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GROWTH CHARACTER AND YIELD CHARACTER ANALYSIS OF RAPESEED (*BRASSICA NAPUS* L.) CULTIVARS: NUGGET, ORO, AND TARGET

BY

© DUNCAN CHARLES CAMPBELL

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Growth and Yield Character Analysis of Rapeseed(Brassica napus L.)" submitted by Duncan Charles Campbell in partial fulfillment of the requirements for the degree of Master of Science in Plant Breeding.

Supervisor

Date Sept 3, 1976

ABSTRACT

The feasibility of reducing the time to maturity without reducing seed yield was studied in *Brassica napus*. The cultivars Nugget, Oro, and Target, their crosses and the reciprocal crosses of the F_1 abd F_2 generations were grown. Observations were made in the field on a single plant basis on growth characters including growth stages, growth periods, and rates of development, as well as on morphological characters and yield characters.

Target exhibited many characteristics which would tend to make it a late variety. However, Target was the earliest cultivar and the major characteristic leading to earliness for Target was early first flower.

There were few high correlations among the growth characters and none of the correlations of the growth characters with the yield characters were high, thus indicating that these characters are all largely independent. However, the growth characters which tended to produce earliness were in general positively associated with the yield characters.

Earliness of the initial growth stages, shortness of the initial growth periods, and high rates of development were all associated with earliness of the stages subsequent to first flower, including maturity. They were also associated with high seed yield.

Rapid development during the rosette period was associated with early first flower and both were associated with longer duration of the flowering periods first flower on the main raceme to first flower on the last secondary raceme to flower and first flower on the main raceme to end of flowering on the main raceme. Longer flowering periods were associated with higher seed yield.

High developmental rates at different times and for different aspects of growth were positively associated. High leaf emergence rate and early emergence of the seventh true leaf were associated with rapid flowering rates and early maturity but also with longer flowering periods. High flowering rates are associated with reduced duration of the flowering periods and high flowering rate on the main raceme is associated with reduced time from the first flower to maturity.

Almost all of the significant correlations among the yield characters were positive. High seed yield was indicated to be largely determined by high vegetative yield. Association of high seed yield with early growth stages and shortness of the initial growth periods was indicated to be largely independent of vegetative yield. The positive association of longer flowering periods and high rates of development with high seed yield were largely due to their association with high vegetative yield. The yield characters exhibited a similar relationship. However, the number of tertiary racemes and number of pods for all three cultivars, number of secondary racemes for Oro and Target and number of leaves for Oro all showed significant positive associations with high seed yield independent of their association with high vegetative yield.

Significant reciprocal differences were found for the population means of many of the characters studied and large reciprocal differences in the heritability estimates calculated were also found. Heterosis was indicated for some of the growth characters and several of the yield characters.

ACKNOWLEDGEMENTS

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Table Of Contents

List Of Tables

List Of Figures

INTRODUCTION

The importance of rapeseed as a commercial crop in Canada began in 1943 when it was brought into production to help meet wartime demands for industrial oil. Production rose to 1.28 million bushels in 1948, but fell to 2400 bushels in 1950. Since then, production has again increased in response to market conditions. Production peaked in 1971 when 95 million bushels were harvested. In 1974 production was 52 million bushels (White, 1974). Currently rapeseed oil is largely utilized in the edible oil industry, while the meal is used in the production of livestock feeds.

Total demand by the domestic rapeseed-crushing industry has been projected as increasing from 10 million bushels in 1971-72 to 37.7 million bushels in 1986-87(Darcovich, 1973). Export demand is expected to increase from 30.0 million bushels in 1971-72 to 68 million bushels in 1986-87. By 1986-87 it is estimated that 7.5 million acres will be in production compared with only 3.2 million acres in 1974-75(White, 1974). It is apparent that rapeseed production has expanded remarkably in the past and more expansion may be expected in the future.

One of the major factors leading to the rapid increase in rapeseed production has been the improvements in yield and oil and meal quality. As well, improved methods of processing have been developed by Canadian scientists. Today

Canada is the world's leading rapeseed exporter and is also a leader in rapeseed research and development.

Of major importance for the production of any field crop is the seed yield per acre. Factors leading to high yield have been intensively studied in cereals such as wheat and barley, but little work has been done with rapeseed. However, if Canada is to maintain a competitive position in domestic and world rapeseed markets, these factors must be determined and then utilized to improve agronomic practices and to develop improved cultivars. Approximately 75 percent of the acreage in western Canada is *Brassica campestris*, which is cross-pollinated and early maturing but has less yield potential than *B. napus*, which is largely self-pollinated and late maturing. Major improvements in seed yield per acre could be achieved simply by reducing the time to maturity of *B. napus* so that cultivars of this species could be more widely grown.

The object of this study was to determine the relationships among various growth characters and yield characters in order to indicate the feasibility of reducing the time to maturity without reducing yield.

LITERATURE REVIEW

In recent years, Canadian rapeseed breeders have been preoccupied with the development of new seed quality characteristics. The most recent cultivars in both rapeseed species have been produced in response to the demand for low erucic acid in the end-product oil. Low glucosinolate content in the meal is the major, current goal of breeding programs. As a consequence, the bulk of current literature regarding the oilseed rapes is concerned with quality characteristics, and little research has been done to increase yield.

Engledow and Wadham(1923) were among the first to attempt to systematically study the factors that result in a high yielding cultivar. They state that, ideally, the breeder should first determine the plant characters which control yield and then, by a synthetic system of hybridization, accumulate into one plant cultivar the optimum combination of these yield controlling characters. They further suggested that economic attributes be resolved into biological characteristics. The procedure would then be to determine all the relationships between acceptable plant characteristics and yield. Their proposal was:

1) determine the relationships of yield per plant to other plant characters;
2) find the mode of inheritance of those characters;
3) test all relationships at a succession of spacings.

Engeldow and Wadham also pointed out in reference to tillering in wheat that the origin and nature of inter-tiller differences should be sought in juvenile development, not later when subsequent plant growth has levelled and obscured earlier differences.

Similarly Stoskopf et al.(1963) said that in studying the classical yield components, tillers per plant, kernels per head, and kernel weight, the determinants of yield are not being examined but rather yield itself is being studied. In order to make yield advances the prerequisites of yield, not the expression of yield, must be studied.

Donald(1967) advocated the breeding for plant ideotypes as an alternative to the classical breeding procedures and stated that only the conscious pursuit of ideotypes can lead to the emergence of plants of novel form and of potentially high yield in new environments. Even with this approach, a thorough understanding of the relationships of the factors contributing to yield is necessary, for the ideotype chosen must have the characteristics of a high-yielding plant. His ideal wheat under good environmental conditions has a short, strong stem; a few small, erect leaves; a large, erect ear; and a single culm. No such ideal type has yet been deduced for oilseed rape. Most studies reported have dealt with the yield components, not with ideal yield prerequisites.

Ramanujam and Rai(1963) reported one of the first studies of yield components in Brassica campestris var. Yellow Sarson. They interpreted their results as presenting a rather gloomy picture of the relationship between the basic components of yield considered. They studied the number of primary branches, number of secondary branches, number of pods per plant, number of seeds per pod, 1000 seed weight, and yield per plant. They found significant positive correlations between all the yield components and yield. They also observed positive correlations between the number of primary branches, the number of secondary branches, and the number of pods per plant. The number of seeds per pod was not significantly correlated with number of primary branches but number of seeds per pod was negatively correlated with both number of secondary branches and number of pods per plant. The 1000 seed weight was negatively correlated with each of the other four yield components. They concluded that to increase the seed yield, a compromise in the selection program was necessary so that improvement in one of the components would not be nullified by deterioration in another.

This effect is now recognized as yield component compensation. Adams'(1967) explanation of yield component compensation is that the negative correlations between yield components are developmental rather than genetic and are due to either a limited constant input of metabolites or an oscillatory input of these substances such that input is limited at critical stages in the developmental sequence.

Olsson(1960) reported on the indirect effects of selection for number of seeds per pod upon 1000 seed weight in yellow mustard(*Brassica hirta*) over five years. He found that with selection for increased number of seeds per pod the 1000 seed weight was reduced and conversely, with selection for reduced number of seeds per pod, the 1000 seed weight increased. These results further support the yield component compensation concept.

One of the more recent studies of rapeseed was conducted in Australia by Thurling(1974a). He studied both *B. campestris* and *B. napus* and found significant differences in growth characters and in the correlations among these characters. He found both species had negative correlations between net assimilation rate and leaf area ratio. He also found(1974b) that in *B. napus*, yield was significantly and positively correlated with the number of pods per plant, and its components, number of pod-bearing branches and number of pods per branch. However, in *B. campestris* only the number of seeds per pod, and 1000 seed weight, were significantly positively correlated with yield. In both species the number of pods per plant was negatively correlated with the number of seeds per pod. However, Thurling also found a significant negative correlation between the number of pods and 1000 seed weight in *B. campestris*. One thousand seed weight and the number of seeds per pod were significantly and positively correlated only in *B. campestris*.

Olsson(1960) reported that for *B. campestris*, *B. napus*, and *B. hirta*, the heritability as estimated by parent offspring regression was low or nonsignificant for seed yield per plant.

Singh(1973) used six cultivars of *B. juncea* and studied heterosis in yield, seeds per silique, silique length, raceme length, plant height, secondary racemes, tertiary racemes, and days to flower. Highest heterotic values were found for yield; moderately high values were also found in certain crosses for number of secondary racemes, tertiary racemes, and raceme length, but estimates were in general low for other characteristics. Significant maternal effects were found for yield, silique length, primary branches, and days to flower. The highest narrow sense heritabilities reported were 63.4 percent for days to flower, 58.4 percent for plant height, 23.5 percent for primary branches, and 19.1 percent for yield.

Singh and Singh(1972) studied the inheritance of yield and other agronomic characters in *B. juncea*. Additive and dominance gene effects were found to be important for primary and secondary branches, plant height, and raceme length in the two years of their study. Days to flower, silique length, and seeds per silique also exhibited these effects in 1968, but in 1969 only an additive gene effect was evident. Yield was found to be controlled mostly by dominance components. Heritability estimates(broad sense) were high for days to flower(87%) and plant height(88%) and lower for all other characters(42-61%).

Zuberi and Ahmed(1973) used four strains of B. campestris var. Toria and studied number of siliques per plant, number of seeds per silique, silique length, 100 seed weight, and total seed yield per plant. They found significant heterosis only for number of seeds per silique, but high broad sense heritabilities(68-88%) for all characters. All characters studied showed high positive correlations only with yield except 100 seed weight.

Laosuwan(1969) studied the number of days from seeding to first bloom and number of leaves in B. napus. He found partial dominance for early flowering and dominance for fewer leaves. He also found low broad sense heritabilities for number of leaves(7-59%) and high broad sense heritabilities for days to first bloom(65-78%). Days to first bloom was indicated to be controlled by two genes. Number of leaves and days to first bloom had a high genetic correlation.

Yamaguchi et al.(1965) studied the difference of character manifestation in reciprocal crosses of B. napus(Table 1). Although these results are based on crosses of widely differing genotypes, the importance of the

TABLE 1. Classification of characters by the reaction norm between cytoplasm and nuclear genes and the trait of the group.

Classification of group	Sub-group	Trait of group	Characters
The first (I)		This group mainly contains the vegetative characters appearing before the stage of flower-bud differentiation, and the manifestation of these characters seems to be dependent on the nuclear genes, because they do not show the reciprocal difference in F_1 hybrids and approach to the characters of their pollen parent in the process of reciprocal substitution of nucleus.	In nursery bed: Plant height, Number of leaves, Length of leaf blade, Width of leaf, Shape of leaf, Colour of leaf etc. In field length of stalk (L.S.), Diameter of stalk (D.S.), L.S./D.S. Ratio, Number of the first order branches etc.
The second group (II)		This group includes the floral characters appearing from the stage of flower-bud differentiation to that of fertilization The manifestation of these characters seems to be dependent on the interaction between cytoplasm and nuclear genes, because the matrocliny is remarkably observed in F_1 and hardly changes in the process of reciprocal substitution of nucleus.	Floral characters Rugosity of petal, Size of flower, Length and Width of petal, Bending of style, Quantity of pollen grains, Relative length of Pistil and stamens etc.

Table 1. Continued: Classification of characters by the reaction norm between cytoplasm and nuclear genes and the trait of the group.

Classification of group	Sub-group	Trait of group	Characters
The third group (III)	a	This group contains the characters of the fruiting and the growth stages, which are directly affected by the manifestation of the second grouped characters. And the reciprocal differences	Fruiting characters Grade of fruit set, Reblooming, Number of siliquae per inflorescence, Percentage of fruit set, Number of seeds per silique, Length of silique, Weight of seeds flower, Maturing time etc.
	b	This group includes the characters which are influenced by the manifestation of the third(a) group of characters and the reciprocal differences are observed.	In field Plant height, Length of inflor-esence, Number of total branches etc.

cytoplasmic effect is indicated by their work.

Allen *et al*.(1971) studied the leaf area index, total plant dry weight, and pod dry weight. They were able to define four relatively distinct phases, according to the pattern of dry weight production. They also found that during the pod-filling stage, it is likely that the pods rather than the leaves produce the assimilates required for their own growth and that of the seeds they contained.

Allen and Morgan(1972) studied the effect of nitrogen on the growth of *B. napus* and found that nitrogen application increased plant height, number of flowering branches per plant, number of pods per plant, and number of seeds per pod but average pod weight and average seed weight did not change greatly. Yield of seed and yield of oil were increased although percentage oil decreased.

Thurling(1974a) studied the effects of seeding dates on the morphophysiological determinants of yield for *B. napus*. He found that yield in both species was affected by seeding date. *B. napus* exhibited a continuous decline of yield with later seeding while the *B. campestris* that yielded best was that seeded on the second of three seeding dates. For *B. napus* total plant dry weight was most highly correlated with plant yield, but for *B. campestris* harvest index (based on the ratio of the means of seed yield and total dry weight for ten plants at final harvest) was most highly correlated with yield followed by total plant dry weight.

Friend and Helson(1966) reported on the isolation of a strain of *B. campestris* that required exposure to only one photoperiod with ten hours illumination in order for floral initiation to occur. As early as three days after seeding, exposure to one long day resulted in induction of flower buds in over 80 percent of the plants. They also reported that under continuous illumination flowering buds would be well-developed in seven days and that the final leaf number was usually four under these conditions.

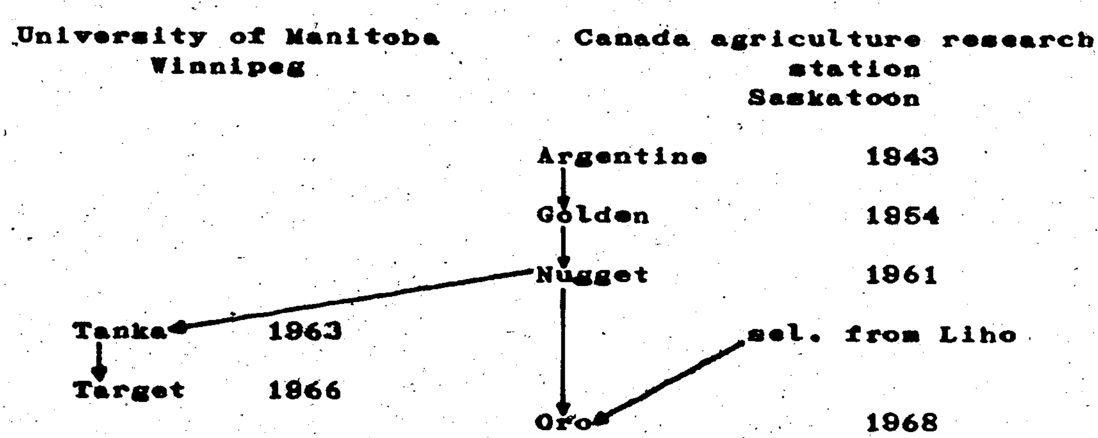
It can be concluded from their work that both the duration of growth stages and the yield component relationships are greatly influenced by the environment.

MATERIALS AND METHODS

Unlicensed commercial lots of Argentine rape were the initial source of most of the *Brassica napus* varieties currently grown in Canada. White(1974) illustrated the development of Argentine rape varieties as in Figure 1.

FIGURE 1. Development of *B. napus* varieties in Canada

In the illustration below the varieties grown in Canada are listed in chronological order under the location of the institution at which the varieties were developed. A single arrow leading from one variety to another indicates that the latter was derived from the former by selection, for example, Tanka was derived from Golden by selection. Two or more arrows leading to a variety indicate that the variety was selected from the progeny or crosses involving the parents indicated for example, Oro was derived from progeny of crosses between Nugget and a selection from Liho. The selection from Liho was used as a source of low erucic acid content in the seed oil.



From White(1974).

In 1970 the *B. napus* cultivars Oro, Target, and Nugget were self-pollinated and reciprocally cross-pollinated. In

1971, the progeny were grown out and self-pollinated. Crosses and reciprocal crosses were again performed among the parental lines, thus providing parental, F_1, and F_2 seed produced in the same year.

On May 14, 1974, this seed was planted at Parkland Farm, Edmonton Research Station, University of Alberta, Edmonton, as single row plots 4 metres long and 30 centimetres apart. Observation plots were separated by two guard rows of the cultivar Target. One hundred and fifty seeds per row were planted. Two rows of each parent population, two rows of each F_1 population and four rows of each F_2 population were planted.

Observations on single plants were made. The number of plants included in the analysis varied with the population(Table 2).

TABLE 2. Number of observations included in the analysis

Population	n	Population	n	Population	n
Nugget	94-117	Oro	109-128	Target	82-99
$(NXT)F_1$	87-109	$(NXO)F_1$	59-124	$(OXT)F_1$	88-99
$(TXN)F_1$	106-111	$(OXN)F_1$	39-48	$(TXO)F_1$	32-41
$(NXT)F_2$	185-210	$(NXO)F_2$	143-170	$(OXT)F_2$	152-204
$(TXN)F_2$	204-262	$(OXN)F_2$	198-239	$(TXO)F_2$	125-158

N=Nugget, O=Oro, T=Target, n=number of plants included

Each plant was observed every day from emergence until July 15, 1974. Subsequently observations were made on alternate days until maturity. At which time the whole plants were pulled by hand. The whole plants, including roots, were individually bagged, dried, and analyzed for yield characters.

At Parkland Farm, the 1974 growing season had only 94 frost free days, from May 29th until September 1stst. Dry conditions prevailed until the middle of June followed by about a month of high moisture conditions.

For the description of the growth stages, a modification of the key proposed by Harper and Berkenkamp(1975) was used(Table 3). In this study a "stage" refers to the number of days from seeding to that stage and a "period" refers to the duration of time between two stages.

The growth stage key of Harper and Berkenkamp uses sequential numbering. This is logical when only the main stem and main raceme are described as in their key. However in the application of this key to the lateral branches it should be noted that the stages are divergent and overlapping in character. For example, in this study four periods which begin at the first flower M(4.10) are studied: first flower M to first flower 3(4.10-4.13), first flower M to last first flower(4.10-4.5), first flower M to end flower(4.10-5.0), and first flower M to maturity(4.10-5.4). These periods are overlapping and describe different aspects of the flowering period. Also, the rate of development in these various periods can be measured. For example the

TABLE 3. Growth stage key and stage names

Stage	Name	Description
2.1	leaf 1	the number of days from seeding to the emergence of the first true leaf
2.3	leaf 3	the number of days from seeding to the emergence of the third true leaf
2.5	leaf 5	etc.
2.7	leaf 7	
2.9	leaf 9	
3.0	initiation of elongation	the number of days from seeding to initiation of internode elongation
4.0	end elongation	the number of days from seeding to initiation of elongation of the uppermost internode on the main stem
4.10	first flower M	first flower on main stem
4.11	first flower 1	first flower on the first secondary raceme
4.12	first flower 2	first flower on the second secondary raceme
4.13	first flower 3	etc.
4.14	first flower 4	
4.15	first flower 5	
4.16	first flower 6	
4.5	last first flower	first flower on the last secondary raceme to flower
5.0	end flower	incipient petal fall of the last flower on the main raceme
5.4	maturity	seeds in the lowest pod of the main raceme all dark colored

appropriate measure of the rate of development for first flower M to first flower 3(4.10-4.13) and first flower M to last(?) first flower(4.10-4.5) would be flowering rate of the racemes while the appropriate rate of development for the period first flower M to end flower(4.10-5.0) would be the flowering rate on the main raceme.

Observations on the stages listed in Table 3 were taken; also recorded were:

1) the total number of leaves and leaf scars on the main stem(number of leaves)
2) the number of secondary racemes
3) the number of tertiary racemes
4) the number of pods on the main raceme(number of pods)
5) 1000 seed weight
6) total plant weight
7) seed yield

Vegetative yield was calculated as the difference between the total plant weight and seed yield. Harvest index was calculated as the ratio of seed yield to total plant weight. Leaf emergence rate was estimated as the regression of the leaf number on the number of days from seeding to the emergence of that leaf. Similarly the flowering rate of the racemes was calculated as the regression of the raceme number on the number of days to first flower of that raceme. The flowering rate on the main raceme was calculated as the ratio of the number of pods on the main raceme to the duration of the period first flower M to end flower(4.10-5.0).

Analysis of variance was done for each variable as a completely randomized design with unequal replication. Single plants were treated as replicates. The difference between the means of the populations were tested by least significant difference. Significance of the difference of the F_1 population means from the mid-parent value(MP) was tested by the 95 percent confidence interval of the mean of the respective F_1 populations.

The simple correlations between the characters observed were calculated. Partial correlations of these characters with seed yield holding vegetative yield constant were calculated as indicated by Steel and Torrie(1960):

$$r_{123} = \frac{r_{12} - r_{13}r_{23}}{(1 - r_{13})(1 - r_{12})}$$

where: r_{123} is the partial correlation of seed yield with the trait holding vegetative yield constant

r_{12} is the simple correlation of seed yield with the trait

r_{13} is the simple correlation of seed yield with vegetative yield

r_{23} is the simple correlation of vegetative yield with the trait concerned.

Broad sense heritability estimates(h) were calculated by two methods:

1) Burton(1951)

$$h = \frac{VF_2 - VF_1}{VF_2}$$

2) Mahmud and Kramer(1951)

$$h = \frac{VF_2 - (VP_1 \cdot VP_2)^{0.5}}{VF_2}$$

VF_1, VF_2, VP_1, VP_2 are the variances of the respective populations: F_1, F_2, P_1, and P_2.

RESULTS AND DISCUSSION

GROWTH ANALYSIS OF THE CULTIVARS

Comparison of means among the cultivars

Oro was earliest and Target latest among the cultivars for the stages from leaf 1(2.1) to leaf 9(2.9)(Figure 2, Table 4). However for leaf 1(2.1) Oro was only significantly earlier than Target. For the stages leaf 3(2.3), leaf 5(2.5), leaf 7(2.7), and leaf 9(2.9), Oro was significantly earlier than both Nugget and Target. Target was significantly later than Nugget for the stages leaf 1(2.1), leaf 3(2.3), and leaf 7(2.7).

There was no significant difference in the days to initiation of elongation(3.0) between the cultivars.

Target was earliest and Oro latest for all the stages from end of elongation(4.0) to maturity(5.4). Target was significantly earlier than both Nugget and Oro for all of these stages except first flower 5(4.15) and first flower 6(4.16) for Nugget. Oro was significantly later than both Nugget and Target for all of these stages except first flower 1(4.11), and end flower(5.0).

For the periods leaf 1 to initiation of elongation(2.1- 3.0), initiation of elongation to first flower M(3.0-4.10), first flower M to last first flower(4.10-4.5), first flower M to end flower(4.10-5.0), and first flower M to maturity(4.10-5.4), Nugget was only

Figure 2
Population Means Of The Growth Characters For The Cultivars: Nugget, Oro, And Target

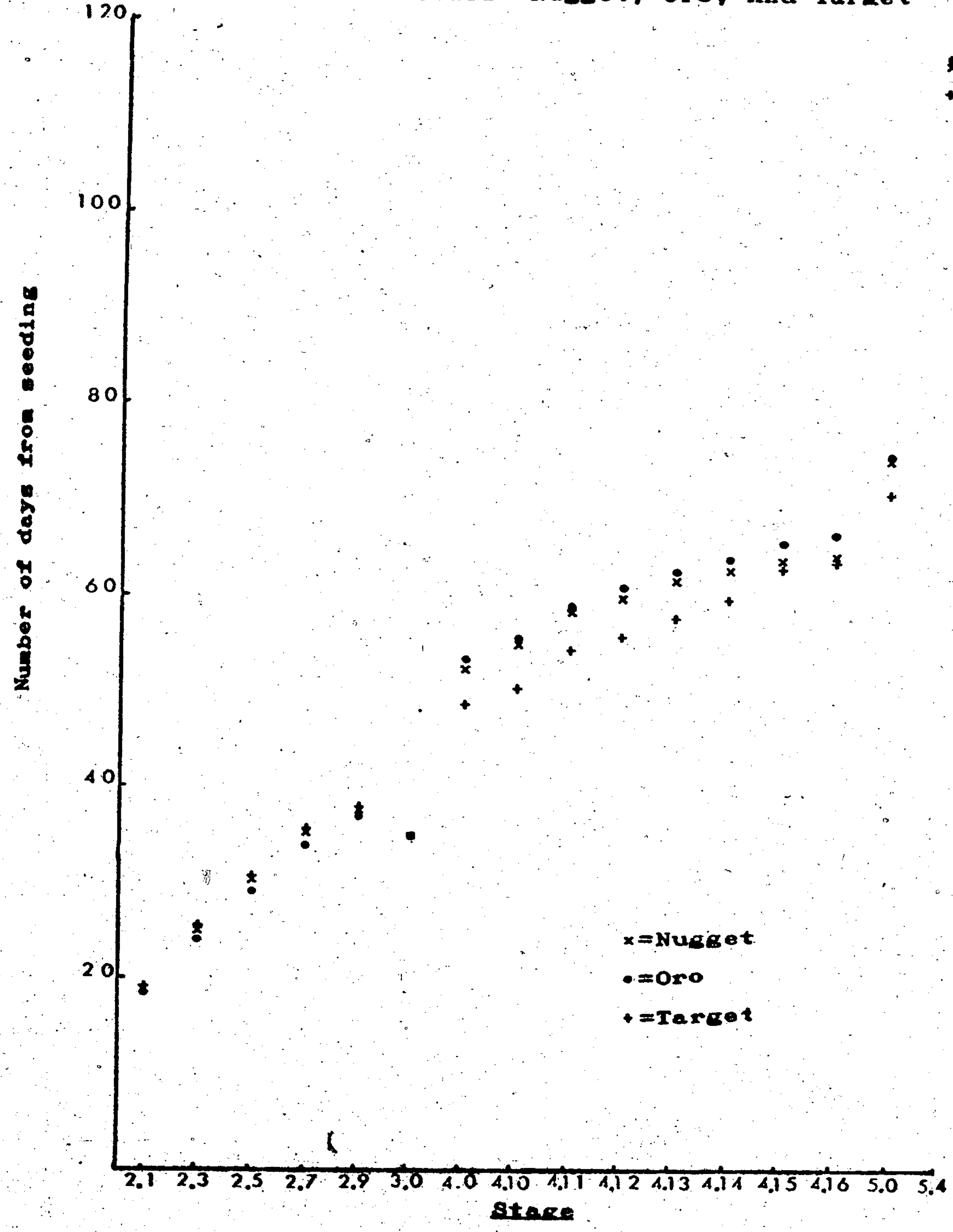


TABLE 4. Population means of the growth characters for the cultivars: Nugget, Oro, and Target

	Days from seeding					
Stage	Nugget	n[1]	Oro	n	Target	n
2.1	18.7a[2]	117	18.6a	128	19.0b	99
2.3	24.9b	116	24.0a	128	25.5c	99
2.5	30.4b	116	29.1a	129	30.6b	99
2.7	35.3b	117	33.8a	128	35.7c	99
2.9	37.8b	44	37.0a	6	38.0b	78
3.0	35.0a	116	35.0a	128	35.0a	99
4.0	52.2b	116	53.3c	128	48.4a	99
4.10	54.8b	116	55.5c	128	50.2a	99
4.11	58.4b	115	59.0b	126	54.2a	98
4.12	59.9b	111	60.7c	124	55.8a	98
4.13	61.5b	102	62.5c	120	57.7a	98
4.14	62.6b	81	63.9c	102	59.8a	88
4.15	63.9a	51	65.6b	77	62.9a	50
4.16	64.1a	17	66.4b	27	63.7a	16
4.5	63.8b	92	65.9c	102	62.9a	78
5.0	74.3b	92	74.6b	102	70.7a	78
5.4	115.1b	92	116.0c	102	112.6a	78

	Duration of period in days					
Period	Nugget	n	Oro	n	Target	n
(2.1–3.0)	16.5b	117	16.4b	128	16.0a	99
(3.0–4.1)	20.0b	116	20.0b	128	15.0a	99
(4.1–4.5)	9.3a	92	10.6b	102	12.0c	78
(4.1–5.0)	19.6a	92	19.4a	102	20.7b	78
(4.1–5.4)	60.1a	92	60.5a	102	62.5b	78

	Rates of development					
Rate[3]	Nugget	n	Oro	n	Target	n
LER	.36b	116	.40c	126	.35a	99
FLR	.45b	92	.44c	102	.35a	78
FR	2.55c	92	2.34b	102	1.85a	78

[1]n is number of observations used for each population in the analysis of variance
[2]population means for each variable followed by the same letter are not significantly different at the 5% level (least significant difference)
[3]LER :leaf emergence rate, leaves per day
FLR :flowering rate of the racemes, racemes per day
FR :flowering rate on the main raceme, flowers per day

significantly shorter than Oro for the period first flower M to last first flower(4.10-4.5). Compared to Nugget and Oro, Target had significantly shorter periods leaf 1 to initiation of elongation(2.1-3.0) and initiation of elongation to first flower M(3.0-4.10) and significantly longer periods leaf 1 to initiation of elongation(2.1-3.0) and initiation of elongation to first flower M to last first flower(4.10-4.5), first flower M to end flower(4.10-5.0), and first flower M to maturity(4.10-5.4) .

Leaf emergence rate(LER), flowering rate of the racemes(FLR), and flowering rate on the main raceme(FR) were all significantly different for each of the three cultivars. Target had the lowest values of all three rates of development, Oro had the highest values of LER and FLR, and Nugget the highest FR.

Discussion

Two of the main objectives of western Canadian rapeseed breeding programs, early first flower M and high yield can explain some of the observed cultivar differences. Selection for early maturity has largely been done through selection for early first flower M. This has usually been followed by selection for high yield.

Target exhibited some traits that would tend to make it a late variety. Target was latest for the stages from leaf 1 to leaf 9 and had the longest periods first flower M to first flower 3, first flower M to last first flower, first flower M to end flower, and first flower M to maturity. Target also had the lowest leaf emergence rate, lowest flowering rate of the racemes, and lowest flowering rate on the main raceme. The major factor leading to early maturity in Target was the time to first flower M. Target was earliest for first flower M and earliest for all subsequent stages.

The observed increased length of the flowering periods for Target may have been necessary in order to maintain high yield while selecting for early first flower M. Altermatively, the increased length of the flowering periods may be due to a smaller response of the later stages to selection for earliness than the response of first flower M when the selection criteria is earliness of first flower M.

It appears that an early maturing cultivar may be produced by combining the earliness of first flower M with earliness of the stages from leaf 1 to leaf 9; with shortness of first flower M to first flower 3(4.10-4.13), first flower M to last first flower(4.10-4.5), first flower M to end flower(4.10-5.0), with high leaf emergence rate, high flowering rate of the racemes, and high flowering rate on the main raceme.

Correlations among the growth stages and rates of development

In the consideration of the characters to be included in the analysis of the relationships among the growth characters it was necessary to avoid redundancy while including sufficient characters to adequately describe the growth pattern and yield characteristics.

All the significant correlations among the growth stages leaf 1(2.1), leaf 7(2.7), first flower M(4.10), first flower 3(4.13), last first flower(4.5), end flower(5.0), and maturity(5.4) were positive(Table 5). Leaf 1(2.1) was significantly correlated for all three cultivars with leaf 7(2.7), first flower M(4.10), and first flower 3(4.13). Significant correlations were also found for leaf 1(2.1) with last first flower(4.5) for Oro, with end flower(5.0) for Nugget, and with maturity(5.4) for Nugget and Target.

Leaf 7(2.7) had significant correlations for all three cultivars with all six of the other growth stages except for the correlation of leaf 7(2.7) with end flower(5.0) which was only significant for Nugget and Target.

Both first flower M(4.10) and first flower 3(4.13) were significantly correlated with all of the other six growth stages for all three cultivars.

Last first flower(4.5) was significantly correlated for

TABLE 5. Correlations among the growth stages and rates of development for the cultivars: Nugget, Oro, and Target[1]

	Stage						Rate of development		
Stage	2.7	4.10	4.13	4.5	5.0	5.4	LER[2]	FLR[3]	FR[4]
2.1	.51**	.36**	.41**	.16	.20*	.31**	.01	-.17	-.15
	.62**	.53**	.62**	.34**	.09	.08	.00	-.23**	.04
	.52**	.35**	.39**	.12	.06	.26**	.38**	-.16	-.13
2.7		.56**	.57**	.34**	.20*	.46**	-.75**	-.29**	-.32**
		.59**	.72**	.34**	.10	.25**	-.72**	-.39**	.08
		.42**	.51**	.22*	.28**	.53**	-.52**	-.24*	-.42**
4.1			.85**	.56**	.38**	.65**	.45**	-.18	-.03
			.85**	.51**	.35**	.50**	-.28**	.08	.24
			.87**	.50**	.42**	.61**	-.12	.14	-.18
4.13				.66**	.43**	.60**	-.38**	-.38**	-.06
				.60**	.32**	.50**	-.38**	-.29**	.14
				.44**	.42**	.60**	-.15	-.11	-.20
4.5					.39**	.36**	-.24*	-.09	.10
					.29**	.33**	-.17	-.20*	.07
					.30**	.24*	-.09	-.36**	-.12
5.0						.49**	-.14	-.02	-.01
						.19*	-.16	.18*	-.40**
						.37**	-.17	-.08	-.55**
5.4							-.40**	-.15	-.20*
							-.19	.02	-.02
							-.31**	.17	-.29**
Rate LER								.26**	.28**
								.34**	.01
								.04	.27**
FLR									.33**
									.20*
									.18

[1]Cultivars: Nugget=top line, Oro=middle line and Target=bottom line
[2]LER = leaf emergence rate, FR = flowering rate on the main raceme
*significant at 5% level, **significant at 1% level

all three cultivars with all six of the other growth stages except leaf 1(2.1) which had a significant correlation only for Oro.

End flower(5.0) was significantly correlated with leaf 1(2.1) for Nugget, leaf 7(2.7) for Nugget and Target and for all three cultivars with the other four stages.

Maturity(5.4) was significantly correlated for all three cultivars with all six of the other stages except with leaf 1(2.1) for Oro.

All the significant correlations of leaf emergence rate(LER) with the growth stages were negative except for the significant positive correlations of LER with leaf 1(2.1) for Target and with first flower M(4.10) for Nugget. For Nugget, significant correlations were found for LER with leaf 7(2.7), first flower M(4.10), first flower 3(4.13), last first flower(4.5), and maturity(5.4). For Oro, significant correlations were found between LER and leaf 7(2.7), first flower M(4.10), and first flower 3(4.13). For Target, significant correlations were found for LER with leaf 1(2.1), leaf 7(2.7), and maturity(5.4).

Flowering rate of the racemes(FLR) had significant negative correlations with leaf 7(2.7) and first flower 3(4.13) for Nugget, with leaf 1(2.1), leaf 7(2.7), first flower 3(4.13), and last first flower(4.5) for Oro, and with leaf 7(2.7) and last first flower(4.5) for Target.

All the significant correlations of flowering rate on the main raceme(FR) with the growth stages were negative except for that with first flower M(4.10) for Oro. Flowering rate on the main raceme was significantly correlated with the growth stages leaf 7(2.7) and maturity(5.4) for Nugget, with first flower M(4.10) and end flower(5.0) for Oro and leaf 7(2.7), end flower(5.0), and maturity(5.4) for Target.

All the significant correlations among the three rates of development were positive. For Nugget there were significant correlations among all three rates of development. For Oro the significant correlations were for LER with FLR and FLR with FR. For Target the only significant correlation was between LER and FR.

Correlations between growth stages and growth periods

Leaf 1(2.1) was significantly negatively correlated with the periods leaf 1 to leaf 7(2.1-2.7) for Nugget and Target, leaf 1 to last first flower(2.1-4.5) for Nugget and leaf 1 to end flower(2.1-5.0) for Target, and positively correlated with leaf 1 to first flower M(2.1-4.10) and leaf 1 to first flower 3(2.1-4.13) for Oro(Table 6). All the significant correlations between the stages subsequent to leaf 1(2.1) and periods beginning at leaf 1(2.1) were positive. High values were found for all three cultivars for the correlation between the respective end point stage and

TABLE 6. Correlations among growth stages, rates of development, and growth periods for the cultivars: Nugget, Oro, and Target[1]

Stage	Period (2.1-2.7)	(2.1-4.10)	(2.1-4.13)	(2.1-4.5)	(2.1-5.0)	(2.1-5.4)
2.1	-.23*	-.04	.04	-.24**	-.17	.08
	-.15	.20*	.34**	-.04	-.13	-.17
	-.34**	.04	.08	-.12	-.29	-.01
2.7	.71**	.37**	.41	.13	.00	.34**
	.69**	.43**	.62**	.12	-.03	.10
	.62**	.24*	-.38**	.10	.09	.40**
4.1	.32**	.92**	.78**	.40**	.25**	.58**
	.21*	.94**	.75**	.33**	.24**	.36**
	.15	.93**	.83**	.41**	.29**	.54**
4.13	.26**	.73**	.93**	.49**	.29**	.53**
	.33**	.74**	.95**	.42**	.19*	.35**
	.21*	.76**	.95**	.35**	.27**	.51**
4.5	.25**	.53**	.63**	.92**	.31**	.31**
	.12	.45**	.57**	.93**	.23*	.25**
	.13	.48**	.44**	.97**	.25*	.22*
5.0	.06	.32**	.40**	.31**	.93**	.46**
	.05	.37**	.33**	.27**	.98**	.15
	.25*	.42**	.44**	.29**	.93**	.36**
5.4	.28**	.57**	.52**	.24*	.38**	.97**
	.24**	.53**	.55**	.31**	.17	.97**
	.33**	.53**	.56**	.17	.26**	.96**
Rate[2]						
LER	-.87**	-.50**	-.45**	-.25**	-.15	-.41**
	-.89**	-.31**	-.44**	-.16	-.15	-.17
	-.93**	-.28**	-.29**	-.18	-.27**	-.43**
FLR	-.18	-.11	-.35**	.01	.05	-.10
	-.29**	.18	-.29**	-.12	.23*	.07
	-.11	.22**	-.07	-.32**	-.01	.22*
FR	-.25*	.04	-.04	.16	.04	-.18
	.05	.26**	.13	.05	-.42**	-.03
	-.33*	-.14	-.18	-.08	-.49**	-.26**

[1]Cultivars: Nugget=top line, Oro=middle line and Target=bottom line
[2]LER = leaf emergence rate, [3]FLR = flowering rate of the racemes, [4]FR = flowering rate on the main raceme. *significant at 5% level, **significant at 1% level

TABLE 6 continued: Correlations among growth stages, rates of development, and growth periods for the cultivars: Nugget, Oro, and Target[1]

Growth periods Stage	(2.7-4.10)	(2.7-4.13)	(2.7-4.5)	(2.7-5.0)	(2.7-5.4)	(4.10-4.13)	(4.10-4.5)	(4.10-5.0)	(4.10-5.4)
2.1	.10	.21	-.13	-.06	.14	.00	-.23*	-.13	.08
	.28**	.46**	.02	-.10	-.14	.21*	-.25**	-.24**	-.32**
	.12	.23*	-.03	-.17	.11	.23*	-.11	-.25*	.04
2.7	.03	.13	-.23*	-.32**	.16	.04	-.30**	-.34**	.22*
	.13	.36**	-.18	-.21*	-.10	.35**	-.21*	-.28**	-.14
	-.03	.18	.07	.17	.24*	.43**	-.05	-.11	.26**
4.10	.85**	.75**	.26**	.10	.56**	-.02	-.50**	-.23**	.06
	.68**	.79**	.22*	.17	.31**	-.14	-.50	-.30**	-.28**
	.89**	.84**	.38**	.24	.53**	.14	-.17	-.50	-.12
4.13	.70**	.89**	.41**	.18	.49**	.31**	-.29**	-.36**	.14
	.61**	.91**	.27**	.10	.26**	.40**	-.27**	-.21*	.14
	.69**	.93**	.30**	.20	.49**	.61**	-.11	-.36**	.01
4.5	.49**	.57**	.84**	.18	.25**	.18	.44**	-.20*	-.05
	.42**	.56**	.87**	.19	.20	.08	.43**	-.03	-.13
	.44**	.42**	.66**		.22*	.09	.77**	-.12	-.12
5.0	.36**	.41**	.29**	.87**	.47**	-.01	-.05	.58**	.32**
	.37**	.37**	.25**	.85**	.15	.02	-.05	.78**	-.09
	.32**	.37**	.23*	.89**	.32**	.20*	.04	.57**	.07
5.4	.48**	.44**	.11	.26**	.95**	-.05	-.41**	-.11	.80
	.43**	.48**	.22*	.10	.84**	.03	-.22*	-.14	.68**
	.41**	.48**	.09	.14	.95**	.23*	-.17	-.19	.72**
Rate[2] LER	-.07	-.03	.18	.25*	-.18	.09	.27**	.30**	-.20*
	.09	-.08	.22*	.10	.08	-.28**	.03	.04	-.03
	.13	.04	.06	.10	-.17	-.17	-.01	-.02	-.26**
FLR	-.02	-.34**	.08	.13	-.05	-.64**	.10	.14	-.00
	.33**	-.16	.01	.30**	.18	-.73**	-.27**	.13	-.06
	.28**	-.05	-.30**	.04	.27**	-.55**	-.51**	-.20*	.06
FR	.16	.04	.29**	.14	-.12	-.17	.14	.10	-.25*
	.25**	-.12	.03	-.43**	-.05	-.24*	-.21*	-.58	-.22*
	.02	-.07	.01	-.38**	-.18	-.24*	.00	-.38	-.19

[1]Cultivars: Nugget=top line, Oro=middle line and Target=bottom line
[2]LER = leaf emergence rate, FLR = flowering rate of the racemes, FR = flowering rate on the main raceme
*significant at 5% level, **significant at 1% level

the periods leaf 1 to first flower M(2.1-4.10), leaf 1 to first flower 3(2.1-4.13), leaf 1 to last first flower(2.1-4.5), leaf 1 to end flower(2.1-5.0), and leaf 1 to maturity(2.1-5.4). These correlations ranged from 0.92 to 0.98. However the correlation of leaf 7(2.7) with the period leaf 1 to leaf 7(2.1-2.7) ranged only from 0.62 to 0.71.

For the periods beginning at leaf 7(2.7), leaf 7(2.7) was significantly and negatively correlated the period leaf 7 to last first flower(2.7-4.5) for Nugget and leaf 7 to end flower(2.7-5.0) for Nugget and Oro. Significant positive correlations were found between leaf 7(2.7) and leaf 7 to first flower 3(2.7-4.13) for Oro, and leaf 7 to maturity(2.7-5.4) for Target.

High significant values were found for all three cultivars for the correlations between the respective end point stages and the periods leaf 7 to first flower M(2.7-4.10), leaf 7 to first flower 3(2.7-4.13), leaf 7 to last first flower(2.7-4.5), leaf 7 to end flower(2.7-5.0), and leaf 7 to maturity(2.7-5.4). These correlations ranged from 0.84 to 0.95.

The significant correlations of first flower M(4.10) with the periods beginning with first flower M(4.10) were all negative. Significant correlations were found with the periods first flower M to last first flower(4.10-4.5) for Nugget and Oro, first flower M to end flower(4.10-5.0) for all three cultivars, and first flower M to maturity(4.10-5.4) for Oro.

The correlations of the respective end point stages with the periods first flower M to first flower 3(4.10-4.13), first flower M to last first flower(4.10-4.5), first flower M to end flower(4.10-5.0), and first flower M to maturity(4.10-5.4) were all significant but most were not high. They ranged from 0.31 to 0.80.

Correlations of the rates of development with the growth periods

The correlations of leaf emergence rate(LER) with periods beginning at leaf 1(2.1) were all negative(Table 6). Significant correlations were found for all three cultivars for LER with the periods leaf 1 to leaf 7(2.1-2.7), leaf 1 to first flower M(2.1-4.10), and leaf 1 to first flower 3(2.1-4.13). Significant correlations were also found for LER with leaf 1 to last first flower(2.1-4.5) for Nugget, leaf 1 to end flower(2.1-5.0) for Target, and leaf 1 to maturity(2.1-5.4) for Nugget and Target. The correlations of LER with leaf 1 to leaf 7(2.1-2.7) were high, ranging from -0.87 to -0.93.

The few significant correlations of LER with the periods beginning at leaf 7(2.7) were positive and included leaf 7 to last first flower(2.7-4.5) for Oro, and leaf 7 to end flower(2.7-5.0) for Nugget.

The significant negative correlations of LBR with the periods beginning at first flower M(4.10) were with the periods first flower M to first flower 3(4.10-4.13) for Oro and with first flower M to maturity(4.10-5.4) for Nugget and Target. The only significant positive correlations with LBR were with first flower M to last first flower(4.10-4.5), and first flower M to end flower(4.10-5.0) for Nugget.

The significant negative correlations of the flowering rate of the racemes with the periods beginning at leaf 1(2.1) were with leaf 1 to leaf 7(2.1-2.7) for Oro, and with leaf 1 to last first flower(2.1-4.5) for Target. The significant positive correlations were for FLR with leaf 1 to first flower M(2.1-4.10) for Target, leaf 1 to end flower(2.1-5.0) for Oro, and with leaf 1 to maturity(2.1-5.4) for Target.

The significant positive correlations of FLR with the periods beginning at leaf 7(2.7) were with the periods leaf 7 to first flower M(2.7-4.10) for Oro and Target, with leaf 7 to end flower(2.7-5.0) for Oro, and with leaf 7 to maturity(2.7-5.4) for Target. The significant negative correlations for FLR were with leaf 7 to first flower 3(2.7-4.13) for Nugget, and leaf 7 to last first flower(2.7-4.5) for Target.

Significant correlations for FLR with the periods beginning at first flower M(4.10) were all negative. These were the correlations of FLR with first flower M to first flower 3(4.10-4.13) for all three cultivars, with first flower M to last first flower(4.10-4.5) for Oro and Target, and with first flower M to end flower(4.10-5.0) for Target. The correlations of FLR with first flower M to first flower 3(4.10-4.13) were relatively large and ranged from -0.55 to -0.73.

The significant negative correlations of the flowering rate on the main raceme(FR) with the periods beginning at leaf 1(2.1) were for FR with leaf 1 to leaf 7(2.1-2.7) for Nugget and Target, leaf 1 to end flower(2.1-5.0) for Oro and Target, with leaf 1 to maturity(2.1-5.4) for Target. The only significant positive correlation was between FR and leaf 1 to first flower M(2.1-4.10) for Oro.

The significant correlations for FR with the periods beginning at leaf 7(2.7) were negative for FR with leaf 7 to end flower(2.7-5.0) for Oro and Target, and positive with leaf 7 to first flower M(2.7-4.10) for Oro, and with leaf 7 to last first flower(2.7-4.5) for Nugget.

All the significant correlations of FR with the periods beginning at first flower M(4.10) were negative. The significant correlations were between FR and the periods first flower M to first flower 3(4.10-4.13) for Oro and Target, first flower M to last first flower(4.10-4.5) for

Oro, first flower M to end flower(4.10-5.0) for Oro and Target, and with first flower M to maturity(4.10-5.4) for Nugget and Oro.

Correlations among the growth periods

A few major periods were selected in order to study the relationships among the growth peiods(Table 7). These included the periods leaf 1 to leaf 7(2.1-2.7), leaf 1 to first flower M(2.1-4.10), leaf 7 to first flower M(2.7-4.10), first flower M to first flower 3(4.10-4.13), first flower M to last first flower(4.10-4.5), first flower M to end flower(4.10-5.0), and first flower M to maturity(4.10-5.4).

The significant correlations of the period leaf 1 to leaf 7(2.1-2.7) with the other periods were all positive except for the correlation with first flower M to end flower(4.10-5.0) for Nugget. The significant positive correlations were with leaf 1 to first flower M(2.1-4.10) for all three cultivars, with first flower M to first flower 3(4.10-4.13) for Oro and Target, with first flower M to end flower(4.10-5.0) for Nugget, and with first flower M to maturity(4.10-5.4) for Target.

Leaf 1 to first flower M(2.1-4.10) had significant positive correlations with leaf 1 to leaf 7(2.1-2.7) and with leaf 7 to first flower M(2.7-4.10) for all three cultivars. Significant negative correlations were found for leaf 1 to first flower M(2.1–4.10) with first flower M to first flower 3(4.10–4.13) for Oro. First flower M to last first flower(4.10–4.5) for Nugget and Oro, first flower M to end flower(4.10–5.0) for all three cultivars, and first flower M to maturity(4.10–5.4) for Oro.

All the significant correlations of leaf 7 to first flower M(2.7–4.10) with other periods were negative except for the high positive correlations with leaf 1 to first flower M(2.1–4.10). Significant correlations were found with first flower M to end flower(4.10–5.0) for all three cultivars, with first flower M to first flower 3(4.10–4.13) for Oro, with first flower M to last first flower(4.10–4.5) for Nugget and Oro, and with first flower M to maturity(4.10–5.4) for Oro and Target.

The significant positive correlations of other periods with first flower M to first flower 3(4.10–4.13) were with leaf 1 to leaf 7(2.1–2.7) for Oro and Target, and with first flower M to last first flower(4.10–4.5) for Nugget and Oro. The significant negative correlations were with leaf 1 to first flower M(2.1–4.10) for Oro and leaf 7 to first flower M(2.7–4.10) for Oro.

The significant negative correlations of the periods with first flower M to last first flower(4.10–4.5) were with leaf 1 to first flower M(2.1–4.10) and leaf 7 to first flower M(2.7–4.10) for Nugget and Oro. The significant positive correlations were with first flower M to first flower 3(4.10–4.13) for Nugget and Oro, with first flower M to end flower(4.10–5.0) for all three cultivars, and with first flower M to maturity(4.10–5.4) for Oro.

The significant positive correlations of first flower M to end flower(4.10–5.0) were with first flower M to last first flower(4.10–4.5) for all three cultivars, and with first flower M to maturity(4.10–5.4) for Nugget. The significant negative correlations were with leaf 1 to leaf 7(2.1–2.7) for Nugget, and with leaf 1 to first flower M(2.1–4.10) and leaf 7 to first flower M(2.7–4.10) for all three cultivars.

The significant positive correlations of first flower M to maturity(4.10–5.4) with the periods were with leaf 1 to leaf 7(2.1–2.7) for Target, with first flower M to last first flower(4.10–4.5) for Oro, and with first flower M to end flower(4.10–5.0) for Nugget. The significant negative correlations were with leaf 1 to first flower M(2.1–4.10) for Oro, and with leaf 7 to first flower M(2.7–4.10) for Oro and Target.

Discussion

The correlations studied were for within cultivar data and are likely to be largely due to environmental effects.

However this does not preclude the possibility that some of the effects within cultivars is also due to genetic variability.

There is a general lack of strong correlations among the growth characters. Among all the correlations of the growth stages and rates of development only the correlation of first flower M with first flower 3 was high. Thus the growth characters measured were largely independent.

All the significant correlations among the growth stages were positive. This indicates that earliness of the initial stages leads to earliness of the later stages. Of particular interest are the values for the correlation between first flower M and maturity. The values were large enough in magnitude to somewhat justify the use of first flower M as a criterion of selection for early maturity. However the correlations were low enough to indicate that factors other than first flower M contribute to determining the time to maturity.

The significant correlations among the rates of development were all positive, indicating that high developmental rates at different times and for different aspects of growth were positively associated. Most of the significant correlations of the rates of development with the growth stages were negative. Thus, high rates of development were associated with earliness of the growth stages. However, for Target lateness of leaf 1 was associated with high leaf emergence rate, and for Oro lateness of first flower M was associated with high flowering rate on the main raceme.

Most of the correlations between stages and growth periods were low indicating little association between the time of the growth stage and the lengths of the growth periods. Many of the correlations of the end point stages with their respective periods were high. These high correlations indicate that the measurement of the end point stage is an adequate indicator of the length of the period. Periods which were not found to be adequately measured by the end point stage were leaf 1 to leaf 7, first flower M to first flower 3, first flower M to last first flower, first flower M to end flower, first flower M to maturity.

The high correlations of first flower M with first flower 3 resulted in the relatively high correlations of first flower M with the periods leaf 1 to first flower 3 and leaf 7 to first flower 3 as well as the relatively high correlations for first flower 3 with the periods leaf 1 to first flower M and leaf 7 to first flower M.

The low correlations of first flower M with the subsequent periods are of particular interest. The low correlations of first flower M with first flower M to first flower 3 were due to the high correlations between first flower M and first flower 3 and indicate that first flower M has little effect on the duration of first flower M to first flower 3. The moderately high negative correlations of first flower M with the periods from first flower M to last first flower and first flower M to end flower indicate later first flower M leads to shorter flowering periods. The low correlations of first flower M with the period first flower M to maturity indicates that first flower M has little effect on the duration of first flower M to maturity.

Almost all the correlations of the rates of development with the growth periods were low. The high values for the correlations of leaf emergence rate with the period leaf 1 to leaf 7, flowering rate of the racemes with first flower M to first flower 3, and flowering rate on the main raceme with first flower M to end flower(4.10-5.0) were not unexpected. No other high correlations were observed. Only the correlation of leaf emergence rate with leaf 1 to leaf 7 was high enough to indicate that the period from leaf 1 to leaf 7 was a good indicator of leaf emergence rate.

All the correlations of leaf emergence rate with the periods beginning at leaf 1 were negative; high leaf emergence rate was thus associated with shortness of these periods. The effect of high leaf emergence rate appears to be largely due to its association with early leaf 7 as there were no significant negative correlations of leaf emergence rate with periods beginning at leaf 7. Both leaf emergence rate and leaf 7 were negatively associated wtth the periods first flower M to first flower 3 and first flower M to maturity, and were positively associated with the periods first flower M to last first flower and first flower M to end flower in some of the cultivars. Thus high leaf emergence rate is associated with rapid flowering, early maturity, and longer flowering periods.

Both the flowering rate of the racemes and the flowering rate on the main raceme have significant negative correlations with leaf 1 to leaf 7 and significant positive correlations with leaf 7 to first flower M. This further indicates that rapid development in the initial period leaf 1 to leaf 7 is associated with rapid development during the later periods. However, longer period leaf 7 to first flower M also as associated with high flowering rates. All the significant correlations of the flowering rates with the periods beginning at first flower M were negative. Thus high flowering rates are associated with a reduced duration of the flowering period, and high flowering rate on the main raceme is associated with reduced first flower M to maturity.

Among the correlations of the growth periods selected, only the correlations between leaf 7 to first flower M and leaf 1 to first flower M were high. Thus the lengths of the various growth periods were largely independent.

The duration of leaf 1 to leaf 7 was about the same as that between leaf 7 to first flower M. However, the correlations between leaf 1 to first flower M and leaf 7 to first flower M were much higher than those with leaf 1 to leaf 7. The correlations of leaf 7 to first flower M with the periods beginning at first flower M were more similar to the correlations of leaf 1 to first flower M with these periods than were the correlations of leaf 1 to leaf 7. Thus leaf 7 to first flower M was a more important determinant of the duration of leaf 1 to first flower M than was leaf 1 to leaf 7 and had a greater influence on the later periods than did leaf 1 to leaf 7.

In general the low correlations among the characters observed indicate that strong associations are not the rule. There is however, evidence that breeding for earliness of early growth stages and high rates of development will result in earliness of the later stages, including maturity. The time to first flower M was indicated to be the major factor in determining the time to later stages, however the duration of the period first flower M to last first flower and first flower M to end flower likely have a strong relationship with the time to overall plant maturity. Thus in selection for earliness of maturity, the length of the periods subsequent to first flower M are also important.

The generally low correlations among the growth characters studied indicates that it should be possible to produce cultivars with the combination of periods of the appropriate lengths and the desired rates of development.

Correlations of the growth characters with the yield characters

All the significant correlations of yield characters with leaf 1(2.1) were negative(Table 8). For Nugget, significant correlations with leaf 1 were found for all yield characters except 1000 seed weight and vegetative yield. For Oro, significant negative correlations with leaf 1 were found for number of tertiary racemes, number of pods, total plant weight, vegetative yield and seed yield. For Target, significant correlations with leaf 1 were found for all yield characters except number of leaves, harvest index and 1000 seed weight.

All the significant correlations of the yield characters with leaf 7(2.7) were negative except for the correlation with 1000 seed weight for Oro. Significant correlations were found for Nugget and Oro for leaf 7 with 1000 seed weight, vegetative yield and harvest index, and for all three cultivars with the remaining yield characters.

For Nugget, all the significant correlations of first flower M(4.10) with the yield characters were negative and there were significant correlations with all the yield characters except number of leaves and 1000 seed weight. For

TABLE 8. Correlation of growth stages and rates of development with yield characters for the cultivars: Nugget, Oro, and Target[1]

Yield characters	Stage 2.1	2.7	4.10	4.13	4.5	5.0	5.4	Rate of development[2] LER[2]	FLR[3]	FR[4]
Number of leaves	-.26**	-.35**	-.07	-.09	-.02	-.01	-.26**	.21*	.19	.20*
	-.18	-.30**	-.07	-.19	-.02	.01	-.38**	.21*	.28**	.16
	-.04	-.21*	.31**	-.15	.15	.05	.02	.17	.27**	.20*
Number of	-.33**	-.47**	-.41**	-.46**	-.07	-.09	-.41**	.42**	.62**	.40**
secondary racemes	-.14	-.36**	-.02	-.20*	.31**	.24*	-.12	.31**	.55**	.11
	-.28**	-.31**	.05	-.10	.13	-.08	.01	-.02	.40**	.24*
Number of	-.24*	-.31**	-.43**	-.46**	-.07	-.10	-.31**	.32**	.52**	.30**
tertiary racemes	-.28**	-.34**	-.09	-.20*	.31**	.24*	-.12	.28**	.45**	.28**
	-.36**	-.37**	-.22*	-.30**	-.07	-.07	-.10	-.02	.16	.17
Number of pods	-.23*	-.44*	-.31**	-.30**	-.02	.37**	-.22*	.41**	.32**	.70**
	-.21*	-.31**	-.13	-.18	.02	.34**	-.16	.17	.35**	.39**
	-.26**	-.50**	-.46**	-.43**	-.22*	.17	-.45**	.27**	.00	.78**
1000 seed weight	-.15	-.21*	-.11	-.16	-.15	-.06	-.04	.06	-.03	-.07
	.18	.22*	.41**	.41**	.40**	.21*	.26**	-.14	.13	.13
	-.03	-.02	-.21*	-.07	.08	-.18	-.16	-.02	-.19	.04
Vegetative yield	-.19	-.32**	-.33**	-.39**	.03	-.04	-.26**	.35**	.54**	.41**
	-.21*	-.23*	.08	.00	.20*	.34**	.19*	.18	.43**	.21*
	-.22*	-.19	-.02	-.08	.07	.00	.04	-.04	.27**	.27**
Total plant weight	-.21*	-.35**	-.37**	-.43**	-.06	-.06	-.30**	.36**	.54**	.43**
	-.24**	-.26**	.04	-.05	.16	.31**	.16	.19	.44**	.22*
	-.24**	-.21*	-.04	-.10	.09	.00	.01	-.04	.26**	.28**
Harvest index	-.32**	-.55**	-.44**	-.50**	-.22*	-.18	-.50**	.43**	.23*	.42**
	-.06	-.27**	-.36**	-.40**	-.25*	-.15	-.42**	.24*	.14	.14
	-.09	-.11	-.18	-.14	.21*	.02	-.31**	.04	-.14	.12
Seed yield	-.25*	-.40**	-.45**	-.51**	-.13	-.11	-.37**	.39**	.51**	.45**
	-.29**	-.32**	-.08	-.18	.06	.23*	.06	.23*	.44**	.23*
	-.28**	-.24*	-.08	-.15	.13	.02	-.07	-.03	.22*	.29**
Partial correlation	-.28**	-.35**	-.45**	-.52**	-.38**	-.25**	-.38**	-.45**	.04	.21*
	-.31**	-.36**	.42**	-.51**	-.33**	-.31**	-.39**	.24*	.21*	.10
	-.19	-.15	-.18	-.16	.38**	.03	-.29**	-.02	-.21*	.12

[1]Cultivars: Nugget=top line, Oro=middle line , and Target=bottom line
[2]LER = leaf emergence rate, FLR = flowering rate of the racemes, FR = flowering on the main raceme
*significant at 5% level, **significant at 1% level.

Oro, the only significant correlations for first flower M were negative with harvest index and positive with 1000 seed weight. For Target, the significant correlations of first flower M were positive with number of leaves and negative with number of tertiary racemes, number of pods and 1000 seed weight.

All the significant correlations of first flower 3(4.13) with the yield characters were negative except for that of first flower 3 with 1000 seed weight for Oro. For Nugget, significant correlations were found with all the yield characters except number of leaves and 1000 seed weight. For Oro, significant correlations were found for first flower 3 with number of secondary racemes, number of tertiary racemes, 1000 seed weight and harvest index. For Target significant correlations for first flower 3 were with number of tertiary racemes and with number of pods.

The significant correlations of last first flower(4.5) with the yield characters for Nugget was the negative correlation with harvest index. The significant correlations with last first flower for Oro were the positive correlations with number of secondary racemes, 1000 seed weight and vegetative yield and negative with harvest index. The significant correlations for Target were positive with harvest index and negative with number of pods.

All the significant correlations of end flower(5.0) with the yield characters were positive. For Nugget, a significant correlation was only found with number of pods. For Oro, significant correlations were found with all the yield characters except number of leaves, number of tertiary racemes, and harvest index. For Target, there were no significant correlations between end flower and yield characters.

For Nugget, maturity(5.4) was significantly and negatively correlated with all yield characters except 1000 seed weight. For Oro, the significant correlations were negative with number of leaves and harvest index, but positive with 1000 seed weight and vegetative yield. For Target, the only significant correlations of yield characters with maturity were the negative correlations with number of pods and harvest index.

All the significant correlations of the yield characters with leaf emergence rate were positive. For Nugget, significant correlations of LER were found with all yield characters except 1000 seed weight. For Oro, significant correlations of LER were found with all yield characters except number of pods, 1000 seed weight, total plant weight and vegetative yield. For Target, the only significant correlation was between LER and number of pods.

The significant correlations of flowering rate of the racemes with the yield characters were all positive. For

Nugget, significant correlations were found for FLR with all the yield characters except number of leaves and 1000 seed weight. For Oro, significant correlations were found for FLR with all the yield characters except harvest index and 1000 seed weight. For Target, significant correlations were found for total plant weight, vegetative yield and seed yield.

All of the significant correlations of flowering rate on the main raceme with the yield characters were positive. Nugget had significant correlations of FR with all the yield characters except 1000 seed weight. Oro had significant correlations of FR with number of tertiary racemes, number of pods, total plant weight, vegetative yield and seed yield. Target had significant correlations of FR with all the yield characters except number of tertiary racemes, 1000 seed weight and harvest index.

All the significant correlations of the period leaf 1 to leaf 7(2.1-2.7) with the yield characters were negative(Table 9). Significant correlations were found for Nugget between leaf 1 to leaf 7(2.1-2.7) and number of secondary racemes, number of pods, harvest index, total plant weight, vegetative yield and seed yield. Significant correlations were found for Oro for leaf 1 to leaf 7(2.1-2.7) with number of leaves, number of secondary racemes, number of tertiary racemes, number of pods, harvest index, and seed yield. The only significant correlation found for Target was between leaf 1 to leaf 7(2.1-2.7) and

TABLE 9. Correlations of growth periods with yield characters for the cultivars Nugget, Oro, and Target[1]

Yield characters	Period (2.1-2.7)	(2.1-4.10)	(2.7-4.10)	(4.10-4.13)	(4.10-4.5)	(4.10-5.0)	(4.10-5.4)
Number of leaves	-.18	.04	.13	.10	.09	.07	-.27**
	-.21*	.00	.09	-.19*	.07	.03	-.34**
	-.19	.34**	.45**	-.20*	-.06	-.23*	-.29**
Number of secondary racemes	-.27**	-.30**	-.20	-.23*	.45**	.31**	-.22*
	-.32**	.03	.17	-.47**	.04**	.26**	-.15
	-.08	.17	.21*	-.38**	.11	-.10	-.02
Number of tertiary racemes	-.13	-.37**	-.33	-.24*	.44**	.29**	-.08
	-.20*	-.01	.08	-.38	.07	.05	.02
	-.05	-.09	-.07	-.24*	.08	.19	.07
Number of pods	-.33**	-.23*	-.11	-.17	.40**	.70**	-.00
	-.1[illegible]**	-.07	.02	-.20*	.17	.43**	-.07
	-.30**	-.38**	-.26**	-.21*	.08	.27**	-.14
1000 seed weight	-.11	-.05	-.05	-.06	.02	.08	.07
	.13	.40**	.36**	.01	-.05	-.04	-.06
	.01	-.21*	-.23*	.18	.24*	.02	.02
Total plant weight	-.26**	-.32**	-.23*	-.22*	.34**	.29**	-.06
	-.15	.11	.18	-.26**	.12	.29**	.11
	-.01	.06	.06	-.20	.13	.14	.05
Vegetative yield	-.25*	-.29**	-.20*	-.21*	.34**	.29**	-.06
	-.13	.15	.21*	-.24**	.11	.29**	-.11
	-.01	.06	.07	-.19	-.10	.11	.07
Harvest index	-.43**	-.35**	-.20*	-.13	.27**	.27**	-.29**
	-.28**	-.39**	-.27**	-.10	.16	.07	-.14
	-.04	-.16	-.15	-.07	.20	-.24*	-.07
Seed yield	-.29**	-.39**	-.29**	-.24*	.36**	.33**	-.12
	-.19*	.00	.08	-.29**	.15	.28**	.12
	-.01	.03	.03	-.24*	.21*	.21*	-.02
Partial correlation with seed yield	-.16	-.39**	-.34**	-.12	.09	.12	-.14
	-.20*	-.40**	-.33**	-.22*	.15	-.02	-.03
	.01	-.06	-.07	-.11	-.40**	.15	-.25*

[1]Cultivars: Nugget=top line, Oro=middle line, and Target=bottom line
*significant at the 5% level, **significant at the 1% level

number of pods.

All the significant correlations between leaf 1 to first flower M(2.1-4.10) and the yield characters were negative except for the correlation of leaf 1 to first flower M(2.1-4.10) with number of leaves for Target and with 1000 seed weight for Oro. Nugget had significant correlations of leaf 1 to first flower M(2.1-4.10) with all the yield characters except number of leaves and 1000 seed weight. Oro had significant correlations for leaf 1 to first flower M(2.1-4.10) with 1000 seed weight and harvest index. Target had significant correlations for leaf 1 to first flower M(2.1-4.10) with number of leaves, number of pods and 1000 seed weight.

All the significant correlations of leaf 7 to first flower M(2.7-4.10) with the yield characters for Nugget were negative. Significant correlations were found for Nugget for leaf 7 to first flower M(2.7-4.10) with all the yield characters except number of leaves, number of pods, and 1000 seed weight. The only significant correlations for Oro were the positive correlations of leaf 7 to first flower M(2.7-4.10) with 1000 seed weight and vegetative yield and the negative correlation with harvest index. The significant correlations of leaf 7 to first flower M(2.7-4.10) with the yield characters for Target were positive with number of leaves and number of secondary racemes and negative for number of pods and 1000 seed weight.

All the significant correlations of first flower M to first flower 3(4.10-4.13) with the yield characters were negative. Significant correlations were found for all three cultivars for first flower M to first flower 3(4.10-4.13) with number of secondary racemes, number of tertiary racemes, 1000 seed weight, and seed yield. For Nugget and Oro significant correlations were found for first flower M to first flower 3(4.10-4.13) with vegetative yield. For Oro and Target significant correlations were found for first flower M to first flower 3(4.10-4.13) with number of leaves and number of pods.

All the significant correlations of first flower M to last first flower(4.10-4.5) with the yield characters were positive. For Nugget, the correlations of first flower M to last first flower(4.10-4.5) with the yield characters were all significant except number of leaves and 1000 seed weight. For Oro, the only significant correlation of first flower M to last first flower(4.10-4.5) was with number of secondary racemes. For Target, the significant correlations of first flower M to last first flower(4.10-4.5) with the yield characters were with 1000 seed weight and seed yield.

Significant and positive correlations of first flower M to end flower(4.10-5.0) were found for Nugget with all the yield characters except number of leaves and 1000 seed weight, and for Oro with number of secondary racemes, number of pods, total plant weight, vegetative yield, and seed yield. For Target significant correlations of first flower M to end flower(4.10-5.0) were negative with number of leaves and harvest index, and positive with number of pods and seed yield.

All the significant correlations of first flower M to maturity(4.10-5.4) with the yield characters were negative and were with number of leaves, number of secondary racemes, and harvest index for Nugget, and number of leaves for Oro and Target.

All of the significant partial correlations with seed yield holding vegetative yield constant(PCY), for the growth stages and periods were negative except for the PCY of first flower M(4.10) for Oro and last first flower(4.5) for Target. The PCY for the growth stages were all significant for Nugget and Oro and for last first flower(4.5) and maturity(5.4) for Target. The significant PCY of the growth periods were for leaf 1 to leaf 7(2.1-2.7) for Oro, leaf 7 to first flower M(2.7-4.10) and leaf 1 to first flower M(2.1-4.10) for Nugget and Oro, first flower M to first flower 3(4.10-4.13) for Oro and first flower M to last first flower(4.10-4.5) and first flower M to maturity(4.10-5.4) for Target.

The significant PCY for the rates of develcpment were positive for LER for Nugget and Oro, for FLR for Oro and for

FR for Nugget and was negative for FLR for Target.

Discussion

The correlations of the growth characters with the yield characters were all low, indicating that no single growth character has a major effect on yield. The significant correlations of the yield characters were mostly negative with the growth stages and initial growth periods(periods prior to first flower M) and positive with the rates of development. These data indicate that the growth characters which were associated with earliness and rapid development were also associated with high yield, an encouraging observation for breeding programs with high yield and early maturity as concurrent objectives. However the relationship of these characters may have been affected by late spring frosts and early fall frost.

The significant PCY of the growth stages and initial growth periods were mostly negative and indicated that the association of growth stages and short initial growth periods with high seed yield is independent of their association with high vegetative yield.

The relationships of the later periods with the yield characters were more varied than the initial periods. A long period first flower M to first flower 3 was observed to be masked in the growth stages by the negative association of first flower M with the yield characters as indicated by the correlations of first flower M and end flower with the yield characters. Only for Oro was a positive association between lateness of these stages and high yield characters observed. However there were no significant positive partial correlations with seed yield for either first flower M to last first flower or for first flower M to end flower. This indicates that the positive association with higher yield characters of a longer duration for these periods was due to their association with high vegetative yield.

All the significant correlations for the three rates of development with the yield characters were positive. However, the PCY were variable and indicated that part of the association of high rates of development with seed yield was due to the association of these rates with high vegetative yield.

Of particular interest is the relationship of first flower M with the yield characters. The stages first flower M, and maturity, and the period leaf 1 to first flower M had many significant negative correlations with the yield characters, expecially for Nugget. However the period first flower M to maturity did not indicate a consistent negative association with the yield characters. This indicates that although the duration of leaf 1 to first flower M was just over half of the duration of first flower M to maturity, the time to first flower M is more important than the subsequent time to maturity in relation to the yield characters.

The correlation of number of leaves with first flower M and leaf 1 to first flower M was significant only for Target. A previous study(Laosuwan, 1969) found no significant correlation for Target.

The only yield character which exhibited a positive association with lateness of the growth stages was 1000 seed weight, but only for Oro.

Under the environmental conditions of this study and for the cultivars included it was found that one need not sacrifice yield to promote early maturity. High yield could be produced by breeding for earliness of the stages and periods up to and including first flower 3, by increasing the duration of the flowering periods first flower M to last first flower and first flower M to end flower, and by decreasing the duration of the period first flower M to maturity, and by increasing the three rates of development.

Correlations among the yield characters

Of the significant correlations among the yield characters all were positive except for the correlation of number of leaves with 1000 seed weight for Target(Table 10).

The significant correlations of number of leaves were

TABLE 10. Correlations among the yield characters for the cultivars Nugget, Oro, and Target[1]

	A	B	C	D	E	F	G	H	I
Number of leaves	.21* .36** .25*	-.03 .19 -.05	.21* .25* .08	.21* -.03 -.21*	-.11 .09 .03	-.13 .07 .03	.29** .25* -.02	-.06 .12 .04	.18 .19* .03
Number of secondary racemes(A)		.81** .51** .46**	.55** .42** .13	.00 .22* -.13	.75** .57** .37**	.75** .56** .35**	.35** .23* .12	.72** .56** .41**	.04 .19* .23*
Number of tertiary racemes(B)			.45** .39** .14	-.06 -.06 -.02	.86** .66 .69**	.85** .64** .67**	.34** .28** .14	.85** .71** .74**	.33** .53 .47**
Number of pods(C)				.06 .08 .00	.55** .62** .01	.53** .60** .01	.52** .29** .24*	.57* .63** .09	.26** .23* .24*
1000 seed weight(D)					-.01 .37** .20*	-.01 .39** .19	.01 -.04 .14	-.00 .39** .21*	-.06 -.15 .06
Total plant weight(E)						1.00 1.00 1.00	.37** .07 .00	.98** .97** .97**	
Vegetative yield(F)							.29** -.02 -.07	.86** .93** .95**	
Harvest index(G)							.52** .31** .21*	.92** .83** .89**	

Seed yield(H)
Partial correlation with seed yield holding vegetative yield constant(I)

[1]Cultivars: Nugget=top line, Oro=middle line, and Target=bottom line
*significant at the 5% level, **significant at the 1% level

with number of secondary racemes, number of pods, and harvest index for Nugget and Oro, and with 1000 seed weight for Nugget and Target.

The significant correlations of the number of secondary racemes were with number of tertiary racemes, total plant weight, vegetative yield, and seed yield for all three cultivars, with number of pods and harvest index for Nugget and Oro, and with 1000 seed weight for Oro.

The significant correlations for number of tertiary racemes with the yield characters were with all the yield characters except number of leaves and 1000 seed weight for Nugget and Oro. For Target, the significant correlations were with number of secondary racemes, total plant weight, vegetative yield, and seed yield.

The significant correlations of the number of pods were with all the yield characters except 1000 seed weight for Nugget and Oro, and with total plant weight, vegetative yield, and seed yield for Target.

The significant correlations of 1000 seed weight were with number of leaves for Nugget and Target, number of secondary racemes and vegetative yield for Oro, and total plant weight and seed yield for Oro and Target.

The significant correlations of total plant weight and vegetative yield were with number of secondary racemes, number of tertiary racemes, and seed yield for all three cultivars, with number of pods for Nugget and Oro, with harvest index for Nugget and with 1000 seed weight for Oro and Target. The correlation of total plant weight with vegetative yield was close to unity for all three cultivars.

The significant correlations for harvest index were with all the yield characters except 1000 seed weight, total plant weight, and vegetative yield for Nugget and Oro, with total plant weight and vegetative yield for Nugget and with number of pods and seed yield for Target.

The significant correlations of seed yield were with all the yield characters except number of leaves, number of pods and 1000 seed weight for all three cultivars, with number of pods for Nugget and Oro and with 1000 seed weight for Oro and Target.

All the significant partial correlations with seed yield holding vegetative yield constant(PCY) for the yield characters were positive. The significant PCY were with number of leaves for Oro, number of secondary racemes for Oro and Target, number of tertiary racemes, number of pods, and harvest index for all three cultivars.

Discussion

All of the significant correlations among the yield characters were positive except for the correlation of number of leaves with 1000 seed weight for Target. The significant positive correlations among the characters number o_ secondary racemes, number of tertiary racemes, and number of pods agrees with the results of Thurling(1974b) for B. napus.

The correlations among the three characters total plant weight, vegetative yield, and seed yield were very high. This indicates that the major determinant of seed yield for B. napus is plant size. This agrees whth the results of Thurling(1974a).

All the correlations of the yield characters with number of leaves were low; also the PCY were not significant. Thus high number of leaves does not show an association with seed yield.

The significant positive correlations of seed yield with the characters number of secondary racemes, number of tertiary racemes, number of pods, and 1000 seed weight were all largely due to their correlations with vegetative yield. This was indicated by the fact that the SCY were higher than the PCY. However the PCY were positive and significant for all three cultivars for number of tertiary racemes and number of pods, for Oro and Target for number of secondary racemes and for Oro only for number of leaves. Thus high levels of these characte[illegible] have an association with high s[illegible] ield which is not due to their association with high vegetative yield.

These data indicate that increased yield can be obtained by increasing one or more of plant size, number of tertiary racemes, or the number of pods on the main raceme.

GENETIC ANALYSIS

Comparison of means

For leaf 1(2.1) although there were significant differences among the populations the range of means for leaf 1(2.1) was only 17.9 to 19.1 days. This small variation among the populations was insufficient for reliable interpretations (Table 11).

For first flower M(4.10) four of the six F_1 values were significantly earlier than the MP. This indicates partial dominance of early first flower M(4.10). However significant reciprocal differences were observed in both the F_1 and F_2 of the cross of Nugget with Target. In this cross the direction of the reciprocal differences was not consistant. Reciprocal differences were also observed in the F_2 of the other two crosses. Thus control of first flower M is not completely by nuclear genotype and genotype X cytoplasm interaction was indicated.

For maturity(5.4) dominance or heterosis of early maturity(5.4) was indicated by the F_1 for both of the crosses of Nugget with Oro and Nugget with Target. Partial dominance of early maturity(5.4) was indicated for the cross of Oro with Target. Significant reciprocal differences were found for maturity(5.4) in the F_2 of all three crosses however the direction of the reciprocal defferences was not

TABLE 11. Population means for growth characters for Nugget, Oro, Target, their F_1 and F_2 populations+

Population	2.1	4.10	5.4	(4.10-4.5)	(4.10-5.0)	(4.10-5.0)	LER	FLR	FR
Nugget	18.7b	54.8d	115.1d	9.1a	19.5a	60.2a	.364b	.438cd	2.52c
$(NXT)F_1$	18.9bc	51.1*b	111.3*a	11.4*bcd	19.9ab	60.2*a	.348*a	.402a	2.22b
$(TXN)F_1$	17.9*a	49.6*a	112.1*abc	11.9*d	19.9ab	62.4*b	.391*c	.459*d	2.49*c
$(NXT)F_2$	18.9bc	51.2b	111.6ab	11.2bc	19.6a	60.3a	.361b	.426bc	2.44c
$(TXN)F_2$	18.8b	52.2c	113.0c	10.9b	19.8ab	60.8a	.365b	.418ab	2.26b
Target	19.0c	50.2a	112.6bc	11.8cd	20.5b	62.4b	.349a	.406ab	1.85a
Mid-parent	18.8	52.5	113.8	10.4	20.0	61.4	.357	.422	2.19
Nugget	18.7bc	54.8b	115.1ab	9.1a	19.5a	60.2ab	.364a	.438a	2.52b
$(NXO)F_1$	18.5ab	53.7*a	114.6*a	10.6*c	19.8a	60.8b	.372*ab	.445a	2.30*a
$(OXN)F_1$	18.2*a	54.6ab	115.7abc	10.4bc	19.6a	60.8ab	.378b	.428a	2.37ab
$(NXO)F_2$	19.0d	56.5c	116.3c	9.7b	19.4a	59.8a	.369ab	.437a	2.39ab
$(OXN)F_2$	18.9cd	55.1b	115.0a	10.2bc	19.1a	60.2ab	.369ab	.430a	2.31a
Oro	18.6b	55.5b	116.0bc	10.5c	19.1a	60.4ab	.400c	.444a	2.34a
Mid-parent	18.7	55.2	115.6	9.8	19.3	60.3	.382	.441	2.43
Oro	18.6bc	55.5d	116.0c	10.5a	19.1a	60.4a	.400c	.444bc	2.34b
$(OXT)F_1$	18.4*ab	52.0*b	113.6ab	11.1abc	20.9*b	61.6bcd	.382b	.437bc	2.29*b
$(TXO)F_1$	18.8cd	52.8bc	113.8ab	11.6bc	20.4ab	61.0abc	.351*a	.404a	1.95a
$(OXT)F_2$	19.1d	53.5c	115.6c	10.64a	19.4a	62.1 cd	.377b	.451c	2.25b
$(TXO)F_2$	18.4a	52.8b	113.8b	10.98ab	19.43a	61.0ab	.382b	.425ab	2.33b
Target	19.0d	50.2a	112.6a	11.8c	20.5b	62.4d	.349a	.406a	1.85a
Mid-parent	18.8	52.8	114.3	11.1	19.8	61.4	.374	.425	2.10

[1]days from seeding to the stage, [2]duration of the period in days, [3]LER:leaf emergence rate in leaves per day, FLR:flowering rate of the racemes in racemes flowering per day, FR:flowering rate on the main raceme in florets per day

+ population means for each variable within each group of populations followed by the same letter are not significantly different at the 5% level(least significant difference)

*F_1 values significantly different from the mid-parent value

consistant. Thus genotype X cytoplasm interaction was indicated.

For first flower M to last first flower(4.10-4.5) five of the six F_1 values were greater than the MP but only three significantly so. Dominance or partial dominance of long first flower M to last first flower(4.10-4.5) was thus indicated for the crosses of Nugget with Target and Nugget with Oro. Additive control was indicated for the cross of Oro with Target. No significant reciprocal differences were observed.

For first flower M to end flower(4.10-5.0) although there were significant differences among the populations the range of means for first flower M to end flower(4.10-5.0) was only 19.1 to 20.5 days. This small variation among the populations was insufficient for reliable interpretations.

The range of values for first flower M to maturity(4.10-5.4) was only 59.8 to 62.5 days thus making interpretation unreliable. However significant reciprocal differences were observed for the F_1 of the cross of Oro with Nugget and the F_2 of the cross of Oro with Target, thus some cytoplasmic influence is indicated for first flower M to maturity(4.10-5.4).

For leaf emergence rate in the cross of Nugget with Oro both F_1 were lower than the MP but only one significantly so. This data indicates partial dominance of low leaf emergence rate for this cross. Significant reciprocal differences were observed in the F_1 of the crosses of Nugget with Target and Oro with Target. The direction of these reciprocal differences was not consistent. This indicated genotype X cytoplasm interaction.

For flowering rate of the racemes the parental differences in the cross of Nugget with Oro was not significant so reliable interpretation of the results is not possible. Reciprocal differences were observed in the F_1 of the cross of Nugget with Target and in the F_1 and F_2 of the cross of Oro with Target. The direction of the F_1 reciprocal differences was not consistent in these two crosses, thus indicating genotype X cytoplasm interaction.

For flowering rate on the main raceme the F_1 of the three crosses did not indicate consistent genetic control. There were significant reciprocal differences in both the F_1 and F_2 of the cross of Oro with Target. The direction of the reciprocal differences was not consistent thus genotype X cytoplasm interaction was indicated for flowering rate on the main raceme.

For number of leaves four of the six F_1 populations were not significantly different from the MP indicating largely additive control of number of leaves(Table 12). Significant reciprocal differences were found in the F_1 of the cross of Nugget with Target and the cross of Oro with

TABLE 12. Population means of the yield characters for Nugget, Oro, Target, their F_1 and F_2 populations+

Population	Number of leaves	Number of secondary racemes	Number of tertiary racemes	Number of pods	1000 seed weight (grams)	Vegetative yield (grams)	Harvest index	Seed yield (grams)
Nugget	12.8c	4.82ab	5.56a	49.5d	3.57a	25.9bc	.275a	10.3ab
(NXT)F1	12.0b	4.58a	5.28a	42.4b	3.99*c	20.2*a	.289*bc	9.2a
(TXN)F1	12.8*c	5.44*c	6.81*bc	49.1*d	3.87*bc	30.2*d	.307*d	13.8*c
(NXT)F2	12.1b	5.19c	7.19c	45.9c	3.88c	27.7cd	.239b	11.7b
(TXN)F2	12.3b	4.89b	6.09ab	43.6b	3.94bc	23.8b	.293b	10.2a
Target	11.1a	4.75ab	6.01ab	43.7a	4.68d	23.3ab	.289b	9.5a
mid-parent	12.0	4.78	5.79	43.6	4.12	24.6	.282	9.9
Nugget	12.8a	4.82a	5.56ab	49.5b	3.57b	25.9ab	.275bc	10.3
(NXO)F1	13.3ab	4.82a	5.81ab	44.1*a	3.92*b	24.9*a	.279*c	10.0a
(OXN)F1	13.3ab	4.53a	5.92abc	46.0ab	3.73a	26.3a	.284*c	10.6a
(NXO)F2	12.6a	4.63a	6.40bc	46.0a	3.72a	29.6b	.249a	10.3a
(OXN)F2	13.3ab	4.72a	5.50a	43.7a	3.94bc	25.4a	.266b	9.1a
Oro	13.5b	4.87a	6.87c	43.6a	4.04c	28.7ab	.265b	10.5a
mid-parent	13.2	4.85	6.22	46.5	3.81	27.3	.270	10.4
Oro	13.5d	4.87ab	6.87ab	43.6b	4.04a	28.7b	.265a	10.5ab
(OXT)F1	12.4b	5.10*b	7.56*b	47.3*c	4.36c	34.2*c	.304*d	14.2*c
(TXO)F1	11.6*a	4.86ab	7.34ab	38.8a	4.28bc	29.5bc	.293*cd	12.4bc
(OXT)F2	12.9c	4.89ab	6.58a	43.4b	4.10a	28.8b	.273ab	10.8ab
(TXO)F2	12.6bc	4.72a	6.10a	43.5b	4.20b	27.2ab	.278bc	10.8ab
Target	11.1a	4.75ab	6.01a	37.7a	4.68d	23.3a	.289c	9.5a
mid-parent	12.3	4.81	6.44	40.7	4.36	26.0	.277	10.0

+ population means for each variable within each group of populations followed by the same letter are not significantly different at the 5% level(least significant difference)
*F+ values significantly different from the mid-parent value

Target. The direction of the reciprocal difference was not consistent; thus genotype X cytoplasm interaction is indicated for number of leaves.

For number of secondary racemes the three parents were not significantly different so reliable interpretation of the results is not possible.

For number of tertiary racemes largely additive control was indicated in the cross of Nugget with Oro. Dominance or heterosis was indicated in the cross of Oro with Target. Significant reciprocal differences were found for the cross of Nugget with Target. Significant reciprocal differences were found in the F_2 of the cross of Nugget with Oro and in the F_1 and F_2 of the cross of Nugget with Target. The reciprocal differences were not consistent in direction thus genotype X cytoplasm interaction was indicated.

For number of pods significant reciprocal differences were found in the F_1 of the cross of Oro with Target and in the F_1 and F_2 of the cross of Nugget with Target. The direction of the reciprocal differences were not consistent thus indicating genotype X cytoplasm interaction.

For 1000 seed weight all of the F_1 were closer to the MP than to either parent thus a largely additive genetic system was indicated. Reciprocal differences were observed only in the F_1 of the cross of Nugget with Oro and the cross of Oro with Target. The direction of the reciprocal differences was not consistent indicating genotype X cytoplasm interaction.

For vegetative yield dominance or heterosis of high vegetative yield was indicated for the cross of Oro with Target. Significant reciprocal differences were found for the F_1 and F_2 of the cross of Nugget with Target and for the F_2 of the cross of Nugget with Oro. The direction of the reciprocal differences was not consistent thus indicating genotype X cytoplasm interaction.

For harvest index all six F_1 values were greater than the larger parent, two significantly so, thus dominance or heterosis of high harvest index was indicated. The only significant reciprocal difference observed was for the F_2 of the cross of Nugget with Oro thus some cytoplasmic influence is involved in control of harvest index.

For seed yield four of the F_1 values were greater than the higher parent, but only two significantly so. Of the other two F_1 values one was close to the higher and the other close to the lower parent. This data indicates dominance or heterosis for high seed yield. Significant reciprocal differences were observed for the F_1 and F_2 of the cross of Nugget with Target. These reciprocal differences were not consistent in direction thus indicating genotype X cytoplasm interaction.

Heritabilities

The heritability estimates for leaf 1(2.1) ranged from -1.4 to 0.46 and nine of the 12 heritability estimates were less than 0.20, indicating a low heritability for leaf 1(2.1)(Table 13). Reciprocal differences were observed by both methods of calculation for the crosses of Oro with Target.

The heritability estimates for first flower M(4.10) ranged from -0.28 to 0.64. Reciprocal differences were observed with all three crosses.

The range of heritability estimates for maturity(5.4) was from 0.00 to 0.53. Only five of the heritability estimates were less than 0.25 indicating a moderate heritability for maturity(5.4). There were reciprocal differences in heritability estimates for all three crosses.

The heritability estimates for first flower M to last first flower(4.10-4.5) ranged from -0.42 to 0.51. Eleven of 12 of the heritability estimates were 0.25 or less, thus the heritability of first flower M to last first flower(4.10-4.5) was low.

The heritability estimates for first flower M to end flower(4.10-5.0) ranged from -0.21 to 0.48. Five of the heritability estimates were 0.25 or lower thus indicating that the heritability of first flower M to end

TABLE 13. Heritabilities of the growth characters for crosses between the cultivars Nugget, Oro, and Target

		Stage			Period			Rate of development[+]		
Cross*	Method[1]	2.1	4.10	5.4	(4.10-4.5)	(4.10-5.0)	(4.10-5.4)	LER	FLR	FR
(NXT)	1	-.45	-.28	.03	.25	-.21	.38	.07	-1.25	-.19
(TXN)	1	-.09	.56	.35	-.08	.20	.30	.42	.00	.41
(NXT)	2	-.87	.17	.31	-.03	.26	.39	-.02	-.26	.61
(TXN)	2	-.12	.43	.31	-.14	.27	.28	.39	-.09	.40
(NXO)	1	.46	.54	.14	-.07	.44	.04	.24	.12	.35
(OXN)	1	-.02	.64	.37	.05	.22	.26	.14	.35	.56
(NXO)	2	.12	.45	.10	-.27	.32	.28	.20	.16	.19
(OXN)	2	.02	.59	.40	.14	.32	.23	.17	.16	.33
(OXT)	1	.41	.09	.15	-.23	.48	.05	-.78	.42	.29
(TXO)	1	-1.35	.45	.45	.51	.30	.17	-.61	-.20	.54
(OXT)	2	.32	.16	.16	-.42	.12	.32	.01	.21	-.20
(TXO)	2	-.25	.59	.53	.17	.25	.41	.32	.12	.48

+LER: leaf emergence rate, FLR: flowering rate of the racemes, FR: flowering rate on the main raceme

*First parent listed in each cross is the female parent [1]1 Burton's method, 2 Mahmud and Kramer method flower(4.10-5.0) was not high.

The range of the heritability estimates for first flower M to maturity(4.10-5.4) was from 0.04 to 0.41. Three of the heritability estimates were 0.25 or lower thus indicating that the heritability of first flower M to maturity(4.10-5.4) was not high.

The heritability estimates for leaf emergence rate ranged from -0.78 to 0.39. Nine of the values were 0.25 or less indicating a low heritability for LER. The cross of Nugget with Target indicated reciprocal differences. Ten of 12 of the heritability estimates for FLR were less than 0.25; thus the

The heritability estimates for flowering rate of the racemes ranged from -1.25 to 0.42. Heritability for flowering rate of the racemes was low.

The heritability estimates for flowering rate on the main raceme ranged from -0.20 to 0.54. Only three of the heritability estimates were less than 0.25 indicating a moderate heritability for flowering rate on the main raceme. The heritability estimates indicated reciproc l differences for the cross of Nugget with Oro and Oro with Target.

The heritability estimates for number of leaves ranged from -0.15 to 0.68(Table 14). Five of the heritability estimates were 0.25 or less, thus the heritability of number

TABLE 14. *Heritabilities of the yield characters for the crosses between the cultivars Nugget, Oro, and Target*

Cross*	Method[1]	Number of leaves	Number of secondary racemes	Number of tertiary racemes	Number of pods	1000 seed weight	Vegetative yield	Harvest index	Seed yield
(NXT)	1	-.15	-.58	-.03	.00	.27	.17	-.03	-.04
(TXN)	1	.59	.31	-.04	.08	.33	-.22	.42	-.52
(NXT)	2	-.13	-.82	-.11	.06	.40	-.30	.08	-.06
(TXN)	2	.05	-.37	.05	.13	.45	-.26	.06	.07
(NXO)	1	.25	.46	.18	.56	-.37	.45	.46	.31
(OXN)	1	.68	-.43	.10	.27	.31	-.04	.44	-.06
(NXO)	2	-.13	.23	.16	.20	.07	.31	.44	.32
(OXN)	2	.58	-.05	.06	.10	.38	.38	.09	.26
(OXT)	1	.28	.30	.44	.02	.37	.16	.13	-.46
(TXO)	1	.52	.07	-.01	-.08	.75	-.67	.57	-.50
(OXT)	2	.26	-.02	.45	.00	.29	.08	.49	.14
(TXO)	2	.48	-.07	.37	.14	.55	-.07	.42	.28

[1] 1 Burton's method, 2 Mahmud and Kramer method

*First parent listed in each cross is the female parent of leaves was moderate or low. The heritability estimates indicated reciprocal differences for the crosses of Nugget with Oro and Oro with Target.

The heritability estimates for number of secondary racemes ranged from −0.82 to 0.46. Nine of the 12 heritability estimates were below 0.25, indicating a low heritability for number of secondary racemes. Reciprocal differences were indicated for the cross of Nugget with Oro

The range of heritability estimates for number of tertiary racemes ranged from −0.11 to 0.45. Nine of the 12 heritability estimates were below 0.25, indicating a low heritability for number of tertiary racemes. However, the heritability estimates for the crosses of Oro with Target indicate a moderate heritability.

The range of heritability estimates for number of pods was from −0.08 to 0.56. Ten of the 12 values were less than 0.25, indicating a low heritability for number of pods.

The range of heritability estimates for 1000 seed weight was −0.37 to 0.75. Only two of the values were below 0.25, thus indicating a moderate heritability of 1000 seed weight. Reciprocal differences were exhibited for all three crosses for the heritability of 1000 seed weight.

The range of heritability estimates for vegetative yield was −0.67 to 0.45. Nine of the heritability estimates were lower than 0.25, indicating a low heritability of vegetative yield.

The range of heritability estimates for harvest index was -0.30 to 0.57. Five of the 12 heritability estimates were less than 0.25 indicating a low or moderate heritability for harvest index.

The range of heritability estimates was from -0.52 to 0.32. Eight heritability estimates were below 0.25, thus the heritability was low.

Discussion

Reciprocal differences were found for the population means for many of the characters studied. The reciprocal differences were not consistent in direction in F_1 or F_2 populations indicating genotype X cytoplasm interaction.

The type of gene action observed for a given character for different crosses was not consistent. Reciprocal differences confounded the interpretation of the F_1 means. None of the heritability estimates was high. The large number of negative values obtained by both methods of estimation indicate that these methods are not adequate for evaluating broad sense heritabilities in these populations. Reciprocal effects further complicate the interpretation of these results.

Considering the reciprocal differences, variable gene action, and low heritabilities, selection for most of these characters in early generations would not be successful.

GENERAL DISCUSSION

B. napus is largely self-pollinated; however there is natural outcrossing. Thus the degree of homozygosity of the parent material is not certain. Part of the variation of the characters within the parent populations was likely due to genetic variation. The within cultivar correlations would be similarly affected and may or may not hold if selection is applied or populations of different morphological or physiological types are included.

The parent cultivars were chosen on the basis of previous data to provide a wide range of maturity types. However, at Parkland Farm in 1974, there was not a great difference in the growth patterns of the cultivars or in the number of days to maturity. Thus the usefulness of the between cultivar data was reduced. The large reciprocal differences observed for many characters also tended to obscure the genetic mechanisms of control of these characters. Further studies of the control and heritability of these characters should be done with lines of later generations of with a greater number or cultivars and with a wider range of expression of the characters studied.

This study was done at only one location for only one season. Thus the peculiarities of that season may have influenced the results. In particular early fall frost may have influenced the correlation of yield with earliness by reduction of the yield of the later plants. However, short seasons and early frosts are common in Alberta and this data can be assumed to be typical of such years.

In general the data indicates that earlier cultivars with equal or increased yield are feasible.

SUMMARY

1) The major characteristic leading to early maturity for Target was early first flower M.

2) Target exhibited many traits which would tend to make it a late variety. It was latest for the stages from leaf 1 to leaf 9, had the longest periods first flower M to first flower 3, first flower M to last first flower, first flower M to end flower, and first flower M to maturity. Target had the lowest leaf emergence rate, lowest flowering rate of the racemes, and lowest flowering rate on the main raceme.

3) There were few high correlations among the growth characters, indicating that the growth characters measured were largely independent of each other.

4) Earliness of the later stages is promoted by earliness of the initial stages, by short initial periods, and by high rates of development.

5) High rates of development at different times and for different aspects of growth were positively associated.

6) High leaf emergence rate and early emergence of the seventh true leaf are associated with rapid flowering rates and early maturity but also with longer flowering periods.

7) The data indicates that high flowering rates are

associated with reduced duration of the flowering periods and high flowering rate on the main raceme is associated with reduced first flower M to maturity.

8) Early first flower M was associated with early maturity and longer flowering periods of first flower M to last first flower and first flower M to end flower.

9) The period leaf 7 to first flower M was indicated to have a greater influence on the later periods than leaf 1 to leaf 7.

10) The correlations of the growth characters with the yield characters were all low indicating that yield is not significantly influenced by any one of the growth characters.

11) The growth characters which were associated with earliness and rapid development were associated with high yield characters.

12) The significant partial correlations with seed yield holding vegetative yield constant of the growth stages and initial growth periods were mostly negative and indicated that these growth characters had an effect on seed yield independent of their association with vegetative yield.

13) Part of the simple effect of high rates of development on seed yield was indicated to be due to the

association of these rates with vegetative yield.

14) Long flowering periods of first flower M to last first flower and first flower M to end flower were positively associated with high yield characters. However this association was indicated as being due to their common association with high vegetative yield.

15) The time to first flower M was indicated as having a stronger association with the yield characters than the subsequent time from first flower M to maturity.

16) All the significant correlations among the yield characters were positive except for the correlation of number of leaves with 1000 seed weight for Target.

17) The correlations among total plant weight, vegetative yield, and seed yield were very high indicating that the major determinant of seed yield for *B. napus* on a single plant basis was plant size.

18) The number of leaves was indicated to not have a large effect on seed yield.

19) The significant positive correlations of seed yield with the number of secondary racemes, number of tertiary racemes, number of pods, and 1000 seed weight were all largely due to their correlations with vegetative yield.

20) The partial correlations with seed yield holding

vegetative yield constant were significant and positive for number of tertiary racemes and number of pods for all three cultivars and for number of secondary racemes for Target and were significant and negative for 1000 seed weight for Oro. Thus these characters showed a significant association with seed yield which was not due to their association with high vegetative yield.

21) Significant reciprocal differences were found for the population means of most of the characters studied.

22) Heterosis was indicated for some of the growth characters and several of the yield characters including maturity, number of tertiary racemes, seed yield, and harvest index.

23) The heritability estimates were inconsistant and not high. Large reciprocal differences in the heritability estimates calculated were also found.

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