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THE EFFECTS OF ROW SPACING AND SEEDING RATE ON SEED YIELD AND CROP MATURITY OF RAPESEED (*B. NAPUS* L. AND *B. CAMPESTRIS* L.)

by

MERAB JENDEKA MAHASI

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

IN

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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 THE EFFECTS OF ROW SPACING AND SEEDING RATE ON SEED YIELD AND CROP MATURITY OF RAPESEED (*B. NAPUS* L. AND *B. CAMPESTRIS* L.) submitted by MERAB JENDEKA MAHASI in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in PLANT BREEDING.

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Supervisor

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Date.....Mar 12/84.....

DEDICATION

To my mother

1925-1984.

ABSTRACT

The effects of row spacing and seeding rate on seed yield and crop maturity of rapeseed (*B. napus* L. and *B. campestris* L.) were studied for two years in Central Alberta. A completely randomized block design was used with seeding rates of 3, 6 and 9 kg/ha for *B. campestris* genotypes (Candle and Tobin) and 4, 8 and 12 kg/ha for *B. napus* genotypes (Westar and 81-58412K). The row spacing used was 11.5 cm and 23 cm in both species.

Data was collected for seed yield per $2m^2$, number of pods on the main raceme, number of secondary racemes per plant, number of pods on secondary racemes per plant, number of racemes per $2m^2$, number of racemes per plant, 1000 seed weight, plant density at one week after emergence, plant density at three weeks after emergence, plant density at first flower, plant height, percent seed oil, percent meal protein, days to first flower, days to last flower, flowering period, seed formation period and time to maturity of first pod.

For *B. campestris*, the 11.5 cm row spacing resulted in a significantly higher seed yield per plot in both years. The narrow row spacing had a significantly higher seed yield per plant in 1984 but was lower in 1985. For *B. napus*, the 23 cm row spacing resulted in a significantly higher number of pods on the secondary racemes in 1985.

There was a significant decrease in the number of racemes per plant, number of pods on the main raceme, number of pods per plant, number of seeds per pod, seed yield per plant, seed yield per plot, percent seed oil and percent

meal protein as seeding rate was increased for both species in both years. However, plant density and number of racemes per plot showed a significant increase with increased seeding rate. Plants were shorter at higher plant densities. The 1000 seed weight was not significantly affected by seeding rate but was strongly affected by the genotype.

Significant seeding rate x genotype and row spacing x genotype interactions were common but three way interactions were rare.

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In all fairness to all those who helped me, my sincere appreciation.

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1. INTRODUCTION

Rapeseed (*Brassica napus* L. and *Brassica campestris* L.) is a major source of vegetable oil and protein meal throughout the world. It ranks fourth in the world's production of edible vegetable oils and fifth in seed production; this difference being due to its comparatively high oil content. Rapeseed production in Canada is a relatively new enterprise compared to the production of cereals. Rapeseed was first grown commercially in Canada in 1942, the stimulus being an acute shortage of rapeseed in the early 1940's (as a result of World War II). The oil was urgently needed as a lubricant for warship steam engines in Canadian, British and American navies. Today, it is mainly valued for its edible oil and high protein content. By-products of the oil crushing industry are used to a limited extent in various manufactured products (Pigden, 1981). Although the value of the oil as an edible product was well known, the first oil extraction for edible purposes in Canada occurred in 1956 (Martin, 1970).

The major commercial production is in the three Prairie provinces (Manitoba, Saskatchewan, Alberta) and in North East British Columbia where it is well adapted to the northern climate, north of 49° latitude. Approximately 3.2 million hectares of spring rape were planted in 1985. Nearly 100,000 hectares in Ontario are devoted to winter rapeseed production.

Rapeseed offers a very important alternative crop to cereal grain production in Western Canada since the land, tillage, harvesting, storage and transportation equipment

and facilities are virtually identical. The oilseed crushing industry in Western Canada is mainly dependent on rapeseed.

Early rapeseed cultivars contained two components which limited their use for human and animal consumption; erucic acid in the oil and glucosinolates in the meal. Rapeseed meal is an excellent source of protein with a favorable balance of amino acid for livestock rations. "Canola" is a registered trademark used to designate cultivars of rapeseed producing seed with less than 5% erucic acid in the oil and 40 mg glucocinolates per gram of oil free meal. Canola thus denotes high quality oil and meal suitable for human and animal consumption. Virtually all of the current rapeseed production in Canada is of Canola quality. Both the quality improvement and wide adaptability have been responsible for the recent expansion in the rapeseed industry both in Canada and Europe (Alberta Agric., 1982).

Rapeseed is the major oilseed produced in Canada and canola oil accounts for almost half of all the edible oil used domestically in Canada. Canada exports half of its rapeseed crop making her the number one exporter in the world. In the past few years, the production of rapeseed has increased to such an extent that it has surpassed barley as Canada's second valuable crop. It is not just a major source of food and feed but a major export crop, second only to wheat in importance as a source of farm cash receipts.

Two species of rapeseed are grown in Canada, the Argentine type (*B. napus*) and the Polish type (*B. campestris*). The spring form is grown in western Canada while the winter form is grown in Ontario. In western

Canada, approximately 50% of the total acreage is devoted to *B. napus* and the remaining 50% to *B. campestris* The *B. campestris* produces a lower seed yield, lower protein and oil but the large proportion of its production is due to early maturity. This is required because many production areas have a low heat unit accumulation and short frost-free period. *B. napus* matures in about 95 - 120 days while *B. campestris* matures in 80 - 90 days.

Reducing the time to maturity for *B. napus* so that it could be grown in areas now producing *B. campestris* would result in an increase in average seed yield and an increased oil and protein content of the commercial crop (Major and Charneski, 1976).

Most Canola growers use seed drills with furrow openers [illegible]ced at 15, 18 and 23 cm, and have reported increased seed [illegible]ds with double seeding. Usually *B. campestris* is seeded at 4-7 kg/ha and *B. napus* at 5-8 kg/ha. Seeding rate has been reported not to have any effect on the seed yield in this crop. The farmer is interested in higher yields which can only be translated into greater profit if the product is attractive to the processor and to the consumer.

The objective of this study was to assess the effects of row spacing and seeding rate on seed yield and crop maturity of rapeseed.

2. LITERATURE REVIEW

2.1 Growth Pattern

The rapeseed plant has five distinct phases of growth as seen from the growth stage key of Campbell and Kondra (1977) i.e. seedling, rosette, bud, flowering and maturity.

Three cultivars of *B. napus* (Target, Nugget and Oro) were evaluated in the field (Campbell and Kondra, 1977). Target was latest for the growth stages during the rosette period. Initiation of elongation occurred on the same day for all cultivars. Target was earliest for first flower and earliest for all other subsequent stages, with the longest duration of periods subsequent to first flower and lowest rates of development in both the rosette and flowering stages. Hence it would appear that time to first flower is a major factor in determining time to maturity.

B. campestris reached all growth stages except onset of stem elongation significantly earlier than *B. napus* and had significantly higher leaf emergence rates during all growth periods (Kasa, 1983). This pattern is in contrast to that among genotypes of *B. napus* where early maturing genotypes with early first flower and early subsequent growth stages had significantly lower leaf emergence rates than did later maturing genotypes. *B. napus* had significantly longer growth periods i.e. stem elongation phase and seed formation period.

Substantial variation exists among cultivars of *B. napus* with respect to the length of the two major pre-anthesis developmental phases; vegetative (seeding to

onset of elongation) and stem elongation (onset of elongation to anthesis) (Thurling and Vijendra, 1977; Major, 1980). Under controlled environments, the duration of the vegetative phase of *B. napus* is strongly influenced by vernalization, photoperiod and growing temperature. The duration of the stem elongation phase is affected by photoperiod and growing temperature (Major, 1980). The direct effect of temperature on leaf node formation of *B. napus* was more important than the inductive response (number of leaf nodes at initiation) in determining flowering in all Canadian cultivars.

Thurling and Vijendra (1977, 1979b) observed considerable variation in flowering behaviour in the field in Australia among cultivars of *B. napus* which can be explained in terms of temperature responses. A decrease in temperature and/or decrease in day length significantly delayed first flower. Under controlled environment, plants grown at low temperature demonstrated a reduction in time to initiation of flowering with increased vernalization up to 8 weeks. By contrast those grown at high temperature were unresponsive to increases in vernalization beyond 4 weeks. The number of leaf nodes formed prior to initiation would reflect the inductive effect of temperature. Most cultivars were found to flower 3 or 4 weeks earlier under 24 hour photoperiod than under natural photoperiod. Under short days, an increase in the length of the vernalization treatment was associated with a significant decrease in time to initiation. An increase in day length is usually associated with a reduction in both vegetative and stem

elongation phases.

In *B. napus* higher seed yield has been found to be associated with a longer period of vegetative growth (Thurling and Vijendra, 1979b). Plant dry weight declined with shortening of either vegetative or stem elongation phases. Time of flowering is normally an important determinant of grain yield in areas where the growing season is of limited duration. This is in contrast to Canadian work with *B. napus* where the growth characters which were associated with earliness and rapid development were also associated with higher yield (Campbell and Kondra, 1978).

The earliest maturing *B. napus* line flowered significantly earlier than the latest maturing genotype and had a significantly shorter flowering period (Degenhardt and Kondra, 1981b). The period of flower production in Great Britain spanned approximately three weeks in both high and low yielding cultivars of *B. napus* (Allen and Morgan, 1975).

The growth periods ending at first flower on main raceme were generally negatively correlated with the subsequent growth periods beginning at first flower (Campbell and Kondra, 1977). This indicates that a long period of development in the initial growth period is somewhat compensated for by a decrease in the length of subsequent periods. However, correlations between time to growth stages were all positive and most were significant indicating that earliness of initial growth stages contributes to earliness of subsequent stages. The low correlation of time to first flower on the main raceme with the period first flower on the main raceme to first flower

on third secondary raceme indicates that time to first flower on the main raceme has little effect on the duration of this period.

The positive correlations of flowering rate on the racemes with yield indicates that a rapid rate of flowering is associated with high yield. The seed filling period was not correlated with yield indicating that it is not a limiting factor (Campbell and Kondra, 1978).

First flower is more readily determined than maturity especially on single plant basis. The heritabilities for first flower ranged from 21% to 61% in crosses between three cultivars and for maturity, they ranged from 16% to 36% (Campbell and Kondra, 1978). This indicates that selection for first flower as an indicator of maturity could result in genetic gains. Evidence of dominance for early flowering and early maturity was found in all the crosses.

Genetic analysis showed that heritabilities of duration of the vegetative phase and number of leaf primodia formed prior to initiation indicated that genetic differences accounted for most of the variation within sowings (Thurling and Vijendra, 1979a). Dominance was a major component of non-additive genetic variation in both characters, whereas non-allelic interactions appeared to be significant only in the case of leaf number. The expression of genes determining development pattern in spring rape was influenced by the environment. There are two types of genes controlling flowering times; genes involved in the regulation of vernalization responses and genes causing earlier flowering but having no influence on the vernalization mechanism.

As for plant height, genotypic differences were quite large, with the later maturing cultivars being significantly taller than earlier maturing genotypes (Degenhardt and Kondra, 1981b). Plant height had a significant negative correlation with harvest index and 1000 seed weight for all genotypes (Degenhardt, 1979). This was not unusual since plant height and harvest index had a positive correlation with vegetative yield and total yield. Similarly, the negative correlation between plant height and 1000 seed weight was expected since plant height correlated negatively with seed yield or harvest index and 1000 seed weight, the latter being positively correlated with harvest index. It appears that shorter plants transfer more nutrients into larger seed size production.

Phenotypically, days to flower in *B. juncea* is not associated with any other traits except plant height (Gubta, 1972). This implies that plant height is influenced by days to flower. There is a significant genotype and phenotype correlation between plant height and number of pods per plant. This indicates that the number of pods per plant increases significantly with plant height.

2.2 Photosynthesis and Assimilate Distribution

As plants grow, the proportion of purely structural material that they contain normally increases (Hunt, 1979). For this reason, Relative Growth Rate (RGR) cannot remain constant for long and eventually must show a decline as more of the plant's material becomes incapable of directly providing further increases in dry weight. Some researchers

thus prefer models which not only allow the possibility of this decline in the RGR with time, but naturally expect it.

The useful yield of any fruit crop depends to a large extent on the effective operation of processes whereby vegetative parts of the plant contribute organic and inorganic nutrients to the developing fruits (Lang and Shaw, 1965).

It is clear that usually the leaf area will increase as growth proceeds, and with increasing leaf area, the rate of production of material by assimilation will also increase; this again will lead to a still more rapid growth and thus a greater leaf area and a greater production of assimilating material and so on (Blackman, 1919).

Growth and development of *B. napus* can be considered physiologically in four more or less distinct phases according to the pattern of dry weight production (Allen et al., 1971).

1. Vegetative or pre-anthesis phase in which crop growth rate (CGR) and leaf area index (LAI) increase linearly and attain a peak.
2. An approximate 2 - 3 week period immediately following anthesis in which there is a marked reduction in CGR coinciding with leaf senescence and declining LAI.
3. A further 2 week period in which CGR increases to a much higher level than that attained in phase 1 and characterized by a marked increase in the size and weight of pods.
4. A final period ending at full maturity during which total plant weight decreases.

The following growth phases together with their duration were identified in the oilseed rape (*B. napus*) in Great Britain (Allen and Morgan, 1975).

1. Seedling and vegetative growth (week1 - week7):
This was a phase when there was predominantly vegetative growth and also development of the flowering branches and early development of flowers. CGR and LAI increased linearly and attained a peak. From (w1 - w4) LAI was increasing on all plots and had reached maximum values by w5.

2. Flowering and early pod growth (week7 - week10):
This was a phase when flowers opened on the terminal and axillary inflorescence. The CGR slowed down even when the leaf area indices were still high.

3. Pod growth and ripening (week10 - week13):
This was a period of rapid growth of older pods on the terminal and some of the axillary inflorescences and abcission of some of the younger and more apically positioned pods. The dry weights increased markedly notwithstanding the fact that leaf area indices were declining and had reached zero by w13.

Brassica napus had greater crop dry weights (CDWs) and CGRs than *B. campestris*, the former could be considered as being more efficient in producing dry matter since the RGRs were significantly greater over all growth periods (Kasa, 1983).

In both species, the maximum LAI was obtained some 2 - 3 months after sowing, but all leaf tissue had generally been lost within 6 weeks after this maximum had been reached (Thurling, 1974). *B. napus* had greater LAIs than *B.*

campestris (Kasa, 1983; Richards and Thurling, 1978). Leaf area is close to its maximum at the start of flowering (Clarke and Simpson, 1978a).

Leaves of both autumn and spring sowings rapidly senesced after flowering and before the main stage of pod development took place (Scott et al., 1973). This indicates that photosynthetic tissue in stems and pods must make a substantial contribution to seed development. It seems unlikely that leaves which do remain will photosynthesize very actively for at this stage of growth the developing pods and stem form a thick layer at the top of the crop and only dim light can penetrate to the few remaining leaves.

Earlier maturing genotypes of *B. napus* tended to have higher axillary branch leaf area indices and a significantly higher axillary branch leaf area duration than did late maturing genotypes (Kasa, 1983). It has been suggested that in selecting earlier maturing, higher yielding genotypes, existing breeding programs are obtaining genotypes that have an ever increasing percentage of total leaf area made up from axillary branch leaves. This is advantageous since it coincides with seed filling and axillary branch leaves are located in close proximity to the seeds.

Stomata distribution in several types of tissue belonging to *B. campestris* c.v. Span and *B. napus* c.v. Zephyr indicates that there is potential for assimilation of atmospheric carbon dioxide in pods, beaks, stems, pedicels and leaves of oilseed rape plants (Major, 1975). Although leaves, stems, pods and beaks were capable of assimilation, only leaves and stems were capable of exporting assimilates

(Major and Charnetski, 1976). The components that acted as sinks were roots, pods, seeds, beaks, apices and barren pods. Proximity of sink to source appeared to be important since assimilates exported to roots came from the lower portion of plants and more labeled assimilates were found in seeds, barren pods and apices when the upper rather than lower portion of plants was exposed to $^{14}CO_2$.

In a similar experiment, Major et al. (1978) using $^{14}CO_2$, *B. napus* c.v. Zephyr have clarified the role of pods in the formation of seeds which was questioned by Major and Charnetski (1976). Although pods were capable of assimilating $^{14}CO_2$, they were still sinks for photosynthates exported from stems and leaves. It was found that lower leaves exported photosynthates to the seeds and pods. The lower portions of the stems and upper pods did not export much photosynthates to other parts. The seed was a strong sink for photosynthates translocated from leaves, pods and stems.

The fully expanded leaves of vegetative rapeseed contribute mainly to the development of the root system and to the younger developing leaves. But in plants beginning to flower, the fully developed leaves promote mainly structural development of the part of the stem bearing the flower (Brar and Thies, 1976). The role of early plant growth of *B. napus* should be interpreted in terms of the accumulation of dry matter in the seeds. The pre-anthesis phase of growth was more important for *B. napus* because dry matter increase between anthesis and harvest represented only 55% of the total dry weight; while the post-anthesis phase of growth in

B. campestris was more important since 85% of the total dry weight in all cultivars was accumulated after anthesis (Thurling, 1974b). The duration of the vegetative phase of growth rather than the rate of growth determined the total dry weight of the plant.

Brassica napus had greater crop dry weights (CDWs) compared to *B. campestris* (Kasa, 1983). CDW was significantly greater for later maturing than earlier maturing genotypes of *B. napus* at first flower and 15 days after flowering.

In *B. napus*, the dry weight of the whole plant has been found to increase slowly till bolting and rapidly thereafter (Inanga et al., 1979). The rapid increase of dry weight of the whole plant was continued also in ripening period in spite of marked defoliation due to senescence. The gross photosynthesis performed by undefoliated plant population began to increase at the middle period of ripening. The dry weight of the pericarp increased rapidly after flowering and reached the maximum value at the earlier stage of pod development (Inanga et al., 1980). On the other hand, the dry weight of seed increased gradually after flowering, and reached maximum value at the later stage of pod development. Most of the dry matter needed for pod growth was translocated from other organs during the period of pericarp growth, and was provided by pod photosynthesis during seed development.

During the ripening period, the pods possess relatively high photosynthetic activity and extensive surface area. Moreover, the pods were located at the upper level in space

of the population receiving most of the sunlight. Hence, most of the photosynthesis of pods plus stems might be contributed by that of pods.

Therefore in rapeseed, leaves are the main photosynthetic organs until flowering but after flowering, pods themselves do play an important role in contributing to the production of dry matter in pods including seeds (Inanga and Kumura, 1974). Seed formation is directly affected by the assimilatory potential during seed formation, length of seed formation and prevailing climatic conditions during seed formation. While late maturing genotypes have a significantly greater production potential, it is often limited by factors affecting seed formation (Kasa, 1983).

The pattern of dry matter and oil accumulation in the seeds is similar and follows a sigmoid pattern (Fowler and Downey, 1970). According to Norton and Harris (1975), this pattern can be divided into 3 phases:

Phase 1:

Seed weight was low, starch and ethanol soluble compounds accounted for 80% dry matter (D.M.)

Phase 2:

Seed growth increased and storage oil and protein were deposited accounting for 40% and 20% D.M. respectively at the end of this stage. Starch, glucose and fructose were utilized in this process.

Phase 3:

Was largely concerned with the deposition of oil and protein in fixed proportions. Seed weight more than doubled while the D.M. composition remained constant. Sugars were

transferred from the hull to the seed to support this growth.

If there is a relatively brief shortage in the supply of carbon assimilates and it does not occur around the time of anthesis, then plants, although forming fewer pods, are able to compensate for the loss in terms of pod and seed yields by increased growth of the remaining pods (Tayo and Morgan, 1979). The capacity for compensation is probably of great practical significance since the oilseed rape plant has a considerable number of pods on the terminal and axillary inflorescences which do not realize their full potential growth. Several *B. campestris* (Brown Sarson) cultivars showed high correlations between pod surface area and yield (Maiti et al., 1970).

Thurling (1974) has concluded that in both species, the metabolic input of the plant during flowering would be diverted to a rapidly increasing number of growing points in the inflorescence, with the result that there is likely to be intra-plant competition between pods on the main stem and newly formed shoots in the leaf axils. The rapeseed species differed, however, with respect to the way in which metabolic input was utilized by the developing inflorescence. Since this limited metabolic input would have to be partitioned amongst a substantially greater number of growing points within the inflorescence, a proportionately smaller amount would be available to seeds developing in each individual pod. As a consequence, the seeds formed in each pod in *B. campestris* were significantly fewer in number and lighter than those in *B. napus*.

2.3 Yield and Yield Components

2.3.1 Seed yield per unit area

Seed yield per unit area of rapeseed is a function of number of pods per unit area, number of seeds per pod and seed weight (Clarke and Simpson, 1978). In *B. juncea*, seed yield of an individual plant is genetically positively correlated with the number of primary branches, number of pods per plant, 1000 seed weight and number of seeds per pod (Gubta, 1972). This points out that unit increase of these characters increases the yield of the plant; and selection for these traits will lead to improvement in yield. For most genotypes of *B. napus* studied, plant density, number of racemes per square metre and number of racemes per plant were not correlated with seed yield per plot (Degenhardt and Kondra, 1984). Only the seed yield per plant was positively correlated with seed yield per plot across all genotypes while plant height correlated negatively with seed yield per plot.

The number of seeds per pod in *B. napus*, *B. campestris* and white mustard is not much influenced by the environment and thus has the greatest influence on yield (Olsson, 1960 and 1974; Gubta, 1972). This has been attributed to the indeterminate flowering habit of rapeseed and the fact that the number of flower initials that develop is usually limited. Since high correlations are observed between number of pods per plant and plant yield, pod number must be strongly influenced by the environment. In mustard, the highly significant and positive simple correlation

coefficient of total yield per plant with pod length, number of pods per plant, number of seeds per pod and seed weight per pod shows that significant improvement in yield can be achieved through breeding and selection (Ahmed, 1980; Gubta, 1972).

Vegetative yield was a major contributor to yield in *B. napus* (Campbell and Kondra, 1978). The number of secondary racemes, tertiary racemes and harvest index were also important contributors. Components of yield have appeared attractive as alternate criteria of selection for high yield as they are easy to measure and are usually more heritable than grain yield itself.

2.3.2 Number of pods on main raceme

Since flowering and pod development in *B. napus* begin first on the main raceme followed by subtending branches in basipetal succession, assimilate availability is probably greater for the main raceme than lower branches (Tayo and Morgan, 1975). The first developed pods have a competitive advantage in attaining full development. Later maturing genotypes derive a significantly greater proportion of their total seed yield per plant from the terminal inflorescence than do earlier maturing genotypes (Kasa, 1983). The pods on the main racemes would be competing for available assimilates with pods on lower branches.

The terminal inflorescence in *B. napus* is particularly important in that it carries more pods (approximately 45% of the total) with a larger number of seeds per pod than the lower branches (Allen and Morgan, 1975; Kasa, 1983; Pechan

et al., 1980).

2.3.3 Number of secondary racemes per plant

Increased number of secondary racemes contributed to increased plant size in *B. napus* thus resulting in higher yield (Campbell and Kondra, 1978). Seed yield per plant had a significant positive correlation with number of secondary racemes per plant.

2.3.4 Number of pods on secondary racemes per plant

There is inter- and intra-inflorescence competition for the supply of assimilates and the earlier developed inflorescences have a competitive advantage over the later formed ones; this is probably of major importance in determining the pattern of flower and pod development within and between inflorescences of *B. napus* (Tayo and Morgan, 1979).

High irrigation rate resulted in an increase in the number of racemes per plant in *B. napus* which was probably due to lengthening of flowering period (Clarke and Simpson, 1978). In *B. juncea*, the number of secondary branches exhibited positive genotypic and phenotypic association with the number of pods per plant and number of seeds per pod while there was no environmental association of the same with secondary branches (Gubta, 1972).

2.3.5 Number of pods per plant

Seed yield per plant in *B. napus* had a positive correlation with number of pods per plant. Increased number

of pods contributes to increased plant size and hence high yield (Campbell and Kondra, 1978). In a greenhouse study of *B. napus*, most pods which matured developed from flowers which opened early in flowering (Tayo and Morgan, 1975). This implies that the ability of the plant to supply assimilates to the inflorescence was of critical importance in establishing the potential number of pods. If there is a relatively brief shortage in the supply of assimilates and it does not occur around the time of anthesis, then plants, although forming fewer pods, are able to compensate for the loss in terms of pod seed yields by increased growth of remaining pods (Allen and Morgan, 1975 and 1979; Macgregor, 1981; Clarke and Simpson, 1978b). The capacity for compensation is probably of great practical significance since the oilseed rape has considerable number of pods on the terminal and axillary inflorescence which do not realize their full growth potential.

2.3.6 Number of seeds per pod

The number of seeds per pod in white mustard is so strongly influenced by the genotype that selection for this character can result in marked differention in the material (Olsson, 1960). The number of seeds per pod was not much influenced by the environment but can be changed by selection in *Sinapis alba* (Olsson, 1960, 1974). However, environmental and genotypic variation in number of seeds per pod in *B. napus* and *B. campestris* have been observed (Allen and Morgan, 1972, 1975; Thurling, 1974b). Irrigation increased the number of seeds per pod in *B. campestris*

(Krogman and Hobbs, 1975).

As pods develop, environmental factors do influence the number of seeds developing in each pod. The number of seeds per pod declined progressively as *B. napus* approached maturity (Mendham and Scott, 1975). Initially, pods of *B. napus* contained 18 - 19 seeds, the number declined rapidly to 9 during early pod growth and was 7 at maturity (Norton and Harris, 1975).

2.3.7 1000 Seed weight

The 1000 seed weight in *B. napus*, *B. campestris* and white mustard was less influenced by the environment than the number of pods; suggesting that selection for seed size would be effective (Olsson, 1960). One thousand seed weight exhibited a significant positive correlation with seed yield per plant and seed yield per plot (Campbell and Kondra, 1978; Degenhardt and Kondra, 1984). Cultivars of *B. napus* and *B. campestris* differed in 1000 seed weight (Thurling, 1974b). Irrigation increased 1000 seed weight of *B. campestris* variety Span (Krogman and Hobbs, 1975). Shading of pods reduced seed weight per pod by 68 - 100% (Maiti et al., 1970). Cultivars having big sized silique suffered the most. Thus it was clear that the yield of Sarson per siliqua was dependent on the photosynthetic green surface of the silique.

2.4 Effects of Row Spacing and Seeding Rate on Yield, Yield Components, Seed Quality and Time to Growth Stages

Rapeseed (*B. napus* and *B. campestris*) is a rather unique crop in that variation in seeding rate or plant population over relatively wide ranges have little effect on yield under normal conditions (Bowren, 1980; Degenhardt and Kondra, 1981a and 1981b; Kondra, 1975). This conflicts the results of Clarke et al. (1978) who found that for both drill and broadcast seeding, each increase in seeding rate resulted in a significant increase in yield.

The narrowest row spacing (15 cm) gave the highest yield in both years at both locations for *B. napus* c.v. Zephyr and *B. campestris* c.v. Span and generally produced the highest oil content (Kondra, 1975). Percent meal protein was not affected by row spacing. Doubling the space between rows from 7.5 cm to 15 cm significantly reduced yields in both species (Christensen and Drabble, 1984), the magnitude of response being affected by varietal factors. In *B. napus*, increased seeding rate resulted in a significant decrease in seed yield per plant, harvest index, number of racemes per plant and plant height (Degenhardt and Kondra, 1981a; Vulliourd, 1974). The rate of seeding had no significant effect on 1000 seed weight.

Doubling seeding rate from 3 to 6 kg/ha and 6 to 12 kg/ha resulted in a 70% increase in actual plant density while doubling seeding rate from 7 to 14 kg/ha resulted in an 85% increase in plant density (Degenhardt and Kondra, 1981b; Christensen and Drabble, 1984).

When plant population density is low, the individual plants tend to branch and spread out more and pods generally extend lower on the plant. At high seeding rates, most pods are on the main raceme and thus in a favorable position for interception of radiant energy for photosynthesis (Clarke and Simpson, 1978; Bowren, 1980). At lower seeding rates, the pods are distributed over a greater depth in the canopy and light could have been rate limiting for photosynthesis in the lower branches. With heavy stands, particularly under drought conditions, competition between plants often results in fewer and smaller pods concentrated on the upper part of the plant. The number of racemes per plant had a direct positive relationship with seed yield per plant (Degenhardt and Kondra, 1981a; Clarke et al., 1978). Plants with more racemes had higher yields.

It appears that more competition results in shorter plants since plants in the higher seeding rates were significantly shorter (Bowren, 1980; Degenhardt and Kondra, 1981a). Higher seeding rates in *B. napus* are sometimes used to reduce straw length. Lodging was increased at high seeding rates in *B. napus* c.v. Zephyr, *B. campestris* c.v. Span and Winter *B. napus* (Kondra, 1975; Vulliourd, 1974).

Increased seeding rate had no significant effect on 1000 seed weight in most studies (Degenhardt and Kondra, 1981a; Huhn and Schuster, 1975). However, 1000 seed weight tended to increase with increased seeding rate in both drilled and broadcast material (Clarke et al., 1978).

Increased seeding rate had no significant effect on percent seed oil and percent meal protein (Ohlsson, 1971 and

1972; Kondra, 1975; Degenhardt, 1979). The lowest seeding rate resulted in slightly higher oil while the highest seeding rate tended to reduce oil content. In *B. napus*, high seeding rates reduced seed oil content in widely spaced but not narrowly spaced rows (Ohlsson, 1971 and 1972; Kondra, 1975). This indicates that oil content of the seeds is insensitive to plant competition.

Increased seeding rate resulted in a significant decrease in days to last flower, seed formation period and days to maturity of first pod but had no significant effect on days to first flower and flowering period in *B. napus* (Degenhardt and Kondra, 1981b). Since time to first flower and last flower seem to act as good indicators of time to maturity of first pod, then one could hasten maturity by increasing seed rate. The time to various growth stages and duration of growth periods was not consistently correlated with seed yield. (Campbell and Kondra, 1978; Degenhardt and Kondra, 1984).

Where weeds are controlled, a higher seeding rate (6 - 8 kg/ha) with a narrow row spacing (12 cm) is recommended for *B. napus* (Nordestaagard, 1979). Hence in plants, plastic responses and degree of plant plasticity make seeding rates, row width and plant spatial arrangements important considerations in crop production (Skoskopf, 1981).

3. MATERIALS AND METHODS

3.1 Plant Material

Plant material used were two genotypes of *B. napus* Summer Type (Westar and 81-58412K), the latter being from the University of Alberta rapeseed breeding program and two genotypes of *B. campestris* Summer Type (Candle and Tobin).

3.2 Location

The two tests were conducted at the University of Alberta, Edmonton Research Station (53° 30'N. Latitude, 113° 32' W. Longitude) during the 1984 and 1985 summer season, on a clay loam soil (solonetzic black soil type).

The test was severely hit by drought in both years which led to a significant seed yield reduction in *B. napus* which suffered moisture stress at anthesis. Precipitation figures for 1984 was 46.1 mm in July and 23.0 mm in August and in 1985 the precipitation for July was 38.2 mm and 76.0 mm in August compared to the long term average of 88.7 mm and 77.9 mm respectively.

3.3 Study Treatments and Experimental Design

The field plot design was a 2x2x3 factorial in a completely randomized block design with four replicates. A separate experiment was conducted for each species consisting of 2 genotypes, 2 row spacings and 3 seeding rates. For *B. campestris*, the seeding rates were 3, 6 and 9 kg/ha with row spacing of 11.5 cm and 23.0 cm while *B. napus* was seeded at 4, 8 and 12 kg/ha with the same spacing

between rows. Individual plots consisted of 8 rows, 7 metres long.

The linear model for these experiments can be expressed as:

$$Y_{ijkl} = \mu + B_i + V_j + S_k + R_l + (RS)_{kl} + (RV)_{jl} + (VS)_{jk} + (RSV)_{jkl} + E_{ijkl}$$

where

Y = Observed treatment mean

μ = The potential population mean

B = Replication effect (i)

V = Genotype (j)

S = Row spacing (k)

R = Seeding rate (l)

E = Random error

3.4 Seeding

Seeds were treated with granular Furadan (Carbofuran) for protection against flea beetles. Weeds were controlled in this experiment by incorporation of granular Treflan herbicides at 0.5 kg/ha active ingredient in the fall of 1983 and 1984. Some hand weeding was done prior to the fourth true leaf stage. Fertilizer was broadcast and worked in the Spring of 1984 and 1985 at the recommended rate of 100 kg/ha 11-55-0. In 1984 and 1985, plots were seeded on May 18th and May 3rd respectively.

Plots were seeded with a Swift Current power seeder, four row belt cone type press drill with double disc openers, which has packing wheels before and after the seed is placed in the soil. The pre-packing results in better depth control while the after-packing results in better soil

seed contact for better germination. Row spacing of the seeder was 23.0 cm. The 11.5 cm was accomplished by overseeding.

3.5 Analysis of Variance (ANOVA)

The data were analysed as a three factor completely randomized factorial. The model was of a fixed form.

Table 1. Analysis of variance

Source of variation	Degrees of freedom
Blocks or replications(B)	3
Genotype(V)	1
Row spacing(S)	1
Seeding rate(R)	2
VS	1
VR	2
SR	2
VSR	2
Error BV+BS+BVS+BR+BVR+BSR+BVSR	33

Student Newman Keuls, SNK, (P=0.05), was the statistical method used to show differences among row spacing, seeding rate and genotype means. Days to different growth stages and growth periods were not analysed on a treatment combination basis by analysis of variance since no differences between replicates were observed.

3.6 Seed Yield per $2m^2$

The sample harvested from the two square metre area was air dried in cotton bags after cutting, until two days prior to threshing at which time they were put in forced air driers at approximately 35°C for two days. The seed yield was determined from the total yield sample. An Almaco Plot Thresher, rub-bar type was used.

3.7 Number of Pods on the Main Raceme

The number of pods was determined by counting all pods on the main racemes from ten plants chosen at random from each plot outside the area to be harvested for yield, the same plants were used to obtain 3.8, 3.9, 3.10, 3.11, 3.12, 3.13 and 3.14.

3.8 Number of Secondary Racemes per Plant

The number of secondary racemes per plant was determined by counting all those racemes apart from the main raceme from ten plants chosen at random from each plot.

3.9 Number of Pods on Secondary Racemes per Plant

This was determined by counting all pods on secondary racemes from ten plants chosen at random from each plot.

3.10 Number of Pods per Plant

The sum of pods on main raceme and those on secondary racemes.

3.11 Number of Seeds per Pod

The number of seeds per pod was determined from:

$$\text{No. of seeds per pod} = \frac{\text{Seed yield per plant}}{\text{No. of pods per plant}} \times \frac{1}{\text{weight/seed}}$$

3.12 Seed Yield per Plant

The seed yield per plant in grams was calculated from the seed yield per plot and the plant density.

3.13 Number of Racemes per $2m^2$

The number of racemes per plot was calculated from the number of racemes per plant and the plant density.

3.14 Number of Racemes per Plant

The number of racemes per plant was determined on five plants of each of the center two rows directly behind the harvested area. A raceme had one or more pods.

3.15 1000 Seed Weight

A thousand seed weight in grams was calculated from four samples of 500 seeds for each plot.

3.16 Plant Density

An area of two square metres was staked out after germination. All density observations were made within this area. Plants were counted at one week after emergence, three weeks after emergence and at first flower.

3.17 Plant Height

Plant height in centimetres was determined from two measurements within each plot when the plants were at the stage of maturity of first pod.

3.18 Percent Seed Oil

The percent seed oil of the whole seed was obtained by analysis of a 26.2 gram sample from each seed yield sample by a Newport, Nuclear Magnetic Resonance Analyser.

3.19 Percent Meal Protein

The 26.2 gram sample used for oil analysis was ground in a coffee grinder. A 0.5 gram was subsampled for micro-Kjeldahl method analysis using acid digestion and steam distillation. The percent meal protein was calculated using the percent oil and the percent protein of the seed.

$$\text{Percent meal protein} = \frac{\text{Percent seed protein}}{100 - \text{percent seed oil}} \times 100$$

3.20 Days to First Flower

Days from seeding to first flower was recorded when 75% of the plants had at least three open flowers on the main raceme.

3.21 Days to Last Flower

Days from seeding to last flower was recorded when 75% of the plants appeared to have terminated flowering on the main raceme.

3.22 Flowering Period

This was calculated as the period from first flower to last flower on the main raceme.

3.23 Seed Formation Period

The seed formation period is the number of days from first flower to maturity of first pod.

3.24 Number of Days to Maturity of First Pod

Days from seeding to maturity of the first pod was recorded when the majority of the plants had all black seeds in the lowest pod of the main raceme.

4. RESULTS AND DISCUSSION

4.1 Analysis of Variance

Row spacing had a significant effect on seed yield per plot and seed yield per plant for *B. campestris* but not *B. napus* in both years. However, *B. napus* showed a significant row spacing effect for number of pods on the secondary racemes in 1985 (Table 2). Row spacing significantly affected the plant density for *B. napus* in 1984 but not 1985. The converse being true for *B. campestris*. Plant density was significantly affected by seeding rate for both species in both years. The genotype had a significant effect on plant density for both species in 1985 but only for *B. napus* in 1984.

Generally both seeding rate and genotype had a significant effect on seed yield per plant, number of seeds per pod, number of racemes per plant, number of racemes per plot, number of secondary racemes per plant and plant height for both species in both years. Seeding rate significantly affected the number of pods per plant and number of pods on main raceme for both species in both years. The percent seed oil was significantly affected only by seeding rate in *B. campestris* in 1985. While the genotype had a significant effect on 1000 seed weight and percent seed oil for *B. campestris* in 1985 and 1984 respectively.

Most of the significant two way interactions in *B. campestris* were between genotype and seeding rate for the

number of pods on the main raceme, number of pods per plant, seed yield per plant and plant height. Genotype x seeding rate and row spacing x seeding rate interactions were significant for seed yield per plant for *B. napus* in 1984.

Because only three of the three way interaction of means were significant, the comparison of means is restricted to the two way means. The three way interaction means are presented in appendices 1 and 2.

4.2 Seed Yield per $2m^2$

For *B. campestris*, the 11.5 cm row spacing yielded significantly higher than the 23 cm row spacing in both years (Table 3). Row spacing had no significant effect on the seed yield of *B. napus* in both years (Table 4). The former agrees with the results of Christensen and Drabble (1984) while the latter conflicts.

Seeding rate had no significant effect on the seed yield of *B. campestris* in both years (Table 3). This agrees with the results of Degenhardt and Kondra (1981a and 1981b), Degenhardt (1979) and Kondra (1975) The lowest seeding rate (4 kg/ha) produced significantly higher seed yields for *B. napus* in 1984 but there was no significant effect in 1985.

There was no significant difference in the seed yield of the two *B. campestris* genotypes (Tobin and Candle) in 1984 (Table 3). However, the seed yield of Tobin was significantly higher in 1985. For *B. napus*, Westar yielded significantly higher than 81-58412K in 1984 but there was no

significant difference in 1985.

There was a significant genotype x row spacing interaction for *B. campestris* in 1985 (Table 2). This implies that the response to row spacing varies with the genotype.

4.3 Number of Pods on the Main Raceme

Row spacing had no significant effect on the number of pods developing on the main raceme for both species in both years (Tables 3, and 4). The lowest seeding rates, 3 kg/ha and 4 kg/ha for *B. campestris* and *B. napus* respectively, resulted in a significantly higher number of pods on the main raceme in both years.

Tobin produced significantly more pods on the main raceme for *B. campestris* in 1985. There was no significant difference between the *B. napus* genotypes in both years. The genotype x seeding rate interaction was significant for *B. campestris* in 1984 (Table 2). This implies that the effect of seeding rate on the number of pods developing on the main raceme varies with genotype.

4.4 Number of Secondary Racemes per Plant

Row spacing had no significant effect on the number of secondary racemes per plant for both species in both years (Tables 3, and 4). The lowest seeding rates, 3 kg/ha and 4 kg/ha for *B. campestris* and *B. napus* respectively, produced significantly more racemes per plant in both years. This

suggests that an increase in the space available to each plant results in larger number of racemes. These results are in agreement with the findings of Olsson (1960) and Degenhardt and Kondra (1981a).

Tobin and Westar produced significantly more secondary racemes per plant on average for *B. campestris* and *B. napus* respectively in both years.

4.5 Number of Pods on Secondary Racemes per Plant

Row spacing had no significant effect on the number of pods developing on the secondary racemes in *B. campestris* (Table 5) but had a significant effect in *B. napus* only in 1985 (Table 6) with the 23 cm row spacing producing more pods on the secondary racemes per plant. The lowest seeding rates, 3 kg/ha and 4 kg/ha, produced significantly more pods on secondary racemes for *B. campestris* and *B. napus* respectively in both years (Tables 5 and 6). These low seeding rates had corresponding high seed yields suggesting that pod number has a large influence on seed yield. Pod number was dependent on plant density showing a decline with increasing seeding rate. These results agree with those of Allen and Morgan (1972) that the ability of the oilseed rape plant to supply assimilates during flowering is important in determining the number of pods formed. The pods and seeds on the upper portion of the main raceme would be competing for available assimilates with pods on the lower branches.

Candle produced significantly more pods on the secondary racemes for *B. campestris* in 1984 while Tobin produced significantly more in 1985.

There was a significant genotype x seeding rate interaction for *B. campestris* in 1985 (Table 2). This indicates that the effect of seeding rate on number of pods on secondary racemes varied with the genotype.

4.6 Number of Pods per Plant

Row spacing had no significant effect on the number of pods per plant for both species in both years (Tables 5 and 6). More pods were produced in the low seeding rates, 3 kg/ha and 4 kg/ha for *B. campestris* and *B. napus* respectively. Compensation for thin stands occurred via increased number of pods per plant. This resulted in *B. campestris* showing no significant difference in seed yield in both years and in only one year for *B. napus*

Tobin produced significantly more pods per plant for *B. campestris* in 1985 but there was no significant difference in 1984 (Table 5). There was a significant genotype x seeding rate interaction for *B. campestris* in both years (Table 2). This implies that the effect of seeding rate on number of pods per plant varied with the genotype.

4.7 Number of Seeds per Pod

Row spacing had no significant effect on the number of seeds per pod for both species in both years (Tables 5 and 6). The 4 kg/ha seeding rate produced significantly more seeds per pod for *B. napus* in both years while the 3 kg/ha produced significantly more for *B. campestris* only in 1984. Compensation for the low plant density due to low seeding rates occurred through increased number of seeds per pod for both species in both years.

Tobin and Westar produced significantly more seeds per pod for *B. campestris* and *B. napus* respectively in both years.

4.8 Seed Yield per Plant

Seed yield per plant varied significantly between row spacings for *B. campestris* in both years but there was no clear pattern (Table 7). There was a significant effect of seeding rate on seed yield per plant for both species in both years with the lowest seeding rates, 3 kg/ha and 4 kg/ha, producing the highest seed yield per plant for *B. campestris* and *B. napus* respectively (Tables 7 and 8). These results agree with those of Degenhardt and Kondra (1981a).

Westar had a significantly higher seed yield per plant in both years for *B. napus* (Table 8) while Tobin produced a significantly higher seed yield per plant for *B. campestris* only in 1985 (Table 7).

4.9 Number of Racemes per $2m^2$

Row spacing had no significant effect on the number of racemes per plot for both species in both years (Tables 7 and 8). The highest seeding rates, 9 kg/ha and 12 kg/ha, produced significantly more racemes per plot for *B. campestris* and *B. napus* respectively in both years. This agrees with the results of Degenhardt and Kondra (1981a). The increase in the number of racemes per plot was probably due to a corresponding increase in plant density.

Candle and 81-58412K produced significantly more racemes per plot for *B. campestris* and *B. napus* respectively in both years.

4.10 Number of Racemes per Plant

Row spacing had no significant effect on the number of racemes per plant for both species in both years (Tables 7 and 8). The lowest seeding rates resulted in significantly more racemes per plant for both species in both years. These results agree with those of Degenhardt and Kondra (1981a).

Westar produced significantly more racemes per plant for *B. napus* in both years (Table 8). The number of racemes per plant varied significantly between genotypes of *B. campestris* but there was no clear pattern (Table 7).

4.11 1000 Seed Weight

Seeding rate had a significant but variable effect on the 1000 seed weight for both species in both years (Tables 11 and 12). Tobin produced significantly heavier seeds than Candle for *B. campestris* in both years (Table 11). The strong genotypic effect on 1000 seed weight (Table 2) agrees with the results of Degenhardt and Kondra (1981a). Seeds of 81-58412K were significantly heavier than Westar for *B. napus* in 1985 but not in 1984 (Tables 12). This component was not much influenced by many of the treatments applied hence selection for seed size would be effective. High seed yields were associated with heavier seeds while low seed yields were associated with lighter seeds. This is in agreement with the results of Kondra (1975b and 1977a) and Clarke (1978b). Overall, *B. napus* genotypes had bigger seed size than *B. campestris* genotypes.

4.12 Plant Density per $2m^2$

The 11.5 cm row spacing resulted in a significantly higher plant density at one and three weeks after emergence, and at first flower in 1985 but was significantly lower in 1984 for *B. campestris* (Tables 9 and 10). Whereas the 23 cm row spacing resulted in a significanly higher plant density at one and three weeks after emergence, and at first flower for *B. napus* in 1984 but was lower in 1985. Plant density was significantly higher with each increase in seeding rate for both species in both years. Since the lower plant

density had a significantly higher seed yield for *B. napus* in 1984, then these results agree with Donald (1963) that density dependent mortality did not reduce plant population to a level giving the maximum seed yields.

4.13 Plant Height

Row spacing had no significant effect on plant height for both species in both years (Tables 11 and 12). The highest seeding rate (12 kg/ha) resulted in significantly shorter plants in *B. napus* in 1985. This is in agreement with the results of Degenhardt and Kondra (1981b). The presence of competing neighbors in the higher seeding rate reduces plant height.

Candle was significantly taller than Tobin for *B. campestris* in 1984 (Table 11) while Westar was significantly taller than 81-58412K for *B. napus* in both years (Table 12). The genotype x seeding rate interaction was significant for *B. campestris* only in 1985 indicating that seeding rate had a variable effect on *B. campestris* genotypes with respect to plant height.

4.14 Percent Seed Oil

Row spacing had no significant effect on oil content for both species in both years (Table 13 and 14). *B. campestris* produced significantly high oil content in the 3 kg/ha seeding rate in 1985 (Table 13).

Tobin produced significantly higher oil content for *B. campestris* in both years while Westar produced significantly higher oil content for *B. napus* in 1984 but not in 1985 (Tables 13 and 14). These variable results agree with Olsson (1960) that although the oil content of the seed is modified by weather during ripening, plant nutrition and degree of ripening, it is less variable than seed yield and yield components.

4.15 Percent Meal Protein

Row spacing and seeding rate had no significant effect on percent meal protein for both species in both years (Tables 13 and 14). Tobin had a significantly higher meal protein in 1985 for *B. campestris* while 81-58412K had a significantly higher meal protein for *B. napus* in 1985. The genotypes that had a lower percentage seed oil had a corresponding higher meal protein. Although this relationship is likely to restrict simultaneous selection for both percent seed oil and percent meal protein, Grami and Stefan son (1977) have shown that these characters are under additive gene action and that standard plant breeding procedures, e.g. recurrent selection, are likely to increase percent protein and percent oil either independently or together.

4.16 Days to First Flower

Means for row spacing, seeding rate and genotype did not show much variation (Tables 15 and 16) for both species in both years.

4.17 Days to Last Flower

Means for row spacing, seeding rate and genotype did not show much variation (Tables 15 and 16). All genotypes terminated flowering early in both years. This could have been due to moisture stress at anthesis which led to early flower senescence.

4.18 Flowering Period

Means for row spacing, seeding rate and genotypes did not show much variation (Tables 15 and 16). This period took about two weeks in both species increasing to three weeks for *B. campestris* genotypes in the second year.

4.19 Seed Formation Period

Means for row spacing, seeding rate and genotype did not show much variation for the seed formation period (Tables 17 and 18). Apart from *B. campestris* in 1985, this period was of two weeks duration.

4.20 Time to Maturity of First Pod

Means for row spacing, seeding rate and genotype did not show much variation (Tables 17 and 18). The data indicates that the time to maturity of first pod was nine days longer in the second year for *B. napus* genotypes whereas it was only two days longer for the *B. campestris* genotypes.

5. CONCLUSIONS AND RECOMMENDATIONS

The 11.5 cm row spacing was superior to the 23 cm row spacing for *B. campestris* since it produced a higher seed yield per plot and per plant. The lack of advantage for the narrow row spacing in *B. napus* may have been due to the drought conditions which severely reduced seed yield in this species.It appears that *B. campestris* would benefit from narrow row spacing in terms of seed yield. Researchers should further evaluate the merits of narrow row spacing in both species in other environments. It could be recommended to producers on trial basis since the same conclusion is supported by Christensen and Drabble (1984).

The lowest seeding rate produced the highest seed yield in both species, and doubling seeding rate from 3 to 6 kg/ha and 4 to 8 kg/ha reduced seed yield by about 4% and 9% for *B. campestris* and *B. napus* respectively. However, the higher seeding rate may be required where stand establishment and weeds are a problem. The 3 kg/ha and 4 kg/ha could be used in areas where environmental conditions are favorable and stand establishment is not a problem. Plants tended to be shorter at higher plant densities therefore, the possibility of reducing straw length using higher plant densities should be looked into. The farmers have to strike a balance in this case because there is a risk of increased lodging at higher plant densities.

Tests should be conducted to determine the advantages of broadcast seeding over drilled seeding; and the most

suitable seeding rate in either case. Broadcast seeding should result in a better distribution of plants than drilling in rows if uniform stand establishment can be achieved. The significant two way interactions between genotype and seeding rate, row spacing and seeding rate emphasize the need to test new genotypes for the most appropriate row spacing and seeding rate in a particular environment.

This study supports that of Degenhardt and Kondra (1981a) that plant density or the number of racemes per unit area are not major factors determining seed yield per unit area, hence more studies should be done on actual pod number, seed number per pod and seed size as the three important components of seed yield. Plant breeders should select plants with many pods with the hope that increased productivity will be achieved.

Table 2. A summary of the factorial analysis of variance for all the variables.

Variables	Species	Treatments 1984 B	V	R	S	1985 B	V	R	S
Seed yield per 2m'	*B. campestris*	*	-	-	**	*	*	-	*
	B. napus	-	**	**	-	-	-	-	-
No.of pods on main rac.	*B. campestris*	-	-	**	-	-	**	**	-
	B. napus	-	-	**	-	-	-	**	-
No.of sec. rac./plant	*B. campestris*	-	**	**	-	-	*	**	-
	B. napus	-	*	**	-	-	**	**	-
No. of pods on sec. rac. / plant	*B. campestris*	-	-	**	-	-	**	**	-
	B. napus	-	-	**	-	-	-	**	**
No.of pods /plant	*B. campestris*	-	-	*	-	-	**	**	-
	B. napus	-	-	**	-	-	-	*	-
No.of seeds /pod	*B. campestris*	-	*	**	-	-	**	**	-
	B. napus	-	**	**	-	-	**	**	-
Seed yield /plant	*B. campestris*	-	-	**	**	-	**	**	*
	B. napus	*	**	**	-	-	**	*	-
No.of rac. /2m'	*B. campestris*	-	**	**	-	**	**	**	-
	B. napus	-	**	**	-	-	**	**	-
No. of rac. /plant	*B. campestris*	-	**	**	-	-	*	**	-
	B. napus	-	*	**	-	-	**	**	-
1000 seed weight	*B. campestris*	-	**	-	-	-	**	-	-
	B. napus	-	-	-	-	-	**	-	-
Plant dens. 1 week	*B. campestris*	-	-	**	-	**	**	**	**
	B. napus	-	**	**	**	-	**	**	-
Plant dens. 3 weeks	*B. campestris*	-	-	**	-	-	**	**	**
	B. napus	-	**	**	**	-	**	**	-
Plant dens. first flo.	*B. campestris*	-	-	**	-	*	**	**	**
	B. napus	-	**	**	**	-	**	**	-
Plant height	*B. campestris*	-	**	-	-	**	-	*	-
	B. napus	-	**	**	-	*	**	**	-
% Seed oil	*B. campestris*	**	**	-	-	*	**	**	-
	B. napus	-	**	-	-	*	-	-	-
% Meal protein	*B. campestris*	**	-	-	-	-	**	-	-
	B. napus	-	-	-	-	*	**	-	-

B, V, R, S = Replication, Genotype, Seeding rate, and Row spacing respectively.

-, *, ** = Not significant, Significant at 5%, and Significant at 1% respectively.

Table 2 cont. A summary of the factorial analysis of variance for all variables.

		Interactions							
		1984				1985			
Variables	Species	VS	VR	SR	VSR	VS	VR	SR	VSR
Seed yield /2 m'	*B. campestris*	-	-	-	-	•	-	-	-
	B. napus	-	-	-	••	-	-	-	-
No.of pods on main rac.	*B. campestris*	-	•	-	-	-	-	-	-
	B. napus	-	-	-	-	-	-	-	-
No. of sec. rac./plant	*B. campestris*	-	-	-	-	-	-	-	-
	B. napus	-	-	-	-	-	-	-	-
No. of pods on sec.rac.	*B. campestris*	-	-	-	-	-	••	-	-
	B. napus	-	-	-	-	-	-	-	-
No. of pods /plant	*B. campestris*	-	•	-	-	-	••	-	-
	B. napus	-	-	-	-	-	-	-	••
No.of seeds /pod	*B. campestris*	•	-	-	-	-	-	-	-
	B. napus	-	-	-	-	-	-	-	-
Seed yield /plant	*B. campestris*	••	-	-	••	-	••	-	-
	B. napus	-	••	•	-	-	-	-	-
No. of rac. /2 m'	*B. campestris*	-	-	-	-	-	-	-	-
	B. napus	••	••	•	-	•	-	-	-
No. of rac. /plant	*B. campestris*	-	-	-	-	-	-	-	-
	B. napus	-	-	-	-	-	-	-	-
1000 seed weight	*B. campestris*	-	-	-	-	-	-	-	-
	B. napus	-	-	-	-	-	-	-	-
Plant dens. 1 week	*B. campestris*	-	-	-	-	-	••	-	-
	B. napus	••	••	••	-	-	•	-	-
Plant dens. 3 weeks	*B. campestris*	-	-	-	-	-	••	-	-
	B. napus	••	••	••	-	-	•	-	-
Plant dens. at first flo.	*B. campestris*	-	-	-	-	•	•	-	-
	B. napus	••	••	••	-	-	•	-	-
Plant height	*B. campestris*	-	-	-	-	-	••	-	-
	B. napus	-	-	-	-	-	-	-	-
% Seed oil	*B. campestris*	-	-	-	-	-	-	-	-
	B. napus	-	-	-	-	-	-	-	-
% Meal protein	*B. campestris*	-	-	-	-	-	-	-	-
	B. napus	-	-	-	-	-	-	-	-

Table 3. Effects of row spacing, seeding rate and genotype on seed yield per 2m², number of pods on the main raceme and number of secondary racemes per plant for *B. campestris*

			Seed yield per 2m²		No. of pods on main rac. per plant		No. of sec.rac. per plant	
			1984	1985	1984	1985	1984	1985
Row spacing (cm) (S)		11.5	632b	468b	49a	41a	3.8a	7.1a
		23.0	558a	424a	48a	41a	3.7a	8.0a
Seeding rate (kg/ha) (R)		3	618a	461a	52b	45b	4.3b	9.2b
		6	590a	441a	46a	39a	3.6a	6.9a
		9	576a	436a	46a	39a	3.4a	6.6a
Genotype (V)		Candle	587a	427a	48a	39a	4.1a	6.8a
		Tobin	603a	465b	48a	43b	3.4a	8.3b
SxR	11.5	3	667b	481a	52b	44b	4.3b	8.3ab
		6	622b	461a	47c	40a	3.7b	6.9a
		9	606ab	461a	48bc	39a	3.5a	6.1a
	23.0	3	570a	441a	52b	45b	4.3b	10.1b
		6	558a	420a	46a	38a	3.6a	6.8a
		9	547a	412a	45a	39a	3.3a	7.2a
VxS	Candle	11.5	623b	431a	50a	38a	4.2b	6.4a
		23.0	551a	423a	57a	40ab	4.1b	7.2ab
	Tobin	11.5	640b	504b	48a	44c	3.4a	7.8ab
		23.0	566a	426a	48a	42bc	3.4a	8.8b
VxR	Candle	3	605a	458a	54a	42b	4.8d	7.9a
		6	581a	416a	44c	37a	3.9b	6.2a
		9	575a	407a	46bc	37a	3.7bc	6.1a
	Tobin	3	631a	465a	50ab	47c	3.8bc	10.4b
		6	600a	465a	48bc	40ab	3.3ac	7.5a
		9	578a	466a	46bc	41ab	3.1a	7.1a

a - d groupings within a column, means followed by the same letter do not differ significantly (SNK P = 0.05)

Table 4. Effects of row spacing, seeding rate and genotype on seed yield per $2m^2$, number of pods on the main raceme per plant and number of secondary racemes per plant for *B. napus*

		Seed yield per $2m^2$		No. of pods on main rac. per plant		No. of sec.rac. per plant	
		1984	1985	1984	1985	1984	1985
Row spacing (cm) (S)	11.5	519a	526a	34a	31a	3.7a	4.8a
	23.0	523a	505a	34a	33a	3.6a	5.0a
Seeding rates (kg/ha) (R)	4	568b	539a	38c	37b	4.2c	6.0b
	8	500a	500a	34b	31a	3.6b	4.6a
	12	495a	507a	30a	29a	3.1a	4.1a
Genotypes (V)	Westar	581b	527a	33a	33a	3.8b	5.3b
	81-58412K	462a	504a	35a	31a	3.4a	4.5a
SxR 11.5	4	575b	558a	38a	36b	4.2c	6.0b
	8	512ab	480a	34ab	30a	3.7ac	4.5a
	12	471a	540a	30b	29a	3.2a	4.0a
23.0	4	562b	520a	38a	37b	4.1c	6.0b
	8	489a	520a	34ab	31a	3.5ab	4.7a
	12	519ab	475a	30b	29a	3.0a	4.3a
VxS Westar	11.5	586b	538a	33a	32a	3.9a	5.4b
	23.0	576b	516a	33a	33a	3.7a	5.2b
81-58412K	11.5	452a	514a	35a	30a	3.4a	4.2b
	23.0	471a	494a	35a	32a	3.4a	4.9ab
VxR Westar	4	616c	533a	37ab	37b	4.5b	6.6c
	8	544b	553a	33bcd	31a	3.8b	4.8ab
	12	582bc	495a	29d	29a	3.2ab	4.5ab
81-58412K	4	521b	545a	39a	35b	3.8b	5.5b
	8	456a	447a	35abc	30a	3.4ab	4.3a
	12	408a	520a	31cd	29a	3.0a	3.8a

a - d groupings within a column, means followed by the same letter do not differ significantly (SNK P = 0.05).

Table 5. Effects of row spacing, seeding rate and genotype on number of pods per plant, number of seeds per pod and number of pods on secondary racemes per plant for *B. campestris*

		No.of pods per plant		No.of seeds per pod		No.of pods on sec.rac. per plant	
		1984	1985	1984	1985	1984	1985
Row spacing (cm) (S)	11.5	155.9a	112.8a	6.3a	7.3a	110a	72a
	23.0	152.2a	120.5a	5.5a	7.9a	104a	80a
Seeding rate (kg/ha) (R)	3	197.0b	149.6b	7.8b	8.9a	149b	105b
	6	140.9a	102.1a	5.5a	8.2a	95a	63a
	9	124.1a	98.2a	4.5a	5.7a	78a	50a
Genotype (V)	Candle	162.4a	97.0a	5.5a	5.9a	117b	58a
	Tobin	145.6a	136.3b	6.4b	9.3b	97a	93b
S x R 11.5	3	189.7b	138.5b	8.4c	8.8b	147b	94b
	6	150.4a	101.5a	5.9ab	7.7ab	104a	62a
	9	127.5a	98.4a	4.6a	5.4a	80a	59a
23.0	3	204.3b	160.7b	7.1bc	8.9b	152b	115b
	6	131.5a	102.7a	5.1a	8.7b	85a	65a
	9	120.7a	98.1a	4.4a	6.0ab	76a	59a
V x S Candle	11.5	169.8a	92.6a	5.3a	5.4a	126a	54a
	23.0	155.0a	101.4a	5.6a	6.3a	108a	62a
Tobin	11.5	142.0a	133.0b	7.3b	9.2b	94a	89b
	23.0	149.3a	139.5b	5.4a	9.4b	101a	98b
V x R Candle	3	224.7b	113.4a	6.7ab	7.8b	180b	71a
	6	136.2a	93.1a	5.4ab	5.7ab	92a	56a
	9	126.3a	84.7a	4.3a	4.2a	80a	47a
Tobin	3	169.3a	185.9b	8.8c	10.0c	119a	139b
	6	145.6a	111.1a	5.5ab	10.7c	97a	71a
	9	122.0a	111.8a	4.8ab	7.2b	76a	71a

a-c groupings within a column, means followed by the same letter do not differ significantly (SNK P=0.05)

Table 6. Effects of row spacing, seeding rate and genotype on number of pods per plant, number of seeds per pod and number of pods on secondary racemes per plant for *B. napus*

		No.of pods per plant		No.of seeds per pod		No.of pods on sec.rac. per plant	
		1984	1985	1984	1985	1984	1985
Row spacing (cm) (S)	11.5	77.6a	72.7a	8.9a	7.0a	44a	40a
	23.0	78.0a	84.7a	6.4a	6.4a	51b	51b
Seeding rate kg/ha (R)	4	100.7c	82.8b	12.2b	8.5b	62c	70b
	8	77.6b	87.2b	7.8a	6.3a	44b	38a
	12	55.2a	66.0a	7.1a	5.2a	25a	29a
Genotype (V) Westar		75.0a	83.0a	11.4b	7.7b	42a	49a
81-58412k		80.6a	74.3a	6.7a	5.6a	46a	43a
S x R 11.5	4	104.2c	83.1ab	11.1b	8.9c	66a	66c
	8	75.2ab	77.3ab	8.2a	6.3ab	41bc	32ab
	12	53.5a	57.5a	7.3a	5.7a	24c	23a
23.0	4	97.1bc	82.6ab	13.3b	8.1bc	59ab	74c
	8	80.0abc	97.1b	7.3a	6.3ab	46abc	45b
	12	56.9a	74.5ab	6.9a	4.8a	27c	35ab
V x S Westar	11.5	77.6a	78.4a	11.0b	7.7b	45a	46ab
	23.0	72.4a	87.6a	11.7b	7.8b	39a	52b
81-58412k	11.5	77.7a	66.9a	6.7a	6.3ab	42a	35a
	23.0	83.6a	81.8a	6.6a	4.9a	49a	50b
V x R Westar	4	102.8c	92.8a	14.3c	9.5c	66a	76c
	8	72.3ab	86.2a	9.9b	7.9c	39bcd	40a
	12	49.9a	70.1a	9.9b	5.8ab	21d	31a
81-58412k	4	98.5c	72.9a	10.1b	7.5bc	59ab	64b
	8	82.9bc	88.2a	5.7a	4.6a	48abc	36a
	12	60.5ab	61.9a	4.2a	4.7a	30cd	27a

a-d grouping within a column, means followed by the same letter do not significantly different (SNK P=0.05)

Table 7. Effects of row spacing, seeding rate and genotype on number of racemes per plant, number of racemes per $2m^2$ and seed yield per plant for *B. campestris*

		No.of rac. per plant		No.of rac. per $2m^2$		Seed yield per plant(g)	
		1984	1985	1984	1985	1984	1985
Row spacing (cm) (S)	11.5	4.8a	8.1a	311a	572a	2.8b	2.1a
	23.0	4.7a	9.0a	312a	500a	2.5a	2.3b
Seeding rate kg/ha (R)	3	5.3b	10.2b	201a	434a	4.1c	3.2c
	6	4.6b	7.9a	321b	473a	2.2b	2.1b
	9	4.4a	7.6a	412c	700b	1.6a	1.4a
Genotype (V)	Candle	5.2b	7.8a	343b	682b	2.6a	1.3a
	Tobin	4.4a	9.3b	281a	389a	2.7a	3.0b
SxR 11.5	3	5.3b	9.3ab	212a	461a	4.2d	3.0c
	6	4.7a	8.0a	301b	547ab	2.4c	1.9b
	9	4.5a	7.1a	421c	707b	1.6ab	1.3a
23.0	3	5.3b	11.1b	191a	407a	4.0d	3.4c
	6	4.6a	7.8a	341b	399a	1.9b	2.2b
	9	4.3a	8.2a	404c	692b	1.5a	1.4a
VxS Candle	11.5	5.2b	7.4a	354b	719b	2.6a	1.2a
	23.0	5.1b	8.2ab	332b	645b	2.6a	1.5b
Tobin	11.5	4.4a	8.8ab	269a	424a	3.0b	3.0c
	23.0	4.4a	9.8b	293a	354a	2.4a	3.1c
VxR Candle	3	5.8d	8.9a	216a	569d	4.1c	2.0c
	6	5.0c	7.2a	349c	591d	2.1b	1.2b
	9	4.7bc	7.2a	463d	886e	1.5a	0.8a
Tobin	3	4.8bc	11.4b	187a	300a	4.1c	4.4e
	6	4.3ab	8.5a	293b	354b	2.2b	2.8d
	9	4.1a	8.1a	362c	513c	1.7a	1.9c

a-d groupings within a column, means followed by the same letter do not differ significantly (SNK P=0.05)

Table 8. Effects of row spacing, seeding rate and genotype on number of racemes per plant, number of racemes per $2m^2$ and seed yield per plant for *B. napus*

			No. of rac. per plant		No. of rac. per $2m^2$		Seed yield per plant(g)	
			1984	1985	1984	1985	1984	1985
Row spacing (cm) (S)	11.5		4.7a	5.8a	322a	387a	2.2a	2.3a
	23.0		4.6a	6.0a	353a	370a	2.2a	2.5a
Seeding rate kg/ha (R)		4	5.2c	7.1b	199a	249a	3.8c	3.9c
		8	4.6b	5.6a	343b	386b	1.8b	1.9b
		12	4.1a	5.2a	471c	500c	1.2a	1.3a
Genotype (V)	Westar		4.8b	6.3b	292a	338a	2.8b	2.8b
	81-58412k		4.4a	5.6a	383b	418b	1.7a	2.0a
SxR	11.5	4	5.2c	7.1b	212a	261a	3.6e	3.8c
		8	4.7bc	5.5a	324b	392b	1.9d	1.7ab
		12	4.2a	5.0a	430c	508c	1.2b	1.3a
	23.0	4	5.1c	7.1b	186a	237a	3.9f	3.9c
		8	4.6abc	5.7a	362b	380b	1.6c	2.1b
		12	4.0a	5.3a	511d	492c	1.1a	1.4a
VxS	Westar	11.5	5.0b	6.4b	299a	373b	2.7b	2.6b
		23.0	4.7ab	6.2b	284a	304a	2.8c	2.9b
	81-58412k	11.5	4.4a	5.2a	345b	401b	1.7a	2.0a
		23.0	4.4a	5.9ab	421c	436b	1.7a	2.0a
VxR	Westar	4	5.5c	7.6c	190a	238a	4.5f	4.3d
		8	4.8b	5.8ab	300b	340b	2.2d	2.5b
		12	4.2ab	5.5ab	385c	438c	1.6c	1.6a
	81-58412k	4	4.8b	6.5b	208a	260a	3.0e	3.4c
		8	4.5ab	5.4a	385c	433c	1.4b	1.4a
		12	4.0a	4.8a	556d	562d	0.8a	1.1a

a-f groupings within a column ,means followed by the same letter do not differ significantly (SNK P=0.05)

Table 9. Effects of row spacing, seeding rate and genotype on plant density at one week after emergence, three weeks after emergence and at first flower for *B. campestris*

			Plant density 1 week emergence		Plant density 3 weeks emergence		Plant density first flower	
			1984	1985	1984	1985	1984	1985
Row spacing (cm) (S)		11.5	256a	289b	262a	316b	263a	303b
		23.0	273a	234a	275a	247a	273a	238a
Seeding rate kg/ha (R)		3	151a	170a	151a	176a	153a	175a
		6	272b	240b	277b	259b	277b	253b
		9	371c	373c	378c	409c	374c	383c
Genotype (V)	Candle		273a	351b	275a	382b	276a	365b
	Tobin		256a	171a	263a	180a	261a	175a
SxR	11.5	3	155a	189ab	156a	196a	159ac	200a
		6	246b	277c	251b	295b	257a	290b
		9	366c	399e	279c	457d	373b	417d
	23.0	3	146a	151a	147a	156a	147c	149a
		6	298b	204b	303d	222a	298ac	215a
		9	376c	346d	376c	362c	375b	349c
VxS	Candle	11.5	270a	388d	275a	430c	277a	407c
		23.0	276a	314c	274a	335b	274a	323b
	Tobin	11.5	241a	189b	249a	202a	249a	198a
		23.0	270a	153a	277a	158a	273a	152a
VxR	Candle	3	146a	232c	146a	241c	148a	243c
		6	278b	328d	283b	347d	282b	339d
		9	394c	393e	295c	560e	397c	513e
	Tobin	3	155a	108a	156a	111a	158a	106a
		6	265b	152b	272b	170b	273b	167b
		9	247d	252c	361c	259c	352d	253c

a-d groupings within a column, means followed by the same letter do not differ significantly (SNK P=0.05)

Table 10. Effects of row spacing, seeding rates and genotype on plant density at one week after emergence, three weeks after emergence and at first flower for *B. napus*

			Plant density 1 week emergence		Plant density 3 weeks emergence		Plant density first flower	
			1984	1985	1984	1985	1984	1985
Row spacing (cm) (S)		11.5	287a	257a	291a	280a	285a	284a
		23.0	332b	242a	334b	257a	324b	260a
Seeding rate kg/ha (R)		4	151a	136a	156a	144a	156a	143a
		8	307b	260b	310b	278b	298b	278b
		12	469c	352c	470c	383c	460c	395c
Genotype (V)	Westar		256a	205a	261a	220a	254a	226a
	81-58412k		262b	294b	363b	317b	356b	317b
SxR	11.5	4	153a	144a	162a	152a	164a	150a
		8	278b	264b	282b	286b	276b	288b
		12	429c	364c	428c	402c	413c	413c
	23.0	4	148a	129a	151a	135a	147a	136a
		8	336d	257b	339d	271b	320d	268b
		12	509e	340c	511e	365c	506e	376c
VxS	Westar	11.5	247a	226a	254a	243b	248a	247b
		23.0	265a	184a	268a	196a	259a	205a
	81-58412k	11.5	326b	288b	328b	317c	321b	321c
		23.0	398b	300b	399c	318c	390c	315c
VxR	Westar	4	127a	118a	136a	126a	137a	124a
		8	261b	222b	267b	225b	250b	232b
		12	380c	276bc	380c	308c	273c	323c
	81-58412k	4	174d	154a	176d	162a	174d	162a
		8	354c	299c	354c	332c	346c	324c
		12	560e	429d	560e	459d	546e	467d

a-e groupings within a column, means followed by the same letter do not differ significantly (SNK P=0.05)

Table 11. Effects of row spacing, seeding rate and genotype on plant height and 1000 seed weight for *B. campestris*

			Plant height (cm)		1000 seed weight (g)	
			1984	1985	1984	1985
Row spacing (cm) (S)		11.5	104.9a	98.7a	2.882a	2.397a
		23.0	104.6a	97.4a	2.865a	2.422a
Seeding rate kg/ha (R)		3	105.8a	99.2a	2.871a	2.409b
		6	104.2a	99.3a	2.877c	2.432c
		9	104.3a	95.7a	2.872b	2.387a
Genotype (V)		Candle	106.8b	98.4a	2.857a	2.343a
		Tobin	102.7a	97.8a	2.890b	2.476b
SxR	11.5	3	104.9a	99.6a	2.891f	2.407d
		6	105.2a	101.4a	2.885e	2.387b
		9	104.7a	95.2a	2.870c	2.397c
	23.0	3	106.8a	98.9a	2.952a	2.411e
		6	103.2a	97.2a	2.869b	2.477f
		9	103.8a	96.2a	2.875d	2.377a
VxS	Candle	11.5	106.6b	99.2a	2.875b	2.325a
		23.0	107.0b	97.6a	2.847a	2.361b
	Tobin	11.5	103.2a	98.2a	2.897d	2.470c
		23.0	102.2a	97.3a	2.883c	2.482d
VxR	Candle	3	108.3d	102.4b	2.869c	2.365c
		6	106.3cd	99.0ab	2.861b	2.347b
		9	105.8bcd	93.9a	2.842a	2.317a
	Tobin	3	103.4abc	96.1ab	2.874d	2.454d
		6	102.0a	99.6ab	2.893e	2.517f
		9	102.7ab	97.6ab	2.903f	2.457e

a-f groupings within a column, means followed by the same letter do not differ significantly (SNK P=0.05)

Table 12. Effects of row spacing, seeding rate and genotype on plant height and 1000 seed weight for *B. napus*

			Plant height (cm)		1000 seed weight (g)	
			1984	1985	1984	1985
Row spacing (cm) (S)		11.5	103.7a	103.3a	3.219a	4.494a
		23.0	102.3a	102.6a	3.194a	4.454a
Seeding rate kg/ha (R)		4	104.2b	105.8b	3.274c	4.397a
		8	103.5b	102.6a	3.178b	4.468b
		12	101.2a	100.4a	3.167a	4.556c
Genotype (V)		Westar	107.8b	108.9b	3.252a	4.350a
		81-58412k	98.1a	97.0a	3.161a	4.462b
SxR	11.5	4	103.8b	105.6b	3.238e	4.462b
		8	104.6b	103.6ab	3.179d	4.462b
		12	102.7ab	100.7ab	3.165a	4.556d
	23.0	4	104.6b	106.0b	3.311f	4.331a
		8	102.4ab	101.6ab	3.178c	4.474c
		12	99.8a	100.1a	3.168b	4.556d
VxS	Westar	11.5	108.7b	109.7b	3.207c	4.337a
		23.0	107.1b	108.1b	3.297d	4.362b
	81-58412k	11.5	98.7a	96.9a	3.181b	4.650d
		23.0	97.5a	97.1a	3.141a	4.546c
VxR	Westar	4	108.3c	111.1c	3.362f	4.219a
		8	108.6c	109.0c	3.181c	4.374b
		12	106.7c	106.6c	3.212e	4.456c
	81-58412k	4	100.1b	100.5b	3.186d	4.575e
		8	98.4ab	96.2a	3.176b	4.562d
		12	95.8a	94.2a	3.121a	4.656f

a-f groupings within columns, means followed by the same letter do not differ significantly (SNK P=0.05)

Table 13. Effects of row spacing, seeding rate and genotype on percent seed oil and percent meal protein for *B. campestris*

			% Seed oil		% Meal protein	
			1984	1985	1984	1985
Row spacing (cm) (S)		11.5	43.3a	47.9a	48.2a	51.0a
		23.0	43.6a	48.0a	48.5a	51.1a
Seeding rate kg/ha (R)		3	43.6a	48.3b	48.1a	50.8a
		6	43.5a	47.8a	48.6a	51.0a
		9	43.3a	47.7a	48.4a	51.2a
Genotype (V)		Candle	43.1a	47.4a	48.4a	51.2a
		Tobin	43.8b	48.5b	48.3a	51.4b
SxR	11.5	3	43.6a	48.3d	48.1a	50.9a
		6	43.3a	47.7ab	48.5a	51.0a
		9	43.1a	47.5a	48.0a	51.0a
	23.0	3	43.7a	48.2cd	48.1a	50.8a
		6	43.6a	48.0bc	48.7a	51.1a
		9	43.5a	47.8ab	48.7a	51.3a
VxS	Candle	11.5	43.0a	47.2a	48.2a	51.4b
		23.0	43.3ab	47.6b	48.6a	51.4b
	Tobin	11.5	43.7bc	48.5c	48.2a	50.5a
		23.0	43.9c	48.4c	48.4a	50.8a
VxR	Candle	3	43.2ab	47.8b	48.3a	51.3bc
		6	43.1b	47.3a	48.4a	51.2bc
		9	43.0b	47.1a	48.5a	51.6c
	Tobin	3	44.0a	48.8d	48.0a	50.3a
		6	43.8ab	48.4c	48.7a	50.8ab
		9	43.6ab	48.3c	48.2a	50.8ab

a-c groupings within a column, means followed by the same letter do not differ significantly (SNK P=0.05)

Table 14. Effects of row spacing, seeding rate and genotype on percent seed oil and percent meal protein for *B. napus*

			% Seed oil		% Meal protein	
			1984	1985	1984	1985
Row spacing (cm) (S)		11.5	41.9a	49.7a	52.9a	57.0a
		23.0	41.9a	50.1a	52.5a	56.0a
Seeding rate kg/ha (R)		4	42.3a	50.4a	52.5a	56.1a
		8	41.7a	50.0a	52.7a	56.4a
		12	41.8a	49.5a	53.0a	56.9a
Genotype (V)		Westar	42.9a	50.0a	52.5a	55.0a
		81-58412k	40.9b	49.8a	53.0a	57.9b
SxR	11.5	4	42.6a	50.2a	53.1a	56.3a
		8	41.4a	49.4a	52.5a	56.6a
		12	41.8a	49.7a	53.1a	58.0a
	23.0	4	42.0a	50.5a	51.8a	55.8a
		8	41.9a	50.6a	52.8a	56.3a
		12	41.8a	49.3a	52.9a	55.7a
VxS	Westar	11.5	42.7b	49.6a	52.5a	55.3a
		23.0	43.1b	50.5a	52.4a	54.7a
	81-58412k	11.5	41.2a	49.9a	53.3a	58.6b
		23.0	40.7a	49.8a	52.6a	57.2ab
VxR	Westar	4	43.5b	50.4a	52.3a	54.6a
		8	42.6b	50.2a	52.4a	55.1a
		12	42.6b	49.6a	52.6a	55.3a
	81-58412k	4	41.1a	50.3a	52.6a	57.5a
		8	40.8a	49.8a	52.9a	57.7a
		12	41.9a	49.4a	53.4a	58.4a

a-b groupings within a column, means followed by the same letter do not differ significantly (SNK P=0.05)

Table 15. Effects of row spacing, seeding rate and genotype on days to first flower, days to last flower and flowering period for *B. campestris*

		Days to first flower		Days to last flower		Flowering period	
		1984	1985	1984	1985	1984	1985
Row spacing (cm) (S)	11.5	40.2	42.3	54.6	64.1	14.4	21.8
	23.0	40.3	43.2	54.4	64.6	14.2	21.4
Seeding rate kg/ha (R)	3	40.5	42.9	54.6	64.6	14.1	21.7
	6	40.1	42.9	54.5	64.6	14.4	21.7
	9	40.2	42.6	54.5	64.0	14.3	21.4
Genotype (V)	Candle	40.3	42.7	54.7	63.4	14.4	20.8
	Tobin	40.2	42.9	54.4	65.3	14.1	22.4

Table 16. Effects of row spacing, seeding rate and genotype on days to first flower, days to last flower and flowering period for *B. napus*

		Days to first flower		Days to last flower		Flowering period	
		1984	1985	1984	1985	1984	1985
Row spacing (cm) (S)	11.5	48.4	56.3	61.4	69.2	12.9	12.9
	23.0	48.2	56.9	61.4	70.0	13.1	13.2
Seeding rate kg/ha (R)	4	48.4	57.0	61.5	69.8	13.1	12.8
	8	48.4	56.5	61.2	69.4	12.9	12.9
	12	48.3	56.3	61.4	69.7	13.1	13.4
Genotype (V)	Westar	48.3	55.4	61.3	68.9	13.0	13.4
	81-58412k	48.4	57.8	61.4	70.4	13.1	12.6

Table 17. Effects of row spacing, seeding rate and genotype on the seed formation period and days to maturity of the first pod for *B. campestris*

		Seed formation period		Maturity of first pod	
		1984	1985	1984	1985
Row spacing (cm) (S)	11.5	43.7	41.6	84	86
	23.0	43.7	40.9	84	86
Seeding rate kg/ha (R)	3	43.5	41.1	84	86
	6	43.9	41.2	84	86
	9	43.8	41.4	84	86
Genotype (V)	Candle	43.7	41.2	84	86
	Tobin	43.7	41.2	84	86

Table 18. Effects of row spacing, seeding rate and genotype on the seed formation period and days to maturity of first pod for *B. napus*

		Seed formation period		Maturity of first pod	
		1984	1985	1984	1985
Row spacing (cm) (S)	11.5	49.5	50.6	98	107
	23.0	49.7	50.1	98	107
Seeding rate kg/ha (R)	4	49.7	50.0	98	107
	8	49.7	50.1	98	107
	12	49.6	50.6	98	107
Genotype (V)	Westar	49.6	51.5	98	107
	81-58412k	49.6	49.2	98	107

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Appendix 1.

Appendix 1.Three way interaction means for seed yield per $2m^2$ and the number of pods per plant for *B.napus* in 1984 and 1985 respectively.

Appendix 1.Three way interaction means for seed yield per $2m^2$ and number of pods per plant for *B. napus* genotypes in 1984 and 1985 respectively.

Genotype (V)	Row spacing (cm)(S)	Seeding rate kg/ha (R)	No.of pods per plant 1985	Seed yield per $2m^2$ 1984
Westar	11.5	4	113.6c	662.8d
		8	65.3abc	572.4cd
		12	56.4ab	523.9bc
Westar	23.0	4	71.9abc	569.5cd
		8	107.1bc	516.5bc
		12	83.8abc	640.7d
81-58412k	11.5	4	52.6a	486.8abc
		8	89.4abc	451.0abc
		12	58.6ab	419.0ab
81-58412k	23.0	4	93.2bc	554.4cd
		8	87.0abc	461.3abc
		12	65.2abc	398.0a

a-d within a column, means followed by the same letter do not differ significantly (SNK P=0.05)

s.e of means for seed yield per $2m^2$=26.7
s.e of means for number of pods per plant=10.6

Appendix 2.

Three way interaction means for seed yield per plant for genotypes of *B. campestris* in 1984.

Appendix 2.Three way interaction means for seed yield per plant for genotypes of *B. campestris* in 1984.

Genotype (V)	Row spacing (cm) (S)	Seeding rate kg/ha (R)	Seed yield per plant(g)
Candle	11.5	3	3.9d
		6	2.3bc
		9	1.5a
	23.0	3	4.4e
		6	1.9abc
		9	1.4a
Tobin	11.5	3	4.6e
		6	2.5c
		9	1.8ab
	23.0	3	3.6d
		6	1.9abc
		9	1.6a

a-e within a column, means followed by the same letter do not differ significantly (SNK P=0.05)

s.e of means=0.16