genotype had a significant effect on final height with hybrid B taller than hybrid A.

Percent Double Ears

1990

Date of planting had no significant effect on the percent double ears at Kanawha. Plant population and seed quality had significant effects at both Ames and Kanawha (Table 4), while genotype had a significant influence only at Kanawha. At both locations, percent double ears decreased with increasing plant population. At Ames, there was no significant difference between

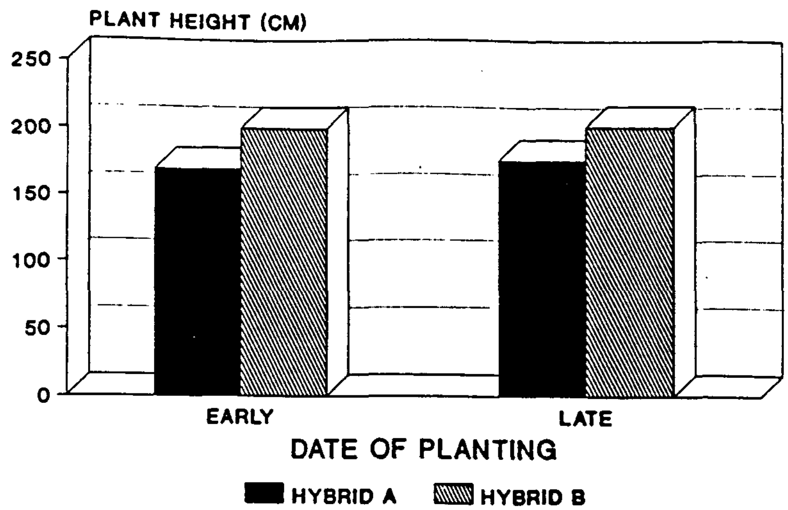

Figure 1. Planting date X genotype interaction effects on final plant height, Kanawha 1990. The 5% LSD for hybrid differences at a given planting date is 2.6.

Table 4. Influence of planting date, plant population, genotype and seed quality on percent double ears

		Percent double ears*			
		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	4.7	2.3a	11.1a	--
	Late	--	3.4a	16.7a	0.9
Plant population (plants/ha)	30,000	10.4a	--	26.7a	--
	45,000	2.3b	5.2a	10.2b	1.4a
	60,000	1.4b	2.1b	4.8c	1.0a
	74,000	--	1.3b	--	0.2a
LSD (0.05)		(3.15)	(1.75)	(2.72)	(0.56)
Genotype	Hybrid A	5.4a	3.6a	15.8a	0.5a
	Hybrid B	4.1a	1.1a	12.0b	1.3a
Seed Quality	High	6.0a	3.0a	15.6a	1.1a
	Low	3.4b	2.7a	12.2b	0.7a
CV (%)		83.4	82.6	39.1	209.0

* Any two means within a column followed by the same letter are not signficantly different at the 5% level according to least significant difference.

medium and highest populations, while at Kanawha, there was a significant difference between medium and highest populations. High seed quality gave a significantly higher percent plants with double ears than low seed quality at both Ames and Kanawha. At Kanawha, hybrid A gave a higher percent of plants with double ears than hybrid B. There were population X seed quality and date X genotype X seed quality interactions at Kanawha (Figures 2 and 3). Lower plant population gave the highest percent of double ears. Except for the highest density (60,000 plants/ha) both 45,000 and 30,000 plants per hectare had higher percent of double ears with high quality seed lots. Also as plant population increased, differences in percent of double ears between high and low seed quality lots decreased. With early planting, the low seed quality lot of hybrid A had similar percent of double ears as high seed quality lot while high quality seed lot of hybrid B had a higher percent of doubles than low seed quality lot. However, with late planting, high seed quality lot of hybrid A had a higher percent of double ears while similar percentages of double ears were obtained with both seed quality lots of hybrid B.

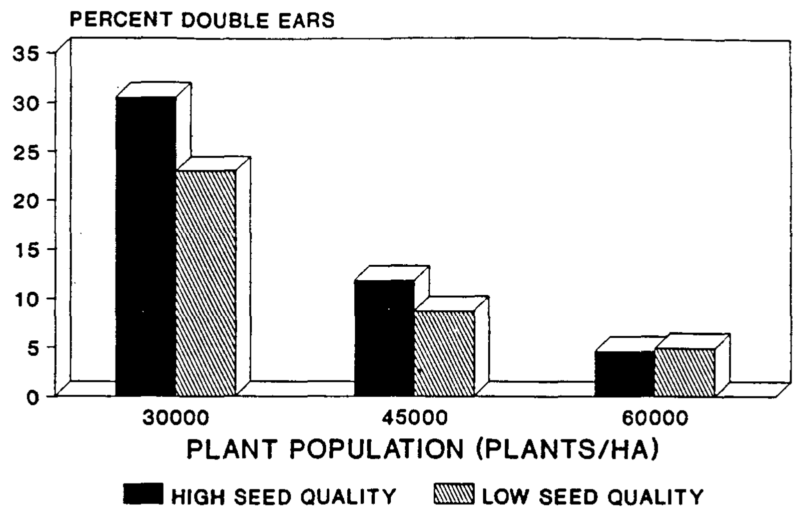

Figure 2. Plant population X seed quality interaction effects on prolificacy, Kanawha 1990. The 5% LSD for seed quality differences at a given plant population is 3.1.

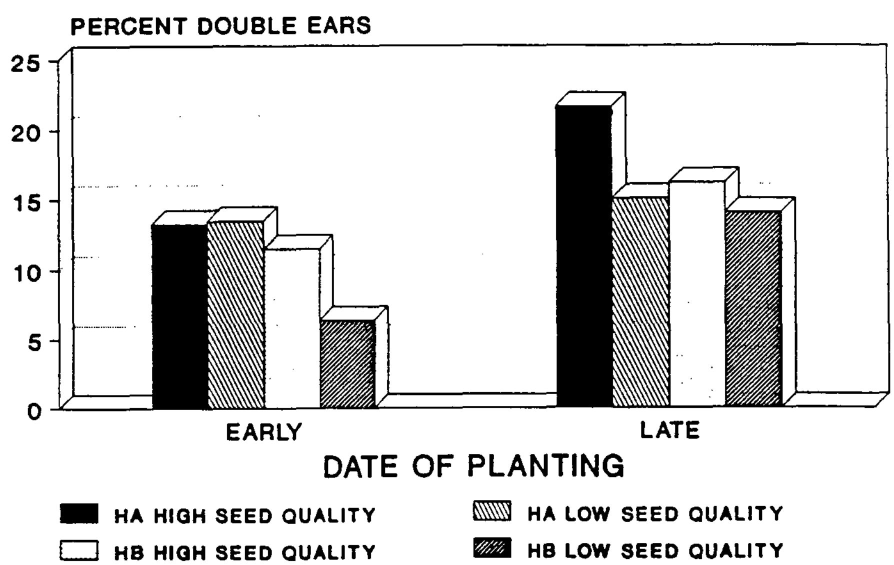

Figure 3. Planting date X genotype X seed quality interaction effects on prolificacy, Kanawha 1990. (HA = Hybrid A, HB = Hybrid B). The 5% LSD for hybrid and seed quality differences at a given planting date is 3.8.

1991

Plant population and genotype had a significant effect on the percent of double ears at Ames. As expected, the lowest plant population had significantly higher percent of double ears than medium and high populations (Table 4). Hybrid A had a higher percent of double ears per plot than hybrid B. At Kanawha however, none of the factors under study had a significant influence on the percent of double ears.

Percent Barren Plants

1990

Only plant population had a significant ($P \leq 0.05$) effect on the percent of barren plants at Ames, while at Kanawha, genotype also had a significant effect. At Ames, the highest plant population (60,000 plants/ha) had higher percent of barren plants, compared to medium and lowest plant populations (Table 5). At Kanawha, hybrid A had a higher number of barren plants than hybrid B. In 1991, none of the factors or their interactions had any effect on barrenness.

Table 5. Influence of planting date, plant population, genotype and seed quality on barrenness

		Percent barren plants*			
		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	2.9	2.3a	1.8a	--
	Late	--	3.4a	2.0a	0.4
Plant population (plants/ha)	30,000	2.1a	--	1.8a	--
	45,000	2.1a	1.5a	1.9a	0.3a
	60,000	4.5a	1.6a	2.0a	0.1a
	74,000	--	1.5a	--	0.8a
LSD (0.05)		(3.32)	(0.93)	(2.0)	(0.84)
Genotype	Hybrid A	2.2a	1.2a	1.2b	0.5a
	Hybrid B	3.6a	1.8a	2.5a	0.3a
Seed Quality	High	1.9a	1.6a	1.6a	0.4a
	Low	4.0a	1.5a	2.2a	0.4a
CV (%)		120.1	139.7	161.3	265.0

* Any two means within a column followed by the same letter are not signficantly different at the 5% level according to least significant difference.

Percent Lodged Plants

1990

Plant population was the only significant factor in the percent of lodged plants. At both locations, the highest plant population had a higher percent of lodged plants than the medium and low populations (Table 6).

1991

There were no differences in percent of lodged plants at Kanawha, while at Ames, date of planting, plant population and genotype all effected percent lodged plants (Table 6). Late planting had a higher percentage of lodged plants than early planting date. Percent lodged plants increased with increases in plant population and hybrid B was more susceptible to lodging than hybrid A.

Ear Length

Plant population and genotype had a significant effect on ear length at both locations and years. Ear length decreased as plant population increased and hybrid B gave longer ears than hybrid A (Table 7). Date of planting had a significant effect on ear length in 1990 at Kanawha and 1991 at Ames where date was included as a

Table 6. Influence of planting date, plant population, genotype and seed quality on lodged plants

		Percent lodged plants*			
		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	6.9	2.3b	5.1a	--
	Late	--	7.4a	6.8a	0.8
Plant population (plants/ha)	30,000	4.9b	--	3.8b	--
	45,000	6.9ab	1.7c	5.6b	0.7a
	60,000	8.9a	5.6b	8.5a	0.9a
	74,000	--	7.2a	--	0.9a
LSD (0.05)		(3.35)	(0.90)	(1.95)	(1.07)
Genotype	Hybrid A	6.2a	4.0b	5.5a	1.0a
	Hybrid B	7.6a	5.7a	6.3a	0.7a
Seed Quality	High	6.7a	4.6a	6.9a	0.9a
	Low	7.1a	5.1a	5.0a	0.8a
	CV (%)	68.5	69.9	88.8	174.4

* Any two means within a column followed by the same letter are not significantly different at the 5% level according to least signficant difference.

Table 7. Influence of planting date, plant population, genotype and seed quality on ear length

		Ear length (cm)*			
		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	17.5	18.2a	18.5a	--
	Late	--	17.1b	17.1b	16.5
Plant population (plants/ha)	30,000	18.4a	--	18.3a	--
	45,000	17.7ab	18.9a	17.9b	17.9a
	60,000	16.3b	17.5b	17.1c	16.2b
	74,000	--	16.6c	--	15.5b
LSD (0.05)		(1.49)	(0.61)	(0.23)	(1.29)
Genotype	Hybrid A	17.0b	16.9b	17.3b	15.7b
	Hybrid B	17.9a	18.a	18.3a	17.3a
Seed Quality	High	17.6a	17.6a	17.8a	16.6a
	Low	17.9a	17.8a	17.7a	16.5a
CV (%)		4.8	5.2	3.1	5.4

* Any two means within a column followed by the same letter are not significantly different at the 5% level according to least signficant difference.

factor in the study. On average, early planting produced longer ears than late planting at both locations. There was a population X genotype interaction at Ames in 1990 (Figure 4). Differences in ear length between the two hybrids was not consistent at different plant populations.

Number of Rows per Ear

Only genotype had a significant effect on the number of rows per ear at both locations and years. Except at Kanawha in 1990, the fixed-ear type hybrid A had more rows than flex-ear type hybrid B (Table 8).

Number of Kernels per Row

1990

None of the factors under study had any significant effect on number of kernels per row at Ames except plant population, while at Kanawha, date of planting, plant population, genotype and seed quality all had a significant effect (Table 9). Early planting, low plant population, fixed ear type hybrid A and high seed quality all favored a higher number of kernels per row. At Kanawha, there were date of planting X genotype and plant population X seed quality interactions. The difference

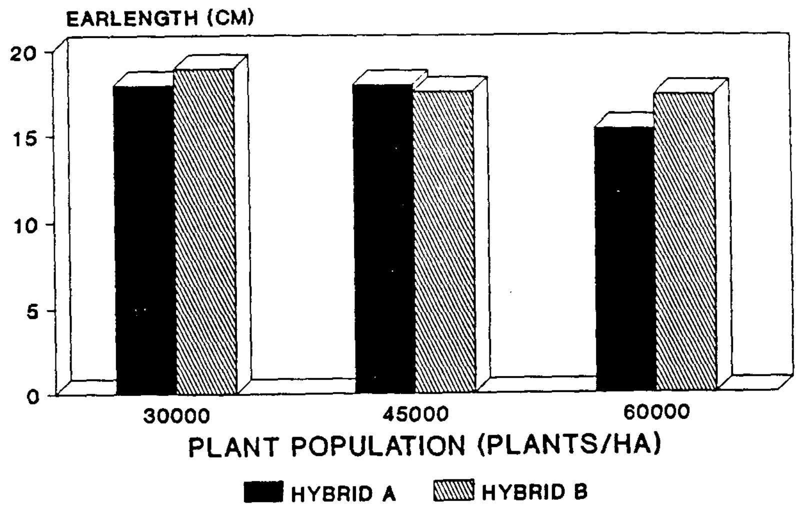

Figure 4. Plant population X genotype interaction effects on ear length, Ames 1990. The 5% LSD for hybrid differences at a given plant population is 1.0.

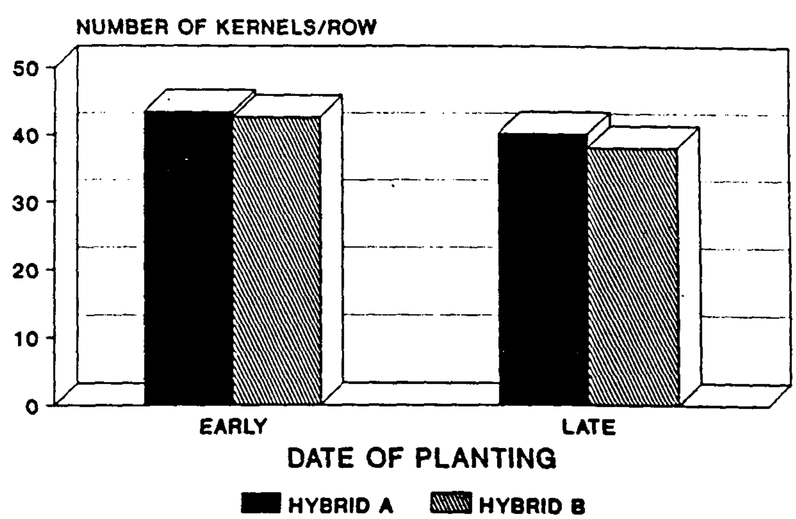

Figure 5. Planting date X genotype interaction effects on number of kernels per row, Kanawha 1990. The 5% LSD for hybrid differences at a given date of planting is 0.9.

Table 8. Influence of planting date, plant population, genotype and seed quality on number of rows per ear

		Number of rows/ear*			
		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	15.3	15.4a	16.4a	--
	Late	--	15.1a	16.2a	15.8
Plant population (plants/ha)	30,000	15.7a	--	16.4a	--
	45,000	15.3a	15.6a	16.2a	16.1a
	60,000	15.0a	15.1a	16.3a	15.9a
	74,000	--	15.1a	--	15.2a
LSD (0.05)		(0.93)	(0.51)	(0.52)	(1.05)
Genotype	Hybrid A	16.7a	16.3a	17.8a	17.5a
	Hybrid B	14.0b	14.3b	14.8a	14.0b
Seed Quality	High	15.4a	15.3a	16.3a	15.8a
	Low	15.2a	15.2a	16.2a	15.8a
CV (%)		5.5	4.8	5.0	4.5

* Any two means within a column followed by the same letter are not significantly different at the 5% level according to least signficant difference.

Table 9. Effect of planting date, plant population, genotype and seed quality on number of kernels per row.

		Number of kernels per row*			
		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	39.0	41.8a	43.0a	--
	Late	--	39.4b	39.2b	38.2
Plant population (plants/ha)	30,000	42.0a	--	42.1a	--
	45,000	39.4ab	43.6a	41.3b	41.6a
	60,000	35.5b	40.1b	39.9c	37.4b
	74,000	--	38.1c	--	35.7b
LSD (0.05)		(5.50)	(1.14)	(0.67)	(2.40)
Genotype	Hybrid A	38.3a	40.2b	41.8a	37.1b
	Hybrid B	39.7a	41.1a	40.3b	39.4a
Seed Quality	High	39.4a	40.6a	41.7a	38.5a
	Low	38.6a	40.6a	40.6b	37.9a
CV (%)		5.3	4.4	3.6	4.5

* Any two means within a column followed by the same letter are not signficantly different at the 5% level according to least significant difference.

in number of kernels per row between the two genotypes was more pronounced at the late than early planting date (Figure 5). The effects of seed quality were more pronounced at low than at high plant population (Figure 6).

<u>1991</u>

There were significant effects of date of planting, plant population and genotype on number of kernels per row but no seed quality effect at Ames (Table 9). Similar to Kanawha, early planting and low plant population favored a higher number of kernels per row. Flex ear type hybrid B and not fixed-ear type hybrid A produced a larger number of kernels per row. There was a genotype X seed quality interaction effect on number of kernels per row. High seed quality of hybrid A produced similar number of kernels per row as low seed quality (40.6 Vs 39.7) while low seed quality lot of hybrid B produced significantly more kernels per row than high seed quality (41.5 Vs 40.6) (Figure 7). At Kanawha, plant population and genotype had a significant influence on kernel number per row (Table 9). Kernel numbers per row decreased with increasing population. No consistent hybrid response was observed on number of kernels per

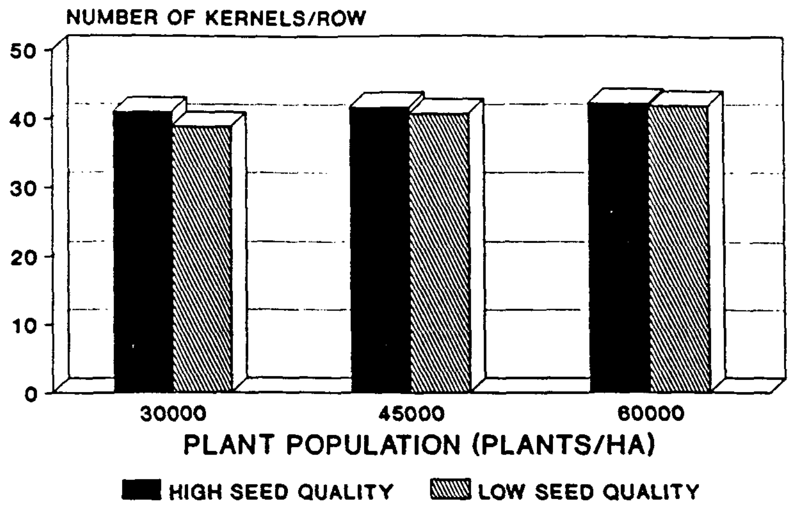

Figure 6. Plant population X seed quality interaction effects on number of kernels per row, Kanawha 1990. The 5% LSD for seed quality differences at a given plant population is 1.1.

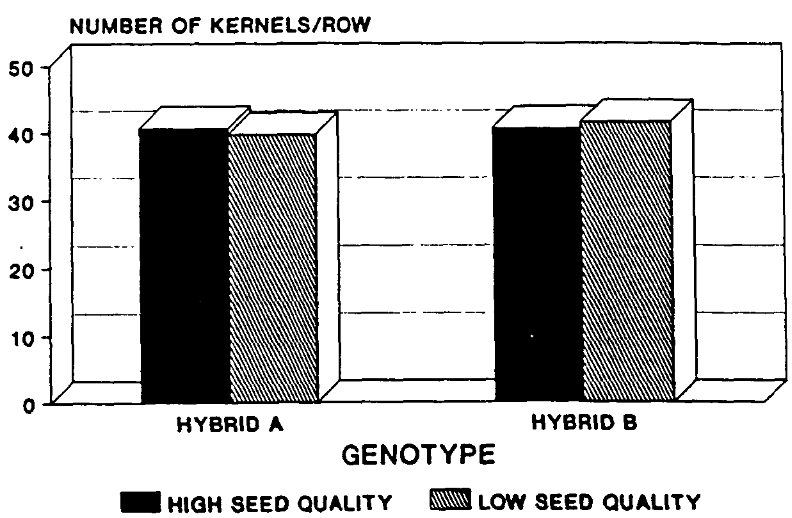

Figure 7. Genotype X seed quality interaction effects on number of kernels per row, Ames 1991. The 5% LSD for seed quality differences at a given genotype is 1.0.

row. A three way interaction between plant population X genotype X seed quality was observed (Figure 8). The differences between number of kernels per row were not consistent at different plant populations for each hybrid.

200 Kernel Weight

1990

Plant population density and genotype had a significant influence on 200 kernel weight at both locations (Table 10). At Kanawha, the late planting date produced a greater 200 kernel weight than early planting. Low plant population and flex ear type hybrid B favored greater kernel weight than high population and fixed ear type hybrid A. At Ames, there was a plant population X genotype interaction (Figure 9). As plant population increased from 30,000 to 60,000 plants/ha, genotype differences in 200 kernel weight decreased.

1991

Plant population and genotype influenced kernel weight at both locations, while date of planting also influenced kernel weight at Ames. Similar to the previous season, low plant population and flex-ear type

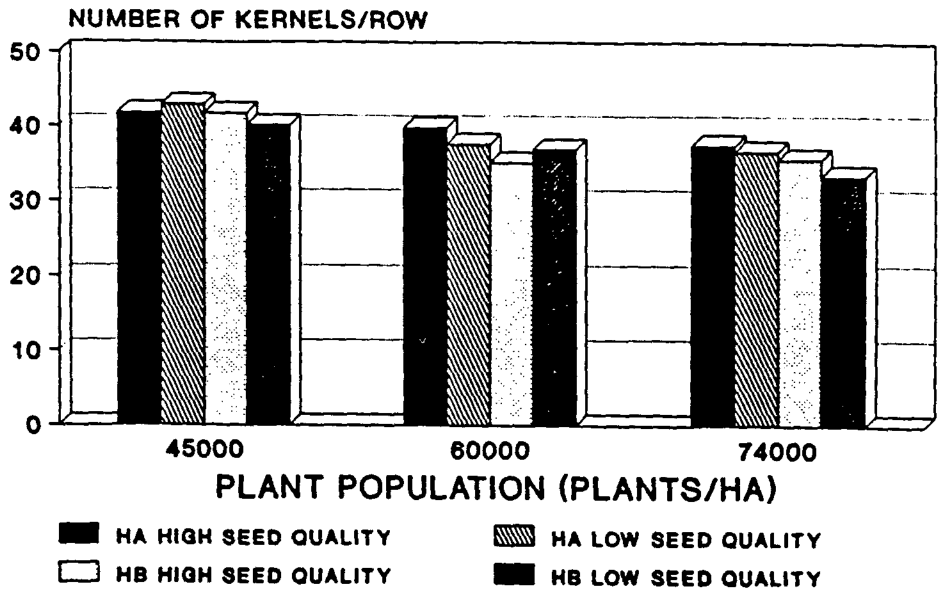

Figure 8. Plant population X genotype X seed quality interaction effects on number of kernels per row, Kanawha 1991. (HA = Hybrid A, HB = Hybrid B). The 5% LSD for hybrid and seed quality differences at a given plant population is 1.0.

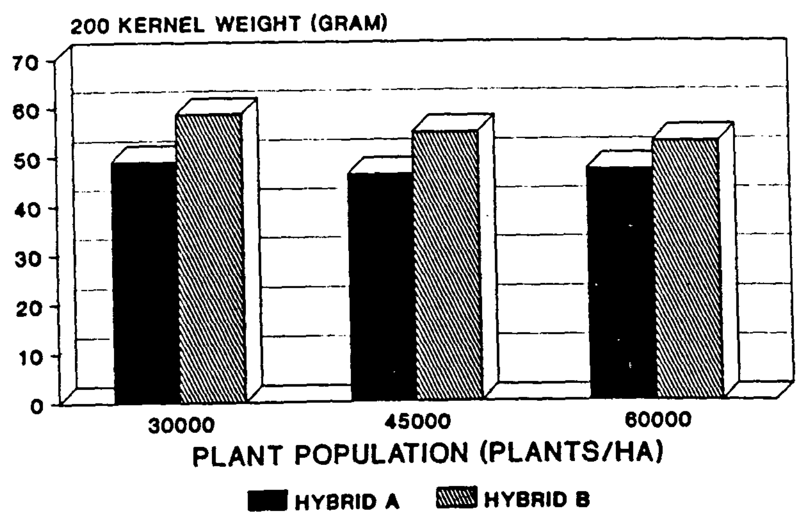

Figure 9. Plant population X genotype interaction effects on kernel weight, Ames 1990. The 5% LSD for hybrid differences at a given plant population is 2.2.

Table 10. Effect of planting date, plant population and genotype and seed quality on 200 kernel weight

		200 kernel weight (g)*			
		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	51.4	63.1a	55.0b	--
	Late	--	60.0b	56.5a	55.5
Plant population (plants/ha)	30,000	53.4a	--	58.6a	--
	45,000	50.6ab	63.5a	57.0b	58.2a
	60,000	49.9b	61.5b	51.6c	54.8b
	74,000	--	59.6c	--	53.6b
LSD (0.05)		(3.23)	(0.95)	(1.64)	(3.0)
Genotype	Hybrid A	47.5b	54.1b	47.5b	49.8b
	Hybrid B	55.4a	69.0a	63.9a	61.2a
Seed quality	High	51.8a	61.7a	55.3a	55.5a
	Low	51.1a	61.4a	56.1a	55.5a
CV (%)		3.6	2.6	5.6	3.9

* Any two means within a column followed by the same letter are not signficantly different at the 5% level according to least significant difference.

hybrid B favored a higher kernel weight than high plant population and fixed ear type hybrid A. Early planting favored a heavier 200 kernel weight than late planting at Ames (Table 10). There was a plant population X genotype interaction at both locations (Figures 10 and 11), while at Ames date of planting X genotype, and date of planting X plant population interactions were also observed (Figures 12 and 13). At both locations, hybrid B had higher 200 kernel weight than hybrid A but the kernel weight differences between the two hybrids were more pronounced as plant population was reduced. At Ames, hybrid B had a higher 200 kernel weight than hybrid A but the weight differences were more pronounced at early than late planting dates. Also, early planting date gave a higher 200 kernel weight than late planting across all plant populations but the weight differences increased as plant population increased.

Grain Yield of Main Ears

<u>1990</u>

Seed quality was the only factor that had a significant influence on grain yield of main ears at Ames. High seed quality yielded significantly higher than low seed quality (Table 11). At Kanawha, all the

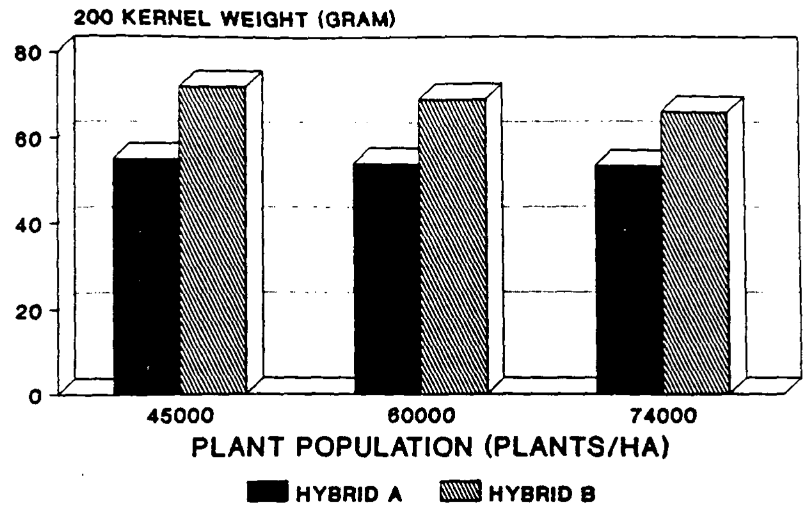

Figure 10. Plant population X genotype interaciton effects on kernel weight, Ames 1991. The 5% LSD for hybrid differnces for a given plant population is 1.2.

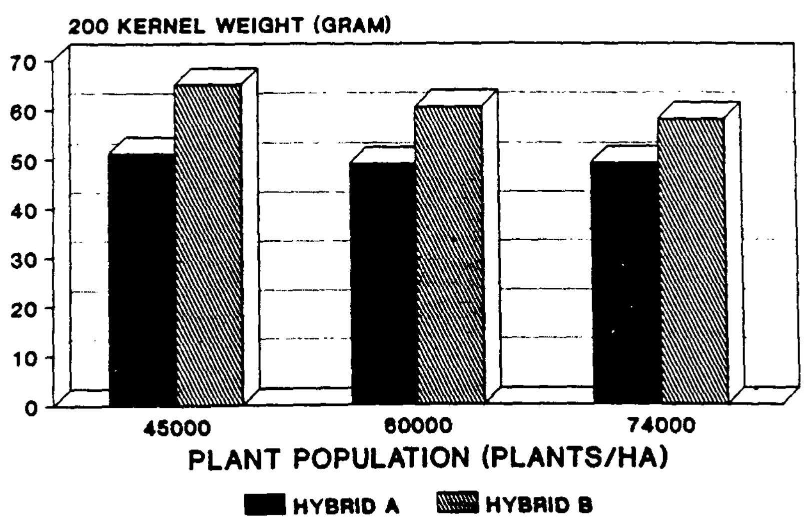

Figure 11. Plant population X genotype interaction effects on kernel weight, Kanawha 1991. The 5% LSD for hybrid differences for a given plant population is 2.2.

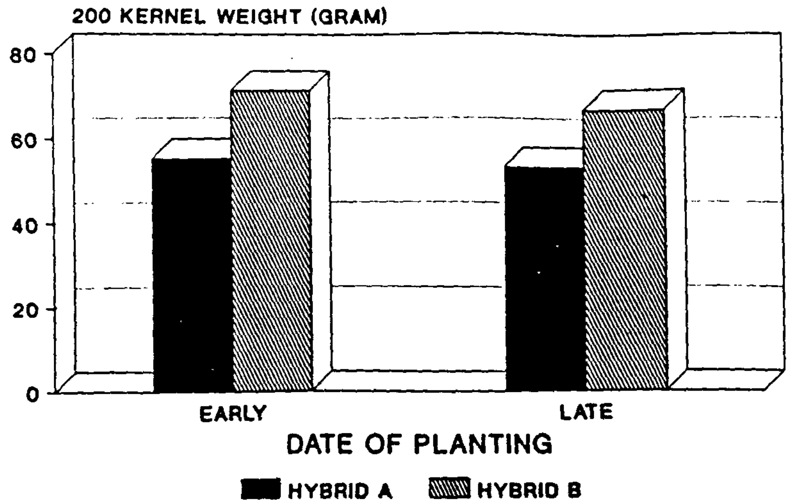

Figure 12. Planting date X genotype interaction effects on kernel weight, Ames 1991. The 5% LSD for hybrid differences at a given planting date is 0.9.

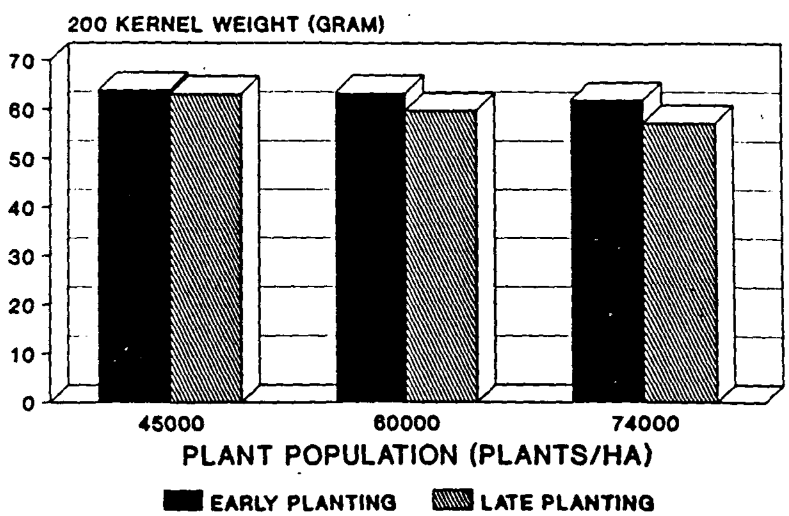

Figure 13. Planting date X plant population interaction effects on 200 kernel weight, Ames 1991. The 5% LSD for planting date differences at a given plant population is 1.3.

Table 11. Influence of date of planting, plant population, genotype and seed quality on grain yield of main ears

		Yield of main ears (kg/ha)*			
		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	5475.3	10663.8a	7329.1a	--
	Late	--	8917.9b	6585.7b	7588.4
Plant population (plants/ha)	30,000	5134.3a	--	5812.6b	--
	45,000	5823.0a	8784.2b	7337.4a	6981.8b
	60,000	5468.6a	10132.1a	7722.2a	7697.0a
	74,000	--	10456.2a	--	8086.4a
LSD (0.05)		(1560.6)	(325.27)	(528.46)	(941.83)
Genotype	Hybrid A	5571.6a	9430.7b	6775.7b	7337.4b
	Hybrid B	5379.0a	10151.0a	7139.1a	7839.4a
Seed quality	High	5692.4a	9821.4a	7192.3a	7719.2a
	Low	5258.2b	9760.3a	6722.4b	7457.6a
CV (%)		9.2	4.8	8.0	8.7

* Any two means within a column followed by the same letter are not signficantly different at the 5% level according to least significant difference.

factors under study ie date of planting, plant population, genotype and seed quality had a significant effect on main ear yield. Early planting, higher plant population, high seed quality and flex ear type hybrid B favored higher grain yield than late planting, lower plant population, low seed quality and fixed ear type hybrid A. There were no interactions among the factors.

<u>1991</u>

Seed quality unlike the previous season did not have any significant influence on yield of main ears. However the trend showed high seed quality to favor higher yield than low seed quality. At Ames, early planting, high plant population and flex-ear type hybrid B yielded significantly higher than late planting, low plant population and fixed ear type hybrid A. Planting date X plant population interaction was observed at Ames (Figure 14). Across all plant populations, early planting yielded higher than late planting but the yield differences between the two planting dates were more pronounced as plant population was increased.

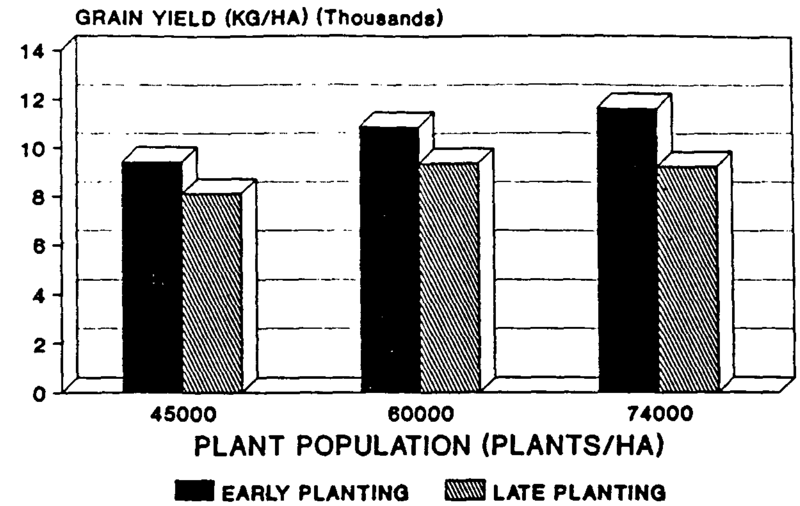

Figure 14. Planting date X plant population interaction effects on yield of main ears, Ames 1991. The 5% LSD for planting date differences at a given plant population is 460.0.

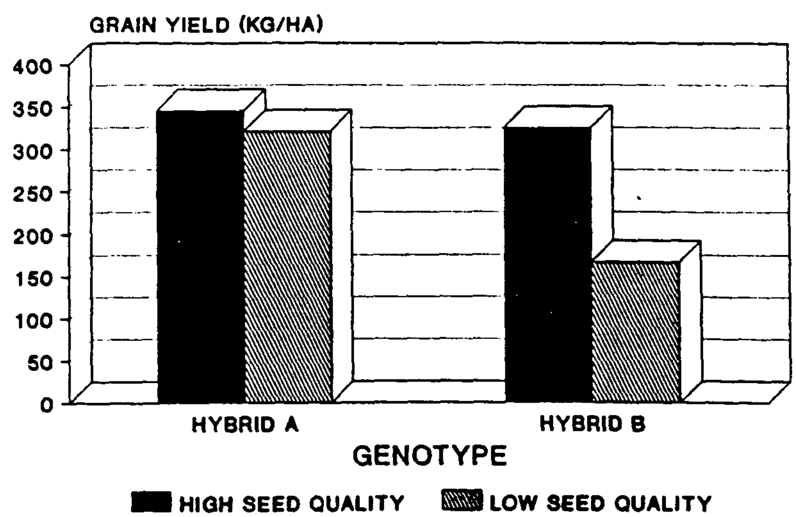

Figure 15. Genotype X seed quality interaction effects on yield of second ears, Kanawha 1990. The 5% LSD for seed quality dfiferences at a given genotype is 79.4.

Yield of Second Ears

1990

Date of planting had no significant effect on yield of second ears at Kanawha. Plant population and seed quality had a significant influence on second ear yield at both locations while genotype had a significant effect at Kanawha. Lower plant population, high seed quality and fixed ear type hybrid A favored higher second ear yield (Table 12). At Kanawha, significant genotype X seed quality, plant population X seed quality and plant population X genotype X seed quality interaction effects were observed (Figures 15, 16 and 17). High seed quality produced higher yield on second ears in both genotypes. However, the effect of seed quality was much more pronounced in flex ear type hybrid B than in fixed ear type hybrid A (Figure 15). At lower plant populations, high seed quality had a more profound effect on yield of second ears. At 60,000 plants per hectare effect of seed quality on second ear yield was non significant (Figure 16). Seed quality differenes in both hybrids were more pronounced at 30,000 plants/ha. High seed quality lots produced higher yield of second ears than low seed quality lots. At 45,000 and 60,000 plants/ha no significant differences in second ear yields were

Table 12. Influence of planting date, plant population, genotype and seed quality on grain yield of second ears

		Yield of second ears (kg/ha)*			
		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	112.1	83.9a	253.2a	--
	Late	--	131.5a	325.9a	34.1
Plant population (plants/ha)	30,000	224.3a	--	427.7a	--
	45,000	69.3b	162.9a	286.8b	63.9a
	60,000	42.6b	101.0b	154.2c	30.2a
	74,000	--	59.3b	--	8.3a
LSD (0.05)		(84.28)	(66.80)	(74.22)	(86.41)
Genotype	Hybrid A	137.5a	115.6a	332.9a	11.3a
	Hybrid B	86.7a	99.9a	236.1b	56.9a
Seed quality	High	154.0a	111.4a	335.3a	56.1a
	Low	70.1b	104.1a	243.8b	12.1a
CV (%)		74.0	89.1	47.5	235.3

* Any two means within a column followed by the same letter are not signficantly different at the 5% level according to least sgnificant difference.

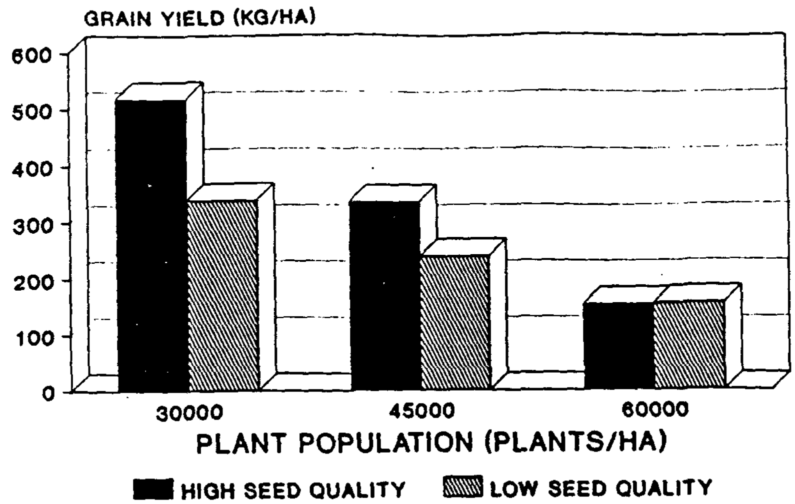

Figure 16. Plant population X seed quality interaction effects on yield of second ears, Kanawha 1990. The 5% LSD for seed quality differences at a given plant population is 97.1.

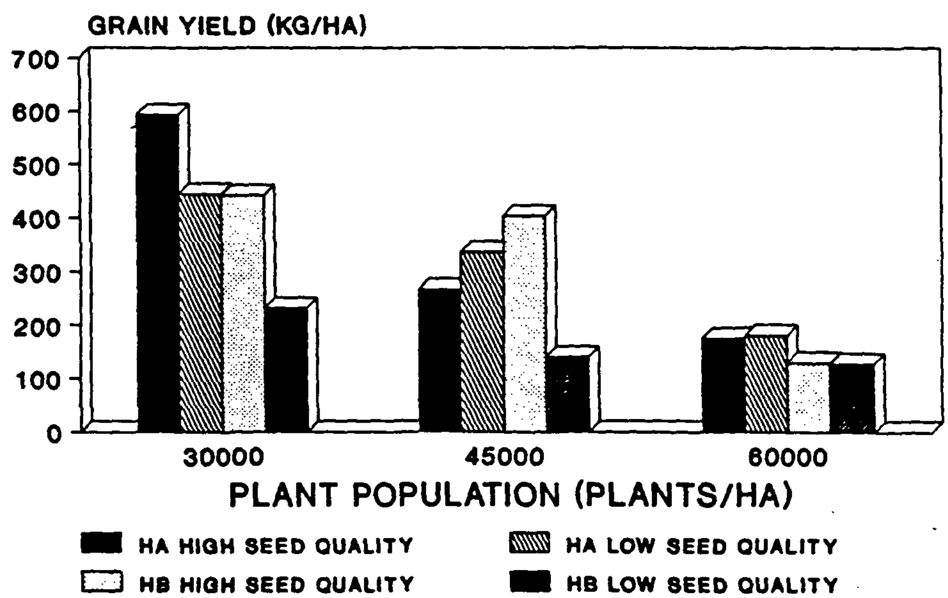

Figure 17. Plant population X genotype X seed quality interaction effects on yield of second ears, Kanawha 1990. (HA = Hybrid A, HB = Hybrid B). The 5% LSD for genotype and seed quality differences at a given plant population is 137.6.

observed except for hybrid B which favored higher yield for high than low quality seed lots (Figure 17).

1991

Only plant population and planting date X genotype interaction had a significant effect on yield of second ears at Ames. As expected, lower plant population favored more yield on second ears than higher plant population (Table 12). Effects of genotype were more pronounced at early than late planting (Figure 18).

Total Grain Yield

1990

Total grain yield was the sum of main and second ears. All the factors studied ie date of planting, plant population, genotype and seed quality had a significant effect on total grain yield and no interactions among the factors were observed at Kanawha. Early planting, high plant population, flex ear type hybrid B and high seed quality favored higher total grain yield compared to late planting, low plant population, fixed ear type hybrid A and low seed quality. At Ames, only seed quality affected total grain yield. High seed quality lot yielded significantly higher than low seed quality lot.

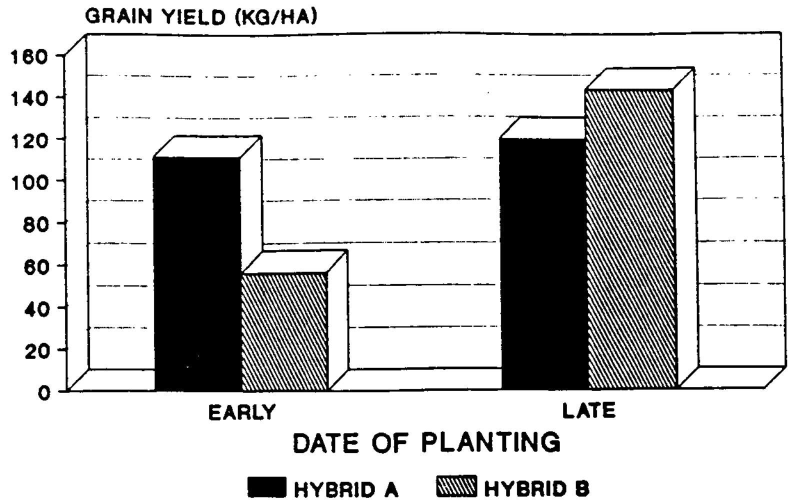

Figure 18. Planting date X genotype interaction effects on yield of second ears, Ames 1991. The 5% LSD for hybrid differences at a given date of planting is 55.4.

Plant population had no significant effect on total grain yield (Table 13).

1991

Date of planting and plant population had a significant influence on total grain yield at Ames while genotype had a significant effect at both locations. Early planting, high plant population and flex ear type hybrid B favored higher total grain yield than late planting, low plant population and fixed ear type hybrid A (Table 13). Seed quality, unlike in the previous season did not significantly affect total grain yield. At Ames, date of planting X seed quality and date of planting X plant population interactions were observed. High seed quality yielded equally as low seed quality at early planting date but yielded higher at late planted date (Figure 19). Across all plant populations, early planting yielded higher than late planting but the yield differences between the two planting dates were more pronounced as plant population was increased (Figure 20). These interactions are similar to those observed for yield of main ears.

Table 13. Influence of planting date, plant population, genotype and seed quality on total grain yield

		Total grain yield (kg/ha)*			
		Ames		Kanawha	
		1990	1991	1990	1991
Date of planting	Early	5587.4	10747.7a	7582.3a	--
	Late	--	9049.4b	6911.6b	7622.5
Plant population (plants/ha)	30,000	5358.6a	--	6240.2b	--
	45,000	5892.3a	8947.2b	7624.1a	7045.7b
	60,000	5511.2a	10233.0a	7876.4a	7727.2a
	74,000	--	10515.5a	--	8094.7a
LSD (0.05)		(1604.0)	(329.3)	(549.72)	(961.85)
Genotype	Hybrid A	5709.1a	9546.2b	7108.6b	7348.7b
	Hybrid B	5465.6a	10250.9a	7385.2a	7896.3a
Seed quality	High	5846.5a	9932.8a	7527.6a	7775.3a
	Low	5328.3b	9864.4a	6966.2b	7469.7a
CV (%)		9.3	4.7	7.7	8.9

* Any two means within a column followed by the same letter are not significantly different at the 5% level according to least significant difference.

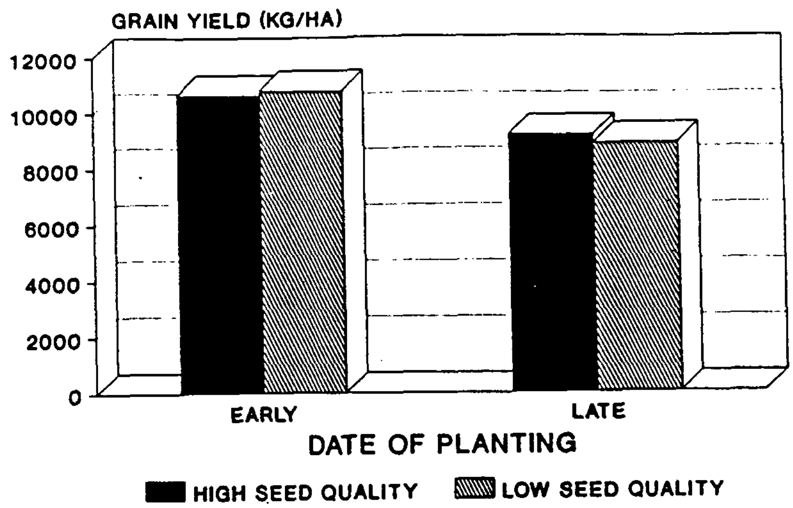

Figure 19. Planting date X seed quality interaction effects on total grain yield, Ames 1991. The 5% LSD for seed quality differences at a given date of planting is 270.0.

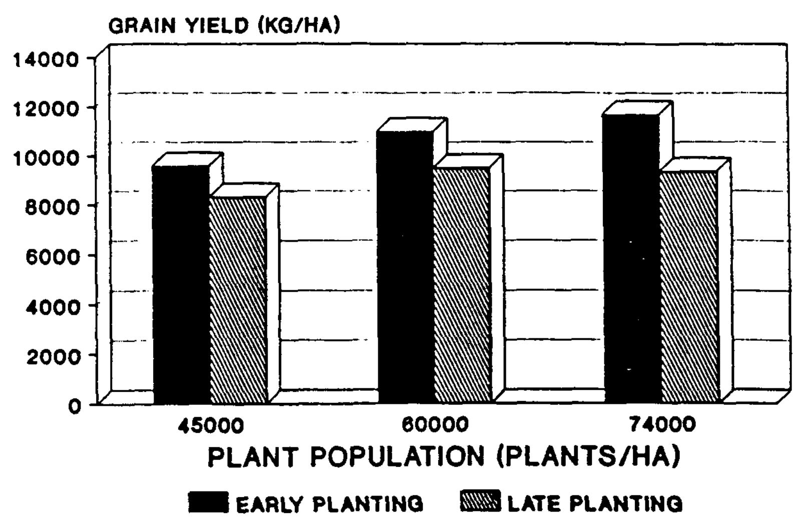

Figure 20. Planting date X plant population interaction effects on total grain yield, Ames, 1991. The 5% LSD for date of planting differences at a given plant population is 465.7.

DISCUSSION

Field Emergence

As expected, the percent field emergence of high quality seed lots was higher than from low quality seed lots at both locations and years. These findings are similar to those reported by Perry (1973), Leudders and Burris (1979) and Tekrony et al. (1989) which indicated a positive influence of high vigor on field emergence.

Final Plant Height

Late planting produced taller plants than early planting at Kanawha in 1990 while the reverse occurred at Ames in 1991. Knapp et al. (1981) and Carter (1984) have reported that late planting produces plants that are taller and more slender while early planting produces shorter plants that allow increased light penetration and tend to lodge less at high populations. Reducing plant population resulted in reductions in final plant height because of reduced competition between plants for light.

Prolificacy

The ability of plants to produce double ears increased with a decrease in plant population probably due to less plant competition for those environmental factors of yield that each plant is forced to share with its competing neighbors. This agrees with Duncan (1956) and Parks et al. (1965) in which they reported that average yield of the individual plant increases with a decrease in plant population.

High seed quality gave a significantly higher percentage of plants with double ears than low seed quality at both locations and years. This was probably due to more vigorous plants from high quality seed lot which were more capable of producing double ears compared to plants from low quality seed lots. Burris (1975) reported increased barrenness with decrease in seedling vigor. He concluded that this was possibly due to unequal plant competition. As plant population increased, differences in number of double ears between high and low quality seed lots decreased. This could probably be explained by the increase in plant competition which confounded or eliminated vigor differences.

Barrenness

The tendency for barrenness increased with increase in plant population. Similar results have been reported by Lang et al. (1956), Woolley et al. (1962), Parks et al. (1965) and Alessi and Power (1975). These reports show that increased plant population had a marked increase in barrenness and resulted in fewer ears per stalk.

Percent Lodged Plants

Stalk lodging increased with increase in plant population. These results agree with those reported by Stringfield and Thatcher (1947); Termude et al. (1963); Vanderlip (1968) and Kruger (1978). Late planting had a higher percent lodged plants than early planting date probably because late planting produced plants that were taller and more slender than earlier planted corn. This is consistent with reports by Lang et al. (1956); Giesbrecht (1969); Alessi and Power (1975); Knapp et al. (1981); and Carter (1984) which indicated that early planting produces shorter plants that tend to lodge less at high populations. No consistent hybrid differences in lodging were found. This is similar to the results reported by Vanderlip (1968).

Ear Length

Ear length decreased as plant population increased at both locations and years. This is no doubt caused by decrease in the supply of those environmental factors of yield that each plant is forced to share with its competing neighbors (Duncan, 1956). Wang et al. (1987) also have reported similar results. Flex ear type hybrid B produced longer ears than fixed ear type hybrid A due to genetic difference between the hybrids. On average, early planting date produced longer ears than late planting at both locations. This is similar to reports by Lang et al. (1956); Giebrecht (1969); Alessi et al. (1975); and Knapp et al. (1981). Differences in ear length between the two hybrids was not consistent at different plant populations.

Number of Rows Per Ear

Number of rows per ear seems to be more of a function of genotype than environmental factors. Fixed ear type hybrid A had more rows per ear than flex ear type hybrid B.

Number of Kernels Per Row

Early planting, low plant population, flex ear type hybrid B and high seed quality all favored a higher number of kernels per row at both locations and years. This was probably due to the fact that early planting and low plant population favored longer ears hence more kernels per row. These results agree with those reported by Wang et al., (1987) who showed increased kernel number with decreasing plant population density. High seed quality favored a higher number of kernels per row compared to low seed quality only at Kanawha in 1990 despite having similar effective ear length. Fixed ear type hybrid A produced more kernels per row at Kanawha in 1990 despite having a shorter effective ear length probably due to smaller kernels compared to flex ear type hybrid B.

200 Kernel Weight

200 kernel weight increased with decrease in plant population. This agrees with the findings of Sharma et al. (1984) in which he reported higher 100 kernel weight as plant population decreased.

Similar results have been reported by Woolley et al., (1962); Parks et al., (1965); Baenziger and Glover, (1980); Sotomayor et al. (1980); and Wang et al. (1987). Flex ear type hybrid B favored higher kernel weight than fixed ear type hybrid A at both locations and years and early planting produced heavier kernels than late planting date at Ames in 1991. This was probably due to the fact that late planting shortened the period of vegetative growth and grain filling and kernels did not mature properly resulting in lighter kernels. Zuber (1968) reported only small differences in test weights for planting dates from April 20 to June 1 but decreased significantly for the June 20 date.

Yield of Second Ears

Date of planting had no significant effect on yield of second ears or prolificacy. Yield of second ears increased with a decrease in plant population at both locations and years except at Kanawha in 1991, which generally had very few double ears across all plant populations and genotypes. These results are similar to those by Parks et al., (1965) in which he reported a decrease in prolificacy with increase in plant population density due to increased competition between plants for nutrients and light.

Fixed ear type hybrid A generally gave higher yield of second ears than flex ear type hybrid B although significant differnces were observed only at Kanawha in 1990. Hybrid A had the ability to give more than one ear per plant while the flex ear type hybrid B produced single, longer ears.

High seed quality produced significantly more plants with double ears at both locations in 1990 while no significant differences were observed at both locations in 1991. However the trend showed a higher second ear yield with high than low seed quality lots. This would probably be due to more vigorous plants from high seed quality lots than from low quality seed lots which had more potential for producing second ears.

The effect of seed quality on yield of second ears was much more pronounced in flex ear type hybrid B than in fixed ear type hybrid A at Kanawha in 1990, possibly indicating genotypic differences in the way seed quality influenced yield of second ears. At lower plant population, high seed quality had a more profound effect on yield of second ears. At high plant populations, the effect of seed quality on second ear yield was negligible. This would probably be due to increased competition between plants which diminished the benefits of high quality seed.

Total and Main Ear Yield

Total grain yield was the sum of main and second ear yields. A large portion of total grain yield was yield from main ears and only a very small fraction came from second ear yield, therefore the factors studied influenced total grain yield in much the same manner they influenced yield of main ears. What can be said about yield of main ears can also be said for total grain yield.

As expected, early planting date yielded higher than late planting date. Early planting produced longer ears which had more kernels per row than late planting. Although late planting had higher number of plants with double ears than early planting, this did not compensate for the late planting. Stalks were more susceptible to lodging in late than early planting but this probably did not affect yield as all lodged plants were harvested. These results are similar to those reported by Bretzlaff and Boon (1970); Crookston et al. (1976), Johnson and Mulvaney (1980) and Benson (1984). Increased yields from early planting has been attributed to several variables including; more efficient use of sunlight, less injury from summer heat and moisture stress and reduced frost damage in fall.

Pendleton and Egli (1969) stated that early planted corn generally yields better because the grain formation period occurs when the days are longer and the sun is at a steeper angle of incidence and thereby more radiant energy is available for photosynthesis as compared with late planted corn which matures during shorter day lengths.

Generally both total and main ear yield increased with increase in plant population at both locations and years. Although lower plant population favored prolificacy, less lodging, longer ears, more kernels per row and heavier 200 kernel weight, they still yielded less than higher plant population. This would indicate that these yield components did not compensate for the reduced number of plants although yield per individual plant increased with a decrease in plant population. These findings are similar to those reported by Duncan, (1956); Parks et al. (1965); Woolley et al., (1962) and Giesbrecht (1969).

Flex ear type hybrid B yielded higher at all locations and years except at Ames in 1990, where no significant differences were observed between the two hybrids. Hybrid B had a taller final height, longer ear length, more kernels per row, higher 200 kernel weight and higher main ear yield. However, hybrid A had more plants with double ears resulting in higher second ear yield and more rows per ear, but still yielded lower than hybrid B.

High seed quality produced significant higher yield than low seed quality at both locations in 1990, while no significant differences were observed at either location in 1991. However, general trend showed increased yield with high quality seed lots. The percent field emergence of the high quality seed lots was higher than the low quality seed lots. This was probably not a factor in the determination of yield per se as all plots were thinned to their respective population densities. However, differences in distribution of plants could have occurred between the two seed qualities. Plants from high quality seed had more double ears than those from low quality seed. The trend generally showed higher number of kernels per row for high than low quality seed lots although they were not significantly different from each other except at Kanawha in 1990. Literature indicates no consensus regarding the relation between seed quality and crop performance. However, these results agree partly with Burris (1975) in which he concluded that in many genotypes, reductions in seedling vigor result in reduced yield even though stand density is held constant.

At early planting date, high seed quality lot yielded the same as low seed quality lot at Ames in 1991 while at late planting date high seed quality lot yielded higher than low seed quality lot. Yield differences between the two planting dates were more pronounced as plant population was increased. This would probably be due to shorter plants produced from early planting that allow increased light penetration and are more tolerant to high plant population densities yielding much higher than early planted corn at lower plant populations.

CONCLUSIONS

As expected, total grain yield from the early planting date was higher than from the late planting date. Planting date had a significant effect on final plant height, ear length, number of kernels per row, 200 kernel weight and yield of main ears at both locations and years. However, date of planting did not have any profound influence on percent emergence, prolificacy, barrenness and number of rows per ear. Planting date had a significant effect on lodging only at Ames in 1991. The higher total grain yield from early planting date was a result of longer ear length, more kernels per row and eventually higher yield of main ears. 200 kernel weight of early planting date at Kanawha in 1990 was lower than that of late planting date but this did not lower the overall total grain yield of early planting date. These results agree with the findings of previous research which have shown that yields begin to decline when planting occurs later than the optimum planting date for an area (Hicks and Wright, 1987; Crookston et al., 1976; Bretzlaff and Boon, 1970; Johnson and Mulvaney, 1980; Benson, 1984; and Carter, 1984).

Total grain yields were reduced at the lowest plant populations at both locations and years except at Ames in

1990 where plant population had no significant effect. However, the yield of medium and highest populations were not significantly different from each other. Generally, plant population had a significant effect on final plant height, prolificacy, lodging, ear length, number of kernels per row, 200 kernel weight and yield of main ears. Despite lowest plant populations favoring prolificacy, less lodging, longer ears, more kernels per row and heavier 200 kernel weight, compared to higher populations, they still yielded less indicating the inadequacy of these yield components to compensate for the reduced plant populations although yield per individual plant increased with a decrease in plant population. These data support the research findings reported in literature which indicate sizable increases in yield with increasing plant population up to the optimum density (Duncan, 1956; Parks et al., 1965; Woolley et al., 1962 and Giesbrecht, 1969).

Flex ear type hybrid B yielded significantly higher than fixed ear type hybrid A at both locations and years except at Ames in 1990 where no significant differences were detected between the two hybrids. In general, flex ear type hybrid B had a taller final height, longer ear length, more kernels per row, higher 200 kernel weight and higher main ear yield compared to the fixed ear type hybrid A. Hybrid A however had more plants with double ears resulting in higher second ear yield and also had more rows per ear compared to hybrid B, but the contributions of these yield components was not adequate to compensate for the lower total yield. Despite the flex ear type hybrid B having longer ears and yielding higher than the fixed ear type hybrid A, the flex ear type characteristic was not manifested as plant population was changed. Ear length of the flex ear type responded similary as that of the fixed ear type hybrid to varying plant population. Very little data is available on the behavior of flex ear type characteristic to varying plant populations, therefore the findings based on these two ear type hybrids are not conclusive. It is possible that other genotypes with flex ear types would manifest this character at varying plant populations.

Total grain yield from high quality seed lots was significantly higher than from low quality seed lots at both locations in 1990 while no significant differences were observed in 1990. However, the trend showed increased yield with high quality seed lots.

Plants from high quality seed had more double ears than those from low quality seed. This agrees with reports by Burris (1975) which indicated an increase in number of double ears with increase in seedling vigor. Many workers have evaluated the effect of seed quality on performance of subsequent crops but literature indicates no concensus regarding the relation between seed vigor and crop performance. However, these results tend to agree partly with Burris (1975) who concluded that in many genotypes reductions in seedling vigor result in reduced yield even though stand density is held constant. The results obtained in this study show some yield benefit with planting seed from high quality lots. The purpose of planting high quality seeds should not only be to establish adequate final stands in the field, but the yield advantage of using seed from high quality lots should also be a consideration.

Recommendations for future research is to do more extensive work to be able to fully answer the questions of flex ear type and seed quality and how these would relate to corn replanting decisions. To be able to do this, one option would be to include several genotypes with flex ear type characteristic in the study and monitor their responses in relation to varying plant populations.

LITERATURE CITED

Adegbuyi, E. and J. S. Burris. 1989. Effects of seed vigor on crop characters in uniform and reduced populations of corn (Zea Mays L.). J. Agronomy and Crop Science 162:10-20.

Alessi, J. and J. F. Power. 1975. Response of an early-maturing corn hybrid to planting date and population in the northern plains. Agron. J. 67:762-765.

Association of Official Seed Analysts. 1983. Seed vigor testing handbook 32. Assoc. Off. Seed Anal., Springfield, IL.

Baenziger, P. S. and D. V. Glover. 1980. Effect of reducing plant population on yield and kernel characteristics of sugary-2 and normal maize. Crop Sci. 4:444-447.

Bauman, F. L. 1960. Relative yields of first (Apical) and second ears of semi-prolific southern corn hybrids. Agron. J. 55:220-222.

Benson, G. O. 1984. Replanting or late planting decisions with corn and soybeans. In. Proc. 36th Annual Fertilizer and Ag. Chem. Dealers Conf.; Iowa State Univ. Coop. Ext. Service. CE 2081 Z.

Benson, G. O. 1990. Corn replant decisions. A. review. Journal of Production Agriculture 3(2).

Benson, G. O., H. E. Thomson and J. P. Shroyer. 1978. Late planting of corn and soybeans. Iowa State University. Coop Ext. Serv. Pm 843.

Bretzlaff, W. G. and L. V. Boone. 1970. Corn yields as affected by row fertilizers, planting date and nitrogen level. Illinois Res. (Winter):3-4.

Brotslaw, D. J., L. L. Darrah, M. S. Zuber and G. F. Krause. 1988. Effect of prolificacy on grain yield and root and stalk strength in maize. Crop Sci. 28(5):750-755.

Brown, E. B. 1920. Relative yields from broken and entire kernels of seed corn. Agron. J. 12:196-197.

Brown, R. H., E. R. Beaty, W. J. Ethredge and D. D. Hayes. 1961. Influence of row width and plant population on yield of two varieties of corn (Zea mays L.). Agron. J. 62:767-770.

Bryant, H. T. and R. E. Blaser. 1968. Plant constituents of an early and a late corn hybrid as affected by row spacing and plant population. Agron. J. 60:557-559.

Burris, J. S. 1975. Seedling vigor and its effect on field production of corn. Proc. 30th Annu. Corn and Sorghum Res. Conf. (ASA) 30, 185-195.

Burris, J. S. 1976. Seed/seedling vigor and field performance. J. Seed Technol. 1(2):58-74.

Burris, J. S. and R. J. Navratil. 1979. Relationship between laboratory cold-test methods and field emergence in maize inbreds. Agron. J. 71:985-988.

Carter, P. R. 1984. Optimum corn planting practices. Univ. of Wisconsin Ext. Pub. A3264.

Collins, W. K., W. A. Russell and S. A. Eberhart. 19965. Performance of two-ear type of corn belt maize. Crop Sci. 5:113-116.

Crookston, R. K., D. R. Hicks and G. R. Miller. 1976. Hail help in deciding whether to replant corn and soybeans. Crops Soils 28(8):7-11.

Cross, H. Z., J. T. Kamen and L. Brun. 1987. Plant density, maturity and prolificacy effects on early maize. Can. J. Plant Sci. Rev. Can. Phytotechnie Ottawa: Agricultural Institute of Canada 67(1):35-42.

Delouche, J. C. and W. P. Caldwell. 1960. Seed vigor and vigor tests. Proc. Ass. Off. Seed Anal. 50, 124-129.

Douglas, J. A., C. B. Dyson and D. P. Sinclair. 1981. Effect of plant population on the grain yield of maize under high yielding conditions in New Zealand. New Zealand Journal of Agric. Resarch, 25(2):147-149.

Dungan, G. H. and B. Koehler. 1944. Age of seed corn in relation to seed infection and yielding capacity. Agron. J. 36:436-443.

Duncan, W. G. 1956. The relationship between corn population and yield. Agron. J. 50, 82-84.

Duvick, D. N. 1974. Continuous back crossing to transfer prolificacy to a single-eared inbred line of maize. Crop Sci. 14:69-71.

Fleming, A. A. 1966. Effect of seed age, production, producer and storage of corn (Zea mays L.). Agron. J. 58:227-229.

Free, G. R., C. S. Winkelblech, H. M. Wilson and C. E. Bay. 1966. Time of planting in a comparison of plow-plant and conventional seed bed preparation of corn. Agron. J. 58:333-336.

Funk, C. R., J. C. Anderson, M. W. Johnson and W. R. Atkinson. 1962. Effect of seed source and seed age on field and laboratory performance of fields corn. Crop Sci. 2:318-320.

Gardner, J. C., B. G. Schatz and H. M. Olson. 1987. Performance of a prolific and a non-prolific corn hybrid in Central North Dakota. N.D. Farm Res. N.D. Agric. Expt. Stn. Fargo, N.D.: The Station 44(6):21-24.

Giesbrecht, J. 1969. Effect of population and row spacing on the performance of four corn (Zea mays L.) hybrids. Agron. J. 61:439-441.

Giskin, M. and Y. Efron. 1986. Planting date and foliar fertilization of corn grown for silage and grain under limited moisture. Agron. J. 78:426-429.

Hallauer, A. R. and A. F. Troyer. 1972. Prolific corn hybrids and minimizing risk of stress. Proceedings of the 27th Annual Corn and Sorghum Research Conference, 27:140-158.

Herbek, J. H., L. W. Murdock and R. L. Blevins. 1986. Tillage system and date of planting effects on yield of corn on soils with restricted drainage. Agron. J. 78:824-826.

Hicks, D. R. 1979. Corn replanting: Is it necessary? Univ. of Minnesota Agric. Extension Service, Crop News No. 46.

Hicks, D. R. and D. L. Wright. 1987. Maximizing the advantages of early corn planting. National Corn Handbook, Publication NCH-35.

Hoff, D. J. and H. J. Mederski. 1960. Effect of equidistant corn plant spacing on yield. Agron. J. 52:295-297.

Hunter, R. B., L. W. Kannenberg and E. E. Gamble. 1970. Performance of five maize hybrids in varying plant populations and row width. Agron. J. 62:255-256.

Imholte, A. A., P. P. Carter. 1987. Planting date and tillage effects on corn following corn. Agron. J. 79:746-751.

Johnson, R. R. 1978. Considerations in replanting corn. In. Proc. 33rd Ann. Corn and Sorghum Res. Conf., Chicago, IL, 68-76.

Johnson, R. R., D. R. Hicks and D. L. Wright. 1986. Guidelines for making corn replant decision. National Corn Handbook Publication NCH - 30.

Johnson, R. R. and D. L. Mulvaney. 1980. Development of a model for use in maize replant decisions. Agron. J. 72:459-464.

Johnson, R. R. and L. M. Wax. 1981. Stand establishment and yield of corn as affected by herbicides and seed vigor. Agron. J. 73:859-862.

Karlen, D. L. and C. R. Camp. 1985. Row spacing, plant population and water management effects on corn in the Atlantic costal plain. Agron. J. 77:393-398.

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

Kiesselbach, T. A. 1937. Effects of age, size and source of seed on the corn crop. Nebraska Agric. Expt. Station Bull. 305, 16 p.

Knapp, W. R. and W. S. Reid. 1981. Interactions of hybrid maturity class, planting date, plant population and nitrogen fertilization on corn performance in New York. Search Agric. N.Y. State.f Agric. Exp. Stn. Ithaca (21) 27 pp.

Krall, J. M. H. A. Esechie, R. J. Raney, S. Clark, G. TenEyck, M. Lundquist, N. E. Humburg, L. S. Axthelm, A. D. Dayton and R. L. Vanderlip. 1977. Influence of within-row variability in plant spacing on corn grain yield. Agron. J. 69:797-799.

Kruger, W. 1978. Effect of fertilization and plant population density on stalk rot, stalk breakage and yield of maize. Z. Acker - Pflanzenbau 147(3):190-203.

Lang, A. L. J. W. Pendleton, and G. H. Dungan. 1956. Influence of population and nitrogen levels on yield and protein and oil contents on nine corn hybrids. Agron. J. 48:284-9.

Leudders, V. D. and J. S. Burris. 1979. Effects of broken seed coats on field emergence in soybean. Agron. J. 71:877-879.

Lucas, E. O. and S. U. Remison. 1984. Effect of population density on yield and dry-matter partition of maize varieties in Nigeria. Indian J. Agric. Sci. New Delhi 54(4):284-290.

Lutz, J. A., Jr., H. M. Camper and G. H. Jones. 1971. Row spacing and population effects on corn yields. Agron. J. 63:12-14.

Lutz, J. A., Jr. and G. D. Jones. 1969. Effect of corn hybrids, row spacing and plant population on the yield of corn silage. Agron. J. 61:942-45.

McDonald, M. B. 1980. Vigor test sub-committee report. Ass. Off. Seed Anal. Newsl. 54(1):37-40.

Mock, J. J. and D. C. Erbach. 1977. Influence of conservation tillage environments on growth and productivity of corn. Agron. J. 69:337-340.

Mooers, C. C. 1920. Planting rates and spacing for corn under southern conditions. Agron. J. 12(1):1-22.

Navratil, R. J. and J. S. Burris. 1980. Predictive equations for maize inbred emergence. Crop Sci. 20:567-571.

Nunez, R. and E. Kamprath. 1969. Relationships between N response, plant population and row width on growth and yield of corn. Agron. J. 62:767-70.

Obendorf, R. L. 1972. Factors associated with early germination in corn under cool condition. Proc. Corn Sorghum Res. Conf. 27:132-139.

Parks, W. L, R. A. McLean, J. F. Schneider and John Hodges, III. 1981. Corn yields as affected by row spacing and plant population. Univ. of Tennessee Agric. Exp. Stn., Knoxville, Tennessee Bull. 64, 5 pp.

Parks, W. L., J. A. Odom, J. R. Overton and E. J. Chapman. 1965. Plant population and row spacing for corn. Knoxville University of Tennessee, Agric. Exp. Stn. Bulletin 392, 16 p.

Pendleton, J. W. and D. B. Egli. 1969. Potential yield of corn as affected by planting date. Agron J. 61:70-71.

Prior, C. L. and W. A. Russell. 1975. Yield performance of nonprolific and prolific maize hybrids at six plant densities. Crop Sci. 15:482-486.

Russell, W. A. 1968. Test crosses of one- and two-ear types of corn belt maize inbreds. I. Performance at four plant stand densities. Crop Sci. 8:244-247.

SAS Institute. 1989. SAS users guide: Statistics. SAS Institute Inc. Cary, North Carolina N.C.

Sharma, T. R. and I. M. Adamu. 1984. The effects of plant population on the yield and yield attributing characters in maize (Zea mays L.). Z. Acker. Pflanzenbau J. Agron. Crop Sci. 153(4):315-318.

Sotomayor, R. A., C. Torres, M. Ellis. 1980. Effect of plant density on yield and plant characters of twelve corn hybrids and selections. Journal of Agric. Exp. Stn. State Agriculture Puerto Rico 64(4):407-413.

Stevenson, C. K. 1984. Corn hybrid and plant population interactions in maximum yield research. Better-crops-plant-food, Atlanta, GA, Potash and Phosphate Institute 69(4):12-13.

Stickler, F. C. 1964. Row width and plant population studies with corn. Agron. J. 56:438-441.

Stringfield, G. H. and L. E. Thatcher. 1947. Stands and methods of planting corn hybrids. Agron. J. 39:995-1010.

Tekrony, D. M. and D. B. Egli. 1991. Relationship of seed vigor to crop yield. A Review. Crop Sci. 31(3):816-822.

Tekrony, D. M., D. B. Egli and D. A. Wickham. 1989a. Corn seed vigor effect on no-tillage field performance. I. Field emergence. Crop Sci. 29:1523-1528.

Tekrony, D. M., D. B. Egli and D. A. Wickham. 1989b. Corn seed vigor effect on no-tillage field performance. II. Plant growth and grain yield. Crop Sci. 29:1528-1531.

Termunde, D. E., D. B. Shank and V. A. Dirks. 1963. Effects of population levels on yield and maturity of maize hybrids growth on the Northern Great Plains. Agron. J. 55:551-555.

Tetio-Kagho, F. and F. P. Gardner. 1988a. Responses of maize to plant population density. I. Canopy development, light relationships and vegetative growth. Agron. J. 80:930-935.

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

Thomas, W. 1956. Effect of plant population and rates of fertilizer nitrogen on average weight of ears and yields of corn in the south. Agron. J. 48 228-230.

Vanderlip, R. L. 1968. How plant populations affect yields of corn hybrids. Manhattan, Kan. Agric. Expt. Stn., Kansas State University of Agriculture and Applied Science, 19 (35) pp.

Walker, W. M. and D. L. Mulvaney. 1980. Planting date, starter fertilizer and corn yield. Illinois Research Agricultural Experiment Station, Urbana, The Station, 22(4):7.

Wang, C. S., S. H. Tsao and D. J. Liu. 1987. Effect of population density on the accumulation of dry matter in maize. Chung. hau. Nung. Yeh Yen. Chiu. J. Agric. Res. China. Taiwan, China: The Taiwan Agricultural Research Institute 36(1):15-28.

Woolley, D. G., N. P. Baracco and W. A. Russell. 1962. Performance of four corn inbreds in single-cross hybrids as influenced by plant density and spacing patterns. Crop Sci. 2:441-444.

Yao, A. Y. M. and R. H. Shaw. 1964. Effect of plant population and planting pattern of corn on water use and yield. Agron. J. 56:147-152.

Zuber, M. S. 1968. Date of planting studies with corn in Central Missouri Agric. Expt. Stn. B 868.

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