DEVELOPMENT OF WIDELY ADAPTED POPULATIONS OF MAIZE (*Zea mays* L.)

by

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INTRODUCTION

Vegetative and reproductive development in maize usually is dependent on adaptation to a particular climate. Major factors in the environment which condition the growth pattern of maize plants include temperature, moisture, fertility, radiation intensity and photoperiod (10).

Jensen (13), pointing out the importance of genetic variability, says that maize breeders have found that the highest yields in a particular environment are usually made by single crosses rather than by genetically variable double crosses. However, the same single cross rarely gives the highest yield over a wide range of environments, i.e., in different years or at different locations.

Even though very uniform materials may have advantages such as uniform size and maturity, disease resistance, good market quality, and high yield, there is evidence that mixtures or more heterogeneous materials give higher and more consistent yields (12, 13, 24).

Day-neutral, i.e. widely adapted plants which are relatively insensitive to photoperiod, should provide a useful means to facilitate crossing of divergent materials from widely different latitudes for specific environments. Furthermore, the day-neutral trait would promote easy exchange of desirable genes of lines from improvement programs from different countries in which corn is grown (10).

Genotypic stability in crop plants generally refers to the repeatability or consistency of performance in different environments. An inverse measure of stability is simply environmental variance about the genotypic mean (14).

The main objectives of this study were to determine whether measurable changes in agronomic traits occurred in sub-populations of maize due to selection pressure present in the geographic areas of seed production, and to measure progress towards development of widely adapted maize populations.

LITERATURE REVIEW

Photoperiod and flowering date

Maize reacts as a quantitative short day-plant (8 hours of daylight with air temperatures above 20°C.) in respect to flower initiation. Anthesis (first release of pollen from the male inflorescence) and silking (emergence of stigmas from the female inflorescence) are reduced when plants are grown under shorter days (8 hours of daylight with air temperatures above 20°C). Silking is generally affected more than anthesis (17).

Tropical maize varieties grown at latitudes farther from the equator tend to extend the period of vegetative growth. Pollination seldom occurs early enough to produce seed under field conditions. Conversely, materials such as U.S. corn belt hybrids from temperate latitudes mature more rapidly when grown near the equator than in areas where they were developed and frequently do not attain normal plant height and number of nodes (10).

Bonaparte (3) observed that rate of tassel development and emergence was slowed by low day temperatures, soil fertility stress (low nutrient levels), and soil moisture stress.

Photoperiod responses and daytime temperatures are the predominant influences which determine the lengths of vegetative and reproductive phases during growth and development of particular genotypes (10). Short photoperiods, by advancing the time of ear development, tend to cause the growth of the apical and lateral inflorescence to occur simultaneously (17).

Ear and plant height

Ear height of corn (*Zea mays* L.) is generally treated as a quantitative character although several signle genes for ear height are known. It is an important agronomic character which has a significant bearing on harvest operations and farmer acceptance (25).

Sizeable genetic interrelationships are indicated between: (1) yield and number of ears, (2) number of ears and number of tillers, (3) days to tassel and plant height, (4) days to tassel and ear height. Yield and number of ears generally are expected to be associated genetically since number of ears is considered as a component of yield. Since the late flowering plants have a longer period of time for growth, the association of days to tassel with plant height and ear height appears reasonable (23).

Patil et al. (18), indicated that in general among multi-ear plants, the ear at the top is generally more vigorous and yields more grain than the lower ears. They also stated that this trend appears to hold through among the whole sequence of ears on each multi-ear plant. The pattern of decreasing vigor of ears in descending order of ear height gives rise to the hypothesis that a given ear would yield more if it had been borne at a greater height. They conducted an experiment and found that yield of grain was positively and significantly correlated with ear height even when the number of internodes was kept constant; number of internodes gave an inverse relationship with internode length; and grain yield showed a negative correlation with number of internodes when the ear height was kept constant.

Shorter photoperiods result in formation of the first female inflo-resence at lower nodes for a given genotype and accelerate its development in relation to the male. The shift of sex balance is also seen in the formation of pistillate flowers in the tassel (17).

Studies by Pendleton (19) show that short corn plants surrounded by tall corn plants suffer from competition, whether the reason for taller plants is genetic or environmental. Thus, this appears to be the shading effect of the taller plant.

According to the United States Department of Agriculture (1), a corn field with plants of different heights would increase air turbulance and thereby increase the CO_2 available to individual plants for photosynthesis. However, the results reported by Pendleton and Seif (19) suggested that the competition for light or shading of the shorter plants might adversely affect yields to a greater extent than the small increase in CO_2.

Tassel size

Maize yields might be increased by selecting genotypes with smaller tassel, by mixed populations with tasseless or male sterile genotypes, or by other means that might reduce light interception by tassels (6, 15, 20). The tassel structure, after supplying essential pollen, obstructs penetration of light into the foliage canopy (6). Duncat et al. (6) also say that high population densities which result in differences in illumination could have a large effect on the number of barren plants and on yield.

The factor that is most obviously associated with reduced grain yields at high plant densities and narrow row spacing is barrenness. Increased barrenness under high plant densities is related to a reduced photosynthetic supply per plant, which could perhaps be improved with better light penetration into the canopy (5).

Lambert and Johnson (15) used three tassel treatments applied shortly after anthesis: (a) control, (b) removal of all primary lateral branches, and (c) complete tassel removal. They found a positive increase in grain yields with the tassel treatments, averaged over leaf types and hybrids used in the experiment.

Moss and Heslop-Harrison (17) reported that shorter days during tassel initiation reduce the number of florets formed and depress the fertility of those that are produced. In extreme cases no fertile anthers are formed, resulting in plants that are functionally female only.

Day length affects the number of branches and incidence of femaleness and hermaphroditism in the normally male tassel (17). This effect is amplified as short days and cool nights interact. Hanway (12) indicated that tassel differentiation occurred about two weeks after emergence (stage 1 - collar of 4th leaf visible) in the materials he studied.

Leaf number

Studies of Bonaparte (3) reveal that leaf number decreases with lower daytime temperature. Fewer leaves were developed in 12-hour days than 16-hour days in the same temperature regime.

Soil fertility and moisture stress on plants resulted in development of fewer leaves. Short-day regimes tend to reduce leaf number, while rate of growth is increased by higher effective temperatures (3).

No new leaves develop in the main stalk after initiation of the terminal inflorescence (3, 7, 8, 22).

Duncan and Hesketh (7) found that earlier floral induction results in fewer leaves, fewer nodes, and hence shorter plants. Eik and Hanway (8) observed an increase in about one leaf per plant for starter (pre-plant) fertilizer nitrogen application as compared with the unfertilized plots. Eik and Hanway (8) also say that leaf primordia cease with the initiation of the tassel about 21 days after planting.

Stapper et al. (22), found leaf number depended on day length and temperature in the period from emergence to tassel initiation. A long season genotype reaches tassel initiation later than a short season genotype and, therefore, will have more leaves with flowering and maturity occurring later.

Bonnet (4) says that usually when the plants have 8 to 10 leaves, the ear shoot and tassel had begun to form; however, the number of leaves that a plant has is not a reliable guide to the stage of development of the inflorescence.

Ear number

Yield levels seem to be more closely related to the number of ears than other traits such as kernel row number or kernel depth. Under heavy populations, prolific genotypes yield higher than the single-eared varieties (9).

Moss and Heslop-Harrison (17) observed that long photoperiods increase the mean number of ears developing. Short photoperiods accelerate development of ears whether long days occur or by night interruption with artificial lights.

Under adverse conditions, such as severe drought stress, two-eared corn hybrids can produce one ear per plant and thus may avoid a crop failure. Since average ear weight remains rather stable over most environments, ears per plant is the yield component mainly responsible for large changes in yield per plant (21).

Yield

Assuming a uniform stand, Grafius (11) says that the components of yield, W, of corn are: ear number per plant, R; kernels per row, S; rows per ear, T; and kernel weight, V. Then W = RSTV; so that yield in corn can be considered as a "mental construct" and would not exist as a genetic entity. Under these conditions Grafius (11) says there could be no additive effects, no dominance effects, no overdominance, and finally, no heritability of yield per se.

The primary effects of genes are undoubtedly biochemical in nature. It follows that characters such as ear number, kernels per ear, and weight per kernel, are themselves secondary effects of genes. Since the primary effects of genes are biochemical it might be more reasonable to think of yield as some function of the total energy produced minus the amount used for structural growth and chemical energy (16).

Corn yield may be reduced if there is lack of air movement during a number of sunny days - preventing plants from getting sufficient carbon dioxide to sustain maximum growth, according to USDA and State scientists (1).

MATERIALS AND METHODS

Experimental Design and Field Layout

Field tests for this study were conducted in 1981 in a randomized complete block design with three replications within each of two locations. The locations were : (a) Kansas River Valley Experimental Field at Rossville and (b) Ashland Agronomy Farm, Manhattan, Kansas. Both locations are situated at about 39^{o} 11' north latitude at about 310 M elevation. The type of soil was Eudora Silt Loam for both locations.

Each experimental plot consisted of four rows spaced 75 cm apart. Planting was done on a spacing of 75 cm between rows and 30 cm between plants. The population density was 44,444 plants per hectare.

Genetic Sources

Twelve entries including six sub-populations previously produced at different geographical areas from each of two different gene pools were used for this study. The gene pools and sites of selection used are shown in Table 1. Each of the two different gene pools was made up of a mixture of many genotypes (Appendix-Tables 1a and 1b). The limiting restriction for each sub-population was that seed must be produced at a given location. For convenience, the pools will be referred to as Temperate Region Pool (TRP) and Exotic Gene Pool (EGP) where TRP is the Intermediate Temperate Region Pool and EGP is the CIMMYT-Germany Exotic Gene Pool.

Cultural Operations

All plots were planted with a modified White air corn planter at one seed per hill, at Ashland Agronomy Farm on April 30 and Kansas River

Table 1. Sub-populations of maize for each of the two gene pools.

GENE POOL	
Intermediate Temperate Region Pool (TRP)	CIMMYT-Germany Exotic Gene Pool (EGP)
1. Minnesota (USA)	7. Switzerland
2. Cornell (USA)	8. Austria
3. Toluca TRP (Mexico)	9. Poland
4. Tlaltizapan (Mexico)	10. Germany
5. El Batan TRP (Mexico)	11. Toluca EGP (Mexico)
6. Kansas (USA)	12. El Batan EGP (Mexico)

Valley Experimental Field on May 1.

Fertilizer applications were 112 kg/ha N, 34 kg/ha P_2O_5 and 40 kg/ha K_2O. Herbicides used were alachlor (Lasso) 3.40 kg/ha a.i. and cianazine (Bladex) 2.27 kg/ha a.i. at Ashland Location, at Rossville location a mixture of atrazine (AATREX-4L) 1.40 kg/ha a.i. and butylate (Sutan +) 4.50 kg/ha a.i. was used.

Measurements

Measurements for each of the following traits were recorded from each population.

a) Days to flower: days from planting to 50% silking.

b) Tassel size: 0 to 5 where 0 = small, few branches and 5 = large, many branches

c) Stalk diameter: cm across the node below primary ear.

d) Plant height: cm from soil surface to the flag leaf.

e) Ear height: cm from soil surface to primary ear node

f) Leaf number: total number of leaves per plant

g) Ear number: number of ears per plant; secondary undeveloped ears were not considered

h) Average ear weight: kg/ear.

i) Yield: adjusted to 14% moisture.

RESULTS

Agronomic traits

Stalk diameter

Mean values for the 12 sub-populations of maize were significantly different at the two locations (Duncan's Multiple Range Test). At the Ashland location, stalk diameters varied from 1.81 cm for El Batan (EGP) to 1.68 cm for Kansas maize sub-population (Table 2 and Appendix Figure 1). At Rossville location, Cornell showed the highest stalk diameter value (1.92 cm) in comparison to Toluca (TRP) which presented a value of 1.68 cm; however, these two maize sub-populations were not significantly different from some of the other sub-populations (Table 3 and Appendix Figure 1).

The Rossville location presented a higher average value for stalk diameter (1.81 cm) being significantly different from Ashland location which average value was 1.75 cm (Table 4).

The mean difference for stalk diameter for the two gene pools was not significant (Table 5).

Although differences among stalk diameter means were significant for the sub-populations of maize these differences were in general very small at each of the two locations.

Tassel size

Significant differences were found among mean values for tassel size for the 12 sub-populations of maize at each of the two locations (Tables 2 and 3).

At the Ashland location, Switzerland produced the largest tassel size (3.51) in comparison to Poland which tassel size value was 3.00

Table 2. Mean Values for nine traits for each of the 12 sub-populations of maize at Ashland, 1981.

Gene Pool	Trait / Sub-Population	Yield (kg/ha)	Tassel Size	Plant Height (cm)	Ear Height (cm)	Leaf Number	Ear Number	Ear Weight (kg)	Days To Flower	Stalk Diameter (cm)
INTERMEDIATE TEMPERATE REGION POOL	TLALTIZAPAN	5142.90 a*	3.4 ab	177.5 abcd	80.5 abc	11.9 ab	1.15 a	0.114 a	71.0 abcd	1.7 ab
	MINNESOTA	4932.15 a	3.4 ab	170.6 d	72.5 c	11.5 ab	1.15 a	0.096 bc	69.3 cd	1.7 ab
	KANSAS	4910.97 ab	3.2 abc	183.7 ab	82.8 abc	12.2 a	1.1 ab	0.105 ab	70.3 bcd	1.6 b
	TOLUCA	4692.67 abc	3.0 c	187.1 a	90.3 a	11.4 abc	1.1 ab	0.091 cde	72.0 abc	1.7 ab
	EL BATAN	4518.72 abcd	3.4 ab	174.7 bcd	78.5 abc	11.7 ab	0.8 c	0.091 cde	70.3	1.7 ab
CIMMYT-GERMANY EXOTIC GENE POOL	TOLUCA	4278.73 bcde	3.1 bc	186.5 a	87.9 ab	10.9 bc	1.0 abc	0.077 e	73.0 a	1.7 ab
	GERMANY	4273.16 cde	3.4 ab	180.1 abcd	85.5 ab	10.2 c	0.9 bc	0.082 de	72.3 ab	1.7 ab
	EL BATAN	4253.69 cde	3.4 ab	180.4 abc	79.9 abc	11.3 abc	1.0 abc	0.082 cde	71.0 abcd	1.8 a
	POLAND	4221.00 cde	3.0 c	171.6 cd	77.7 bc	11.1 abc	0.9 bc	0.086 cde	72.3 ab	1.7 ab
	AUSTRIA	4135.00 cde	3.2 abc	180.4 abc	87.1 ab	11.4 abc	1.0 abc	0.082 de	72.3 ab	1.7 ab
	SWITZERLAND	3961.88 de	3.5 a	171.2 cd	80.9 abc	11.1 abc	1.0 abc	0.082 de	71.0 abcd	1.7 ab
	CORNELL[a]	3799.68 e	3.2 abc	180.1 abcd	82.5 abc	11.4 abc	1.0 abc	0.086 cde	70.3 bcd	1.7 ab

* Means within a column followed by the same letter are not significantly different (Duncan 5%)

[a] Cornell sub-population of maize is a sub-population from the Intermediate Temperate Region Pool.

Table 3. Mean values for nine traits for each of the 12 sub-populations of maize at Rossville, 1981.

Gene Pool	Trait / Sub-Population	Yield (kg/ha)	Tassel Size	Plant Height (cm)	Ear Height (cm)	Leaf Number	Ear Number	Ear Weight (kg)	Days To Flower	Stalk Diameter (cm)
INTERMEDIATE TEMPERATE REGION POOL	MINNESOTA	4461.03 a*	3.4 ab	193.7 ab	96.0 ab	11.4 abc	1.0 ab	0.109 ab	67.0 cd	1.7 ab
	TLALTIZAPAN	4407.24 ab	3.5 a	192.4 ab	87.6 abcd	11.7 ab	1.0 ab	0.118 a	69.0 abc	1.8 ab
	GERMANY[a]	4325.05 abc	3.3 ab	179.9 b	81.4 cde	11.5 abc	0.9 b	0.105 abc	69.0 abc	1.8 ab
	EL BATAN	4259.66 abcd	3.3 ab	182.9 b	76.1 e	12.0 a	0.9 b	0.109 ab	67.0 cd	1.8 ab
	CORNELL	4165.29 abcd	3.2 abc	183.9 ab	78.5 de	10.4 d	1.0 ab	0.109 ab	65.3 d	1.9 a
	KANSAS	4143.32 abcd	3.1 bc	200.5 a	96.6 a	11.8 ab	1.0 ab	0.105 abc	70.6 a	1.7 ab
	TOLUCA	3753.89 abcde	3.3 ab	193.1 ab	89.1 abc	12.0 a	1.0 ab	0.105 abc	67.3 d	1.6 b
CIMMYT-GERMANY EXOTIC GENE POOL	AUSTRIA	3654.16 bcde	3.5 a	190.4 ab	88.1 abcd	11.2 bc	0.9 b	0.082 d	70.0 ab	1.7 ab
	SWITZERLAND	3604.15 cde	3.2 abc	192.1 ab	89.8 abc	11.4 abc	1.1 a	0.091 cd	68.0 bc	1.8 ab
	EL BATAN	3553.52 de	3.4 ab	188.5 ab	83.6 cde	11.0 cd	0.9 b	0.091 cd	68.6 abc	1.8 ab
	TOLUCA	3459.47 de	3.4 ab	189.6 ab	68.1 bcde	11.4 abc	1.0 ab	0.096 bcd	69.6 ab	1.8 ab
	POLAND	3191.71 de	2.8 c	183.6 b	82.1 cde	11.0 cd	1.0 ab	0.096 bcd	67.3 c	1.7 ab

* Means within a column followed by the same letter are not significantly different (Duncan 5%).

[a] Germany sub-population of maize is a sub-population from the CIMMYT-Germany Exotic Gene Pool.

Table 4. Mean values by location for nine traits, 1981.

Trait / Location	Stalk Diameter (cm)	Tassel Size	Plant Height (cm)	Ear Height (cm)	Leaf Number	Ear Number	Ear Weight (kg)	Days To Flower	Yield (kg/ha)
Ashland	1.7 b*	3.3 a	178.7 b	82.2 a	11.3 a	1.0 a	0.086 b	71.2 a	3914.87 a
Rossville	1.8 a	3.3 a	189.2 a	86.2 a	11.4 a	1.0 a	0.100 a	68.2 b	4426.71 a

* Means within a column followed by the same letter are not significantly different (Duncan 5%).

Table 5. Mean values of each gene pool at two locations for nine traits, 1981.

Trait / Gene Pool	Stalk Diameter (cm)	Tassel Size	Plant Height (cm)	Ear Height (cm)	Leaf Number	Ear Number	Ear Weight (kg)	Days To Flower	Yield (kg/ha)
Intermediate Temperate Region Pool	1.7 a*	3.3 a	185.0 a	84.3 a	11.6 a	1.0 a	0.105 a	69.1 a	4432.29 a
CIMMYT-Germany Exotic Gene Pool	1.7 a	3.2 a	182.9 a	84.2 a	11.1 b	1.0 a	0.086 b	70.3 b	3909.29 b

* Means within a column followed by the same letter are not significantly different (Duncan 5%).

(Table 2 and Appendix Figure 2). At Rossville, Poland also showed the smallest tassel size (2.89) in comparison to Austria which tassel size value was 3.56 (Table 3 and Appendix Figure 2).

The difference between location means for tassel size was not significant; neither was the difference between gene pool means for the same trait (Tables 4 and 5).

Although differences among the sub-populations of maize were statistically significant, they were very small and some of the sub-populations fall within the same group according to Duncan's Multiple Range Test, therefore were not significantly different from each other (Tables 2 and 3).

Plant and ear height

Plant and ear height mean values differed significantly for the 12 sub-populations of maize at each of the two locations (Duncan's Multiple Range Test-Tables 2 and 3).

At Ashland, Toluca (TRP) showed the highest value for both traits, 187.18 cm and 90.36 cm for plant and ear height respectively (Table 2 and Appendix Figures 3 and 4). At the same location Minnesota had the lowest value for both traits, 170.69 cm and 72.50 cm for plant and ear height respectively.

At Rossville, Kansas (TRP) showed the largest plant and ear height values; however, it did not differ from some of the other maize sub-populations such as Minnesota, Toluca (TRP), Tlaltizapan, Switzerland and Austria (Table 3 and Appendix Figures 3 and 4).

The difference between plant height mean values for the two locations was significant, however it was not significantly different for ear height (Table 4).

The mean difference between plant and ear height values for the two gene pools was not significant (Table 5).

Leaf number

Differences among leaf number means for the 12 sub-populations of maize at each of the two locations were significant according to Duncan's Multiple Range Test (Tables 2 and 3); however, a maximum difference of two leaves among the 12 maize sub-popolations was observed.

At Ashland, the mean leaf number value for the Kansas maize sub-population was 12.2 as compared to Germany which mean leaf number value was 10.27 (Table 2 and Appendix Figure 5). At Rossville, Kansas also presented one of the highest mean leaf number value, however, it was not statistically different from other sub-populations such as Toluca (TRP), El Batan (TRP), Tlaltizapan, El Batan (EGP) (Table 3 and Appendix Figure 5).

The location means for leaf number were not significantly different (Table 4), but leaf number means between the two gene pools were significantly different (Table 5). In general differences among the 12 sub-populations of maize for leaf number were very small.

Ear number

Mean values for ear number among the 12 maize sub-populations were significantly different (Duncan's test), but these differences were very small and probably not important as far as wide adaptation is concerned (Tables 2 and 3 and Appendix Figure 6). Location and gene pool means for ear number were not significant (Tables 4 and 5).

Ear weight

Mean values for ear weight for the 12 sub-populations of maize at each of the two locations differed significantly according to Duncan's Multiple Range Test (Tables 2 and 3).

At Ashland location ear weight values varied from 0.114 kg for Tlaltizapan to 0.077 kg for Toluca (EGP); at Rossville ear weight value varied from 0.118 kg for Tlaltizapan to 0.082 kg for Austria (Tables 2 and 3 and Appendix Figure 7).

The difference between locations and gene pool means for ear weight was also significant. Rossville location showed the higher ear weight mean value (0.10 kg). The Intermediate Temperate Region Pool showed a higher ear height mean value (0.105 kg) in comparison to the CIMMYT-Germany Exotic Gene Pool which ear weight value was 0.086 kg (Tables 4 and 5).

Days to flower

Mean values for days to flower at each of the two locations differed significantly according to Duncan's Multiple Range Test (Tables 2 and 3). The difference in days to flower for the 12 maize sub-populations was 4 days and 5 days for Ashland and Rossville, respectively (Figure 8).

Significant differences for days to flower between locations and gene pools were also found. The maize sub-populations flowered earlier at Rossville than at Ashland, likewise the Intermediate Temperate Region Pool flowered earlier than the CIMMYT-Germany Exotic Gene Pool. The difference in days to flower between locations was 3 days and between pools it was 2 days (Tables 4 and 5).

Yield

Mean yields among the 12 sub-populations of maize at each of the two locations were significantly different according to Duncan's Multiple Range Test (Tables 2 and 3).

At Ashland, yield ranged from 5142.90 kg/ha for Tlaltizapan (TRP) to 3799.68 kg/ha for Cornell (TRP) maize sub-population (Figure 1).

The Intermediate Temperate Region Pool produced a significantly higher yield than the CIMMYT-Germany Exotic Gene Pool (Table 5).

Yield adjusted to the average stand of the two locations was not significantly different when a comparison between locations was made (Table 4).

Interactions

From all of the nine traits measured in this experiment for the interaction location x sub-population, only ear height, days to flower and leaf number were significant (Table 6 and Appendix Figures 9, 10 and 11).

For sub-population within groups, tassel size, days to flower and yield were all significant.

For the interaction location x Gene Pools only ear number was significant.

No significant interaction for location x sub-population within gene pools was found.

Correlations

Plant and ear height

A positive and highly significant correlation between plant height and ear height at each of the two locations was observed. The correlation coefficients at Ashland and Rossville locations were 0.84 and 0.90, respectively. The regression coefficients for the same two locations were 0.74 and 0.99, respectively (Figure 2). An increase of one cm in plant height results in an increment of 0.74 cm and 0.99 cm in ear height at Ashland and Rossville, respectively.

Days to flower and plant height

The correlation between days to flower and plant height (cm) was

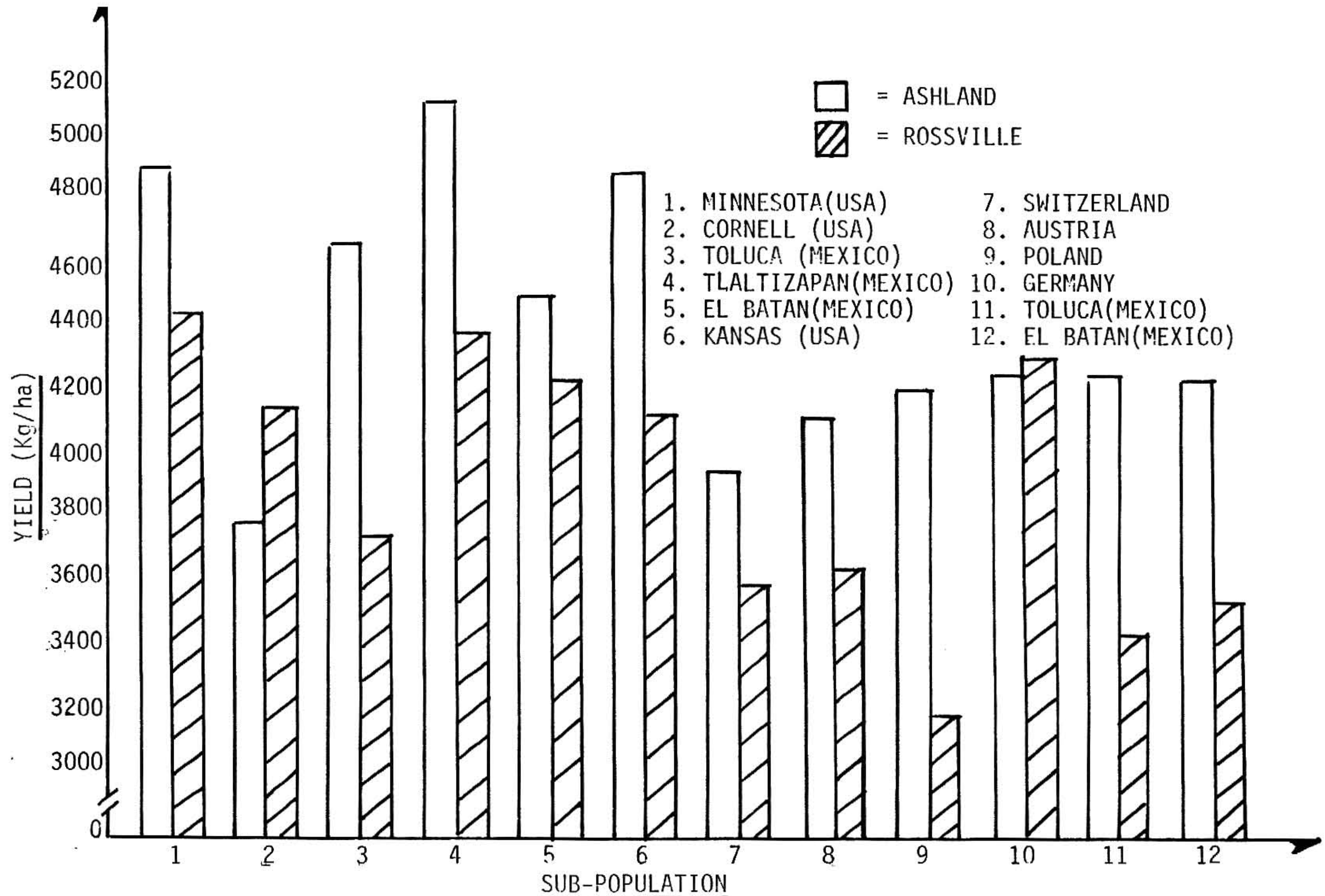

Figure 1. Average yield (Kg/ha) for each of the 12 sub-populations of maize at each of the two locations.

Table 6. Significance responses of sub-population within gene pools and interactions for nine traits including location×sub-population, location×gene pool, and location×sub-population within gene pools, 1981.

LOCATION × SUB-POPULATION								
Stalk Diameter	Tassel Size	Plant Height	Ear Height	Leaf Number	Ear Number	Ear Weight	Days To Flower	Yield
N.S.	N.S.	N.S.	**	*	N.S.	N.S.	**	N.S.
SUB-POPULATION WITHIN GENE POOLS								
Stalk Diameter	Tassel Size	Plant Height	Ear Height	Leaf Number	Ear Number	Ear Weight	Days To Flower	Yield
N.S.	**	N.S.	N.S.	N.S.	N.S.	N.S.	*	*
LOCATION x GENE POOLS								
Stalk Diameter	Tassel Size	Plant Height	Ear Height	Leaf Number	Ear Number	Ear Weight	Days To Flower	Yield
N.S.	N.S.	N.S.	N.S.	N.S.	*	N.S.	N.S.	N.S.
LOCATION × SUB-POPULATION WITHIN GENE POOLS								
Stalk Diameter	Tassel Size	Plant Height	Ear Height	Leaf Number	Ear Number	Ear Weight	Days To Flower	Yield
N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

N.S., *, ** Not significant, significant at the 0.05 level, and significant at the 0.01 level, respectively.

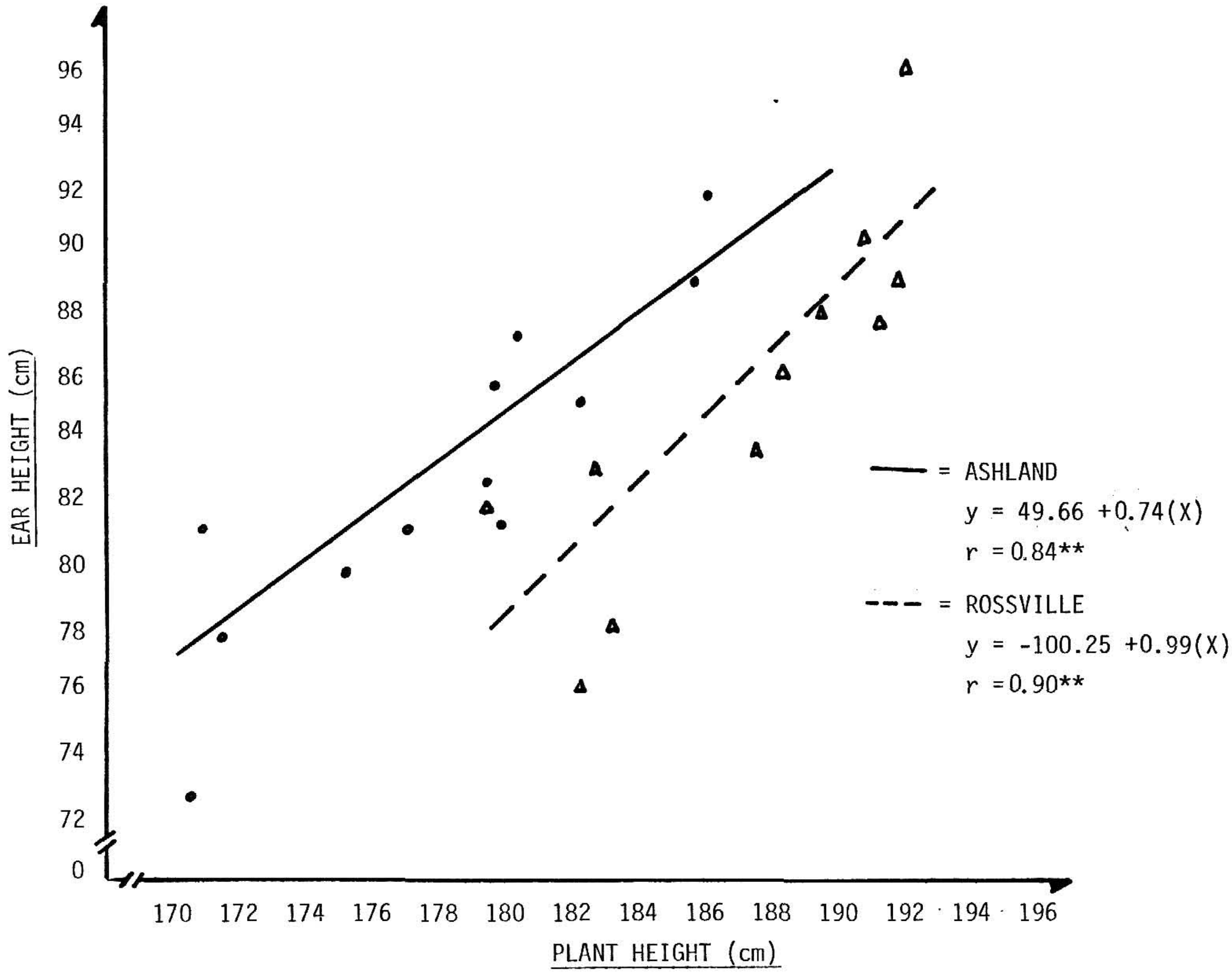

Figure 2. The correlation between plant height (cm) and ear height (cm) at each of the two locations.

positive and significant at each of the two locations. The correlation coefficient for each of the two locations was 0.44, and a regression coefficient of 2.27 and 1.70 for Ashland and Rossville, respectively, was observed (Figure 3). An increase of one day in days to flower resulted in an increment of 2.27 cm and 1.70 cm in plant height at Ashland and Rossville, respectively.

Yield and days to flower

A negative correlation between days to flower and yield at each of the two locations was observed. Correlation coefficients of -0.34 and -0.14 were observed for Ashland and Rossville, respectively. Regression coefficient values of -0.13 and -0.04 were also observed for each of the two locations, respectively (Figure 4). As days to flower increased grain decreased.

Intra sub-population variation

Table 7 shows the average variance values and the test of significance for variation within each of the 12 maize sub-populations.

Differences among variances values were significant at the 0.05 and 0.01 levels for tassel size and ear number, respectively, at Ashland (Table 7).

At Rossville differences among variance values of ear height, plant height and ear number were significant at the 0.01 level (Table 7).

For the traits found to be significant at any one of the two locations, a F test was performed and the arrangement of the sub-populations of maize and different pools is given in Table 8.

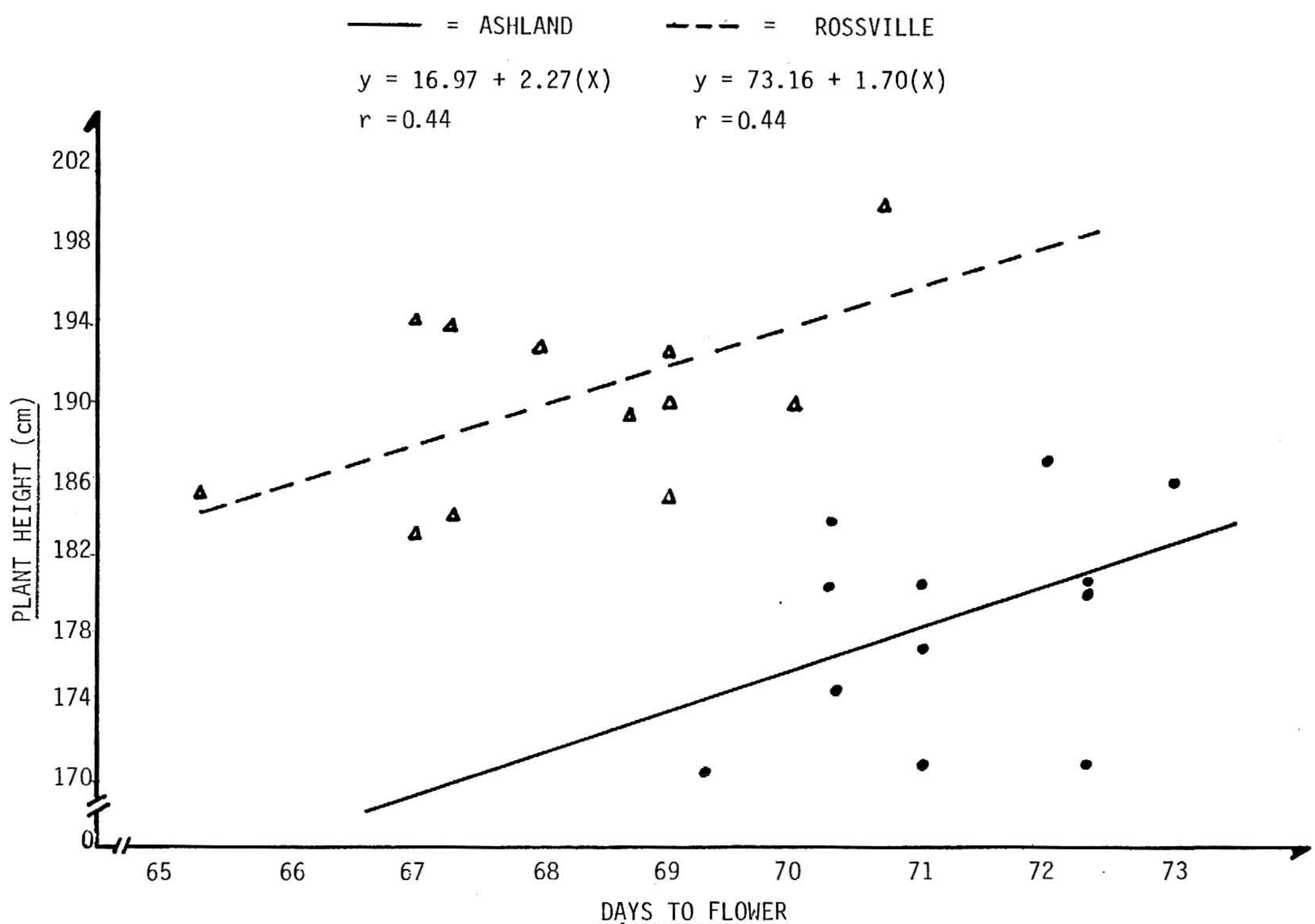

Figure 3. The correlation between days to flower and plant height (cm) at each of the two locations

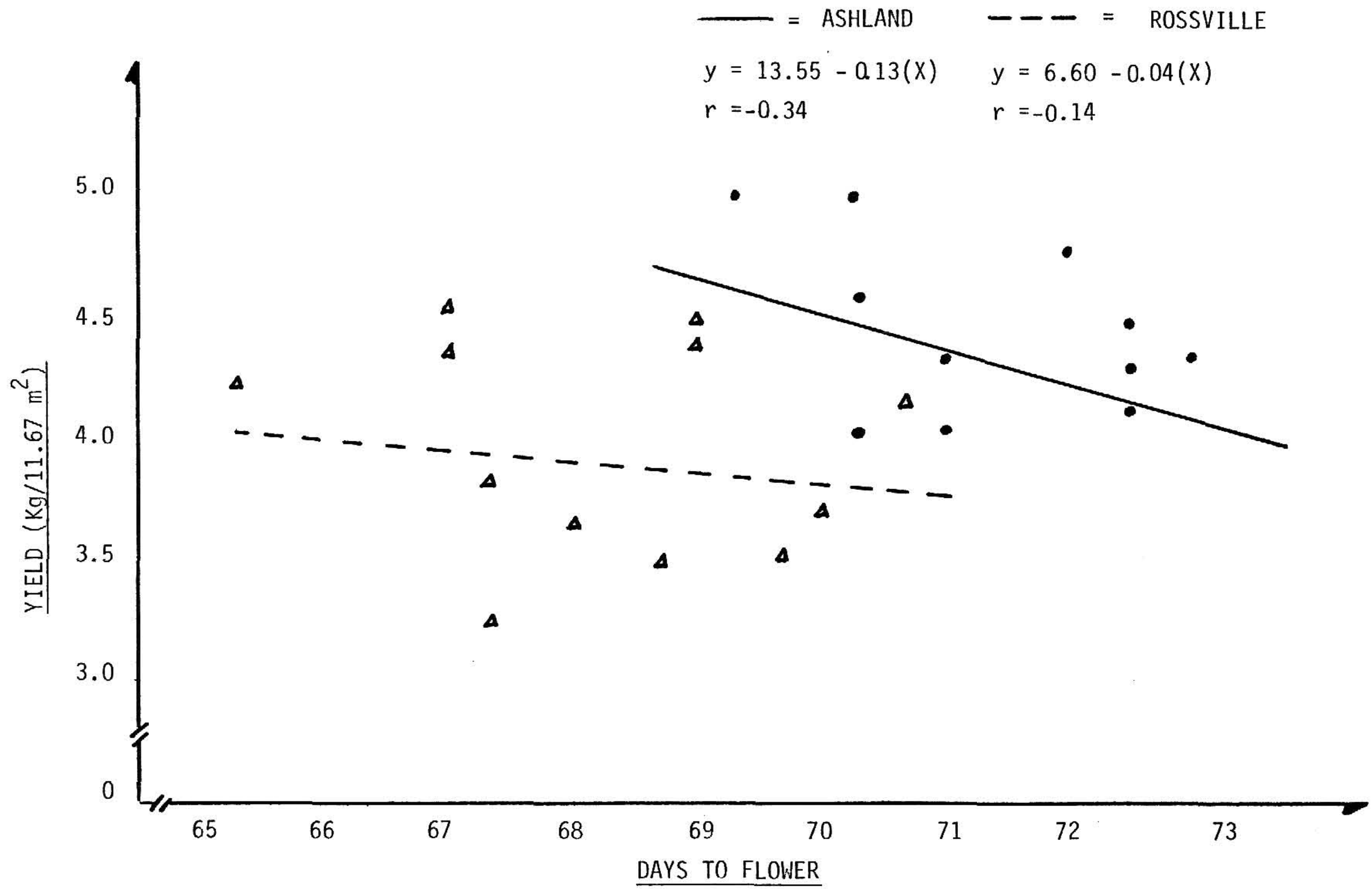

Figure 4. The correlation between days to flower and yield (Kg/11.67 m^2) at each of the two locations.

Table 7. Average variance values and test of significance for variation within each of the 12 sub-populations of maize for 6 traits, at each of the two locations, 1981.

Location	Sub-Pop	Stalk Diameter	Tassel Size	Ear Height	Plant Height	Leaf Number	Ear Number
ASHLAND	1	0.073	0.387	234.500	416.61	1.296	0.015
	2	0.046	0.673	330.943	352.37	2.222	0.022
	3	0.06	0.698	460.189	705.61	2.607	0.086
	4	0.059	0.441	224.656	596.53	2.315	0.102
	5	0.065	0.219	176.282	393.29	0.893	0.092
	6	0.074	0.451	260.601	544.33	1.785	0.130
	7	0.053	0.314	251.782	450.03	1.233	0.022
	8	0.076	0.559	307.674	536.11	1.081	0.152
	9	0.058	0.657	518.456	600.20	1.530	0.111
	10	0.069	0.530	517.233	470.63	2.040	0.069
	11	0.054	0.727	317.364	377.58	1.278	0.069
	12	0.047	0.768	357.973	382.96	1.129	0.089
		N.S.[a]	*	N.S.	N.S.	N.S.	**
ROSSVILLE	1	0.049	0.603	455.408	379.83	1.559	0.022
	2	0.046	0.559	314.648	551.68	2.126	0.044
	3	0.062	0.587	609.462	717.58	2.437	0.178
	4	0.040	0.400	280.273	617.53	0.985	0.092
	5	0.044	0.463	181.636	266.99	0.719	0.088
	6	0.069	0.489	299.062	346.40	2.526	0.044
	7	0.055	0.609	493.300	670.27	2.004	0.114
	8	0.052	0.495	253.777	369.83	1.074	0.022
	9	0.083	0.565	347.233	694.97	2.726	0.158
	10	0.068	0.616	437.674	1075.83	2.233	0.069
	11	0.062	0.727	239.190	614.89	1.370	0.069
	12	0.053	0.425	325.500	549.19	1.459	0.069
		N.S.	N.S.	**	**	N.S.	**

N.S., *, ** Not significant, significant at the 0.05 level, and significant at the 0.01 level, respectively.

[a] Test of significance according to the Hartly's Min-Max Stat. Test.

Table 8. Sub-population variances for the traits found to differ significantly at each of the two locations, 1981.

ASHLAND				ROSSVILLE					
Tassel Size		Ear Number		Ear Height		Plant Height		Ear Number	
Sub-Pop	Variance	Sub-Pop	Variance	Sub-Pop	Variance	Sub-Pop	Variance	Sub-Pop	Variance
12	0.77 a[+]	8	0.15 a	3	609.47 a	10	1075.83 a	3	0.18 a
11	0.72 ab	1	0.15 a	7	493.30 ab	3	717.58 ab	9	0.16 a
3	0.70 ab	6	0.13 ab	1	455.41 abc	9	694.97 ab	7	0.11 ab
2	0.67 ab	9	0.11 ab	10	437.67 abc	7	670.27 ab	4	0.09 b
9	0.65 ab	4	0.10 abc	9	347.23 bcd	4	617.53 b	5	0.09 b
8	0.55 abc	5	0.09 bc	12	325.50 bcd	11	614.89 bc	10	0.07 b
10	0.53 abc	3	0.08 bc	2	314.65 bcd	2	551.68 bcd	11	0.07 b
6	0.45 abcd	12	0.08 bc	6	299.06 bcde	12	549.19 bcd	12	0.07 b
4	0.44 bcd	10	0.07 c	4	288.27 cde	1	379.83 cde	2	0.04 c
1	0.39 cde	11	0.07 c	8	253.77 de	6	346.40 de	6	0.04 c
7	0.31 de	7	0.02 d	11	239.19 de	8	369.83 de	1	0.02 d
5	0.22 e	2	0.02 d	5	181.64 e	5	266.99 e	8	0.02 d
	*[a]		**		**		**		**

+ Variances within a column followed by the same letter are not significantly different.

*,** Significant at the 0.05 and 0.01 levels, respectively.

a Test of significance according to the Hartly's Min-Max Stat. Test.

DISCUSSION

Significant differences among sub-populations for several traits measured were observed in the 1981 evaluation tests, indicating that some genetic changes due to geographic areas of production did occur.

Differences among maize sub-populations for yield were found to be significant. Likewise, a negative correlation between days to flower and yield was also found; in other words, the earlier the sub-population flowers, the higher the yield was. Favorable temperature and daylight conditions might have been present right after flowering time or they might have been unfavorable at the end of the grain filling period, therefore favoring the yield of those sub-populations which flowered earlier.

The average number of days from planting to 50% silking at Ashland and Rossville locations was 71 and 68 days at each location, respectively. These values did not differ much when we compared them to 74 days from planting to 50% silking, which is an average value for five Kansas hybrids, planted at the same time and locations with the same cultural practices including irrigation, fertilizers etc., as used for the sub-populations of maize used in this study. This suggests that days to flower and adaptability of the sub-populations of maize from the two gene pools used in this experiment were not greatly affected, even though the two gene pools are made up of genetic sources from very different latitudes.

Plant height was positively and significantly correlated with days to flower; the later the sub-population flowers, the taller the plants are. This is due to a longer vegetative growth period for the later flowering sub-pouplations.

Yield for the Intermediate Temperate Region Pool, averaged over the two locations, was higher than it was for the CIMMYT-Germany Exotic Gene Pool. The Intermediate Temperate Region Pool is made up of a mixture of 128 genetic sources mostly from temperate regions; this might have resulted in a somewhat better adaptation for the Intermediate Temperate Region Pool to the environmental conditions of the Kansas test site. In general the differences between the two gene pools for all the traits measured were small, and some of them were not statistically significant, but a combined effect of traits such as plant and ear height, leaf and ear number, ear weight and days to flower might have contributed to the higher yield observed for the Intermediate Temperate Region Pool.

From all the traits measured, a significant variation within maize sub-populations was found for ear and plant height, tassel size and ear number.

Tassel size might be an important trait to select for, since it has been reported by many researchers (6, 15, 20) that maize yields might be increased by selecting varieties with smaller tassels. Small tassel size of some varieties contributes to a better penetration of the light into the foliage and also provides a better utilization of the nutritive substances produced by the plant and translocated to the grain during the grain filling period.

Although differences among the 12 sub-populations of maize for ear number were small, variation within sub-populations was found to be significant at the 0.01 level for this particular trait. Many barren plants, i.e. without ears, were also observed. According to Buren et al., barrenness is the factor that is most associated with reduced grain yields, especially at high plant densities. Although the plant density used in this experiment (44,444 plants/ha) might not be the reason for barrenness for this particular case; it is possible that some shading effect due to differences in plant height and irregular distance between plants within the same sub-population might have occurred and resulted in the ear barrenness observed.

Variability for plant and ear heights among and within the sub-populations of maize was significant. Visual observation of the experimental plots under field conditions revealed a considerable amount of variability for these two traits both among and within sub-populations. Plant and ear height are highly correlated in such a way that selection for one trait results in selection for the other, whether the objective of selection is for either short or tall plants.

Even though some of the geographic areas of seed production within the two gene pools were located at widely different latitudes, yields obtained were relatively high. Sub-populations such as Tlaltizapan, Minnesota, and Kansas, yielded 5,142.90 kg/ha, 4,932.15 kg/ha, and 4,910.97 kg/ha respectively at the Ashland location. This is also an indication of the potential of these sub-populations and illustrates ideas expressed by Allard (2) about the advantage and need to have genetic variability in the varieties or populations with which we are working. Maize sub-populations which show a great amount of genetic variability and good adaptability to a wide range of environments, should be useful source materials for maize breeders.

CONCLUSIONS

1. Significant differences among sub-populations were found for all the traits measured, including yield.
2. Yield, adjusted to the average stand of the two locations, was not significantly different between locations.
3. Yield for the Intermediate Temperate Region Pool was higher than it was for the CIMMYT-Germany Exotic Gene Pool.
4. Significant differences among sub-populations for the traits measured within gene pools were observed in the 1981 evaluation tests, indicating that genetic changes due to geographic areas of production did occur.
5. Significant differences due to test location occurred for stalk diameter, plant height, ear weight, and days to flower.
6. There was a negative correlation between days to flower and yield. Correlation between plant and ear height was positive. The relationship between days to flower and plant height was also positive.
7. A comparison among sub-population variances indicated that much more variability occurred within some sub-populations for tassel size and ear number at Ashland; and plant height, ear height, and ear number at Rossville. This suggests that selection for these traits might be effective.
8. Yield for the maize sub-populations was relatively high, considering that a population density of 44,444 plants/ha was used. A tremendous amount of genetic variability was present in these sub-populations which should be useful for improvement of maize.
9. Although variation among sub-populations for yield and other traits

did occur, it was generally small. The original goal of development of widely adapted populations of maize has been at least partially achieved to the extent that the sub-populations produced seed in all geographic areas. In all cases enough genetic variation remains in the sub-populations that crossing with locally adapted sources is possible. Further genetic improvement of the sub-populations for use in specific areas where yields obtained are usually low should also be possible.

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APPENDIX

Table 1a. Genetic sources* included in the Intermediate Temperate Region Pool were the following:

Andaluz; Basta; Blanco; Cuña; Daxa; Enano Levantino; Enano Costeño; Fino; Gallego; Hembrilla; Norteño; Norteño Largo; Queixale; Rastrojero; Tremesino; Vasco; Grano de Trigo; Perla; Rosero; Andaluz; Mengacia; Tolsa; Molledo; Puenfeareas; MV-SC 202; MV-TC 281; MV-TC 290; MV-MSC 291; MV-SC 370; MV-TC 431; MV-DC 59; MV-DC 460; MV-DC 520; MV-SC 530; MV-SC 570; MV-SC 580; MV-SC 405; MV-SC 587; MV-TC 596; MV-DC 602; MV-TC 610; MV-SC 620; MV-TC 635; MV-SC 660; MV-SC 380; MV-SC 429; MV-SC 598; MV-SC 630; MV-TC 540; MV-TC 201; MV-MSC 262; MV-MSC 342; MV-DC 350; BE-KE 270; GK-SC 513; 1A to 34A; 36A to 78A; 80A to 85A; 87A; 90A to 94A; 96A; 97A; 99A to 131A; Yellow dent of Mindszentpuszta; Dent of Szeged; Avanyozon Yell Dent; "F" early Yell. Dent; Red King; White Flint of Midszentpuszta; FB of Martonvasar; Local var. of Bodrogkoz; Local var. of Zala; Local var. of Fehervar; HMV 969-1; HMV 1024-3; HMV 719-2; HMV 832; HMV 833-5; HMV 929; HMV 978; HMV 979; HMV 1027; HMV 424-3; OH 51A; Kutumbuli Selec. Large; Samsun 63; INRA 258; INRA 230; INRA 240; INRA 260; INRA 310; INRA 400; INRA 402; INRA 188; AT; AT1 to AT6; AT 203; AT 209, AT 564; AT 630-S; AT 633; BT; 002; 007; 500; 504; SCP; SCQ; D373; TC 11; TC 182; W 401; Yugoslavia Kol 77 GR 1 to GR 18; Seg. from 1-5; Kohot, Swabi White; Changez; Janey; Chanar; Bannu Yellow; Pinot-France (Italie, Roux de Landes, Bierre, Guchen, Flint French S.C.'s, Yugoslavie, Doue du Rouest, Pyrenes); Kovacs-Hungary (F5 Fix (-), (J.T.E.S.) F_4, (Z.P.-SK-28T)F_4); Jakacki-Poland (SC (1-12) (1-2-1, 1-2-2, 1-3, 3, 10, 12, 21, 32, 34, 41, 42, 72 RF, 79 RF, 129-26, 164-2, 165-17, 191-1, 191-12, 191-13, 192-9, 194-1, 196-2, 200-2, 209-8, 164-2 x 138-1, 200-2 x 138-1, S72 HST x MK-8-2, S72.HST x 138-1); GIE-Pioneer-France (Flint Synt. x #, CB Synt. x #, CDS x ##); KWS-Germany (Garbo, Ibo, Hit, Granat, Iso, Iris, Irha, Micca, Massa, Forla, Garoche, Hausa, Erox, Miris, Moco, Ferro, Edo, Gavott, Giga, Inka, Gabix, Ira, Perdux, Hai, Harpun, Illo); Kojic-Yugoslavia (Yu ZPL (3259/11, 3261/8-10, G-54/1.14, 518-3-12, 2039-9-12, 1703/4-12, 3028, 3216/2-18), Yuzpdc (94/1-77, 16/1-77, 269/1-77, 75/1-76, 42/1-77, 50/1-77, 44/1-77, 45/1-77), Yuzptc 391/3-77, zpdc-150/1-77, zpbl-98-1, zplt-193/1, zpbr-386, zpl 373); Pollacsek-France (Massat, Bareilles, (F-2. F1256) (F1615. F1772); Bossuet-France (GC (1-15), Primeur 170, Silac 233, Master 243, Rega 246, Royal 255, Star 304, Visa 324, Major 560); Majester-France (1190, 1198, 1218, 31H30, 364, 0005, 1307, 1318, 1323, Typhon 204, Beaufort 221, Survit 241, Cuzco 251, Astron 252, P-362, P-365, Phoebus 365, Pau-564, Concorde 560, Synt. ct.f.d.79-1, Synth. Ryrale, Pop. 31, VSH, Synth. Flint 73, Synth. Dent 73, Synth. totale 73, Melange Lardony, BKB, BKA); Kiss-France (20-14, 60-205, 60-206, 60-209, 60-215, 60-216, 60-226).

* More detailed information of individual sources is available from CIMMYT.

Table 1b. Genetic sources* included in the CIMMYT-Germany Exotic Gene Pool were the following:

Chihuahua comp.; Precoz Titicaca; Largo del Día; Morocho; Corn Belt; Blanco Pakistan; Temp. x Trop. H.E.o_2; Comp. Hungary; Amarillo Pakistan; Temperate Early White Flint (Pool 27); Precoz Pisankalla; Confite Puñeño; Cornell Early; Zac. 58; 2417 x 2421; Criollo Barraza; Pakistan Precoz; UNCAC 242; Pairumani Synth.; Lineas Illinois; Shingrachuon White Dent; Peking White Dent; Yellow Ken Chin; Highland materials from Mexico; Synth. 5; LBA; TALAT.

* More detailed information of individual sources is available from CIMMYT.

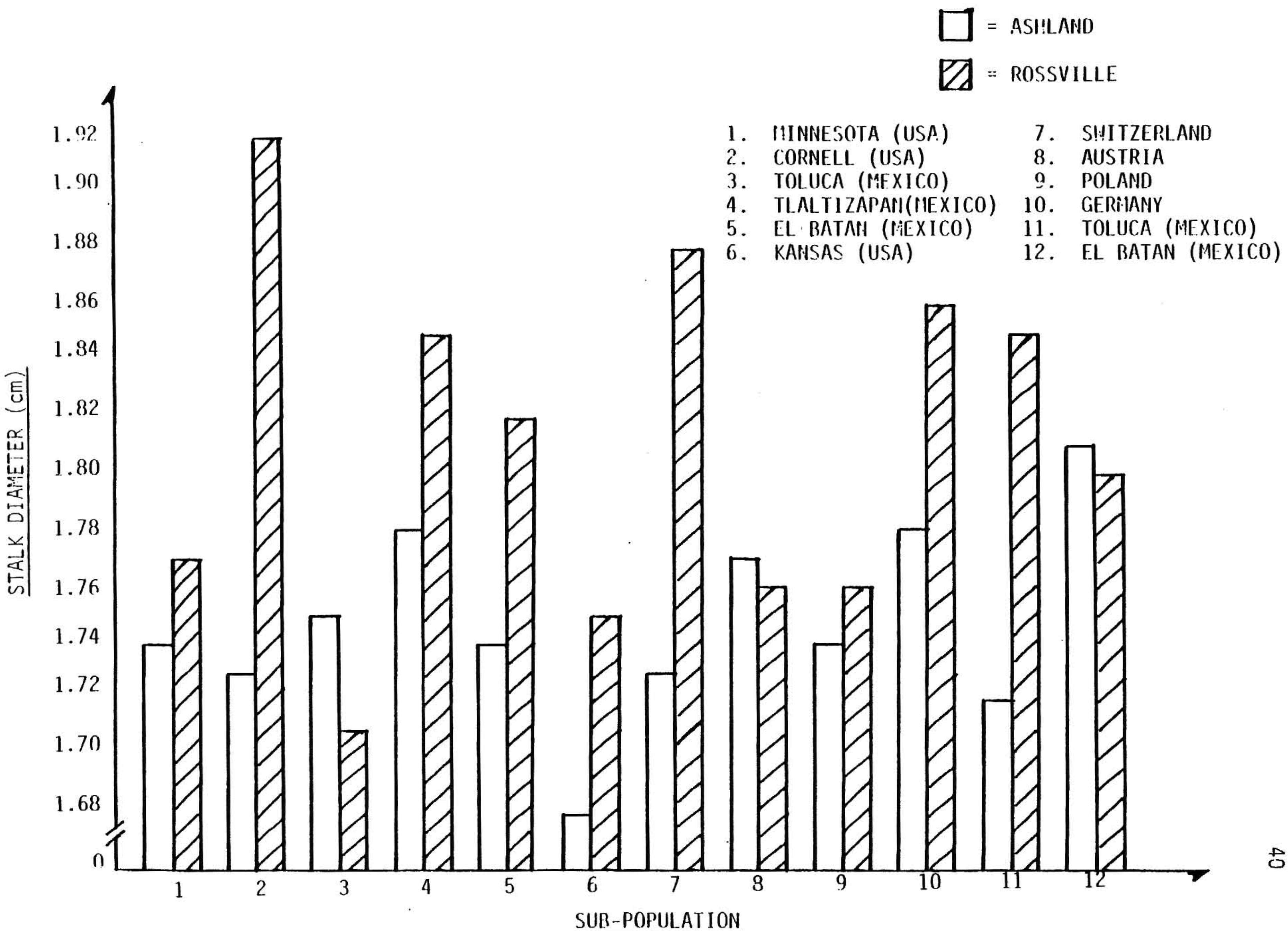

Figure 1. Average stalk diameter (cm) for each of the 12 sub-populations of maize at each of the two locations.

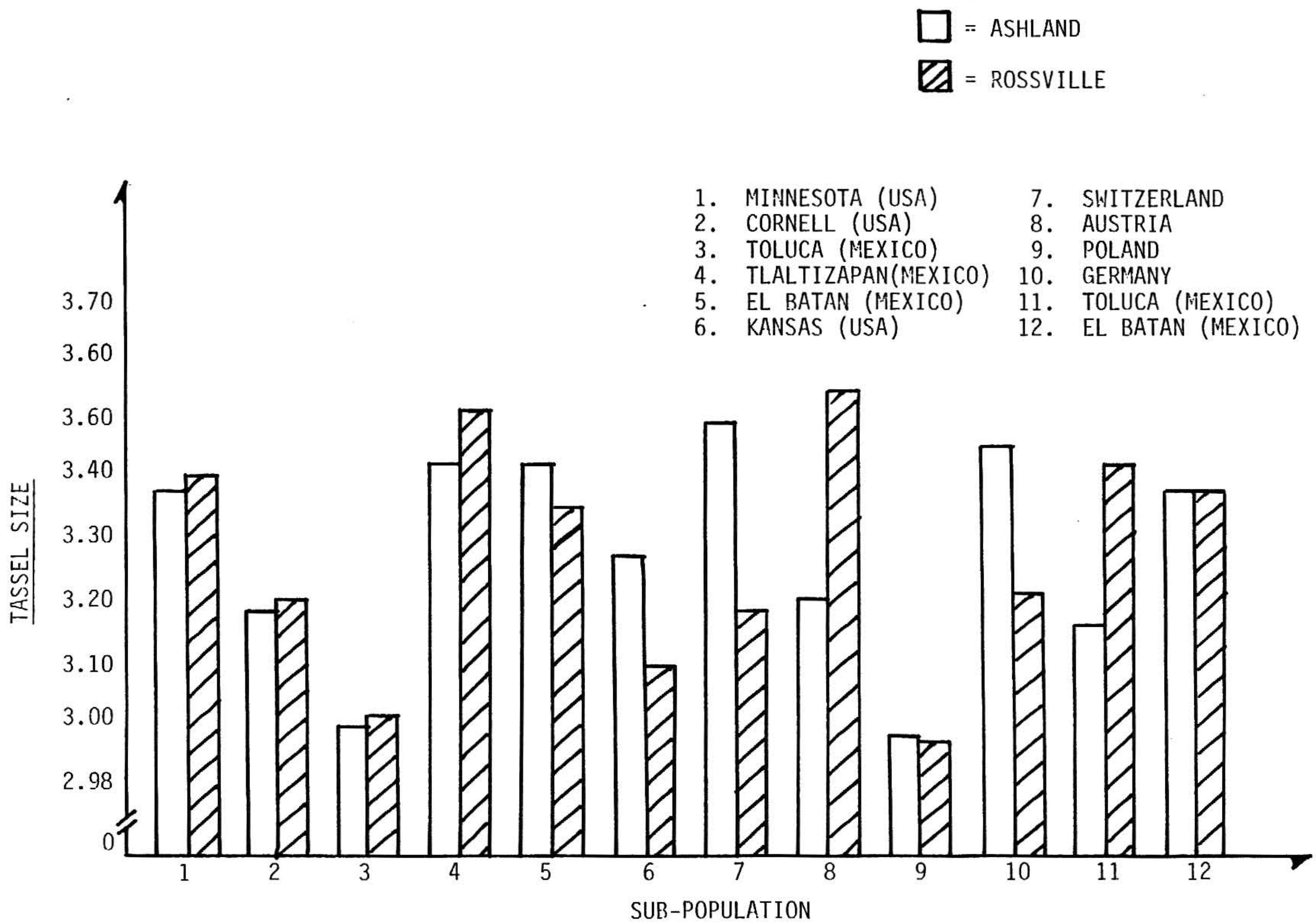

Figure 2. Average tassel size for each of the 12 sub-populations of maize at each of the two locations.

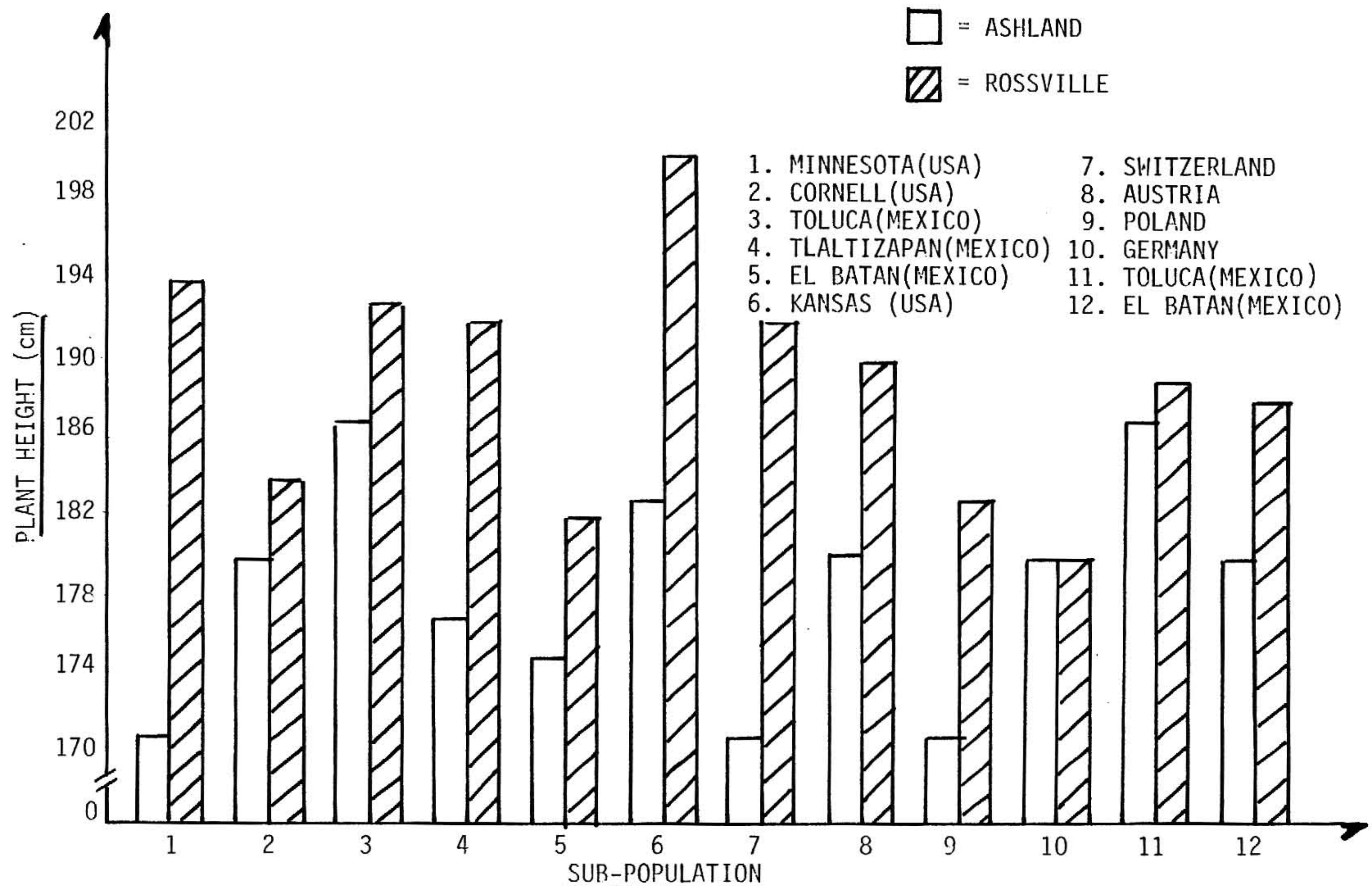

Figure 3. Average plant height (cm) for each of the 12 sub-populations of maize at each of the two locations.

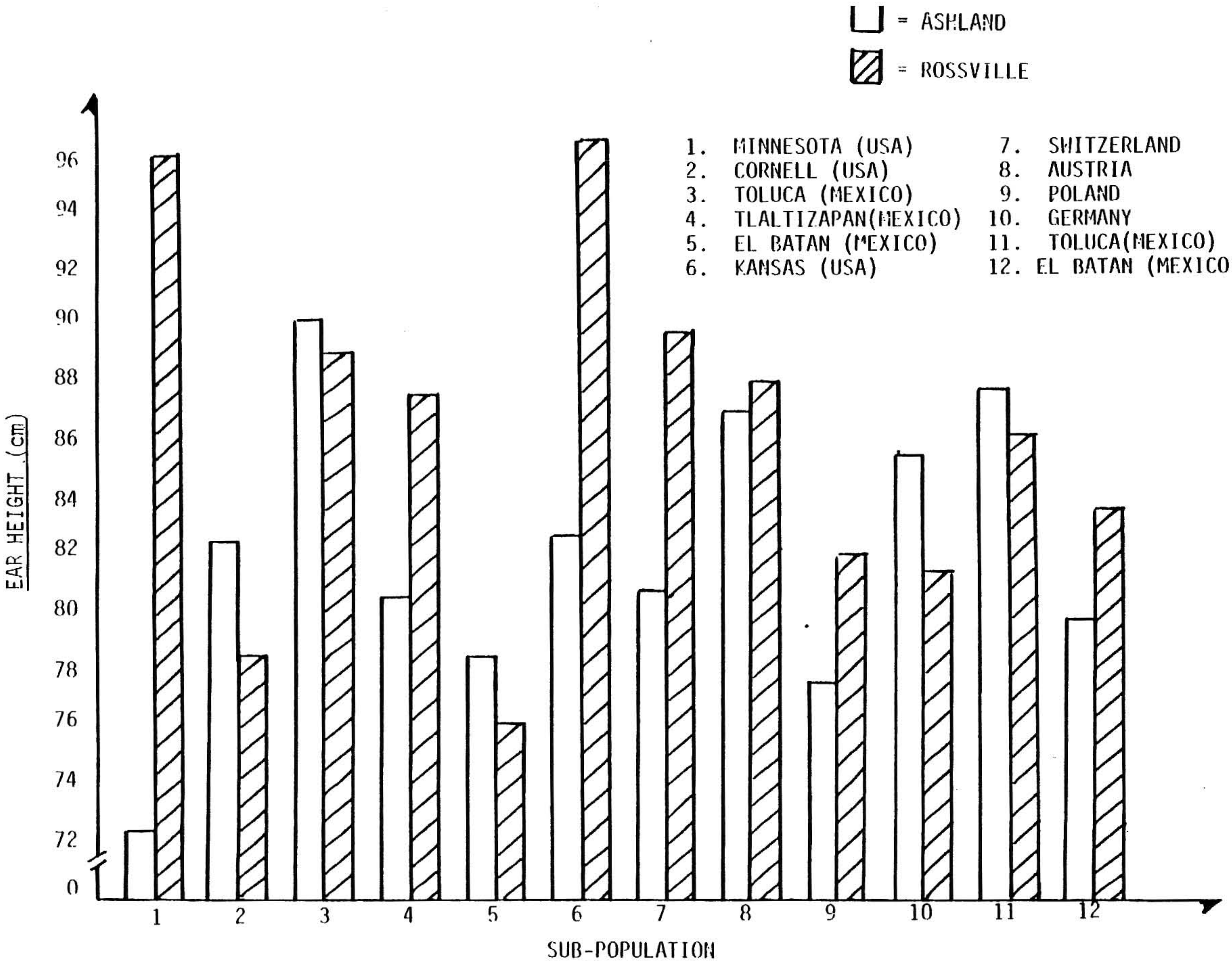

Figure 4. Average ear height (cm) for each of the 12 sub-populations of maize at each of the two locations.

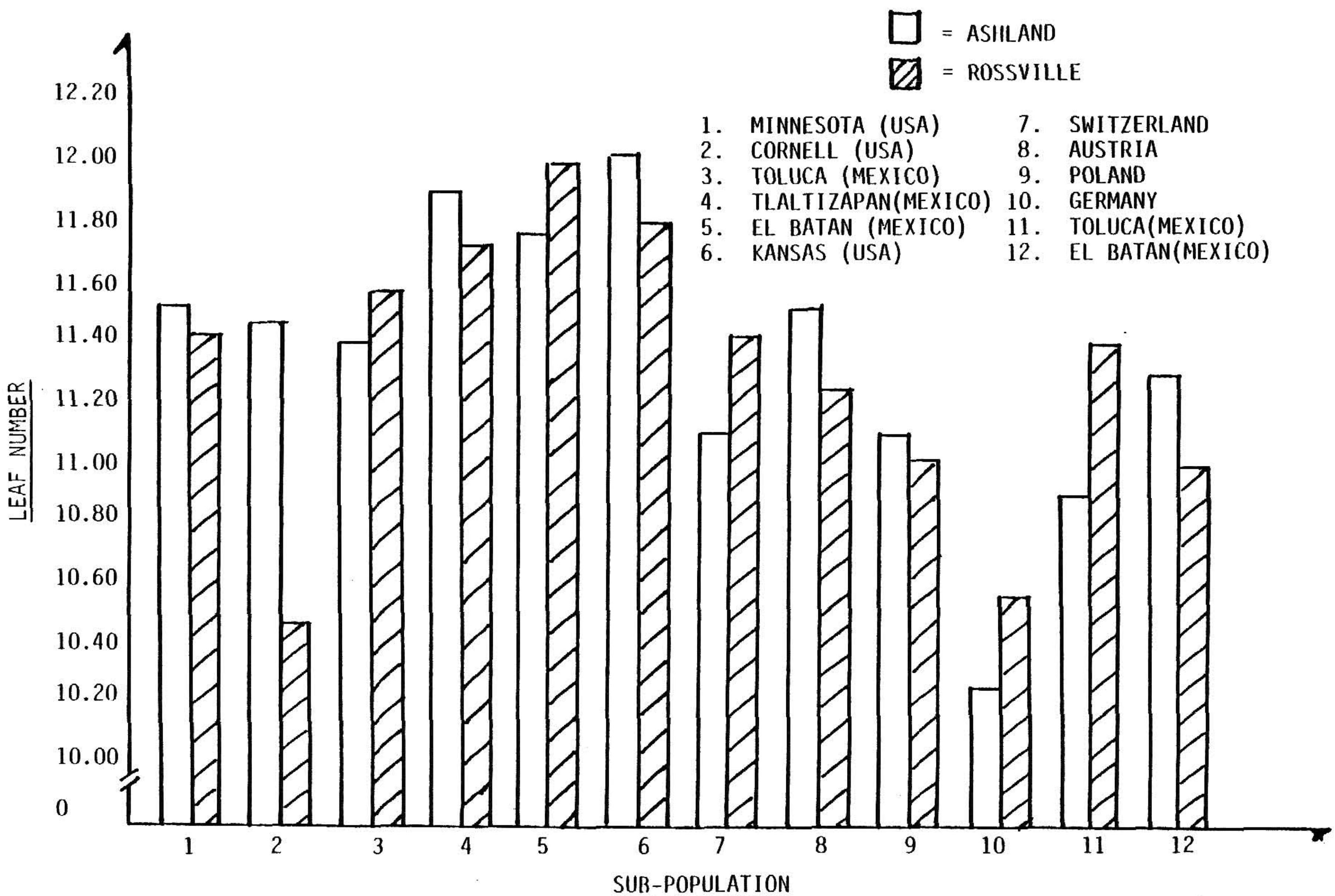

Figure 5. Average leaf number for each of the 12 sub-populations of maize at each of the two locations.

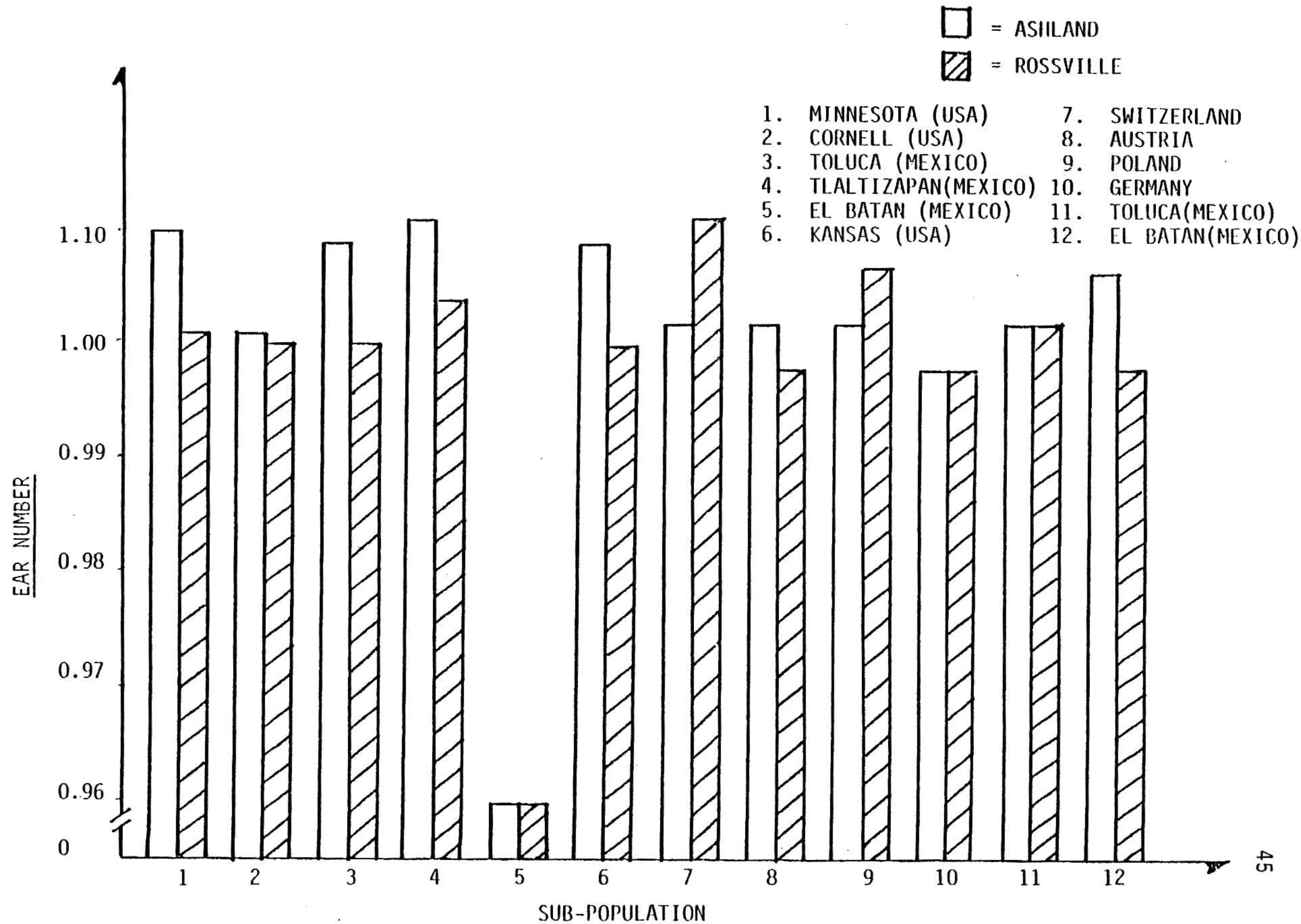

Figure 6. Average ear number for each of the 12 sub-populations of maize at each of the two locations.

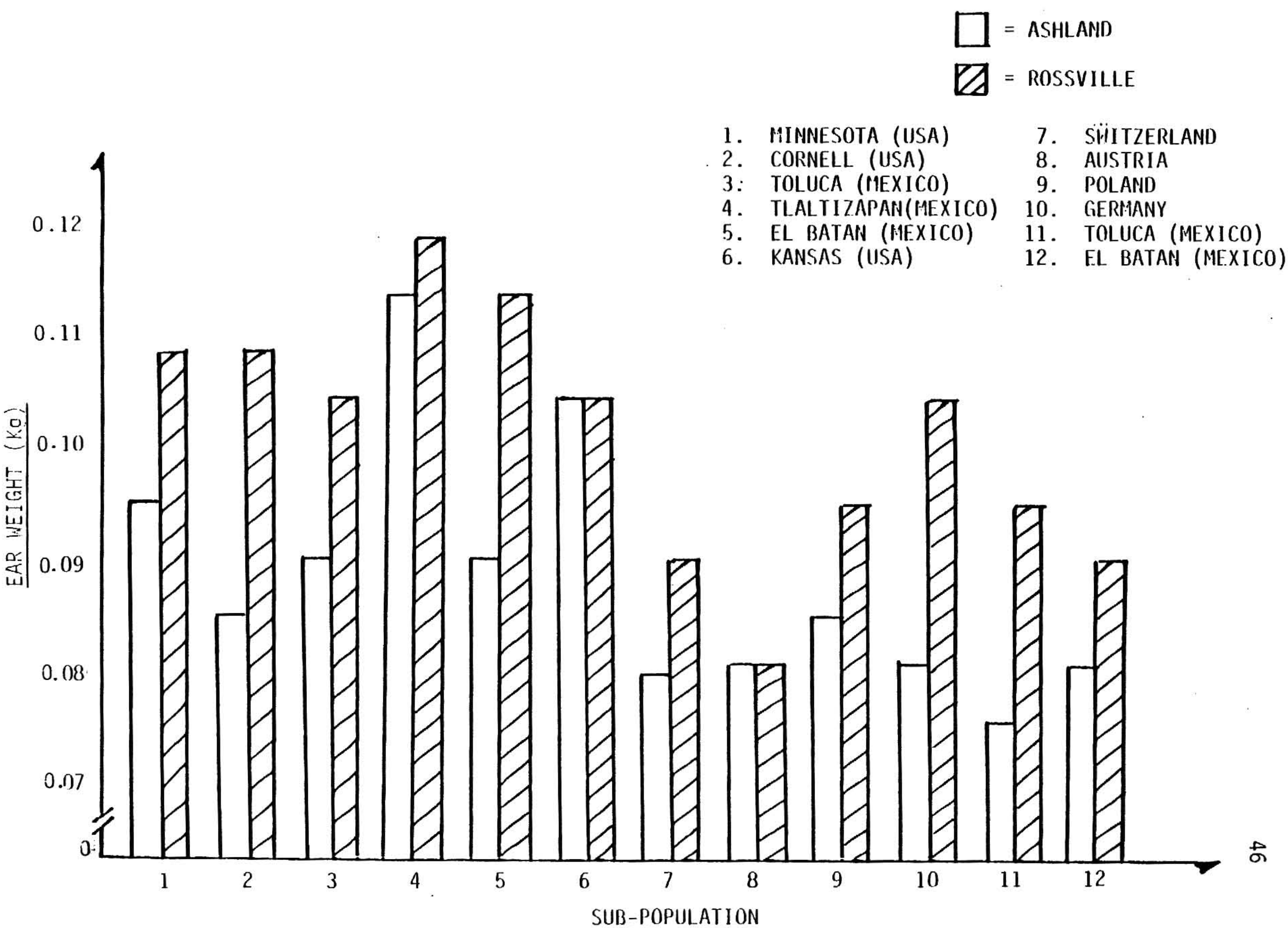

Figure 7. Average ear weight (Kg) for each of the 12 sub-populations of maize at

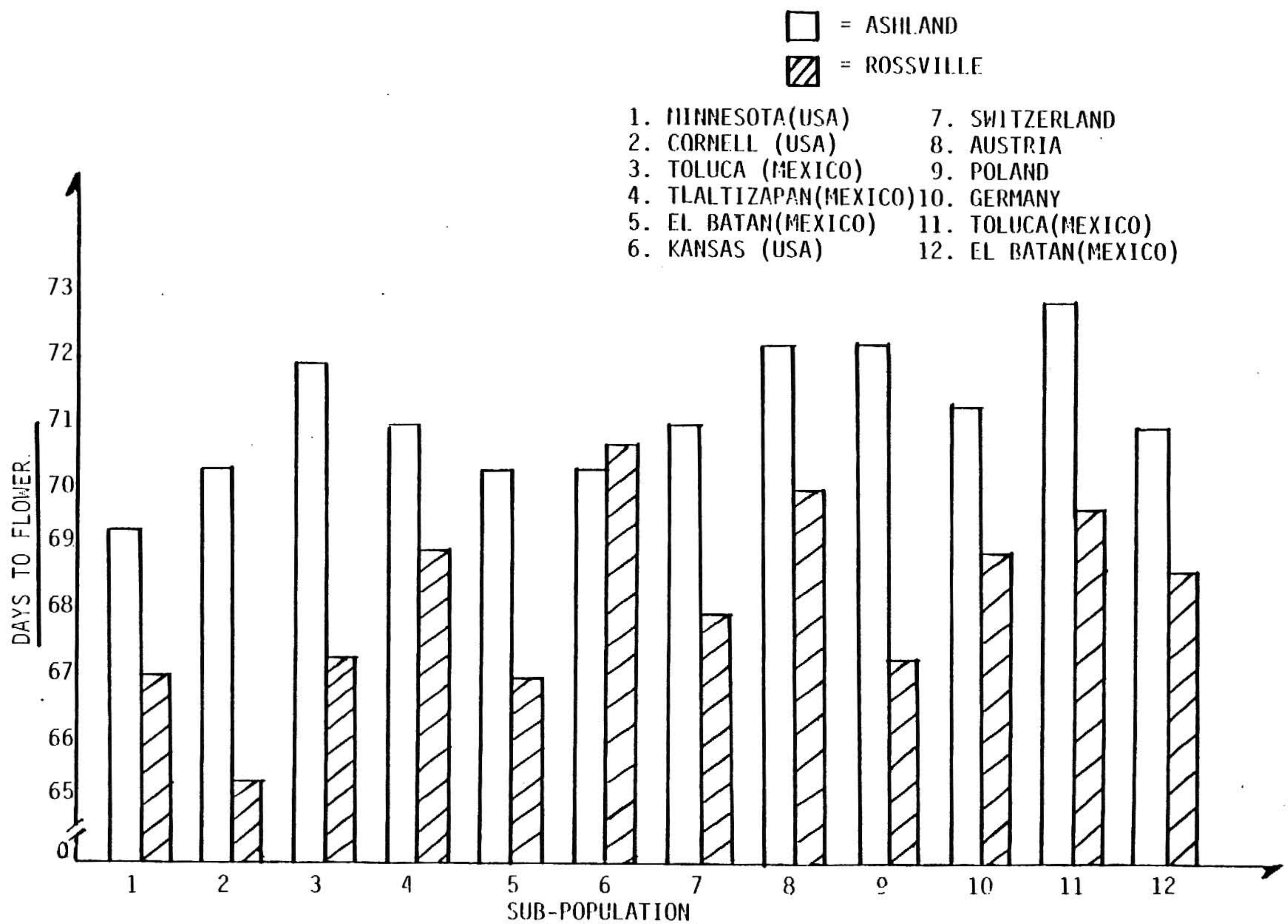

Figure 8. Average days to flower for each of the 12 sub-populations of maize at each of the two locations.

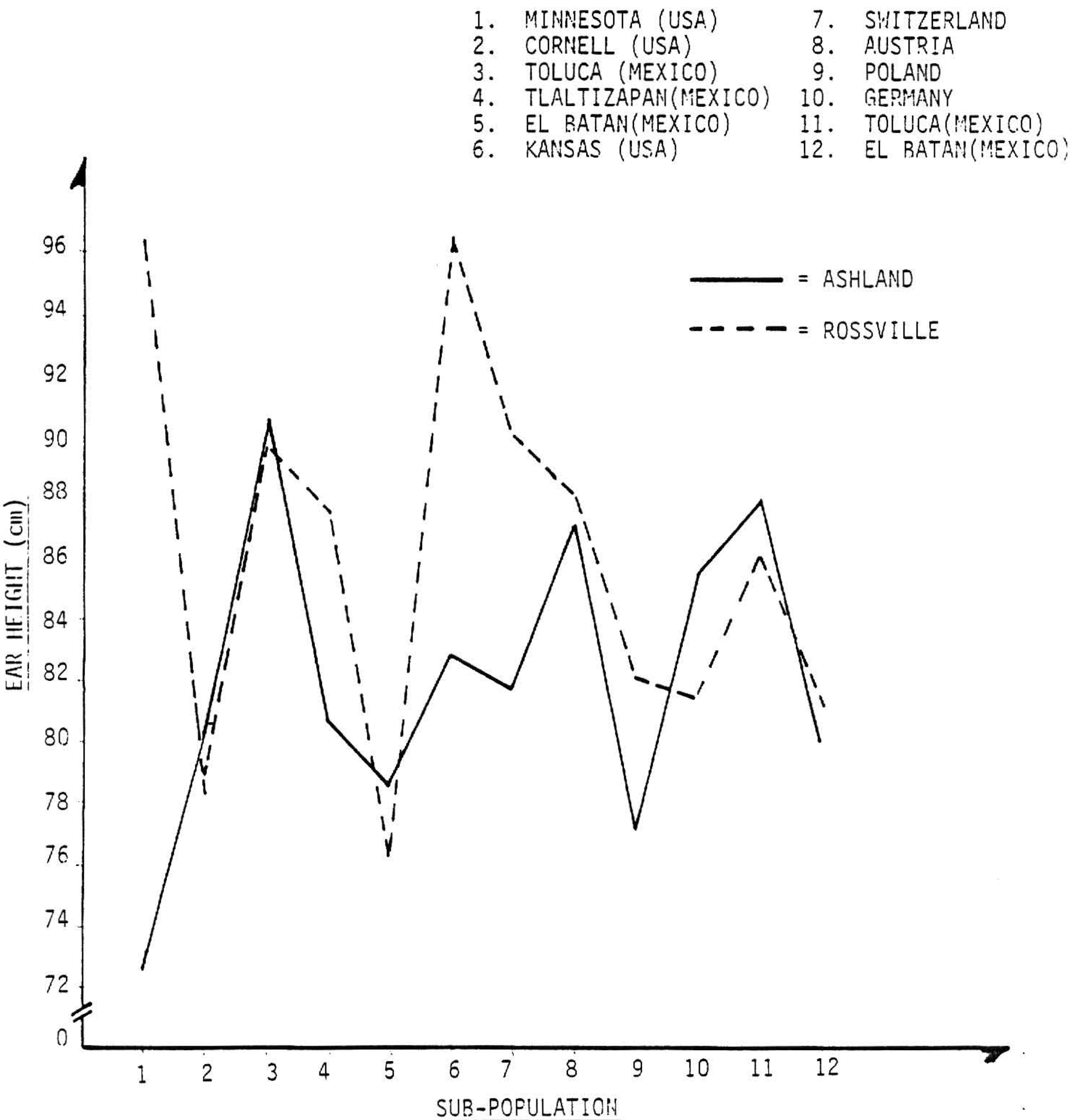

Figure 9. Interaction of ear height (cm) with location for each of the 12 sub-populations of maize.

1. MINNESOTA (USA)
2. CORNELL(USA)
3. TOLUCA(MEXICO)
4. TLALTIZAPAN(MEXICO)
5. EL BATAN(MEXICO)
6. KANSAS(USA)
7. SWITZERLAND
8. AUSTRIA
9. POLAND
10. GERMANY
11. TOLUCA(MEXICO)
12. EL BATAN(MEXICO)

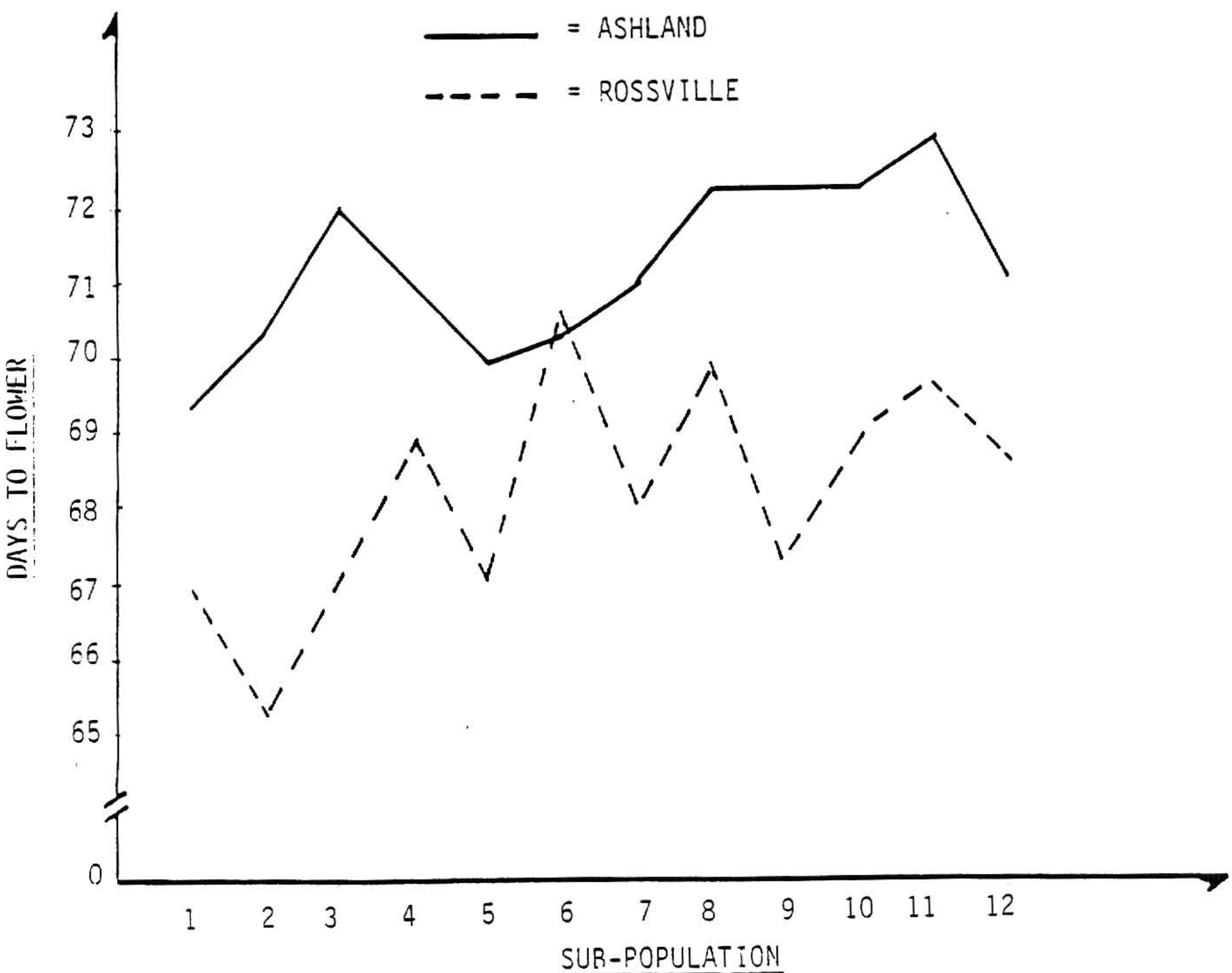

Figure 10. Interaction of days to flower with location for each of the 12 sub-populations of maize.

1. MINNESOTA (USA)
2. CORNELL (USA)
3. TOLUCA (MEXICO)
4. TLALTIZAPAN(MEXICO)
5. EL BATAN(MEXICO)
6. KANSAS (USA)
7. SWITZERLAND
8. AUSTRIA
9. POLAND
10. GERMANY
11. TOLUCA(MEXICO)
12. EL BATAN(MEXICO)

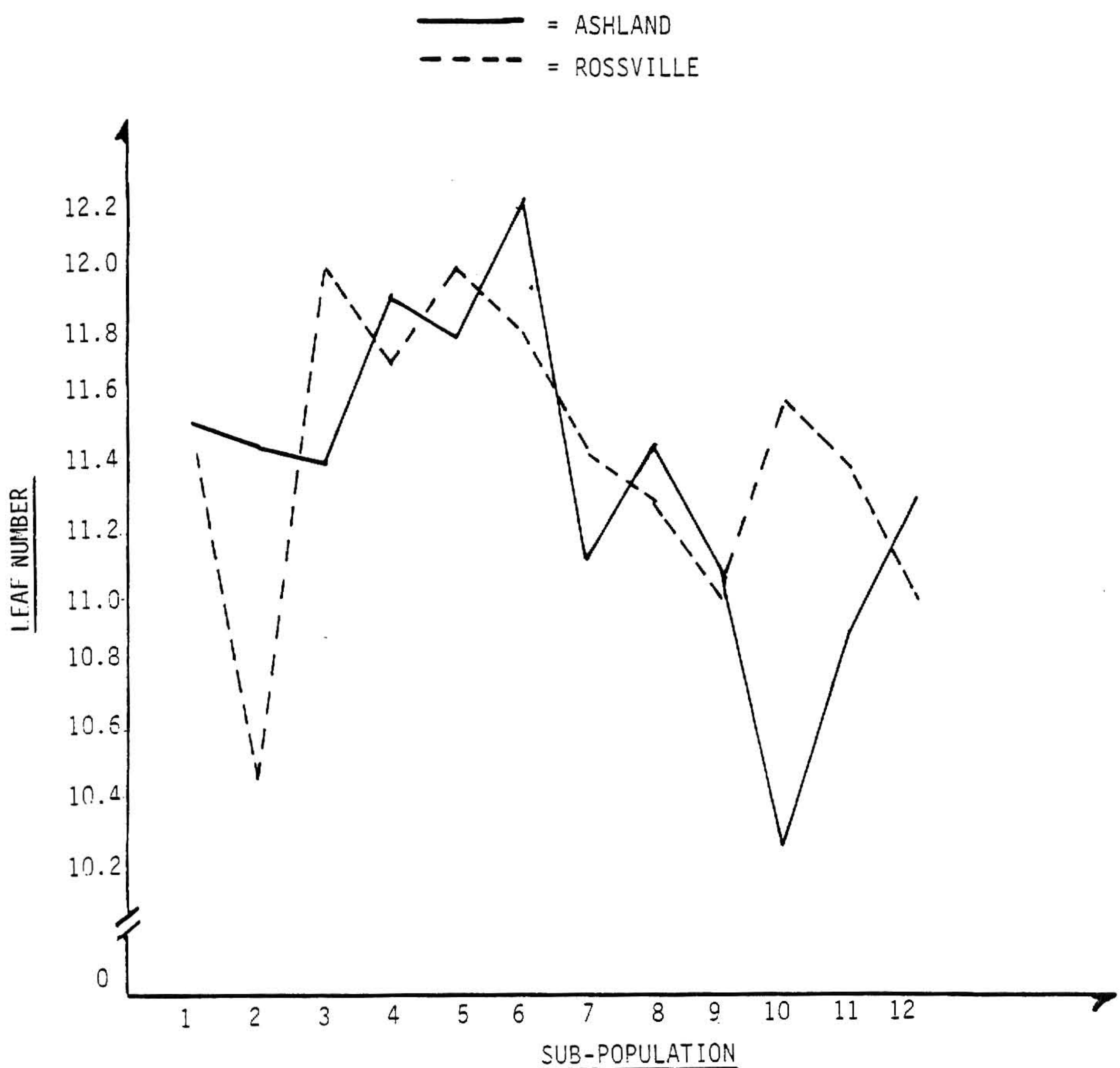

Figure 11. Interaction of leaf number with location for each of the 12 sub-populations of maize.

Table 2. Analysis of variance for stalk diameter, Ashland, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	0.52	0.04	0.86 N.S.
Block	2	0.15	0.07	1.26 N.S.
Sub-popxBlock	22	1.22	0.05	0.91 N.S.
Error	504	30.87	0.06	
Total	539	32.78		

N.S. Not significant
[a] Test of hypotheses using the ANOVA MS for sub-pop.xblock as an error term.

Table 3. Analysis of variance for tassel size, Ashland, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	13.48	1.22	3.18**
Block	2	0.36	0.18	0.34 N.S.
Sub-popxBlock	22	8.49	0.39	0.72 N.S.
Error	504	269.87	0.54	
Total	539	292.19		

N.S. Not significant
** Significant at the 0.01 level
[a] Refer to Table 2, footnote a.

Table 4. Analysis of variance for plant height, Ashland, 1981

Source	d.f.	S.S.	M.S.	F.
Sub-pop[a]	11	16046.41	1458.76	3.92 **
Block	2	2529.18	1264.59	2.60 N.S.
Sub-popxblock	22	8193.92	372.45	0.77 N.S.
Error	504	244703.066	485.52	
Total	539	271472.59		

N.S. Not significant
** Significant at the 0.01 level
[a] Refer to Table 2, footnote a.

Table 5. Analysis of variance for ear number, Ashland, 1981.

Source	d.f.	S.S.	M.S.	F.
Sub-pop[a]	11	1.39	0.12	1.93 N.S.
Block	2	0.29	0.14	1.60 N.S.
Sub-popxBlock	22	1.44	0.06	0.72 N.S.
Error	504	46.13	0.09	
Total	539	49.26		

N.S. Not significant
[a] Refer to Table 2, footnote a.

Table 6. Analysis of variance for ear height, Ashland, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	11397.32	1036.12	2.05 N.S.
Block	2	2045.40	1022.70	3.10 *
Sub-popxBlock	22	11110.54	505.02	1.53 N.S.
Error	468	154348.42	329.80	
Total	503	178901.70		

N.S. Not significant
* Significant at the 0.05 level
[a] Refer to Table 2, footnote a.

Table 7. Analysis of variance for leaf number, Ashland, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop [a]	11	82.86	7.53	1.96 N.S.
Block	2	24.21	12.10	7.49 **
Sub-popxBlock	22	84.51	3.84	2.38 **
Error	324	524.00	1.61	
Total	359	715.60		

N.S. Not significant
** Significant at the 0.01 level
[a] Refer to Table 2, footnote a.

Table 8. Analysis of variance for days to flower, Ashland, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	42.75	3.89	2.87 *
Block	2	6.17	3.09	.
Sub-popxBlock	22	29.83	1.36	.
Error	0	0.00	0.00	
Total	35	78.75		

*Significant at the 0.05 level
[a]Refer to Table 2, footnote a.

Table 9. Analysis of variance for ear weight, Ashland, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	0.0172	0.00156	6.30 **
Block	2	0.0005	0.00025	.
Sub-popxBlock	22	0.0054	0.00024	.
Error	0	0.0000	0.00000	
Total	35	0.0233		

** Significant at the 0.01 level.
[a]Refer to Table 2, footnote a.

Table 10. Analysis of variance for yield, Ashland, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop	11	27.27	2.48	3.81 **
Block	2	4.29	2.15	3.30 *
Stand	1	5.73	5.73	8.80 **
Error	21	13.67	0.65	
Total	35	50.96		

* Significant at the 0.05 level
** Significant at the 0.01 level

Table 11. Analysis of variance for yield, Rossville, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop	11	29.12	2.65	2.65 *
Block	2	4.88	2.44	2.45 N.S.
Stand	1	9.64	9.64	9.67 **
Error	21	20.95	0.98	
Total	35	64.59		

N.S. Not significant
* Significant at the 0.05 level
** Significant at the 0.01 level

Table 12. Analysis of variance for stalk diameter, Rossville, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	2.01	0.18	1.19 N.S.
Block	2	0.15	0.07	1.40 N.S.
Sub-popxBlock	22	3.38	0.15	2.71 **
Error	504	28.63	0.05	
Total	539	34.18		

N.S. Not significant
** Significant at the 0.01 level
[a]Refer to Table 2, footnote a.

Table 13. Analysis of variance for tassel size, Rossville, 1981.

Source	d.f.	M.S.	S.S.	F
Sub-pop[a]	11	16551.10	1504.64	1.49 N.S.
Block	2	1283.71	641.85	1.12 N.S.
Sub-popxBlock	22	22178.64	1008.12	1.76 N.S.
Error	504	287909.20	571.24	
Total	539	327922.65		

N.S. Not significant
[a]Refer to Table 2, footnote a.

Table 14. Analysis of variance for plant height, Rossville, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	16551.10	1504.64	1.49 N.S.
Block	2	1283.71	641.85	1.12 N.S.
Sub-popxBlock	22	22178.64	1008.12	1.76 *
Error	504	287909.20	571.24	
Total	539	327922.65		

N.S. Not significant
* Significant at the 0.05 level
[a]Refer to Table 2, footnote a.

Table 15. Analysis of variance for ear number, Rossville, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	1.17	0.10	1.39 N.S.
Block	2	0.09	0.04	0.57 N.S.
Sub-popxBlock	22	1.68	0.07	0.94 N.S.
Error	504	40.93	0.08	
Total	539	43.88		

N.S. Not significant
[a]Refer to Table 2, footnote a

Table 16. Analysis of variance for ear height, Rossville, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	18380.38	1670.94	4.20 **
Block	2	654.65	327.32	0.93 N.S.
Sub-popxBlock	22	8743.15	397.41	1.13 N.S.
Error	468	165249.35	353.09	
Total	503	193027.55		

N.S. Not significant
** Significant at the 0.01 level
[a] Refer to Table 2, footnote a.

Table 17. Analysis of variance for leaf number, Rossville, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	65.09	5.91	5.10 **
Block	2	0.73	0.36	0.21 N.S.
Sub-popxBlock	22	25.52	1.16	0.66 N.S.
Error	324	572.90	1.76	
Total	359	664.26		

N.S. Not significant
** Significant at the 0.01 level
[a] Refer to Table 2, footnote a

Table 18. Analysis of variance for ear weight, Rossville, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	0.0179	0.0016	3.92 **
Block	2	0.0014	0.0007	.
Sub-popxBlock	22	0.0092	0.0004	
Total	35	0.0286		

** Significant at the 0.01 level
[a] Refer to Table 2, footnote a

Table 19. Analysis of variance for days to flower, Rossville, 1981.

Source	d.f.	S.S.	M.S.	F
Sub-pop[a]	11	76.75	6.9773	6.27 **
Block	2	9.50	4.7500	.
Sub-popxBlock	22	24.50	1.1136	
Total	35	110.75		

** Significant at the 0.01 level
[a] Refer to Table 2, footnote a

Table 20. Analysis of variance for stalk diameter at two locations, 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	1.11	1.11	14.14 *
Block (Loc.)	4	0.31	0.08	1.33 N.S.
Sub-pop[b]	11	1.29	0.12	1.12 N.S.
LocxSub-pop[b]	11	1.25	0.12	1.08 N.S.
Sub-popxBlock (Loc.)	44	4.61	0.10	1.78 **
Error	1008	59.50	0.06	
Total	1079	68.08		

N.S. Not significant
* Significant at the 0.05 level
** Significant at the 0.01 level
[a] Test of hypothesis using the ANOVA MS for Block (Loc.) as an Error term
[b] Test of hypothesis using the ANOVA MS for sub-pop.xBlock (Loc.) as an error term.

Table 21. Analysis of variance for tassel size at the two locations, 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	0.00	0.00	1.00
Block (Loc.)	4	0.42	0.11	0.19 N.S.
Sub-pop [b]	11	21.65	1.97	4.24 **
LocxSub-pop[b]	11	9.36	0.85	1.83 N.S.
Sub-popxBlock (Loc.)	44	20.43	0.46	0.86 N.S.
Error	1008	544.53	0.54	
Total	1079	596.39		

N.S. Not significant
** Significant at the 0.01 level
[a] Refer to Table 20, footnote a.
[b] Refer to Table 20, footnote b

Table 22. Analysis of variance for plant height at two locations, 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	30104.45	30104.45	31.58 **
Block (Loc.)	4	3812.90	953.23	1.80 N.S.
Sub-pop [b]	11	19699.15	1790.83	2.59 *
Loc.x Sub-pop[b]	11	12898.37	1172.58	1.70 N.S.
Sub-popxBlock (Loc.)	44	30372.57	690.29	1.31 N.S.
Error	1008	532612.27	528.39	
Total	1079	629499.70		

N.S. Not significant
* Significant at the 0.05 level
** Significant at the 0.01 level
[a] Refer to Table 20, footnote a.
[b] Refer to Table 20, footnote b.

Table 23. Analysis of variance for ear number at the two locations, 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	0.13	0.13	1.38 N.S.
Block (Loc.)	4	0.39	0.10	1.11 N.S.
Sub-pop[b]	11	1.45	0.10	1.86 N.S.
LocxSub-pop.[b]	11	1.17	0.11	1.42 N.S.
Sub-pop.xBlock (Loc.)	44	3.13	0.07	0.82 N.S.
Error	1008	87.07	0.09	
Total	1079	93.27		

N.S. Not significant
[a] Refer to Table 20, footnote a
[b] Refer to Table 20, footnote b

Table 24. Analysis of variance for ear height at two locations, 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	4173.22	4173.22	6.18 N.S.
Block (Loc.)	4	2700.06	675.02	1.98 N.S.
Sub-pop.[b]	11	14017.75	1274.34	2.82 **
Loc.xSub-pop.[b]	11	15759.96	1432.72	3.18 **
Sub-pop.xBlock (Loc.)	44	19853.70	451.22	1.32 N.S.
Error	936	319597.79	341.45	
Total	1007	376102.48		

N.S. Not significant
** Significant at the 0.01 level
[a] Refer to Table 20, footnote a
[b] Refer to Table 20, footnote b

Table 25. Analysis of variance for leaf number at the two locations, 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	0.73	0.73	0.12 N.S.
Block (Loc.)	4	24.96	6.24	3.69 **
Sub-pop.[b]	11	91.78	8.34	3.34 **
Loc.xSub-pop.[b]	11	56.18	5.11	2.04 *
Sub-pop.xBlock (Loc.)	44	110.04	2.50	1.48 *
Error	648	1096.90	1.69	
Total	719	1380.60		

N.S. Not significant
* Significant at the 0.05 level
** Significant at the 0.01 level
[a] Refer to Table 20, footnote a
[b] Refer to Table 20, footnote b

Table 26. Analysis of variance for days to flower at two locations, 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	162.00	162.00	41.36 **
Block (Loc.)	4	15.67	3.92	
Sub-pop.[b]	11	82.83	7.53	6.10 **
Loc.xSub-pop.[b]	11	36.67	3.33	2.70 **
Sub-pop.xBlock (Loc.)	44	54.33	1.24	
Total	71	351.50		

** Significant at the 0.01 level.
[a] Refer to Table 20, footnote a
[b] Refer to Table 20, footnote b

Table 27. Analysis of variance for ear weight at the two locations, 1981.

Source	d.f.	S.S.	M.S.	F
Loc[a]	1	0.0122	0.0122	25.10 **
Block (Loc.)	4	0.0019	0.0005	.
Sub-pop.[b]	11	0.0310	0.0028	8.47 **
Loc.xSub-pop[b]	11	0.0042	0.0004	1.15 N.S.
Sub-pop.xBlock (Loc.)	44	0.0146	0.0003	
Total	71	0.0641		

N.S. Not significant
** Significant at the 0.01 level
[a] Refer to Table 20, footnote a
[b] Refer to Table 20, footnote b

Table 28. Analysis of variance for yield at two locations, 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	0.27	0.27	0.12 N.S.
Block (Loc.)	4	9.34	2.34	2.90 **
Sub-pop.	11	42.99	3.91	4.85 **
Loc.xSub-pop.	11	13.55	1.23	1.53 *
Stand[b]	1	15.35	15.35	19.06 **
Error	43	34.63	0.81	
Total	71	116.13		

N.S. Not significant
* Significant at the 0.05 level
** Significant at the 0.01 level
a Tests of hypotheses using the type IV MS for Block (Loc.) as an error term.
b Stand used as a covariate. This test indicates if yield must be adjusted due to differences in stand at the two locations.

Table 29. Analysis of variance for stalk diameter at two locations, including groups (gene pools), 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	1.11	1.11	14.14 *
Block (Loc.)	4	0.31	0.08	1.36 N.S.
Group[b]	1	0.09	0.09	0.82 N.S.
Sub-pop. (Group)[b]	10	1.20	0.12	1.11 N.S.
Loc.xGroup[b]	1	0.01	0.01	0.03 N.S.
Loc.xSub-pop.(Group)[b]	10	1.25	0.13	1.15 N.S.
Sub-popxBlock (Loc.)	66	7.16	0.11	1.88 **
Error	986	55.96	0.06	
Total	1079	68.08		

N.S. Not significant
* Significant at the 0.05 level
** Significant at the 0.01 level
[a] Test of hypotheses using the ANOVA MS for Block (Loc.) as an error term.
[b] Test of hypotheses using the ANOVA MS for sub-pop.xBlock (loc.) as an error term.

Table 30. Analysis of variance for tassel size at the two locations, including groups (gene pools), 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	0.00	0.00	
Block (Loc.)	4	0.42	0.11	0.20 N.S.
Group[b]	1	0.09	0.09	0.12 N.S.
Sub-pop (Group)[b]	10	21.56	2.16	2.77 **
Loc.xGroup[b]	1	0.01	0.01	0.01 N.S.
Loc.xSub-pop. (Group)[b]	10	9.35	0.94	1.20 N.S.
Sub-pop.xBlock (Loc.)	66	51.43	0.78	1.50 **
Error	986	513.53	0.52	
Total	1079	596.39		

N.S. Not significant
** Significant at the 0.01 level
[a] Refer to Table 29, footnote a.
[b] Refer to Table 29, footnote b.

Table 31. Analysis of variance for plant height at two locations, including groups (gene pools), 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	30104.45	30104.45	31.58 **
Block (Loc.)	4	3812.90	953.23	1.88 N.S.
Group[b]	1	1250.23	1250.23	1.31 N.S.
Sub-pop.(Group)[b]	10	18448.92	1844.89	1.93 N.S.
LocxGroup [b]	1	662.70	662.70	0.69 N.S.
LocxSub-pop (Group)[b]	10	12235.67	1223.57	2.41 **
Sub-popxBlock (Loc)	66	62970.09	954.09	1.88 **
Error	986	500014.75	507.12	
Total	1079	629499.70		

N.S. Not significant
** Significant at the 0.01 level

[a] Refer to Table 29, footnote a
[b] Refer to Table 29, footnote b

Table 32. Analysis of variance for ear number at the two locations, including groups (gene pools), 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	0.13	0.13	1.38 N.S.
Block (Loc)	4	0.39	0.10	1.12 N.S.
Group[b]	1	0.06	0.06	0.69 N.S.
Sub-pop (Group)[b]	10	1.39	0.14	1.62 N.S.
LocxGroup[b]	1	0.37	0.37	4.30 *
LocxSub-pop (Group)[b]	10	0.74	0.07	0.86 N.S.
Sub-popxBlock (Loc)	66	5.69	0.09	1.01 N.S.
Error	986	84.50	0.09	
Total	1079	93.27		

N.S. Not significant
* Significant at the 0.05 level

[a] Refer to Table 29, footnote a
[b] Refer to Table 29, footnote b

Table 33. Analysis of variance for ear height at two locations, including groups (gene pools), 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	4173.22	4173.22	6.18 N.S.
Block (Loc)	4	2700.06	675.15	2.13 N.S.
Group [b]	1	1.08	1.08	0.001 N.S.
Sub-pop (Group)[b]	10	14016.67	14016.67	1.86 N.S.
LocxGroup[b]	1	1058.62	1058.62	1.41 N.S.
LocxSub-pop (Group)[b]	10	14701.34	1470.13	1.95 N.S.
Sub-popxBlock (Loc)	66	49631.41	751.99	2.37 **
Error	914	289820.07	317.09	
Total	1007	376102.48		

N.S. Not significant
** Significant at the 0.01 level

[a] Refer to Table 29, footnote a
[b] Refer to Table 29, footnote b

Table 34. Analysis of variance for leaf number at the two locations, including groups (gene pools), 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	0.74	0.74	0.12 N.S.
Block (Loc.)	4	24.96	6.24	4.12 **
Group[b]	1	42.53	42.53	10.88 **
Sub-pop (Group)[b]	10	49.25	4.93	1.26 N.S.
Loc.xGroup[b]	1	7.40	7.40	1.89 N.S.
Loc.xSub-pop (Group)[b]	10	48.78	4.88	1.25 N.S.
Sub-popxBlock (Loc)	66	258.01	3.91	2.58 **
Error	626	948.94	1.52	
Total	719	1380.60		

N.S. Not significant
** Significant at the 0.01 level

[a] Refer to Table 29, footnote a
[b] Refer to Table 29, footnote b

Table 35. Analysis of variance for days to flower at two locations, including groups (gene pools), 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	162.00	162.00	41.36 **
Block (Loc.)	4	15.67	3.92	.
Group[b]	1	29.39	29.39	11.16 **
Sub-pop (Group)[b]	10	53.44	5.34	2.03 *
Loc.xGroup[b]	1	0.89	0.89	0.34 N.S.
Loc.xSub-pop. (Group)[b]	10	35.78	3.58	1.36 N.S.
Sub-popxBlock (Loc)	66	173.83	2.63	
Total	93	471.00		

N.S. Not significant
* Significant at the 0.05 level
** Significant at the 0.01 level
[a] Refer to Table 29, footnote a
[b] Refer to Table 29, footnote b

Table 36. Analysis of variance for ear weight at two locations, including groups (gene pools), 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	0.0122	0.0122	25.10 **
Block (Loc)	4	0.0019	0.0005	.
Group[b]	1	0.0235	0.0235	31.06 **
Sub-pop (Group)[b]	10	0.0075	0.0008	1.00 N.S.
LocxGroup [b]	1	0.0001	0.0001	0.12 N.S.
LocxSub-pop (Group)[b]	10	0.0041	0.0004	0.55 N.S.
Sub-popxBlock (Loc.)	66	0.0499	0.0008	
Total	93	0.0992		

N.S. Not significant
** Significant at the 0.01 level
[a] Refer to Table 29, footnote a
[b] Refer to Table 29, footnote b

Table 37. Analysis of variance for yield at two locations, including groups (gene pools), 1981.

Source	d.f.	S.S.	M.S.	F
Loc.[a]	1	0.27	0.27	0.12 N.S.
Block (Loc)	4	9.34	2.34	2.90 *
Group	1	24.03	24.03	29.84 **
Sub-pop (Group)	10	18.38	1.84	2.28 *
Loc.xGroup	1	0.17	0.17	0.20 N.S.
LocxSub-pop (Group)	10	13.38	1.34	1.66 N.S.
Stand[b]	1	15.35	15.35	19.06 **
Error	43	34.63	0.81	
Total	71	115.55		

N.S. Not significant
* Significant at the 0.05 level
** Significant at the 0.01 level
a Test of hypotheses using the type IV MS for Block (Loc.) as an Error term.
b Stand used as a covariate. This test indicates if yield must be adjusted due to differences in stand at the two locations.

DEVELOPMENT OF WIDELY ADAPTED POPULATIONS OF MAIZE (*Zea mays* L.)

by

KENNETH JIMENEZ MIRANDA

B.A., Universidad de Costa Rica, 1978

AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Maize seed from two gene pools produced at 12 different sites was planted at two locations in Kansas. The objective of this study was to determine whether measurable changes in agronomic traits occurred in these 12 sub-populations of maize due to selection pressures present in the geographic areas of seed production, and to measure progress towards development of widely adapted maize populations.

Significant differences among sub-populations within gene pools were observed, indicating that changes due to geographic areas of production did occur.

The Intermediate Temperate Region Pool flowered earlier and produced a significantly higher yield than the CIMMYT-Germany Exotic Gene Pool.

There was a negative correlation between days to flower and yield. Correlation between plant and ear height was positive and the relationship between days to flower and plant height was also positive. Vegetative growth stage, i.e., number of days from planting to 50% silking, for the 12 maize sub-populations was similar to that of five Kansas hybrids for the same period; these hybrids were planted at the same time and location with the same cultural practices including irrigation, fertilizers etc., as used for the sub-populations of maize used in this study. This suggests that days to flower and adaptability of the sub-populations of maize from the two gene pools were not greatly affected, even though the two gene pools are made up of genetic sources from very different latitudes.

A comparison among sub-population variances indicated that much more variability occurred within some sub-populations for tassel size and ear number at Ashland, and plant height, ear height, and ear number at

Rossville. This suggested that selection for these traits might be effective.

Although variation among sub-populations for yield and other traits did occur, it was generally small. The original goal of development of widely adapted populations of maize has been at least partially achieved to the extent that the sub-populations produced seed in all geographic areas. Grain yields at the 1981 test sites were not high when compared to well adapted corn hybrids; yet, in all cases enough genetic variation remains in the sub-populations that crossing with locally adapted sources is possible. Further genetic improvement of the sub-populations for use in specific areas where yields obtained usually are less than the U.S. cornbelt should also be possible.