PERTANIKA 14(3),229-236 (1991)

Productivity of Homogeneous and Heterogeneous Oat Populations at Two Sowing Dates

NARIMAH MD. KAIRUDIN
Biology Department
Faculty of Science and Natural Resources
Universiti Kebangsaan Malaysia, Sabah Campus
Beg Berkunci No. 62, 88996 Kota Kinabalu, Sabah

Key words: *Avena sativa* L., blends, pure lines.

ABSTRAK

Lapan titisan "spring oats" (Avena sativa *L.) yang berbeza dari segi ketinggian dan tempoh kematangan telah dikategorikan kepada tiga kumpulan. Kumpulan I mengandungi titisan-titisan yang berbeza dari segi ketinggian dan tempoh kematangan, manakala Kumpulan II dan III masing-masing berbeza dari segi tempoh kematangan dan ketinggian. Titisan-titisan dari setiap kumpulan ditanam dalam bentuk titisan tulen dan campuran pada dua tarikh penanaman, untuk mengkaji kesan tarikh penanaman yang berbeza ke atas populasi-populasi oats yang homogen dan heterogen. Ciri-ciri yang diukur ialah kadar tumbesaran vegetatif, kadar tumbesaran reproduktif dan hasil biji. Min populasi homogen dan heterogen menunjukkan prestasi yang serupa bagi kedua-dua kadar tumbesaran dan hasil biji. Hasil biji bagi campuran berada di dalam julat komponen titisan tulen masing-masing dan campuran tidak menunjukkan sebarang keuntungan pada tarikh penanaman yang lewat.*

ABSTRACT

Eight spring oat (Avena sativa *L.) lines differing in height and maturity were categorized into three groups. Group I contained lines variable in height and maturity, whereas Groups II and III were variable in maturity and height, respectively. The lines in each group were grown in pure lines and in blends at two sowing dates, to study the effect of different sowing dates on homogeneous and heterogeneous oat populations. The traits measured were vegetative growth rate, reproductive growth rate, and grain yield. The means of homogeneous lines and heterogeneous oat populations performed equally in both growth rate and grain yield. The grain yields of the blends were within the range of their component pure lines and the blends did not show any advantage at the late sowing date.*

INTRODUCTION

Many studies have shown that heterogeneous crop varieties have several advantages over homogeneous ones. The advantages are higher yield, greater stability over environments, and less damage from diseases.

Some researchers have reported that the advantages of mixtures over their mean components occurred only when grown under specific environments. Frey and Maldonado (1967) reported a four per cent advantage for oat mixtures at a late sowing date, whereas at the normal sowing date, mixtures and pure stands yielded equally. Clay and Allard (1969) suggested that the advantage of barley (*Hordeum vulgare* L.) mixtures increased as the environment variability increased. Roy (1960) reported that mixtures of rice (*Oryza sativa* L.) varieties had greatest advantage on low productivity soil. In contrast, Mumaw and Weber (1957) reported that the mixtures of soybeans (*Glycine max* L. Merill) had least value in a drought season. Jensen (1952) suggested that a mixture that yielded below the average of its components grown in pure stands was inefficient.

Some researchers feel that the major advantage of blends is related to their ability to produce stable yields. According to Marshall and Brown (1973), it is easy to develop a stable multiline but difficult to develop a higher yielding one. Likewise, Probst (1957), working with soybeans, suggested that the blends of this crop stabilized yield over years. Allard (1961) found that for lima beans (*Phaseolus vulgaris*), pure lines generally were less stable than mixtures for maintaining consistent yield over locations. Pfahler

(1965), working with rye (*Secale cereale* L.) and oats, suggested the use of mixtures to obtain greater flexibility in production environments. Jensen (1965) found that the multilines of oats had a lower coefficient of variability than pure lines, which indicated greater stability for multilines. In a study of pure lines and simple and complex mixtures of barley, Rasmusson (1968) found that complex mixtures were more stable than pure lines or simple mixtures.

To take advantage of the benefits from heterogeneous varieties, one must know what characteristics and/or plant components are responsible for the cooperation of genotypes in the heterogeneous varieties (Gustafsson 1953; Grafius 1966). Oats is a determinate, cool season crop, with the result that the growth of a given genotype can be terminated abruptly by high temperature. Frey and Maldonado (1967) have shown that a heterogeneous variety with variable maturity has tolerence to high temperature because the components reach temperature sensitive stages at different times. In a mixture of tall and short cereal plants, the short plants are gradually eliminated from the mixture, probably due to the shading effect of the tall ones. The deleterious effect of shading might be excluded if height and maturity of the components of the mixture were positively associated. In this study, we examined the effect of the heterogeneity for height and maturity upon the development and productivity of oats when sown at normal and late dates of planting.

MATERIALS AND METHODS

The eight spring oat lines used for this study were divided into three groups. Group I, comprising 'Lang', 'Garland', and 'M70-6-1-32' contained variation for both plant height and maturity. Group II comprising 'CI 9170', 'Garland', and 'Heritage', contained variation for maturity only; and Group III comprising 'Stout', 'Webster', and 'SD 740065', contained variation for plant height only. Oat lines in a group were evaluated in pure stand and in a blend that contained equal numbers of seeds from each of the three lines.

Oat lines and blends were evaluated in an experiment at the Agronomy Field Research Center near Ames, Iowa in 1983. The experiment was sown on a Webster type soil that had been cropped with soybeans in the previous year. The experiment included two sowing dates, April 24 and May 6, and four replications.

The experiment was sown in a split-plot design with sowing dates as the whole plots and entries as the sub-plot. Each sub-plot consisted of 16 rows, each 2.4m long, and spaced 15 cm apart. Fertilizer of composition: urea (30%N), $P_2 0_5$(46%P) and K_2O(46%K) was applied to the experimental area prior to planting at the rate of 224 kg/ha. The seeding rate was 300 seeds/m^2. Bayleton, a fungicide, was applied on July 1 to preclude the development of foliar fungal diseases. Plots were hand weeded as needed.

Half of each sub-plot was used to obtain samples for growth analyses. At the four-leaf stage, a 50-cm row section chosen randomly in each plot was harvested at ground level, dried at 60°C for 48 h and weighed. Similarly, other random sections were harvested at five-leaf, six-leaf, anthesis, fourteen-days post anthesis and maturity. Samples from the last two harvests were separated into vegetative and reproductive portions separately. Growth rate was computed by linear regression of dry weights upon days to sampling. For the vegetative growth rate, the duration of sampling was from four-leaf stage to anthesis, and for reproductive growth, it was from anthesis to maturity.

When matured, the last four centre rows of eight were harvested at ground level, dried and weighed. After threshing, grain yield was recorded.

Statistical Procedure

In all statistical models, all main effects except entries were considered random. Combined analyses of variances were computed across sowing dates for each trait by using the following model

$$Y_{ijk} = U + B_i + D_j + (BD)_{ij} + G_k + (DG)_{jk} + E_{ijk}$$

where

Y_{ijk} = the trait measured for the designated plot,
U = overall mean,
B_i = the effect of the ith replication,
D_j = the effect of the jth date of sowing,
$(BD)_{ij}$ = the interaction effect of the ith replication with the jth date of sowing,
G_k = the effect of the kth entry,
$(DG)_{jk}$ = the interaction effect between the jth date of sowing and the kth entry, and
E_{ijk} = residual variation due to the designated plot.

For analysing growth rates within sowing dates, the following model was used

$$Y_{ijk} = U + B_i + G_j + (BG)_{ij} + T_{kj} + E_{ijk}$$

where

Y_{ijk} = the trait measured for the designated plot,
U = overall mean,

B_i = the effect of the ith replication,
G_j = the effect of the jth entry,
$(BG)_{ij}$ = the interaction effect of the ith replication with the jth entry,
T_{kj} = the effect of the kth day of sampling within jth entry, and
E_{ijk} = residual variation due to the designated plot.

RESULTS

Vegetative Growth Rate

Within the first sowing date, the vegetative growth rates among pure lines ranged from 187 kg/ha/ da for M70-6-1-32 to 228 kg/ha/da for Webster (Table 1). In Group I, the growth rate of the blend was less than any of the lines used in that group. Highly significant variation was found among vegetative growth rates of the three lines, but the mean vegetative growth rate of the three lines was not significantly different from that of the blend (Table 2). In Group II, where all lines were similar in height and different in maturity, the vegetative growth rate of the blend was within the range of its component lines (Table 1). Among the pure lines, vegetative growth rates were highly significantly different, but the vegetative growth rate of blend and the mean of pure lines did not differ (Table 2). The vegetative growth rates of the blend in Group III exceeded those of all three of its component lines (Table 1), but did not differ significantly from the mean of the lines (Table 2). The means of vegetative growth rates for the three groups of oat lines did not differ (Table 2).

At the second sowing date, vegetative growth rates for the pure lines ranged from 163 kg/ha/da for SD 740065 to 259 kg/ha/da for Heritage (Table 1). In Group I, the vegetative growth rate of the blend was lower than any pure line and significantly lower than the mean of pure lines (Table 2). The vegetative growth rates of the three pure lines differed significantly. In Group II, the vegetative growth rate of the blend was within the range of its component lines (Table 1), and was not significantly different from their mean. Vegetative growth rates among the three pure lines were highly significantly different (Table 2). In Group III, the vegetative growth rate of the blend was within the range of the three pure lines (Table 1), and no significant differences existed among any sources (Table 2). Means of vegetative growth rates for the three groups of oat lines did not differ at both sowing dates but the deviations were significant (Table 2).

In Iowa, if sowing date for oats is delayed, the temperature during the growth period increases,

TABLE 1
Vegetative growth rates (kg/ha/da) for oat lines and blends evaluated at two sowing dates.

Entry	Sowing Date		t
	First	Second	
Group I			
Lang	203	202	0.09
Garland	211	169	7.73**
M70-6-1-32	187	179	1.47
Blend 1	180	145	5.18**
Group II			
CI 9170	225	212	2.33*
Garland	222	179	6.67**
Heritage	213	259	7.63**
Blend 2	224	213	1.92
Group III			
Stout	221	197	3.43**
Webster	228	232	0.53
SD 740065	222	163	8.69**
Blend 3	233	196	4.34**

*Significant at 5% level.
**Significant at 1% level.

TABLE 2
Analysis of variance for vegetative growth rates at first and second sowing dates.

Source of variation	Degrees of freedom	Mean square[a]	
		First	Second
Replications	3	1489	973
Entries	11	760	1385
Replications x entries	33	303	33
Days (Entries)	36	20710	17352
Slopes	11	1128 **	2518 **
(C vs. B)b/GI	11	243	2332 **
(Among C)/GI	2	1803 **	2474 **
(C vs. B)/GII	1	546	688
(Among C)/GII	2	3036 **	9062 **
(C vs. B)/GIII	1	93	6
(Among C)/GIII	2	56	403
Among groups	2	369	398
Deviations	25	29327 **	23878 **
Error	108	322	282

[a]Mean square x 10^3
[b]C = mean of pure lines in a group; B = blend.
**Significant at 1% level.

and generally this causes reduced vegetative growth rates for the oat entries. In this experiment, exceptions were Heritage and Webster, both of which showed increased vegetative growth rates at the late sowing date (Table 1). In fact, the vegetative growth rate for Heritage, the latest line was significantly higher at the late sowing date. For Lang, M70-6-1-32, and Webster, vegetative growth rates for the first and second sowing dates were not significantly different. For the other lines and two of the blends, vegetative growth rates at the second sowing date were significantly less than those at the first one (Table 1).

Reproductive Growth Rate

At the first sowing date, reproductive growth rates ranged from 71 kg/ha/da for CI 9170 to 157 kg/ha/da for Heritage and the variation among them was significant (Table 3). In Groups I and II, reproductive growth rates of the blends were within the ranges of their components and not different from the means of the components lines (Table 4). However, the reproductive growth rates among the pure lines were significantly different in both groups. In Group III, the reproductive growth rate of the blend was within the range of the pure stands and none of the mean squares for this group was significant. Means of reproductive growth rates for the three groups were not different (Table 4).

At the second sowing date, reproductive growth rates ranged from 65 kg/ha/da for CI 9170 to 201 kg/ha/da for Heritage (Table 3). The reproductive growth rates of the blends in all three groups were similar but slightly greater than those from the first sowing date. In Groups I and II, reproductive growth rates varied significantly among pure lines, but in neither group did the reproductive growth rate of the blend differ from the pure line mean. In Group III, the reproductive growth rate of the blend was less than that of any of its components (Table 3) but was not significantly so (Table 4). The deviations were significant at both sowing dates (Table 4).

Delayed planting tended to reduce vegetative growth rate of oats be it pure lines or blends, whereas reproductive growth rate tended to increase, though not significantly so. The interval of reproductive growth was almost the same for the first and second sowing dates. Of interest is the fact that reproductive growth rates were much lower than vegetative growth rates for all entries except Heritage.

TABLE 3

Reproductive growth rates (kg/ha/da) for oat lines and blends evaluated at two sowing dates.

Entry	Sowing date		t
	First	Second	
Group I			
Lang	88	104	1.35
Garland	82	82	0.00
M70-6-1-32	151	193	2.05
Blend 1	108	113	0.79
Group II			
CI 9170	71	65	0.75
Garland	78	82	0.48
Heritage	157	201	2.36 *
Blend 2	95	98	0.37
Group III			
Stout	79	90	1.08
Webster	86	88	0.32
SD 740065	90	92	0.24
Blend 3	84	86	0.24

*Significant at 5% level.

TABLE 4

Analysis of variance for reproductive growth rates at first and second sowing dates.

Source of variation	Degrees of freedom	Mean square[a]	
		First	Second
Replications	3	647	227
Entries	11	4204	2624
Replications x entries	33	172	137
Days (Entries)	24	21316	18630
Slopes	11	726 **	816 **
(C vs. B)[b]/G I	1	44	9
(Among C)/G I	2	1202 **	1363 **
(C vs. B)/G II	1	31	5
(Among C)/G II	2	1885 **	2291 **
(C vs. B)/G III	1	0	24
(Among C)/G III	2	361	44
Among groups	2	506	769 **
Deviations	13	38739 **	33704 **
Error	72	84	152

[a]Mean square × 10^3

[b]C = mean of pure lines in a group; B = blend.

**Significant at 1% level.

Grain Yield

Averaged over sowing dates, grain yield ranged from 3080 kg/ha for CI9170 to 4931 kg/ha for Heritage (Table 5). Analysis of variance showed that the mean grain yields for the three groups of oat lines differed significantly (Table 6). Further, there were highly significant differences among pure lines in all three groups, but in no group did the mean of pure lines differ from the blend yield. In Group I and II, the blends gave higher grain yield than the mean of the respective component lines, but not significantly so. These groups consisted of oat lines that were heterogeneous for height and maturity, and for maturity, respectively. In Group III, in which the lines were heterogeneous for height only, the blend yielded relatively less than the mean of its components (Table 7).

TABLE 5

Grain yields of nine pure lines of oats at two sowing dates (kg/ha).

Entry	Sowing Date		Mean
	First	Second	
Lang	4023	3986	4005
Garland	3414	2991	3203
M70-6-1-32	4953	4630	4792
CI 9170	3350	2810	3080
Garland	3410	3122	3266
Heritage	5061	4800	4931
Stout	3816	3207	3512
Webster	3915	3488	3702
SD 740065	3930	3430	3680
Mean	3916	3607	3762

Trends of grain yields for the pure lines and blends were similar at both sowing dates (Table 8). That is, the blends of pure lines that differed in height and maturity and maturity only had higher yields than the means of components, but the blend of lines that differed in height only, yielded less than its component mean. However, the differences were not significant (Table 6).

In general, entries yielded better at the first sowing date than at the second sowing date. The means of grain yield for the pure stands were 3916 kg/ha at the first sowing date and 3607 kg/ha at the second one (Table 5). However, none of the interactions involving date x entry was significant (Table 6).

TABLE 6

Analysis of variance for grain yields of oat entries.

Source of variation	Degrees of freedom	Mean square[a]
Replications	3	1381
Dates	1	2665
Dates x replications	3	298
Entries	11	2960 **
Among groups	2	2182 **
(C vs. B)/G I	1	93
(Among C)/G I	2	5050 **
(C vs. B)/G II	1	61
(Among C)/G II	2	8304 **
(C vs. B)/G III	1	30
(Among C)/G III	2	652 **
Dates × entries	11	60
Dates × (Among groups)	2	20
Dates × (C vs. B)/G I	1	14
Dates × (Among C)/G I	2	80
Dates × (C vs. B)/G II	1	12
Dates × (Among C)/G II	2	47
Dates × (C vs. B)/G III	1	19
Dates × (Among C)/G III	2	159
Error	66	80

[a]Mean square × 10^3

[b]C = mean of pure lines in a group; B = blend.

TABLE 7

Mean grain yields for the three groups of oat lines and for the blends across sowing dates (kg/ha).

Group	Grain yield	
	Mean of components	Blend
I	4000	4124
II	3759	3859
III	3526	3456

TABLE 8

Mean grain yields for the three groups and for the blends at the different sowing dates (kg/ha).

Group	Date of sowing	Grain yield	
		Mean of components	Blends
I	First	4130	4302
	Second	3869	3945
II	First	3940	4084
	Second	3577	3634
III	First	3677	3663
	Second	3375	3249

Response

Responses of pure lines and blends to dates of planting were derived by plotting the grain yield means of an entry upon environmental index for the two dates. An environmental index was the mean of all entries of a group: thus, separate indexes were used for each group of entries. Responses could not be tested for significance since they were computed on the basis of two data points only.

In Group I, which was heterogeneous for plant height and maturity, the blend was more responsive than the mean of pure lines (*Figure 1*). The response values were 1.25 and 0.91 for the blend and the mean of the pure lines, respectively. In Group II, which was heterogeneous for maturity only, the blend also showed greater response to date of planting than did the mean of pure lines. The response values were 1.77 for the blend and 0.94 for the mean of pure lines (*Figure 2*). Likewise, in Group III, which was heterogeneous for height, the blend had a response of 1.25, whereas the mean of the pure lines had a response of 0.91 (*Figure 3*).

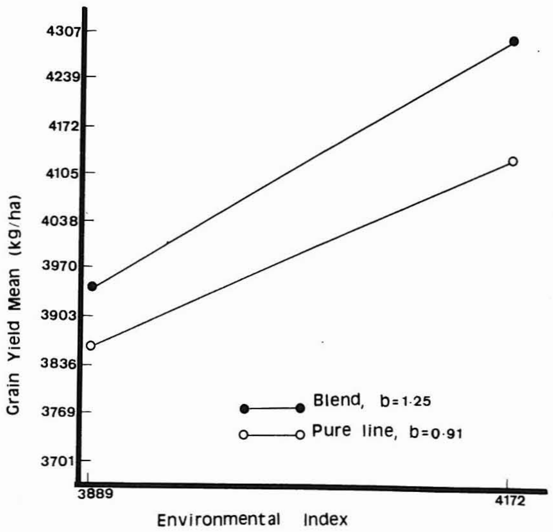

Fig. 1: Grain yield response of oat lines and blends over sowing dates for Group I

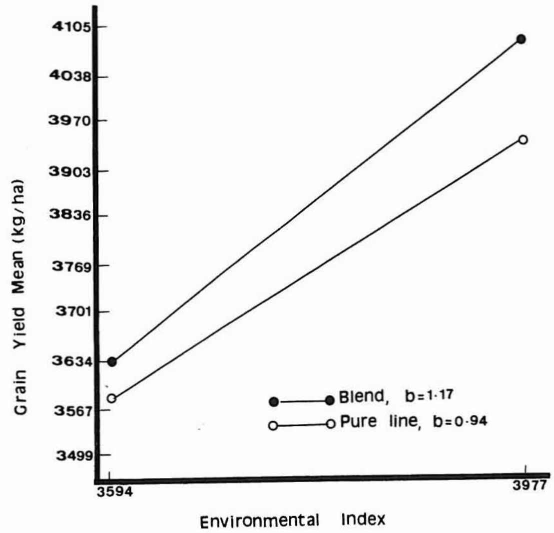

Fig. 2: Grain yield response of oat lines and blends over sowing date for Group II

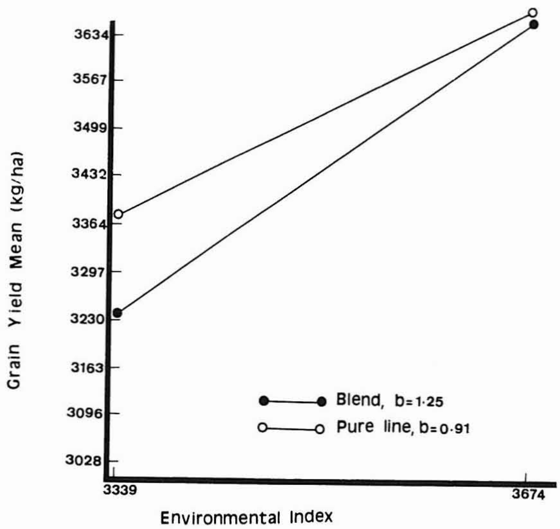

Fig. 3: Grain yield response of oat lines and blends over sowing dates for Group III

DISCUSSION

According to Frey and Maldonado (1967), the primary stress factor from late sowing of oats is high temperature. They showed that oat populations heterogeneous for anthesis date yielded better than did homogeneous ones. They proposed that an oat population heterogeneous for maturity was advantageous at late sowing dates because anthesis, the plant growth stage most sensitive to high temperature, which occurred over a longer period of extremely high temperature affected only a portion of the oat plants in a heterogeneous population, whereas it affected all or none of them in a pure line. Frey and Maldonado (1967) found no increase in yield from blending at the normal date of sowing and a 4% increase at the delayed sowing. This study produced different results. It was found that blends of Groups I and II had a 4% advantage at the first sowing date but only 2% at the second one (Table 9). Group III, which was heterogeneous in height only, had no yield advantage at the first sowing date and a 3% decrease at the second date. These results were similar to those reported for rice by Jennings and Aquino (1968). They found that blends of tall and short varieties caused sterility in the short one with a resultant yield reduction.

TABLE 9

Actual (kg/ha) and relative (%) grain yields of oat blends to the component lines at two sowing dates.

Group	Sowing Date			
	First		Second	
	Actual	Relative	Actual	Relative
I	4302	104	3945	102
II	4808	104	3634	102
III	3663	100	3249	97

The oat populations heterogeneous for anthesis did not show significant yield advantage at the late sowing date. The late sowing date in this study may not have coincided with the occurrence of high temperature stress: In fact, Amaya (1965) found that only in his third planting date did the blend exhibit an advantage over the component means. The interval between his first and third planting dates was three weeks, whereas the interval between the two planting dates in this study was only two weeks. Shorter (1976) did not find a blend advantage at his late sowing date either.

Reproductive growth rates of oat lines and blends were not significantly different at two sowing dates, but vegetative growth rates were higher at the first one. Colville (1983) found that an increased growth rate at later sowing dates compensated for reduced growth duration with the result being no change in grain yield from delayed sowing date. Since vegetative growth rates were not greater at the delayed sowing date in this study, grain yields were reduced by 10-15% and blending pure lines overall was of no advantage for maintaining grain yields.

In heterogeneous populations, intergenotypic competition can be expected to occur. Schutz and Brim (1967) outlined four types of intergenotypic competition: under compensation, complementary compensation, neutral compensation, and over compensation. This experiment was not designed to study competition, but blend outyielded the component lines means in four of six instances; however, none of the blend advantages was significant. Thus, it will be considered that the blends in this study have shown either complimentary or neutral compensation.

Based on the growth analyses, the pure lines used in this study had significantly different growth rates which must have interacted in blends to give a slightly greater responsiveness in blends. Competition in the blends caused the genotypes to compensate each other so the grain yields of the blends did not differ from the means of their pure lines. Complimentary compensation has been found by Eberhart *et al.* (1964) for maize, Early and Qualset (1971) for barley, Khalifa and Qualset (1974) for wheat, Trenbath (1975) for interspecific blends of *Avena.*

Overall the results of this study showed that the blends did not have any yield advantage over their respective component lines. Furthermore, from a practical viewpoint, population heterogeneity for maturity would cause problems for harvesting. The early variety might shatter while waiting for the late variety to become ripe. Heterogeneity for plant height would cause difficulty in threshing. Therefore, it could be concluded that there was no significant justification to grow heterogeneous populations of oats.

REFERENCES

ALLARD, R. W. 1961. Relationship between Genetic Diversity and Consistency of Performance in Different Environments. *Crop Sci.* **1**:127-133.

AMAYA, U. M. 1965. *Association of Adaptation and Heterogeneity of Oat Populations.* Unpublished M. S. Thesis. Library, Iowa State University, Ames, Iowa.

CLAY, R. E. and R. W. ALLARD. 1969. A Comparison of the Performance of Homogeneous and Heterogenous Barley Populations. *Crop Sci.* **9**:575-576.

COLVILLE, D. C. 1983. *Heat Unit Effects on Development of Oats.* Unpublished M. S. Thesis. Library, Iowa State University, Ames, Iowa.

EARLY, H. L. and C. O. QUALSET. 1971. Complementary Competition in Cultivated Barley (*Hordeum vulgare* L.). *Euphytica* **20**:400-409.

EBERHART, S. A., L. H. PENNY and G. F. SPRAGUE. 1964. Intraplot Competiton among Maize Single Crosses. *Crop Sci.* **4**:467-471.

FREY, K. J. and U. MALDONADO. 1967. Relative Productivity of Homogeneous and Heterogeneous Oat Cultivars in Optimum and Suboptimum

Environments. *Crop Sci.* **7**:532-535.

GRAFIUS, J. E. 1966. Rate of Change of Lodging Resistance, Yield and Test Weight in Varietal Mixtures of Oats (*Avena sativa*). *Crop Sci.* **6**:369-370.

GUSTAFSSON, A. 1953. The cooperation of Genotypes in Barley. *Hereditas* **39**:1-18.

JENNINGS, P. R. and R. C. AQUINO. 1968. Studies on Competition in Rice. III. The Mechanism of Competition among Phenotypes. *Evolution* **22**:529-542.

JENSEN, N. F. 1952. Intra-varietal Diversification in Oat Breeding. *Agron. J.* **44**:30-34.

JENSEN, N. F. 1965. Multilines Superiority in Cereals. *Crop Sci.* **5**:556-568.

KHALIFA, M. A. and C. O. QUALSET. 1974. Intergenotypic Competition between Tall and Dwarf Wheats. I. In Mechanical Mixture. *Crop Sci.* **14**:795-799.

MARSHALL, D. R. and A. H. D. BROWN. 1973. Stability of Performance of Mixtures and Multilines. *Euphytica* **22**:405-412.

MUMAW, C. R. and C. R. WEBER. 1957. Competition and Natural Selection in Soybean Varietal Composites. *Agron. J.* **49**:154-160.

PFAHLER, P. L. 1965. Environmental Variability and Genetics Diversity within Populations of Oats (cultivated species of *Avena*) and Rye (*Secale cereale* L.). *Crop Sci.* **5**:271-275.

PROBST, A. H. 1957. Performance of Variety Blend in Soybeans. *Agron. J.* **49**:148-150.

RASMUSSON, D. C. 1968. Yield and Stability of Yield of Barley Populations. *Crop Sci.* **8**:600-602.

ROY, S. K. 1960. Interaction between Rice Varieties. *J. Genetics* **57**:137-152.

SCHUTZ, W. M. and C. A. BRIM. 1967. Inter-genotypic Competition in Soybeans. I. Evaluation of Effects and Proposed Field Plot Design. *Crop Sci.* **7**:371-376.

SHORTER, R. 1976. *Relative Yields of Mixtures and Monocultures of Oat Genotypes Evaluated across Locations and Years.* Unpublished Ph.D. dissertation. Library, Iowa State University, Ames, Iowa.

TRENBATH, B. R. 1975. Neighbour Effects in the Genus *Avena.* III. A Diallel Approach. *J. Appl. Ecol.* **12**:189-200.

(Received 30 October, 1990)